Traffic Analysis

Offshore Wind Farm, Halla

Layout with 160 WTGs

Summary of changes

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Abstract

OX2 is investigating the possibilities for an offshore wind farm (OWF) about 60 km off the coast of Oulu, and about 24 km from the island Hailuoto, in the region of North Ostrobothnia in Finland. The wind farm, Halla OWF, is planned to be about 575 km^2 in size consisting of 160 wind turbines (WTGs) with a total maximum height of 370 metres. This report is a traffic analysis to ascertain how the establishment of the OWF is suitable in relation to sea traffic in the immediate area. The analysis also takes into account ice cover in general.

The traffic analysis indicates that the amount of shipping in the vicinity of Halla OWF is low, and the size of the vessels is small in relation to other vessels and traffic density in other areas further south in the Gulf of Bothnia and the Baltic Sea. This means that traffic in general should have good route options and room to manoeuvre out of the way if necessary.

The shipping area Nordvalen – Kemi/Tornio is estimated to be affected by establishment of the OWF. This is a route adjacent to Halla with most traffic in the analysis area. The recommended safety distance according to concept design (PIANC, 2018) is not fulfilled; however, this can be done by removing the outermost WTG in the north-western corner of the project area. This is also valid concerning future traffic volumes and vessel sizes.

Some traffic currently passes through the area that is intended for the installation of Halla OWF. This traffic will have to choose a different route if Halla is established. This means that traffic in shipping areas that are located outside the OWF may increase. However, due to generally low traffic volumes in the area, the increase does not amount to more than one or in worst case two additional passages per day.

The unofficial pilotage route that runs through Halla project area, is considered the route being most affected. Piloting will have to be moved if Halla is established, either east or west of Halla, depending on draught and ice conditions. However, the diversion might lead to voyage distance somewhat longer.

Consideration has also been given to nearby OWFs that are planned. This mainly applies to the Polargrund and Omega OWF west and south-west of Halla OWF. If these three OWFs are established it is assessed that the traffic in Nordvalen – Kemi/Tornio will have less room to navigate, which may cause congestion in the shipping area. Establishment of Halla OWF and potentially surrounding OWFs reduces possible routes for icebreaker assistance, but there are also great uncertainties about whether the construction of OWFs affects the ice conditions.

Abbreviations and concepts/ Terminology

AIS	**Automatic Identification System**
ALARP	As Low As Reasonably Practicable (area where risks can be tolerated if all reasonable measures are taken)
Study area	The area where AIS data was analysed. The area is 13 409 km^2 and measures approx. The area stretches from the western coast to the eastern coast of the Baltic Sea, and about 70 km northwards and southwards.
ArcGIS Pro	A GIS (Geographic Information Systems) application that performs geographic analysis and data visualisation. Used in this analysis, among other things, to analyse AIS data
Fairway	Seaway in inland waters, inland or near the coast, designated by maritime safety devices or marked on a chart or in a nautical publication
FME	A software that is used to create a layer as a shapefile based upon AIS-data
GW	Gigawatt
M	Nautical mile (1 852 metres)
MMSI-number	Maritime mobile service identity, used to identify vessels and coastal stations in radio communication, as well as aircraft used in maritime rescue.
OWF	Offshore Wind Farm
Project area	Halla's complete area for wind power establishment (synonymous with Halla Offshore Wind farm, Halla OWF)
Shipping area	The maritime spatial planning identifies significant trafficked areas as seafaring areas. Seafaring areas play a crucial role in the current and future use of the marine areas (Maritime Spatial Planning, n.d.). In this report, the term shipping area is used synonymously with seafaring area
Swedish national interest in shipping	Swedish sea areas that are to be considered of national interest for shipping. Is mentioned traffic lanes in this report.
Traffic lane	A traffic lane is a defined area where one-way traffic is established. Natural obstacles, including those forming separation zones, may constitute a boundary (IMO, n.d.)
Traficom	The Finnish Transport and Communications Agency
TSS	Traffic separation system – an area where oncoming traffic is separated into different traffic lanes
Väylävirasto	The Finnish Transport Infrastructure Agency
Wind farm	Project area
WTG	The wind turbine machine construction

1 Introduction

OX2 plans to apply for a permit for the construction of an OWF, Halla, located about 60 km off the coast of Oulu in the region of North Ostrobothnia in Finland.

Where OWFs are located close to fairways or shipping areas, wind turbines (WTG) may pose a risk to the safety of shipping and the use of fairways and shipping areas, or hamper the operational conditions of shipping, especially during ice-covered periods. Furthermore, OWFs may affect the accessibility of ports and shipping conditions more broadly, as OWFs may have an impact on shipping routes and winter shipping routes depending on the current ice conditions, as well as on the need for icebreaking assistance for merchant ships (Traficom, 2022a). It is important that new installations of OWFs do not remarkably affect the accessibility or maritime safety. Due to this, a traffic analysis must be conducted to map shipping traffic and to examine potential impacts on routes and fairways.

To clarify the impact on vessel traffic when establishing Halla OWF, Sweco have carried out a traffic analysis and accounted for area-specific conditions.

1.1 Aim

The purpose of this traffic analysis is to map and analyse the maritime traffic in the vicinity of Halla OWF. Extra emphasis is placed on maritime traffic during ice cover at sea. The traffic analysis is the basis for the continued work with the nautical risk analysis.

1.2 Scope and boundaries

The traffic analysis includes description and/or analysis of the following:

- Number of vessels
- Size of vessels
- Vessel types
- Vessel transits within and nearby the OWF
- Future traffic flows and pattern
- Seasonal variations
- Ice conditions

The report does not include analyses of risks that may arise when establishing OWFs. Risks will be calculated, quantified, and assessed in a separate nautical risk analysis. Only the description and analysis of vessel traffic in the area is undertaken. The ice conditions are also described and analysed based on data from 2022. Throughout the report, information is divided into months with sea ice and months without sea ice.

It should be noted that during the construction phase of the OWFs, traffic in the area may increase slightly temporarily. However, this additional traffic flow is not analysed in this report.

2 Knowledge overview

In energy development planning and maritime spatial planning it appears that the conditions for finding suitable energy extraction areas in the Gulf of Bothnia are considered good (Swedish Energy Agency, 2023) (Maritime Spatial Planning, n.d.) (Virtanen, 2022). At the same time, it is important to find a coexistence between OWFs and shipping.

To reduce the potential impact on vessel traffic, it is important to consider the boundary conditions to ensure human safety. According to Traficom, a safety distance should be created between the outer WTGs and the nearest shipping lane. Furthermore, the establishment of WTGs in the Gulf of Bothnia requires extra careful planning regarding winter traffic.

In this chapter, parts of the background are described which are important for the results of the traffic analysis, and for the nautical risk analysis later. Firstly, different types of ice conditions that can occur in the Gulf of Bothnia and how these can affect maritime traffic are described. Recommendations are then compiled regarding safety distances between maritime traffic and WTGs. Please note that these are recommendations only. The safety distances that may become relevant for Halla OWF are instead discussed, if necessary, in the nautical risk analysis in relation to the risk calculations carried out for the OWF.

2.1 Ice conditions

The fact that large parts of the waters of the Baltic Sea, especially the Bothnian Bay, freeze into ice every year affects shipping, where vessels sometimes become dependent on icebreaker assistance. Where ice obstacles occur, traffic during the ice-covered months at sea is often forced to take different routes than during months without sea ice. Different types of ice cover can also affect sea traffic in different ways.

When establishing offshore wind power, the ice formation in the area may change. However, it is not yet known what the change in ice formation and ice coverage may look like.

2.1.1 Ice types

Ice growth is affected by weather, wind, and temperature, as well as the cooling of water masses in the autumn (SMHI, 2021a). There are different types of ice cover at sea. These are compiled in Table 1.

Sea ice can be divided into different types of ice, Finnish Meteorological Institute (2021) describes how sea ice exists as either fast and or drift ice depending on its mobility. Fast ice is situated in coastal and archipelago areas, and drift ice moves and in some cases gets packed or creates leads in the ice field.

Drift ice

Ice in movement is called drift ice. It covers 1–100% of the sea surface. The movements are caused by the wind and the sea current, whereas in the Baltic Sea, especially wind (Finnish Meteorological Institute, 2021).

Leads

When drift ice moves away from the fast ice, or consolidated ice, it creates a lead in the ice field. During strong winds the width of the lead can reach 10-30 km in about 24 hours. If the wind direction remains constant in a vast area, the lead can become very long. During spring in the northern parts of the Bay of Bothnia, a lead shaped like a crescent is usually being formed. It reaches from Luleå on the Swedish coast to Kemi lighthouse and Merikallat to Raahe and even Kokkola (Finnish Meteorological Institute, 2021).

Pack ice

Drift ice can easily become packed when it reaches an obstacle. Typically, this occurs when the ice field moves towards the fast ice edge. In the shallows, ridges get anchored to the bottom and the visible parts can grow to tens of metres high. Ridged ice appears also in the middle of seas where the ice floes get pressed against each other and break into pieces. The pieces of ice pile up over and under the sea surface forming meandering ice ridges (Finnish Meteorological Institute, 2021).

The wind may disperse or pack the sea ice, generating conditions that affect the marine traffic, for example through ice ridges and packed ice along the coast and harbour entrances. At the Baltic Sea, the prevalent winds are south-westerly. This causes the sea ice moving towards the Finnish coast and "pack", creating areas with ice ridges. Correspondingly, most of the leads appear on the Swedish coast (Finnish Meteorological Institute, 2021), which are cracks in the ice sheet that occur when ice masses drift apart (SMHI, 2021b).

The movement of large sea ice areas is possibly a dangerous phenomenon. Drift ice can create such pressure on vessels that they either drift with the ice and lose control to manoeuvre/steer or freeze in the ice. For shipping, it is primarily brash barriers, ice ridges, floebergs and drift ice that might pose a danger to traffic where these types of ice are created (SMHI, 2021a). The ridges and brash ice barriers are the most significant obstructions to navigation in the Baltic Sea. Powerful, ice-strengthened vessels can break though ice up to almost one metre thick, but they are not capable of navigate through ridges without icebreaker assistance. Ice dynamics affects navigation considerably. High pressure in the ice fields can be dangerous to the vessels, and it may at least cause time delays from hours up to days (Finnish Meteorological Institute, 2021).

Table 1. Different ice types and their characteristics. Rows marked in light red are types of ice that pose danger or cause problems for sea traffic.

Ice type	Characteristics
New ice (Nilas)	A thin film of newly formed ice
Thin level ice	Ice sheet of solid ice, consists of a thick joint of 5 – 15 cm.
Fast ice	A continuous, unmoving solid ice anchored to land or islands.
Brash barrier	Hard winds and waves can compress pancake ice, broken nilas or slush against land or solid ice, forming a thick ridge of brash ice. A jammed brash barrier can be several nautical miles long, causing significant problems for vessels trying to break through it.
Ice ridges	The part above water is only one or a few meters high while the underwater part can extend up to several tens of meters deep. Ice ridges cause problems for sea traffic.
Drift ice	Any sort of sea ice affected by wind and currents, as opposed to fast ice which is attached to islands or the coast. Varying in thickness and roughness. Drift ice covers 1–100% of the sea surface. Drift ice is a continuous hazard to sea traffic.
Floebergs, floebits	As the ice breaks up, single large pieces of drift ice from old ridges are left, called floebergs. These can often be surrounded by open water. Floebergs are a potential threat to sea traffic during darkness or poor visibility.
Rotten ice	As ice starts to melt it becomes honeycombed and porous, and is said to be rotten

The Swedish Transport Agency (2022) lists following scenario regarding sea ice and the establishment of a OWF that could potentially be featured:

- The ice may be broken by the foundations of the WTGs and drift ice could get stuck in the area. Ice ridges could form when the ice sheet pushes on from behind and compresses the ice.
- The ice may be broken by the foundations of the WTGs that passes the OWF, which lead to ice being compressed and form large areas with ice ridges.
- Ice could drift back and forth in the area of the OWF, leading to ice being broken and compressed on several occasions, forming a thick ice barrier which gets stuck in the area.

Furthermore, ice that has been affected by the OWF can also drift and hamper ship traffic at other locations. This can lead to aggravated ice conditions elsewhere and pose limitations in shipping and calling at ports in the Gulf of Bothnia.

The Finnish Transport Infrastructure Agency (Väylä) is tasked with providing icebreaker assistance for vessels calling at Finnish ports when necessary. The ice conditions determine the need, and the Finnish Transport and Communications Agency (Traficom) determines the Finnish ice classes for vessels based on the ice class designation. Finnish icebreakers only assist vessels that meet the ice class requirements in the Finnish-Swedish Ice Class Rules 2017. These are summarized in the Guidelines for the Application of the 2017 Finnish-Swedish Ice Class Rules (Traficom & Swedish Transport Agency, 2019).

Depending on ice conditions, Väylä applies size and ice class restrictions to vessels eligible for icebreaker assistance. Winter traffic restrictions are to ensure safe navigation at sea in ice conditions. The icebreakers provide assistance to the vessels by monitoring, directing, leading and towing (Traficom & Swedish Transport Agency, 2019).

2.1.2 Ice winters

An ice winter is classified based on its maximum ice extent in the entire Baltic Sea region including the Kattegat. Ice winters are divided into mild, normal, or severe, depending on the maximum ice extent set each winter (SMHI, 2021a).

As the large north-south extent of the Baltic Sea entails large temperature differences, comprehensive regional differences in ice conditions are recognized. Meanwhile, there may also be such variations that an ice winter that is mild in the Gulf of Bothnia can be characterized as severe in the southern Baltic Sea. Each ice winter may be assessed based on the nature of the waters in question (SMHI, 2021a).

2.1.2.1 Mild ice winter

During a mild ice winter, only a small area of the Baltic Sea region, consisting mostly of the Gulf of Bothnia, the Northern Kvarken, and the Northern Bothnian Sea is covered with ice. The maximum ice extent is about 115 000 km^2 (SMHI, 2021a).

Weather dominated by a mild temperature and stronger winds usually generate these mild ice winters. At times, the ice may grow, but is often torn up by the wind and the ice is driven towards the coasts. As winter progresses, the total ice extent builds up, which can also lead to the formation of areas with ice ridges, e.g., in the northern Bothnian Bay (SMHI, 2021a).

2.1.2.2 Normal ice winter

Measured during maximum ice extent, usually in March, the entire Gulf of Bothnia, Northern Kvarken, most of the Bothnian Sea, the Gulf of Finland and the Åland Sea are covered by ice in a normal ice winter. Southwards, down to the Kalmar Sound, there is thin ice formation along the coastal areas. The maximum ice extent is around 230 000 km^2 (SMHI, 2021a).

Weather that generates a normal ice winter in the Bothnian Bay and the Bothnian Sea is characterized by several continuous periods of high pressure with weak winds and temperatures below -10 degrees Celsius during the month of November – December (SMHI, 2021a).

2.1.2.3 *Harsh/Severe ice winter*

A severe ice winter begins when the maximum ice extent exceeds 230 000 km^2. The ice grows further southward in the Baltic Sea and in parts of the southern and western waterways (SMHI, 2021a).

The weather is characterized by longer periods of continuous cold and often combined with easterly or north-easterly winds that maintain the transport of ice (SMHI, 2021a).

During extremely severe ice winters, most of the Baltic Sea covers with ice. The ice winter of 1986/1987 is a historical example of which where the maximum ice extent amounted to 394 000 km^2 (Ice conditions in the Baltic Sea, 2021a). That winter, most of the Baltic Sea was covered in ice. A prolonged high-pressure situation with weak winds, clear and cold nights meant that almost the entire Baltic Sea became ice-covered on March 13, 1987. This severe ice winter led to delays and financial losses. Despite some occasionally very difficult conditions for shipping, the ports generally remained open for winter shipping (SMHI; Maritime Administration, 1987).

The last severe ice winter occurred in 2011, and it had a maximum ice extent of 300 000 km^2. Overall, this winter was the largest ice extent since the record year of 1987 (SMHI; Maritime Agency, 2011).

At maximum ice cover, the entire Gulf of Bothnia and the Bothnian Sea were covered with solid ice or with frozen, very dense drift ice. Even large parts of the Baltic Sea were covered by frozen drift ice. Icebreaker operations in the Gulf of Bothnia began on 29 November and the season ended on 20 May.

Severe ice winters are an expected event that historically occurs in the Baltic Sea more often than every 10 years. The most severe ice winters occurred before the year 1990. In the last decade, the climate has mainly been characterized by mild and normal ice winters (SMHI; Maritime Administration, 2020).

SMHI depicts maximum ice extent over the Baltic Sea and Kattegat over years (SMHI, 2022) in a diagram which is shown below in Figure 1.

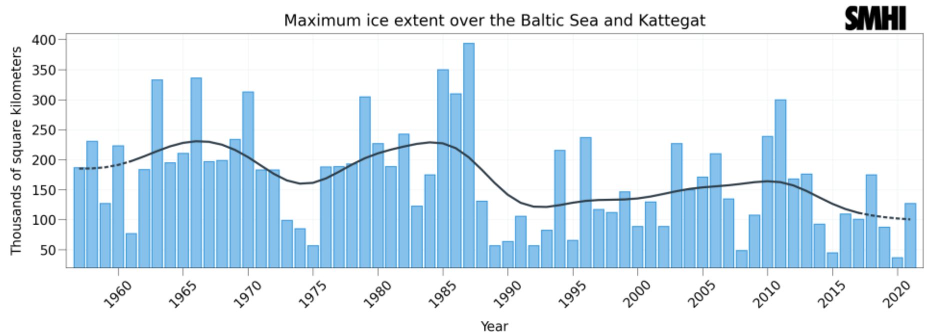

Figure 1. Diagram showing maximum ice extent over the Baltic Sea and Kattegat. The blue bars in the diagram show year's maximum ice extent for the Baltic Sea through the Kattegat. The black line shows a running mean calculated over about ten years. © SMHI

In a future warmer climate, ice winters in the Baltic Sea are expected to be both shorter and milder, and severe ice winters will become increasingly rare.

However, ice cover will continue to be a natural part of the Baltic Sea's annual cycle, and the Gulf of Bothnia is expected to be completely ice-covered in the future as well. It is also not certain that milder ice winters will lead to easier conditions for maritime traffic. Milder winters can mean more drift ice and therefore more difficulties for traffic. In addition, the climate can affect the weather through more frequent and stronger storms and other events which can also negatively affect sea traffic. The extent of the ice will also vary from year to year in the future (SMHI, 2022).

2.2 Safety distance

The right of innocent passage is regulated in the United Nations Convention on the Law of the Sea (UNCLOS) (United Nations, 1994). In this agreement there is, among other things, article 60.7 "Artificial islands, facilities and constructions and safety zones around them may not be established where they can impede the use of recognized waterways of essential importance for international shipping".

In addition to UNCLOS, there is also the International Law of the Sea or International Law of the Sea for the Prevention of Collisions at Sea (COLREG) (IMO, 1972). These are rules according to the convention that regulate the obligations of vessels in terms of avoiding collisions. COLREG describes the obligations of larger merchant vessels to avoid manoeuvres required to avoid collisions at sea. In order to create opportunities for these vessels to fulfil their obligations for evasive manoeuvres, a safety distance between maritime traffic and fixed foundations at sea, including WTGs, is often recommended.

The safety distance is determined on a case-by-case basis, depending on, among other things, the location of the OWF, geographical aspects, and vessel traffic in the area.

PIANC is a global organization that develops recommendations to achieve sustainable transport at sea and on other waterways (PIANC, 2023). The conservative assessment of distance recommendations and space requirements, as specified by PIANC, can be achieved by outlining their recommendations and showcasing the available manoeuvre space in open water. In winter, when ice conditions prevail, authorities may impose specific traffic restrictions. Depending on ice conditions, the Finnish Transport Infrastructure Agency (Väylä) applies size and ice class restrictions to vessels eligible for icebreaker assistance (Traficom & Swedish Transport Agency, 2019). Furthermore, based on the Maritime Traffic Act, Traficom closes certain fairways during the winter season to ensure traffic connections in the archipelago while the fairways are covered with ice (Traficom, 2023). However, there are no official guidelines or recommendations given regarding safety distances during ice-covered conditions.

In the report *MarCom Wg 161: Interaction Between Offshore Wind Farms and Maritime Navigation* (2018), PIANC presents recommendations regarding safety distances to WTGs. The recommendations are based, among other things, on COLREG and its rules regarding safe passages at sea. There are two methods for producing safety distance recommendations:

- Concept design, providing a conservative recommendation of safety distance between WTGs and vessels.

- Detailed design, where the safe distance can possibly be changed after an in-depth nautical risk analysis.

The recommendation, according to Concept design, means that the distance from the vessel to the closest WTG in the OWF should be such that a vessel should be able to perform a complete evasive manoeuvre (360° turn). Such a distance is estimated to be achieved at 5 vessel lengths. To allow room for possible complications, a manoeuvring distance is conservatively estimated to be about 6 vessel lengths. In addition, a safety zone for the OWF of a maximum of 500 metres must also be added (UNCLOS security zone). This distance can be shorter but must not exceed 500 metres. To ensure that a safe evasive manoeuvre can be made in connection with other vessels being nearby, 0.3 M is added to the safety distance on the starboard side. This means that the minimum safety distance (safety zone excluded) between the vessel and the closest WTG in the OWF is recommended to be as follows (see also Figure 2, where d is the shortest recommended distance):

- On the starboard side of the vessel d = 556 metres (0.3 M) + 6 vessel lengths
- On the port side of the vessel d = 6 vessel lengths

The above safety distance is recommended between the closest WTG in an OWF and the nearest border of a Traffic Separation System (TSS). The distance is illustrated in Figure 2. For a TSS or fairway with marked borders, it is clear where the distance is to be measured from. In cases where shipping areas are not designated on nautical charts, measurements will be based on the distance estimated so that the prerequisites exist for a traffic lane based on PIANCs recommendations, and vessels maintaining a distance from the nearest wind turbine that compiles with COLREG, including a potential safety zone according to UNCLOS (2018).

Note that through a *Detailed design* PIANC (2018) a shorter distance than the safety distance, given by *Concept design,* can be proven to be acceptable with a nautical risk assessment.

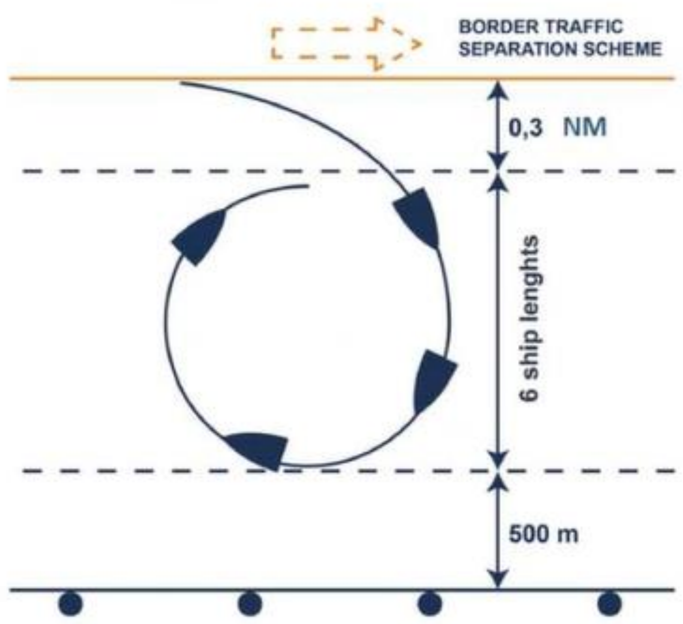

Figure 2. Illustration of distance between a TSS and a OWF according to PIANC (the round turn to starboard side) (PIANC, 2018).

PIANC gives examples of how wide a traffic lane could be. The traffic lane should be assigned an appropriate width based on the amount of traffic in the traffic lane (PIANC, 2018). Appropriate width of traffic lane depends on the number of vessels operating in the route, and is compiled below:

Number of vessels using the route, allowing 2 ship lengths per vessel:

<4 400 vessels per year	2 vessels side to side
> 4 400 vessels and <18 000 vessels per year	3 vessels side to side
> 18 000 vessels per year	4 vessels side to side

The vessel length is based on the largest length of vessels using the route, taking into account future traffic and developments in ship size[1].

The Ministry of Infrastructure and the Environment in the Netherlands (2014) also mentions the traffic lane widths according to the guidelines above as suitable. They state that the length of a reference vessel corresponding to the 98.5 percentile, i.e., only 1.5% of other vessels are longer, operating the lane is appropriate to use when deciding on the width of the lane.

It is important to take into account the boundary conditions to ensure safety and operational capacity for shipping. Traficom and Väylävirasto (2023) refer in their document with instructions on risk assessment in spatial planning of offshore wind power to “The Spatial Planners’ guide to distances between Shipping & Offshore Renewable Energy Installations” which incorporates, inter alia, PIANCs recommendations as well as Dutch guidelines.

[1] Example: a traffic lane which accommodates 18,000 vessels per year with a maximum size of 400 metres should be at least 3 200 metres wide (= 4 x 2 x Length = 4 x 2 x 400)

3 Study area

In this chapter, the conditions that underlie the analysis are described.

3.1 Halla OWF

Halla OWF is located about 60 km off the coast of Oulu in the region of North Ostrobothnia in Finland. Between the coast and the OWF is the island Hailuoto. The island is about 24km from the OWF. The OWF is about 575 km^2 in size and is planned for 160 WTGs with a total maximum height of 370 metres. The technology used is planned to be bottom fixed offshore WTGs with installed capacity amounts to approximately 2.4 GW. Other structures within the offshore OWF are offshore substations and away cables, and/or platforms for hydrogen production and pipelines. Export cables and/or pipelines will transfer the power or hydrogen to the onshore network. The traffic analysis extends to the area within which AIS data is collected and amounts to an area of approximately 14 300 km^2, which is shown in the map below (Figure 3).

The area of AIS data will henceforth be referred to as the analysis area.

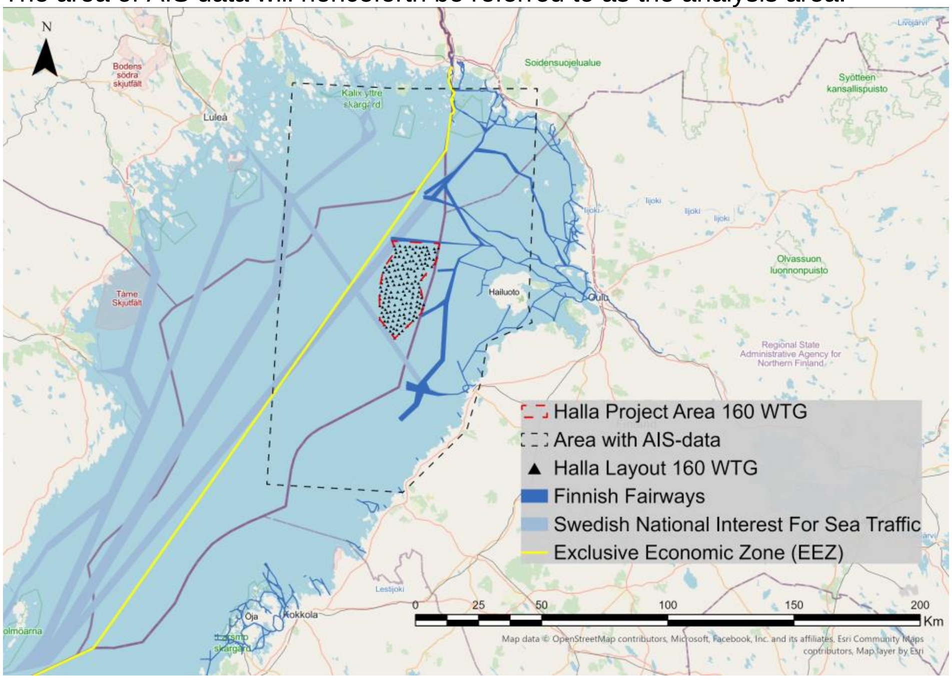

Figure 3. Map showing the Halla Project Area and area with AIS-data, analysis area.

3.2 Bathymetry

The mean water depth in the project area is 31 metres, with a greater depth in the western parts and shallower in the eastern parts. The bathymetric is illustrated in Figure 4.

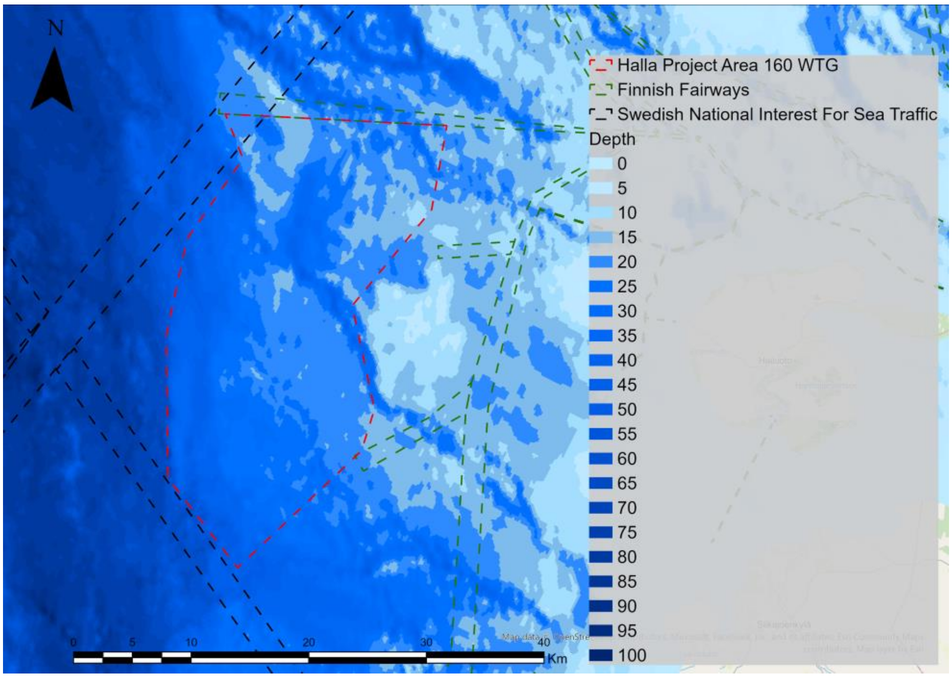

Figure 4. Figure showing water depths in metres in adjacent to Halla project area. Note that the bathymetry is based on a grid where depth conditions are reproduced in 90 metre resolution (NOAA, 2022). This causes depth data to be generalized and thus does not illustrate exact depth values.

3.3 Nearby OWFs

There are several planned OWFs in the area near Halla OWF (see Figure 5. The cumulative effect of these OWFs are all studies and assessed in the project’s Environmental Impact Assessment (EIA), but only some of them are assumed to (together with Halla) have cumulative effects regarding changes in traffic patterns and are accounted for below.

- Polargrund Offshore (henceforth referred to as Polargrund OWF) is planned and located approximately 2.8 kilometres northwest of the Halla OWF, hence it is the closest OWF.
- Bothnia Offshore Omega (henceforth referred to as Omega OWF) is planned and located approximately 19 kilometres southwest of Halla OWF.
- Bores Krona 1, 2, 3 OWF is planned and located approximately 33 kilometres west of Halla OWF.
- Suurhiekka OWF is planned and located approximately 20 kilometres northeast of Halla OWF.
- MH OWF is planned and located approximately 21 kilometres south of Halla OWF.
- Maanahkiainen OWF is planned and located approximately 27 kilometres south of Halla OWF. Maanahkiainen OWF is located close by MH OWF, but even further from Halla OWF

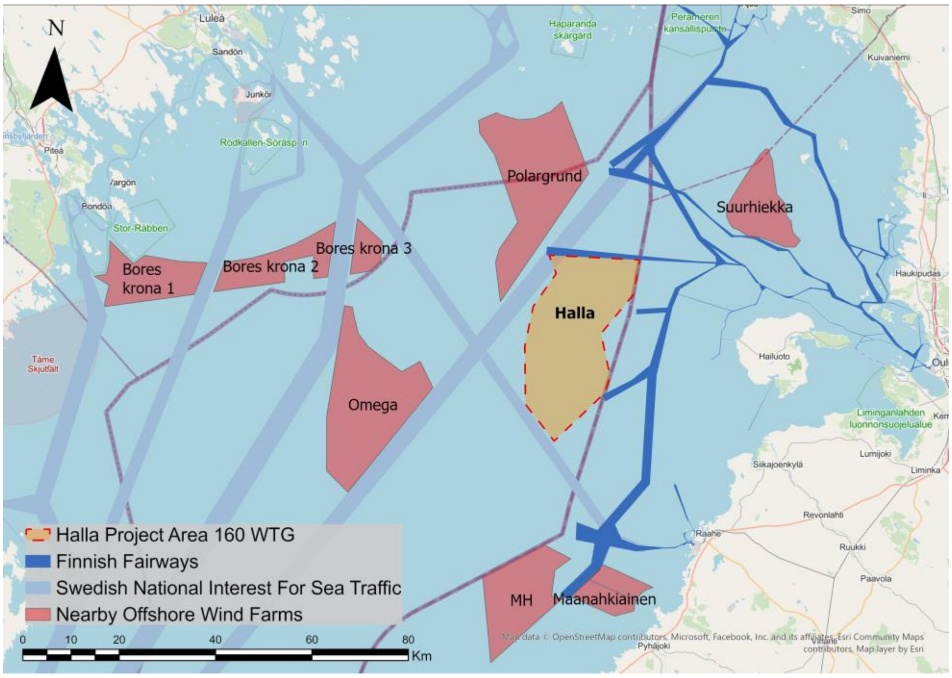

Figure 5. Map showing the Halla Project Area and nearby OWFs.

3.4 Ice conditions

In this chapter, the ice conditions during the winter 2021-2022 is described. This is the year in which the traffic in the area is analysed. To be able to analyse ice conditions in relation to traffic patterns, more detailed information about ice conditions during winter 2021-2022 is described.

The 2021–2022 ice winter was a mild ice winter, though it was longer than usual in the Gulf of Bothnia. The Swedish Transport Administration's assistance restrictions for winter shipping came into force in the ports of Torneå, Kemi and Oulu during the month of December 2021. The month of December was colder than usual, and the ice cover spread. In January 11, it reached an area of

77.460 km^2 where the Gulf of Bothnia and the Quark froze almost completely. The Bothnia Bay's ice was 20–35 cm thick. After this the weather became milder and very windy. South-westerly storm in the Gulf of Bothnia caused all the drift ice at sea to pack together into an arc outside the Kemi I lighthouse on January 13 and the ice became very difficult to break. Lasting until the end of the month, the weather alternated between mild south-westerly winds and shorter cold snaps.

February began with cold weather and on February 4 the ice reached its maximum extent with an area of 93 000 km^2 (Figure 6), and the Gulf of Bothnia was then completely ice-covered. According to this measure, the ice winter is classified as mild. The longest distance for the vessels to travel in ice from Kemi to the ice edge was on February 4, 194 M.

At the beginning of March, a wide rut ran along the Swedish coast in the Gulf of Bothnia, and the vessels going to the northernmost Finnish ports had to make their way through thick pack ice. This condition lasted through the month of March without major changes. In the Gulf of Bothnia, the thickness of the ice increased to 85 cm. At the end of the month, the extent of the ice was close to the long-term average. The ice melting that the warm days had set in motion now slowed down and the northerly wind caused the southern Gulf of Bothnia's ice to be pushed together.

The month of April was very cold at the beginning and the drift ice in the Gulf of Bothnia was moved further south by the northerly wind. A stream was quickly covered by thin, even ice and stretched from Kemi to the west and further south along the western part of the Gulf of Bothnia, which then drifted towards the Swedish coast. In the northern Gulf of Bothnia, a large area of open water opened up and the Bothnian sea ice rotted. In the Quark and in the Gulf of Bothnia, 6 Finnish and 4 Swedish icebreakers assisted. The ice gradually began to rot in the Vasa archipelago as well. The amount of ice decreased in the Gulf of Bothnia and by the end of the month practically all drift ice had moved down to the southern Gulf of Bothnia.

In the first part of May, the Bothnian Sea area was colder than normal, and the rate of ice melting was slow. The sea was completely ice-free on June 3. Therefore, the number of ice days on the Baltic Sea amounted to 221 during the ice winter 2021–2022. During the ice winter 2021–2022, 5 Swedish icebreakers and 8 Finnish were deployed. Number of towed vessels was measured in Finland at 224 and assisted vessels at 2 271. Operational season started 2021-12-03 and ended 2022-05-30 (FMI, 2022).

In general, in the vicinity of the Halla project area, the ice conditions are such that drift ice are common and ice ridges occur occasionally, which are difficult to force and constitute an obstacle to navigation according to the Finnish Transport Infrastructure Agency (Finnish Transport Infrastructure Agency, 2023). The ice conditions at maximum extent from 2010 to 2023 are also depicted in Appendix 1.

Maximum ice cover during the winter of 2021–2022 is illustrated in Figure 6. Maximum ice extent occurred on February 4, 2022.

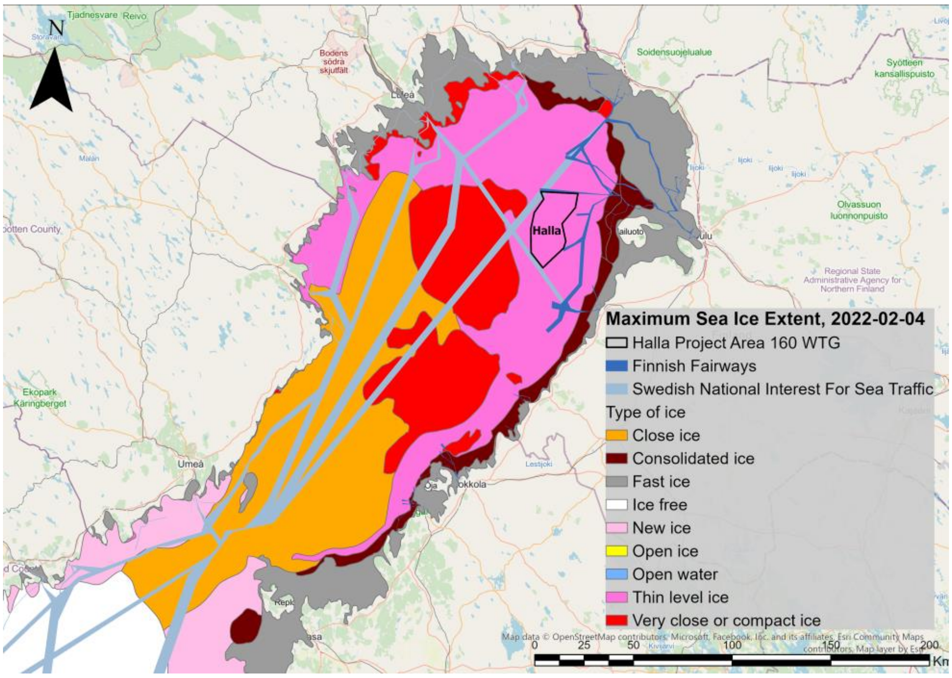

Figure 6. Map showing maximum sea ice extent during ice winter 2021-2022, adjacent to Halla project area.

3.5 Wind conditions

Wind data is compiled in Figure 7 and shows that the prevailing wind direction is from the south-southwest (SSW). 14% of the wind is southwest. The wind data is deemed to be representative of the entire Halla project area. The average wind speed in the centre point at 10 metres amounts to 6.38 m/s and is generally between 5–10 m/s.

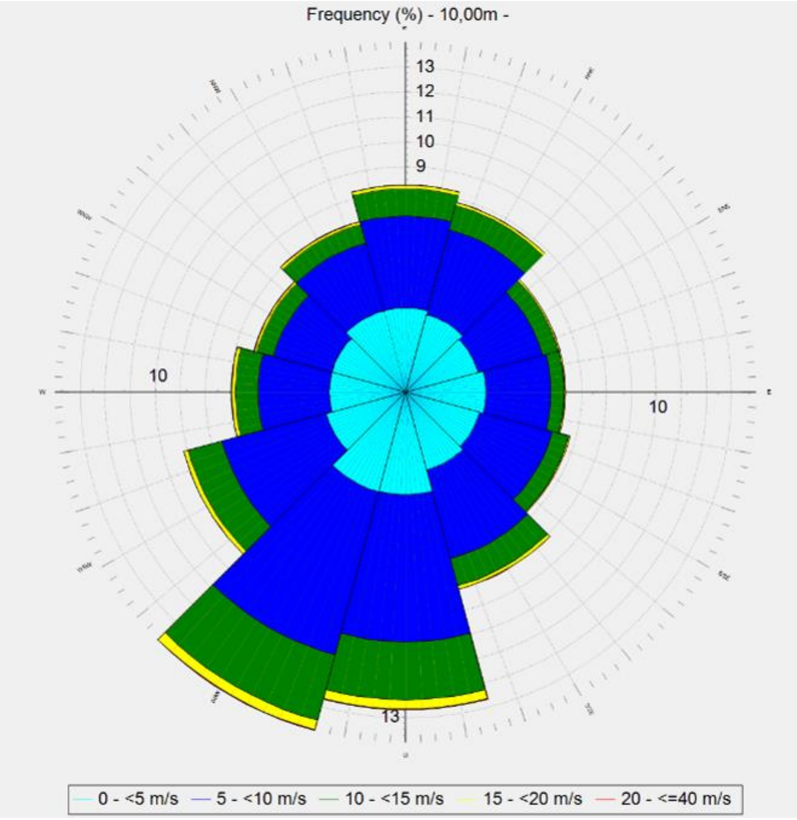

Figure 7. The figure shows a Wind rose which is based on a compilation of wind data from measurement points where the wind speed was measured at a level 10 metres above sea level.

On several of the Finnish shipping lanes there is an open sea area and thus the shipping lanes are unprotected against all winds. The navigation conditions are generally such that strong winds and heavy seas can pose obstacles to navigation. In some places, the fairways lie in the lee of, for example, small islands or skerries. Navigational conditions are summarized by the Finnish Transport Infrastructure Agency (2023) in charts for waterways in the vicinity of the area.

3.6 Shipping areas and routeing measures

The planned OWF is surrounded by several traffic lanes and shipping areas (see Figure 8). Along the northern edge of the project area runs the Oulu 1 fairway. Further north goes Kemi/Ajos/Tornio, which leads into the shipping lane Nordvalen – Kemi/Tornio. Nordvalen – Kemi/Tornio (shipping area also recognized within the Swedish national interest for sea traffic) also passes directly adjacent to the project area in the northwest. In the southwest, there is a shipping area Farstugrunden – Raahe (also recognized within the Swedish national interest for sea traffic). Outside Hailuoto and east of the Halla project area, the Raahe-Oulu-Kemi waterways run NW.

In addition, according to Traficom, a so-called pilotage route, however not a public right of way, runs through the Halla OWF (Traficom, 2022a). As it is not an established link, it is therefore not illustrated in Figure 8 below. The pilotage route is for pilotage of vessels with the largest draughts since it is a water-depth-secured area.

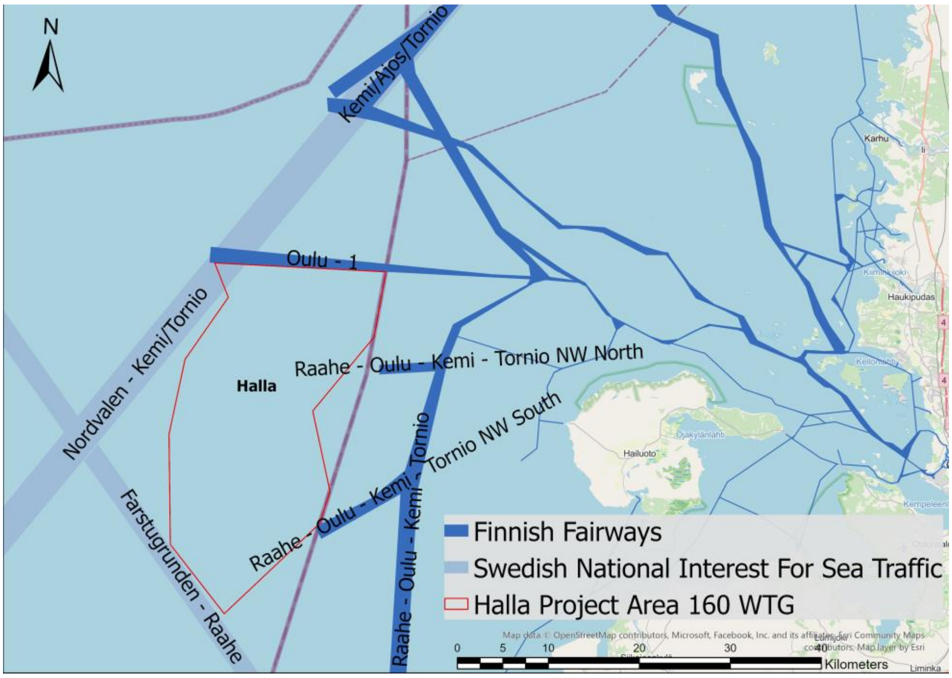

Figure 8. Map showing traffic lanes and fairways adjacent to Halla project area.

The fairway classification of the Finnish waterways (Traficom, 2021) describes that the intended use of the fairway. Kemi/Ajos/Tornio, Oulu 1 and Raahe-Oulu-Kemi NW are as trade routes regulated by the "Act on the Transport and Communications Agency (935/2018), § 2 Maritime Traffic Act (782/2019). This means that the fairways have primarily been built and maintained for merchant vessels, which refer to vessels in coastal traffic that pay fairway dues. Furthermore, all previously mentioned waterways have waterway class VL1, which means that they are main waterways for merchant vessels and are of national or regional importance and are used for the majority of goods flows within maritime traffic. Furthermore, these waterways can be operated all year round in all visibility conditions.

The shipping areas Nordvalen – Kemi/Tornio and Farstugrunden – Raahe which are reflected in the area are maritime traffic lanes. This means that it is the shortest navigable path between two points given sufficient water depth. These lanes are not fairways and prescribed or marked on the chart, except where they are covered by route systems. Maritime traffic lanes are often seen further out to sea and are also affected by international legislation (The Swedish Transport Administration, 2022).

3.7 Finland’s Maritime Spatial Plan 2030

Finland's Maritime Spatial Plan 2030 (Maritime Spatial Planning, u.d.) covers Finland's territorial waters and economic zone and complies with the Land Use and Construction Act. Notable is that the Maritime Spatial Plan is not a legally binding plan. In marine planning, areas with potential for the development of offshore wind power are identified for energy production. Other areas that are suitable for offshore wind power, but which sit outside the designated areas are also included in the Maritime Spatial Plan. During the planning round, it became evident that the Gulf of Bothnia has particularly good conditions for extensive establishment of offshore wind power.

The potential areas have been designated taking into account, among other things, shipping areas, depth, Natura 2000 areas, fishing areas and other designations, valued landscape and Defence Force’s requirements.

The conditions for the establishment of offshore wind power are good in the North Bothnian Sea, the Quark and the Gulf of Bothnia, especially in the open sea areas in the northern part of the Bothnian Sea and in the Gulf of Bothnia. Areas of shallow sea and ice conditions are distinctive for the area.

Maritime planning also identifies shipping areas, which are areas with significant traffic. These areas are generally used in shipping and are based on AIS data from 2016.

In Figure 9 Halla OWF is illustrated in relation to Finland’s Maritime Spatial Plan 2030. Pink areas are areas designated to be used for energy production. The southern half of Halla OWF consists of such an area.

The figure also illustrates what is known as a shipping area. These are areas that are recommended to be used by shipping and often function as extensions of the Finnish fairways established within the territorial sea of Finland. One such area passes through Halla's project area.

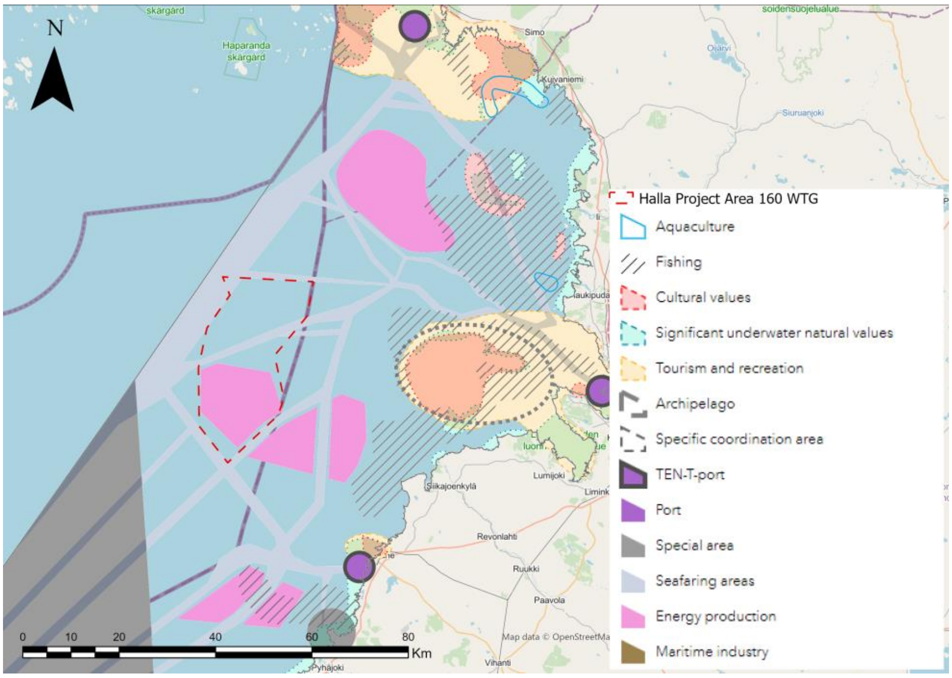

Figure 9. Illustrates Finnish maritime planning in the area around Halla OWF.

4 Data and method

4.1 Research design

The method is mainly based on the analysis and processing of geographical data and Automatic Identification System (AIS) data. AIS is a system that makes it possible to identify a vessel and follow its movements. Data reports are gathered from each individual vessel, regularly sending out information on a digital radio channel. AIS data is analysed in the ArcGIS Pro software to find out, among other things, how the traffic moves in the analysis area, how much traffic and what kind of vessels move in the vicinity of the Halla project area and how big the vessels that pass the project area are.

4.2 Data acquisition and sample

Automatic Identification System (AIS) data through 2022 has been obtained from the company Vessel Finder Ltd and delivered in a CSV file. The data contains information such as MMSI number, Timestamp, latitude, longitude, speed, size measures and vessel type.

4.3 Processing and management

4.3.1 FME

The software FME is used to create a layer as a shapefile based upon AIS-data. The output is a layer containing lines that represents transits with accompanying attributes. The spatial distribution of the lines is based on time stamps with a resolution every five minutes with associated coordinates. A transit is defined based on time stamps and MMSI number, which are a unique ID number per vessel. A new transit is registered on the unique ID number if more than 23 hours have passed since the previous time stamp.

In order to discern spatial patterns in shipping traffic, FME is used to process data of the transits. A grid with 500x500 metre spatial resolution is created and passage lines are imposed on the grid. Number of lines that overlaps are assigned with a Z-value. Centre points for the grid are created and based on this, a Digital Elevation Model (DEM) is created as a raster. The DEM layer is a visual representation of how traffic moves in the area. Visualisation is done in the form of a heatmap. The heatmap shows how high the concentration of vessel passages is at various locations. The concentration is put in relation to other areas within the same withdrawal area that is shown in the specific map.

4.3.2 ArcGIS pro

ArcGIS Pro has been used to process, analyse, and visualise the data in the report.

4.3.2.1 Vessel types

When processing data, all vessel types in the database are categorized into the categories describes in Table 3. To compile these, similar vessel types are merged. Class divisions are considered appropriate to assign the same designation to similar types of vessels to make patterns in traffic more visible.

Table 2. Table showing processing of AIS data where a reclassification of vessel types has been made.

Reclassified	AIS-type
Cargo/Ro-Ro	Cargo, all vessels of this type; Ro-Ro Cargo; Cargo, No additional information; Cargo, Reserved for future use; Cargo Cement Carrier
Assistance and Safety Vessels	Pilot Vessel; Tug; Towing; Law Enforcement; Search and Rescue; Military ops; Utility Vessel; Icebreaker
Passenger	Passenger, all vessels of this type; High speed craft (HSC)
Cargo/Tanker, Hazardous goods	Cargo Hazardous category A; Cargo Hazardous category B; Cargo Hazardous Category C; LNG Tanker; LPG Tanker; Tanker Hazardous category A; Tanker Hazardous category B; Tanker Hazardous category C; Tanker Chemical/Oil; Tanker Bitumen; Tanker No additional information; Cargo/Tanker with Oil Products; Tanker Reserved for future use
Other	Diving ops; dredging or underwater ops; antipollution equipment; Non-combatant vessel according to RR Resolution No. 18; Reserved; Spare-Local Vessel
Fishing	Fishing
Sailing and Pleasure Craft	Sailing; Pleasure Craft
Not available	Other Type; Not available (default)

4.3.2.2 Vessel size and distribution

To see the size of the vessel passages in relation to the project area, a diagram is created that illustrates vessel sizes. A selection (section) of the vessel passages is made for the diagram. The section is placed where the vessel passages are deemed to be the most but also representative of the route that runs along the intended project area.

4.3.2.3 Overlap analysis

A unique safety distance is applied as a buffer zone to all transit tracks within 5 M of the project area (as well as within the project area). The unique safety distance is based on the vessel length that each unique vessel has (6 vessel lengths are assumed according to PIANC safety distance recommendations). In all unique safety distances, 0.3 M (556 metres) has been included. The safety distance for each unique vessel is then made into a buffer zone illustrating the area that the vessel would have needed for an evasive manoeuvre. The proportion of buffer zones that overlap with the Halla project area illustrates the proportion of vessels that, according to the model, had not been able to make an evasive manoeuvre and thus risked colliding with a WTG.

To do this, the following unique safety distances (safety zone excluded) for every vessel are measures and applied as specified in PIANC's recommendations:

- d = 556 metres (0,3 M) + 6 vessel’s lengths

To make a conservative assessment and considering uncertainties, safety distances are applied on both starboard and port side. This is due to the vessels moving direction cannot be ensured.

4.3.2.4 Ice conditions

In order to be able to put traffic flow and any changes in this in relation to ice coverage in the project area, a division of traffic is also made during the months when ice occurs in the vicinity of the project area for wind power. Months with sea ice in 2022 consist of the months of January, February, March, April and May and AIS data over these months are thus categorized under months with sea ice and the remaining months are categorized under months without sea ice. During the month of December there are elements of sea ice, but extremely little and ice that melted quickly. Therefore, the month of December falls within the division that includes months without sea ice.

4.3.2.5 Bathymetry

The depth conditions in the analysis area are also studied. A bathymetry (ocean depth) is created over the analysis area in the GIS. Depth data is downloaded from the National Centers for Environmental Information (Bathymetric Data Viewer) in a raster (NOAA, 2022).

The depth values are given in meters and are stored as 32-bit floating point values. The cell size has a resolution of ~90 metres. Raster data is processed, and cell values (float) were converted to whole numbers (integer) using the Raster calculator tool in ArcGIS Pro. Then a reclassification is done, and breakpoints are created in 5 metre intervals from 0 – 100 metres. The raster layer is then converted to a polygon layer. The bathymetry shows an interval of 5 metres where value 0 is depth values from 0–5 metres, value 5 is depth values 5–10 metres etc. Value 100, on the other hand, represents depth value 100 and deeper.

5 Traffic analysis

5.1 Vessel types

Figure 10 shows the vessel length of the vessels within the analysis area in 2022. The average vessel is 102 metres, and the median vessel is 110 metres. There are relatively few longer vessels in the analysis area. The longest vessel is 242 metres. Some vessels are assigned as 0 metres. These are vessels where data for length is missing, which explains the number of vessels with this number (0-7.5 metres). The length of the standard vessel is defined so that 98.5% of the vessels using the current route are not larger than the standard vessel. The standard vessel in the analysis area (98.5 percentile) amounts to 229 metres. In general, the vessels' lengths within the selected area for the traffic analysis are relatively short, this in comparison with other areas that include an equally large area of AIS data, for example in more southerly waters.

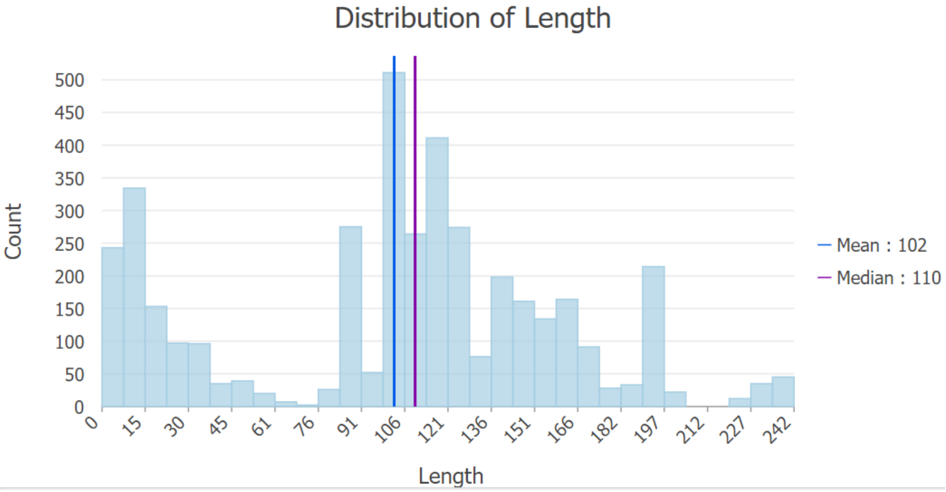

Figure 10. Figure showing vessel size and distribution.

As shown in Figure 11 and Figure 12 below, the traffic in the area mainly consists of Cargo/Ro-Ro vessels, followed by Assistance and Safety Vessels and Cargo/Tankers, Hazardous Goods, both during months with and without sea ice. Months with sea ice, the vessels are fewer overall, but the number of Assisting and Safety Vessels are larger. There are more vessels that are defined as the "Other Vessel" category during months without sea ice, the same applies to Passenger vessels and Fishing vessels. Sailing and Pleasure Craft Vessels are not seen in the area at all during sea ice months. The reason for this could be that these vessels are not suitable for traveling in ice conditions as they do not have the size or engine power necessary to force sea ice. The icebreaker operation only assists vessels that achieve a certain ice class, which many smaller vessels do not.

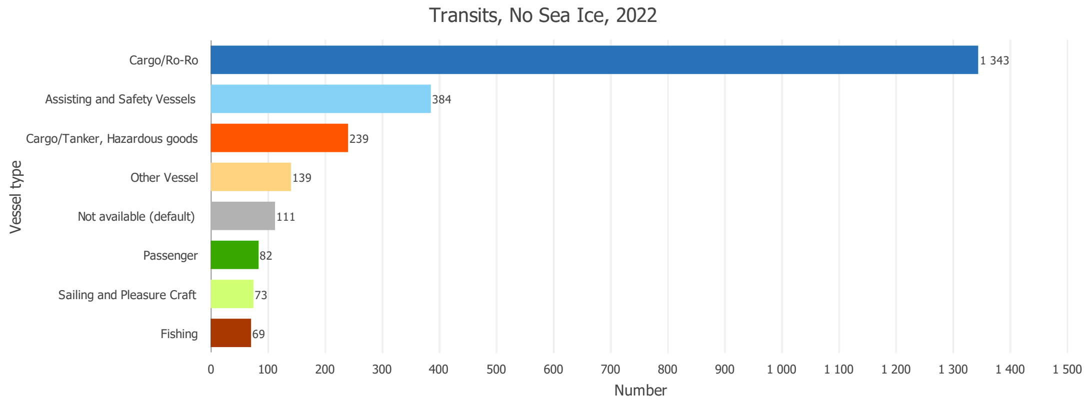

Figure 11. Diagram showing vessel types and frequency in the area of analysis during No Sea Ice, 2022

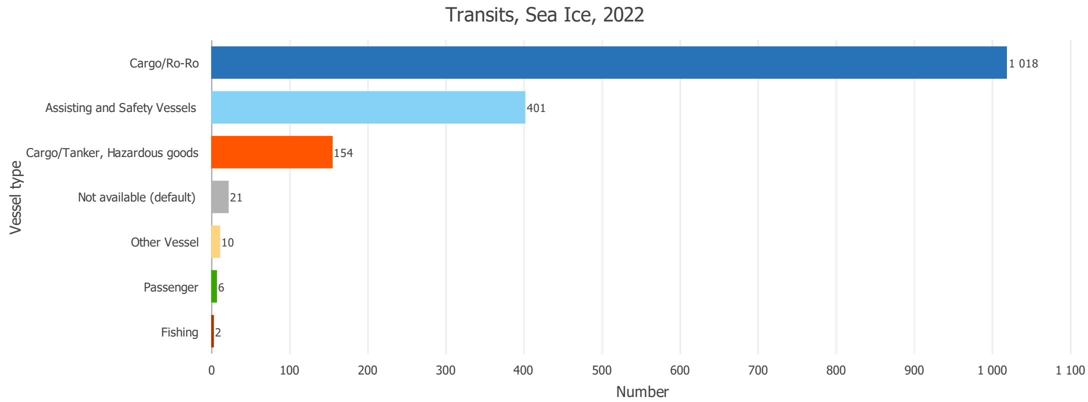

Figure 12. Diagram showing vessel types and frequency in the analysis area data during Sea Ice, 2022

Distribution of the number within each vessel type for the vessel category Assistance and Safety Vessels is illustrated in Table 4.
During ice-free months, assistance and safety vessels mainly consist of tug(boat)s, followed by Pilot Vessels, Pusher Tugs and Towing boats, and then Search and Rescue Vessel. During sea ice it is mainly icebreakers that move in the area followed by Pilot Vessels, Pusher Tugs and Tugboats.

Table 3. Table showing Assistance and Safety Vessels and frequency in the area of analysis during months with sea ice, and with no sea ice, 2022.

Vessel type	Number during sea ice	Number during no sea ice
Icebreaker	160	15
Pilot Vessel	115	76
Pusher Tug	68	67
Tug	46	118
Towing	5	59
Utility Vessel	0	2
Law enforcement	5	11
Search and Rescue Vessel	0	35
Military ops	2	1
Total number	**401**	**384**

Hazardous Goods are transported in the area and are reported below in Table 5, both during months without sea ice and with sea ice. A clear majority of dangerous goods traffic consists of Chemical/Oil Tankers. Tankers transporting LNG are also more common, followed by Tankers transporting Bitumen. Tankers transporting LPG and Cargo of Hazardous category A, B and C occur rarely in the analysis area.

Table 4. Table showing Hazardous goods and frequency in the analysis area during months with sea ice, and with no sea ice, 2022.

Vessel type	Number during sea ice	Number during no sea ice
Cargo/Tanker Chemical/Oil	115	163
Tanker, Bitumen	4	26
Tanker, LNG	19	22
Tanker, LPG	2	12
Cargo, Hazardous category A	5	11
Cargo, Hazardous category B	1	0
Cargo, Hazardous category C	8	5

Table 5 below reports statistics on ship types and sizes during months with and without sea ice. In general, the various routes that run along the shipping areas and fairways are operated by Cargo/Ro-Ro during months with and without sea ice. Oulu 1 and Farstugrunden – Raahe stand out during sea ice months as being dominated by Assistance and Safety Vessels. In general, during months with sea ice, a large number of vessels that fall within the category of Assistance and Safety Vessels make up the route. Also common are Cargo/Tankers, Hazardous goods, especially in Raahe – Oulu – Kemi and the north-west running routes, both northbound and southbound. Other vessel types otherwise appear sparingly in the lanes around Halla OWF.

Table 5. Table showing statistics of vessel type and vessel length over transits during sea ice, and during no sea ice in the different fairways and traffic lanes. Statistics with less than 2% is not shown in the table.

Shipping area/Fairway	Vessel type	Mean (m)	98,5 (m) percentile	Vessel type	Mean (m)	98,5 (m) percentile
	Months with sea ice			Months with no sea ice		
Raahe – Oulu – Kemi - Tornio	Cargo/Ro-Ro (61%) Cargo/Tanker, Hazardous goods (22%) Assisting and Safety Vessels (16%)	130	193	Cargo/Ro-Ro (64%) Cargo/Tanker, Hazardous goods (31%) Assisting and Safety Vessels (3%)	134	242
Raahe – Oulu – Kemi - Tornio NW North	Cargo/Ro-Ro (56%) Cargo/Tanker, Hazardous goods (26%) Assisting and Safety Vessels (17%)	132	193	Cargo/Ro-Ro (72%) Cargo/Tanker, Hazardous goods (27%)	149	201
Raahe – Oulu – Kemi - Tornio NW South	Cargo/Ro-Ro (63%) Assisting and Safety Vessels (17%) Cargo/Tanker, Hazardous goods (17%) Passenger (3%)	123	195	Cargo/Ro-Ro (62%) Cargo/Tanker, Hazardous goods (37,5%)	137	242
Nordvalen – Kemi/Tornio	Cargo/Ro-Ro (73%) Cargo/Tanker, Hazardous goods (10%) Assisting and Safety Vessels (9,5%)	118	190	Cargo/Ro-Ro (87%) Cargo/Tanker, Hazardous goods (10%) Assisting and Safety Vessels (2%)	124	191
Oulu 1	Assisting and Safety Vessels (41%) Cargo/Ro-Ro (33%) Cargo/Tanker, Hazardous goods (26%)	123	176	Cargo/Ro-Ro (83%) Assisting and Safety Vessels (17%)	126	180
Farstugrunden - Raahe	Assisting and Safety Vessels (55%) Cargo/Ro-Ro (45%)	142	226	Cargo/Ro-Ro (58%) Assisting and Safety Vessels (38%) Cargo/Tanker, Hazardous goods (4%)	143	187
Pilotage Route	Cargo/Ro-Ro (79%) Cargo/Tanker, Hazardous goods (10%) Assisting and Safety Vessels (10%)	124	193	-	-	-

5.2 Vessel transits

5.2.1 Shipping areas

In 2022, 1 125 vessel transits were registered through the Halla project area. Considering transits through Halla and 5 M around the project area, 2 253 vessels are counted.

The whole area of analysis that is presented in Figure 13 counts to approximately 14 300 km^2 and contains 4 052 transits during 2022.

In Figure 13 below, a random selection of 5% of the vessel traffic in 2022 is illustrated. It gives an overview and an indication of how the traffic moves and what types of vessels there are in the area.

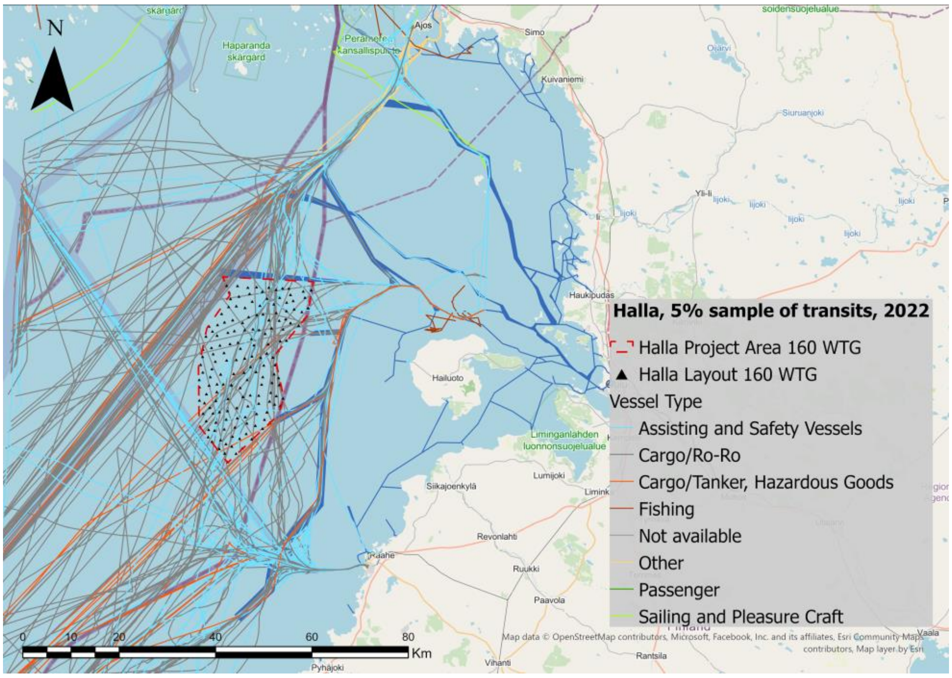

Figure 13. Map showing 5% sample of the transits in the analysis area during 2022, full year.

The traffic that follows the various shipping lanes is limited to a few vessels per day. Table 6 below shows the number of passages within various shipping areas in total in 2022 as well as the average number of passages per day.

Table 6. The table shows the number of passages within various shipping areas and the outcome per day based on average traffic within shipping area. This means that the number illustrated in the table is not an exact figure. The number may change slightly if an average of the traffic is taken at another cross section of shipping area.

Route	Transits in total	Average transits per day[2]	Transits in total	Average transits per day[3]
	Months with sea ice		Months without sea ice	
Raahe – Oulu – Kemi - Tornio	237	1,6	421	2,0
Raahe – Oulu – Kemi – Tornio NW North	152	1,0	123	0,6
Raahe – Oulu – Kemi – Tornio NW South	30	0,2	248	1,2
Nordvalen – Kemi/Tornio	226	1,8	595	2,8
Oulu 1	27	0,2	6	0,03
Farstugrunden – Raahe	55	0,4	142	0,7
Pilotage route	330	2,2	-	-

Where ice obstacles arise, vessels are often forced to take other routes. This makes shipping navigation during months with sea ice different from shipping navigation during months with no sea ice which is shown in Figure 14 and Figure 15.

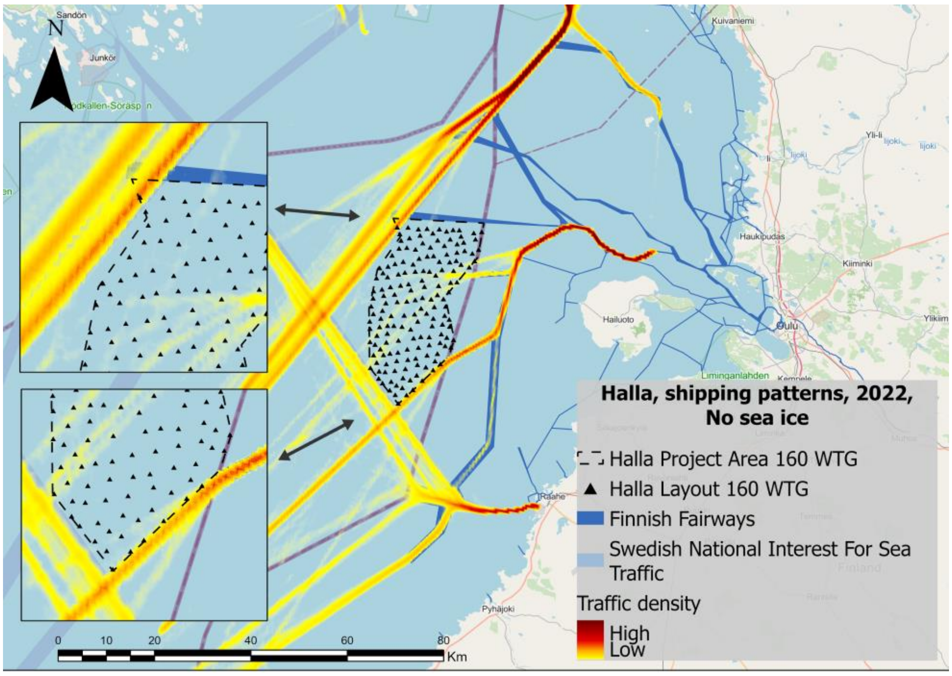

Figure 14. Heatmap of shipping patterns around Halla during periods with no sea ice (2022-06-01 – 2022-12-31).

[2] Transits in total / 151 days
[3] Transits in total / 214 days

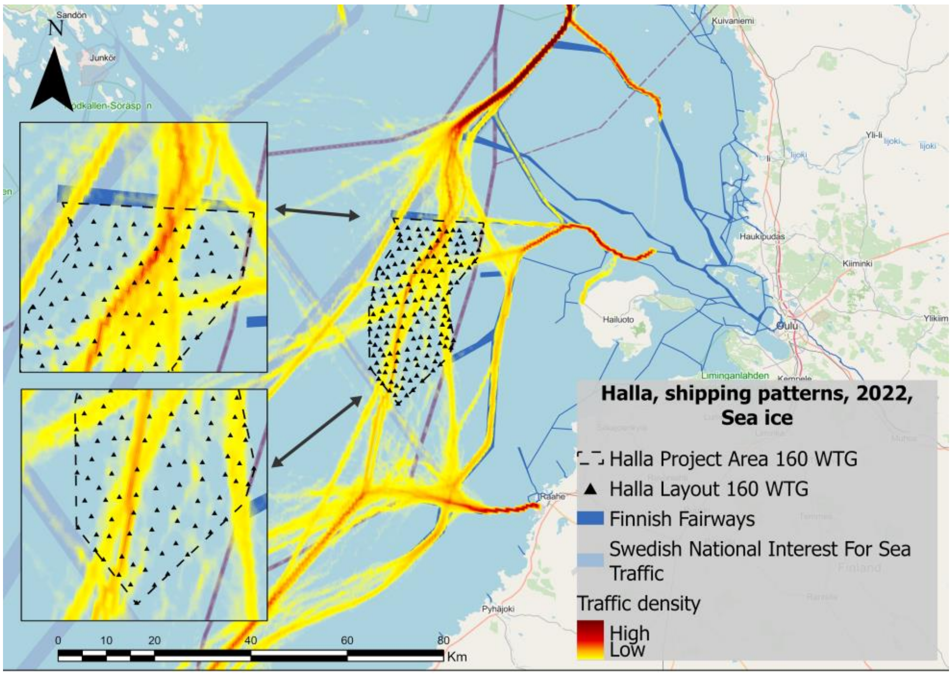

Figure 15. Heatmap of shipping patterns around Halla during periods with sea ice (2022-01-01 – 2022-05-31).

The traffic is primarily in the shipping route northwest of the project area, Nordvalen – Kemi/Tornio. According to AIS data, traffic density is highest in Nordvalen – Kemi/Tornio during months without sea ice. The lane that extends the Raahe-Oulu-Kemi-Tornio NW fairway also has a higher traffic density. During months with sea ice, the traffic density Nordvalen – Kemi/Tornio is reduced. There is also some traffic moving through the Halla project area. A higher traffic density is seen through the project area, especially during months with sea ice. The vessels passing through the Halla project area during months with sea ice creates an unofficial pilotage route (Traficom, 2022a) which is used as a water-depth-secured area, serving pilotage for vessels with the largest draughts. Traffic on Raahe-Oulu-Kemi-Tornio NW continues to be reduced during months with sea ice. What is also clear is that the intensity is low throughout the year along Oulu 1, the fairway north of the Halla project area.

Correspondingly with shipping patterns during periods with sea ice within Halla project area, icebreakers follow the same pattern which is shown in Figure 16. This visualizes the pilotage route. A total of 11 different icebreakers made 175 passages in the analysis area during 2022.

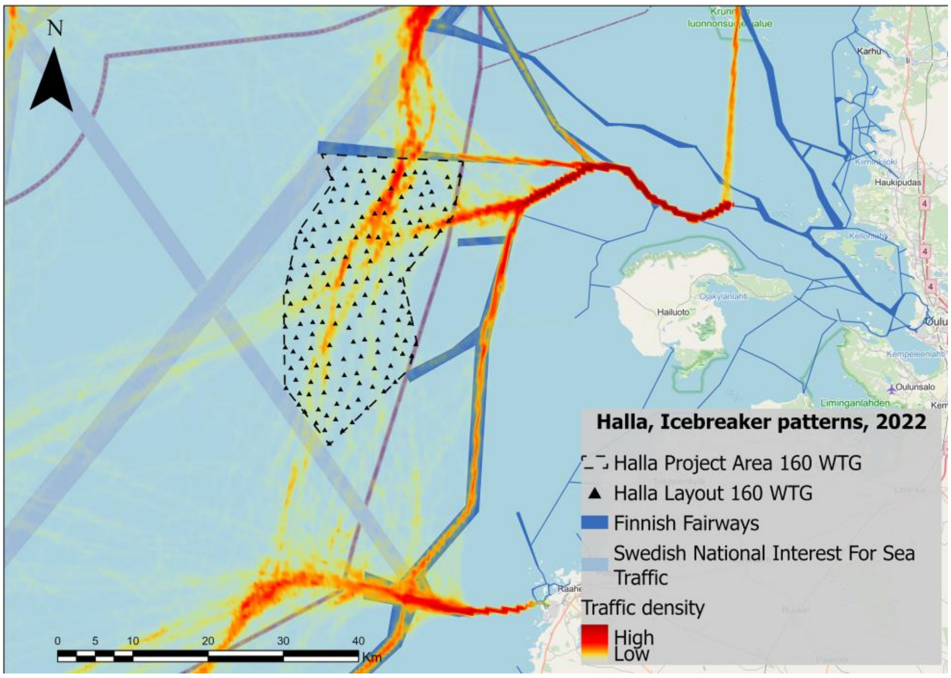

Figure 16. Heatmap showing icebreaker patterns during 2022 around Halla project area.

During months without sea ice, the highest concentration of traffic nearby Halla OWF is centred in Nordvalen – Kemi/Tornio, northwest of Halla. During months with sea ice, the highest concentration of traffic is through the pilotage route. Furthermore, the traffic is overlapping with the north-western corner, throughout the year.

During months without sea ice, there is more dense traffic southwest of the project area in the shipping area Farstugrunden – Raahe (see Figure 14), especially in comparison to during months with sea ice.

The traffic that runs southeast of Halla, in the shipping area Raahe-Oulu-Kemi NW overlaps with the project area somewhat and generally runs directly along the edge of the project area. The traffic that passes through the project area during months without sea ice is more dispersed but appears to be linked with the north-west route Raahe-Oulu-Kemi-Tornio NW which is seen east of the Halla project area.

The conclusion is that the during months with sea ice the traffic is concentrated in the pilotage route, and to a lesser extent also in Nordvalen – Kemi/Tornio and Raahe – Oulu – Kemi NW. During months without sea ice, the traffic is concentrated primarily in Nordvalen – Kemi, Raahe – Oulu – Kemi NW South and Farstugrunden – Raahe.

5.2.2 Vessel distribution

To illustrate how vessel traffic passes in relation to the Halla project area and the busiest routes Nordvalen – Kemi/Tornio northeast of the OWF and Raahe-Oulu-Kemi-Tornio NW southeast of the OWF, diagrams of the number of passages at different distances from a reference point in the Halla project area have been produced. The diagrams are illustrated in Figure 17 and Figure 18. The section and midpoint of the diagram are illustrated in Figure 19.

The diagram in Figure 17 below shows how the vessels during months without sea ice in the area mainly go in Nordvalen – Kemi/Tornio northwest of Halla project area and in the route outside Raahe-Oulu-Kemi-Tornio NW which runs along the south-eastern edge of the project area. What is also apparent is that there is a shift in traffic in a north-westerly direction in relation to the shipping lane Nordvalen – Kemi/Tornio. Furthermore, the traffic that is concentrated in a lane outside Raahe-Oulu-Kemi-Tornio NW also has a north-west shift, which in practice means that the majority of the traffic is concentrated closer to the Halla project area.

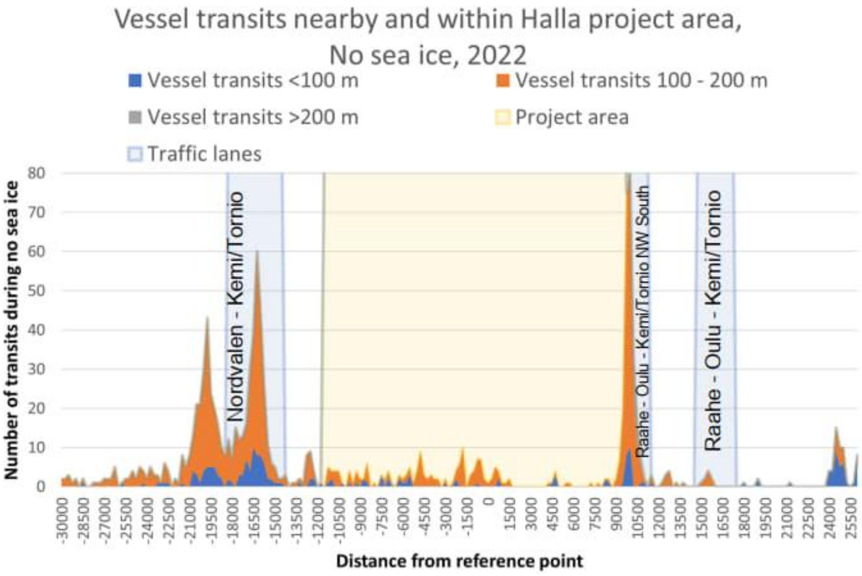

Figure 17. Vessel transits nearby and within Halla project area during no sea ice and their distribution according to ship length.

Figure 18 reflects that a larger part of the traffic during months with sea ice positions itself in lanes through the Halla project area. The traffic in Nordvalen – Kemi/Tornio is slightly shifted to the southeast, which means closer to the outer edge of the project area.

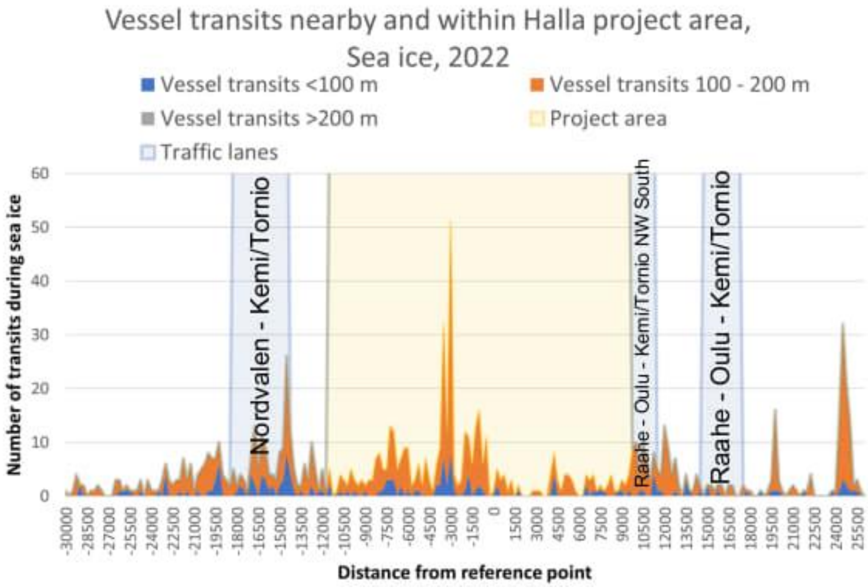

Figure 18. Vessel transits nearby and within Halla project area during sea ice and their distribution according to ship length.

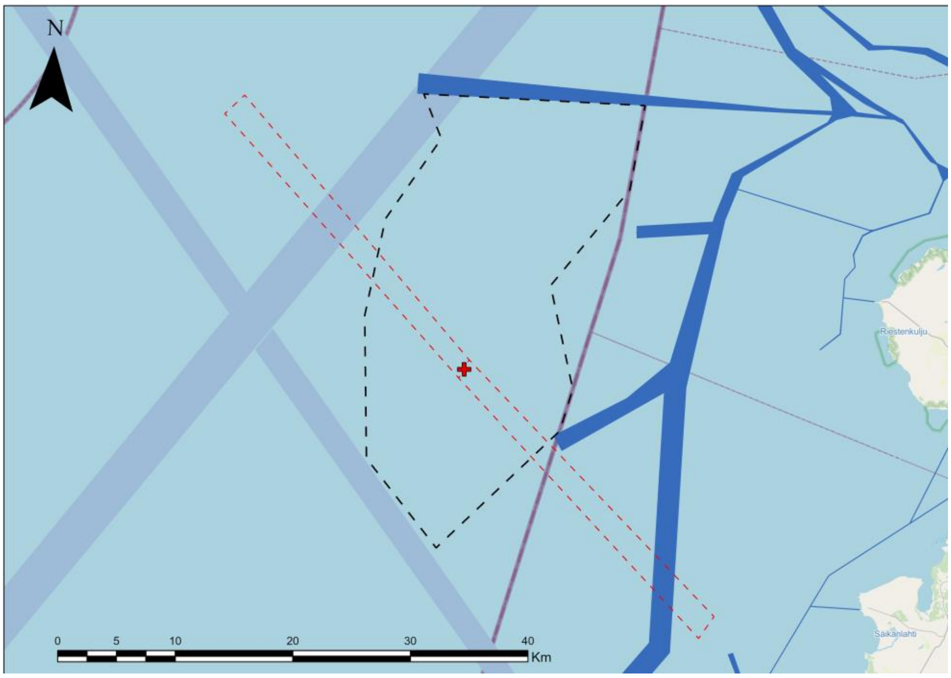

Figure 19. Map showing the cross section where data for the size distribution of the vessels moving in the shipping areas Nordvalen – Kemi/Tornio, Raahe – Oulu – Kemi/Tornio NW South and Raahe – Oulu – Kemi/Tornio, as shown in Figure 17 and Figure 18 around the OWF area is extracted.

5.2.3 Overlap analysis

In order to safely carry out a manoeuvre (such as anchoring and round turns), a safe, navigable distance must be provided between OWFs and traffic lanes according to (PIANC) recommendations which is described in chapter 2.2.

In order to determine the proportion of current traffic within 5 M that needs to be relocated if Halla is established, an individual safety distance is calculated for each vessel based on the space required for each vessel to perform a safe evasive manoeuvre. The safety distance for each vessel is based on the individual length of the vessel and is illustrated as a buffer zone from the vessel passage[4]. An overlap analysis then studies how many buffer zones overlap with the project area (representing the required space for evasive manoeuvres).

As shown in Table 7 below, in 2022, 519 vessel transits passed through the Halla project area during periods with no sea ice. For periods during sea ice, 706 vessel transits passed through the Halla project area. Within a zone of 5 M there were 1 246 vessel transits with no sea ice and 1 007 vessel transits with sea ice. Within Halla project area, with a safety distance including safety zone, there were 809 transits during sea ice and 877 transits during no sea ice.

Table 7. Table showing data of transits whose required space for evasive manoeuvres is overlapping the project area.

Transit area	Transits during sea ice	Transits during no sea ice
Within 5M	1 007	1 246
Within the project area	706	519
Within the project area with safety distance	781	790

A greater proportion of vessels within 5 M of the project area (77% during months with sea ice[5], 63% during months without sea ice[6]) passing the area would not be able to manoeuvre without overlapping with the project area, thus would need to choose a different route with Halla established.

5.3 Future traffic

Traficom states in its report of national traffic forecasts (Traficom, 2022b) that freight transport by sea is expected to increase and has produced forecasts until 2060. According to foreign maritime traffic forecasts for 2060, total exports in the maritime traffic in Finland will by 2060 be approximately 9 percent greater in terms of tonnage than in 2021. Correspondingly, according to the forecast, total imports will be approximately 19 percent greater. Total exports are expected to remain stable until 2035, after which they are expected to start growing. Total imports are expected to increase significantly in the next few years, as imports from Russia transported by rail are replaced by imports from other countries transported by sea. After this, total imports are expected to decrease due to decreasing crude oil imports, among other factors. However, there are significant uncertainties in the starting points of traffic forecasts due to major changes in the operating environment.

The Swedish Transport Agency's forecasts indicate that freight transport by sea is expected to increase by approximately +1.7 % per year until 2040

[4] Calculation of safety distance for example vessels of 200 meters: 200 m x 6 vessel lengths + 556 m (0,3 M) = 1 756 m

[5] 781 transits / 1 007 transits = 77% of all transits within 5 M from project area would not be able to perform a 360-degree turn without overlapping with the project area.

[6] 790 transits / 1 246 transits = 63% of all transits within 5 M from project area would not be able to perform a 360-degree turn without overlapping with the project area.

(Trafikverket, 2023) in terms of the number of tonne kilometres per year. This means that freight transport (measured in the number of tonne kilometres) in 2040 will increase by approximately 33.2 % compared to 2023.

There are several reasons for the increased share of traffic and larger vessels. Traficom points out (2022a) that the draught on the new Oulu Strait and the deepening of Kemi Ajos fairway will increase maritime traffic and enable larger vessels. Furthermore, traffic to Ajos will increase significantly following the completion of Metsä Group's new bio-factory, which will use a larger vessel fleet.

As stated previously in the analysis, establishment of the Halla OWF would lead to some changes in traffic and patterns. Potential scenarios could mean that even more traffic will concentrate in Nordvalen – Kemi/Tornio, and in Raahe – Oulu – Kemi/Tornio NW South.

Considering the above information, it is likely that the vessels in the area around Halla OWF will rather increase in size and not as much in number. However, it is uncertain whether the expected increase in transport work leads to a greater number of ships or to the ships themselves becoming larger and heavier.

5.4 Nearby OWFs

Halla OWF and nearby other planned OWFs are illustrated below in Figure 20.

Polargrund OWF is planned and located approximately 2,8 kilometres northwest of the Halla OWF, hence it is the closest OWF. However, the closest distance between turbines within Halla project area and Polargrund project area is 4 725 metres. The shipping area Nordvalen – Kemi/Tornio is located between Halla and Polargrund OWF and is the shipping area with most traffic in the area. The establishment of Halla and Polargrund OWF is assumed to result in higher traffic density (both more traffic as well as congested traffic) due to traffic currently passing through the OWFs will have to use the shipping area as well as keeping a safe distance to the OWFs. Thus, establishment of both OWFs are assumed to result in cumulative effects on traffic. Note that traffic is expected to increase by one or two vessels per day in Nordvalen – Kemi/Tornio.

Omega OWF is planned and located approximately 19 kilometres southwest of Halla OWF. It is also located close to the shipping area Nordvalen – Kemi/Tornio, and there is a possibility that it can affect the traffic to move closer to Halla OWF. Traffic currently passing though Omega OWF will also have to use Nordvalen – Kemi/Tornio, hence increasing traffic in the shipping area. Thus, establishment of both OWFs are assumed to result in cumulative effects to some extent on traffic, with traffic being shifted slightly more eastwards.

Bores Krona 1, 2, 3 OWF is planned and located approximately 33 kilometres west of Halla OWF. Due to the long distance from Halla OWF, the cumulative effects of Bores Krona 1, 2, 3 OWF are assumed to have negligible impact on traffic patterns closer to Halla.

Suurhiekka OWF is planned and located approximately 20 kilometres northeast of Halla OWF. Between Suurhiekka and Halla OWF 3-4 fairways are located. Traffic currently passing through the OWFs is likely to use the closest fairway to navigate around the OWFs once established. Due to the location of the fairways between the OWFs, the traffic changes for Halla OWF are not assessed to affect the traffic patterns around Suurhiekka OWF, and vice versa. Thus, the cumulative effects on traffic patterns of Suurhiekka OWF are assessed to be negligible.

MH OWF is planned and located approximately 21 kilometres south of Halla OWF. The shipping area Farstugrunden – Raahe is located between MH and Halla OWF. The location of MH OWF is not expected to affect the traffic in Farstugrunden – Raahe notably, and thus the cumulative effects on traffic patterns of MH OWF are assessed to be negligible.

Maanahkiainen OWF is planned and located approximately 27 kilometres south of Halla OWF. Maanahkiainen OWF is located close by MH OWF, but even further from Halla OWF. Thus, the cumulative effects on traffic patterns of Maanahkiainen OWF are assessed to be negligible.

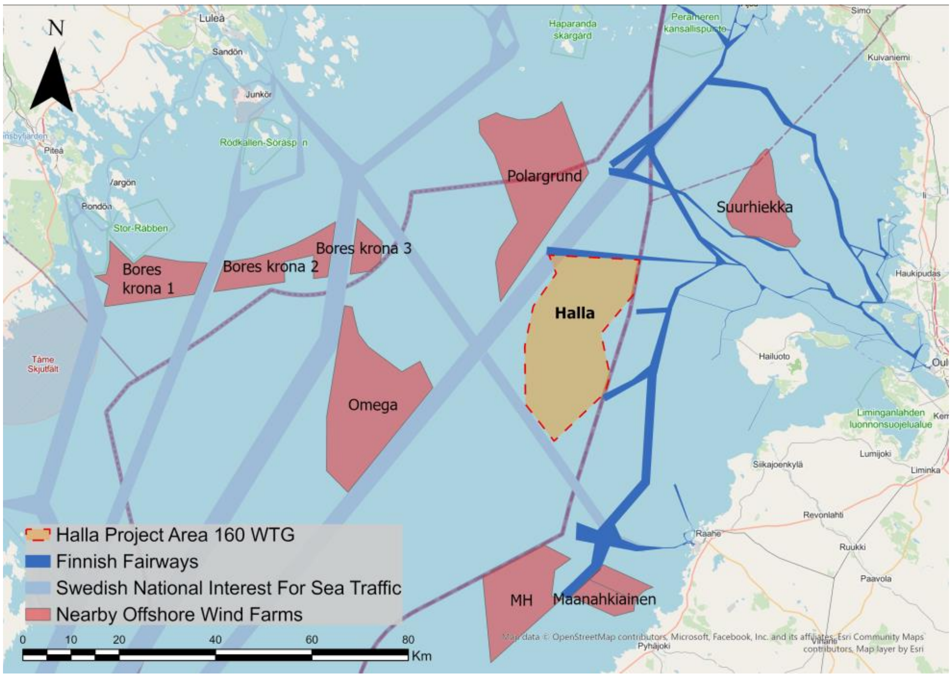

Figure 20. Map showing the Halla Project Area and nearby OWFs

Establishment of the Polargrund OWF could mean that the amount of traffic increases in Nordvalen – Kemi/Tornio. This may also lead to traffic being shifted closer to the Halla project area. Traficom states (2022a) that with the Polargrund OWF, shipping patterns could change compared to the current situation, especially during winter.

Polargrund is planned to be established on the western side of Nordvalen – Kemi/Tornio, close to the Halla project area. As shown in Table 8, there was during 2022 only about 1-3 passages per day pass through Nordvalen – Kemi/Tornio. A smaller shipping area runs from the fairway Ajos - Kemi/Tornio and through parts of Polargrund. This route will probably have to go through Nordvalen – Kemi/Tornio when Polargrund is established, which means that the traffic density in this lane may increase slightly. However, it is roughly not more than 1 vessel per day. Polargrund is also planned to be so close to Nordvalen – Kemi/Tornio that parts of the shipping area touch Polargrund's project area. Establishment of Polargrund may therefore mean that traffic is shifted in an eastern direction, i.e., towards Halla OWF. This would potentially result in less space for traffic through Nordvalen – Kemi/Tornio than the current situation. Thus, fewer opportunities for evasive manoeuvres if necessary.

Table 8. The table shows the number of passages within Nordvalen – Kemi/Tornio in total during 2022 and the outcome per day. It also shows a hypothetical scenario based on estimation with establishment of Polargrund OWF. The data is based on average traffic within the shipping area. This means that the number illustrated in the table is not an exact figure. The number may change slightly if an average of the traffic is taken at another place within the shipping area.

Fairway	**Transits in total**	**Transits per day**[7]	**Transits in total**	**Transits per day**[8]
	Months with sea ice		**Months without sea ice**	
Nordvalen – Kemi/Tornio	226	1,8	595	2,8
Nordvalen – Kemi/Tornio with establishment of Polargrund[9]	322	2,1	655	3

It should be noted that during the construction phase of the OWFs, traffic in the area may increase temporarily.

5.5 Safety distance

According to the guidelines regarding the width of a traffic lane based on PIANC (2018) and The Ministry of Infrastructure and the Environment, Netherlands (2014), the future shipping lanes for transport to and from the Bothnian Bay, require a width of around 916 metres[10]. All transits within the area of analysis amounts to 4 052, which requires 2 vessels side to side (less than 4 400 vessels per year using the route). Hence, the calculation considers potential increase in number of transits. Therefore, the vessels using each fairway or shipping lane, will not exceed 4 400 vessels per year taking into account Traficom (2022b) and the Swedish Transport Agency's (2023) forecasts.

There are different ways to define a safety distance. Traficom (2022a) and PIANC (2018) are presented and compiled below.

<u>Traficom safety distance</u>

To meet Traficom's (2022a) desire of 1.5 km safety distance between fairway areas and OWF, in combination with a recommended width of the shipping area being 916 metres, the total distance between Halla OWF and Polargrund OWF is recommended to be 3 916 metres.

<u>PIANC safety distance</u>

Considering guidelines of PIANC (2018), the recommended safety distance amounts to 1 930 metres[11]. In total, the recommended width, including shipping

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[7] Transits in total / 151 days
[8] Transits in total / 214 days
[9] In a hypothetical scenario based on estimation
[10] Shipping lane = 2 x 2 x 229 (98,5 percentile) = 916. 98.5 percentile is based upon all traffic within area of analysis.
[11] PIANC:s recommended safety distance = 556 metres (0,3 M for starboard manoeuvres) + 229 (98,5 percentile vessel) x 6 = 1 930 metres

lane and a safety distance on each side of the shipping lane, results in a minimum distance of about 4 776 metres[12].

Conclusively, with a distance of 4 725 metres between the closest WTGs within Halla and Polargrund OWF (see Figure 21), the recommended safety distance is not fulfilled. However, the second closest WTG is located at a distance of 5 833 metres OWF (see Figure 21), which does meet the PIANC (2018) safety distance guidelines as well as Traficom's (2022a) recommendations. Overall, the general width of the passage between Halla OWF and Polargrund OWF is around 6 200 metres, with the third closest WTG is located at a distance of 6 385 metres from Polargrund OWF (see Figure 21). It is only in the upper left corner, north of Halla on the western side, where it's a narrower passage, with the closest distance of 2 860 between Halla project area and Polargrund OWF (see Figure 21).

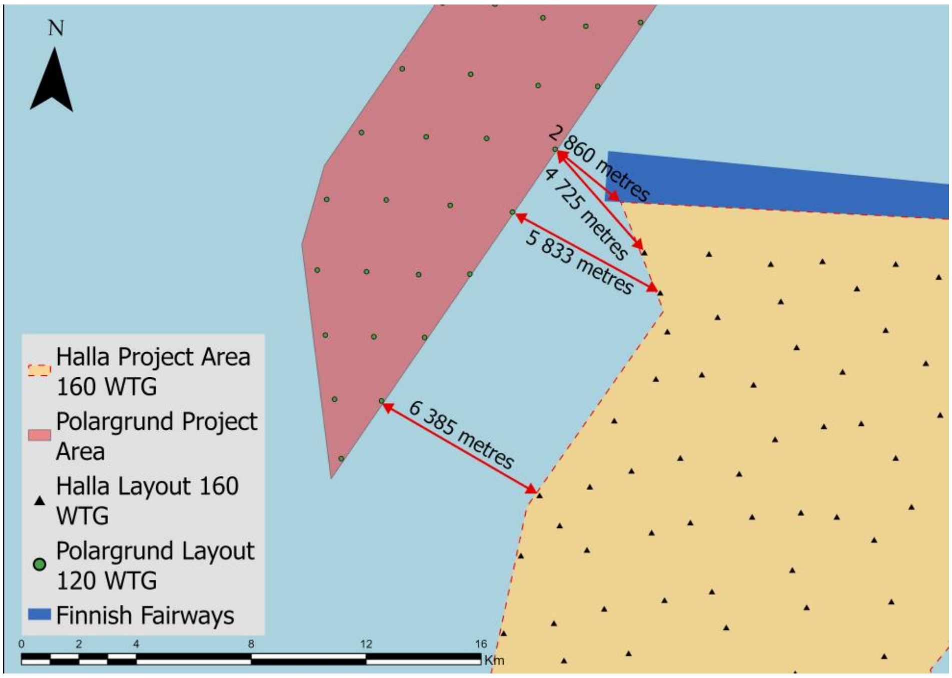

Figure 21. Distances between Halla OWF and Polargrund OWF.

The calculated safety distances also apply with an increase in traffic in terms of more transits, however, no consideration has been given to accommodate larger ships than the 98,5 percentile which is 229 metres.

An uncertainty analysis is performed to study a possible future scenario with a larger number of larger vessels to consider the future increase in terms of tonnage. In this study, a CMA CGM Panama-vessel with a length of 366 metres is used to indicate how much the safety distances would have to be adjusted to maintain a safe distance. If the vessel passes once a month, it will have no effect on the safety distances based on the current 98,5 percentile. However, if the vessel passes twice a month, the safety distance based on a modelled 98,5 percentile would increase to 242 metres. With an 98,5 percentile of 242 metres,

[12] Total width = Shipping lane + safety distance on each side of the shipping lane = 916 + 1 930 x 2 = 4 776 metres

the recommended width of a shipping lane has to be 968 metres[13], which results in a minimum distance including shipping lane and safety margin of about 4 984 metres[14]. By removing the outermost WTG(s), there should be room for vessels to perform a complete evasive manoeuvre even in a future scenario with more and larger vessels.

[13] 2 x 2 x 242 (98,5 percentile) = 968. 98.5 percentile is based upon all traffic within area of analysis.
[14] 968 + (556 x 2) (0,3 M for starboard manoeuvres on each side of the shipping lane) + 242 x 6 x 2 (6 vessel lengths on each side of the shipping lane) = 968 + (556 x 2) + (6 x 242 x 2) = 4 984 metres

6 Discussion

6.1 Vessel types and sizes

Vessel traffic in the area mainly consists of Cargo/Ro-Ro and Tankers, as well as Assistance and Safety Vessels. This reflects the purpose of the Finnish waterways, which is that they have primarily been implemented and maintained for the safe passage of merchant ships. Hence, merchant ships are considered to be of the vessel type that will be most affected by establishment of Halla. Additionally, the fact that merchant ships are normally the longest vessels in the area, indicates that in emergency situations they might be of the vessel type class that will have the most difficulty of manoeuvring. Meanwhile, the mean vessel length is 102 metres with the average representative 98,5 percentile being 229 metres. In comparison to other, equally large areas further south in the Baltic Sea, there are significantly smaller vessels that operate around Halla project area. The length of the vessels determines the turning radius and shorter vessels mean that they are easier to manoeuvre, and therefore require a smaller safety distance. Assistance and Safety Vessels are of great importance, above all to maintain and ensure the functioning of merchant vessels and shipping. Since Assistance and Safety Vessels such as Tugs and Pilot Vessels, normally use the unofficial Pilotage Route, establishment of Halla is also expected to impact these vessels to a greater extent since those vessels will have to relocate and operate, either west, or east of Halla to be able to assist vessels calling at ports at the northernmost and eastern ports.

6.2 Future scenarios, traffic patterns and safety distances

The traffic analysis shows that there are relatively few vessels within the shipping areas in the analysed area, usually about 1-2 vessels per day within each shipping area. This means that the vessels in general can be assumed to have room to position themselves in the lane in such a way that sufficient space can be created between the lane and the OWF so that evasive manoeuvres can be carried out, if necessary, without hampering other traffic. There is a low density of traffic moving in the vicinity of the Halla project area, especially in comparison to other, similarly sized areas further south in the Bothnian Bay and the Baltic Sea. To ensure compliance with PIANC guidelines in a scenario of both Halla OWF and Polargrund OWF being established, it is recommended to remove the outermost WTG in the north-western corner of the project area to create sufficient space for vessel traffic. Removing the outermost WTG ensures safety for future traffic, taking into account larger vessels.

In the fairway east and south-east of the project area, Raahe-Oulu-Kemi/Tornio NW, vessel traffic positions itself significantly closer to the project area, both during months with and without ice. This means that vessels would need to plan a minor route adjustment in a south-easterly direction so that vessels within the fairway are able to carry out a safe evasive manoeuvre if necessary.

Southwest of the project area, in Farstugrunden-Raahe, vessels pass mainly during months without ice cover. These vessels are also positioned relatively close to the project area and a minor route adjustment in a south-westerly direction may be needed. As mentioned, the traffic in this shipping area is only about 1 transit per day and the adjustment should therefore be relatively easy to implement. This applies, due to the low traffic flow, to all shipping areas around Halla.

The unofficial pilotage route through the project area will have to be moved as a result of the Halla OWF establishment. This may mean changes to the traffic pattern within the analysed area.

The traffic that goes along the route that follows Raahe-Oulu-Kemi/Tornio NW that runs right through the Halla project area seems to have margins to choose other routes, such as Raahe-Oulu-Kemi/Tornio NW that runs south of the project area, alternatively in the less trafficked fairway Oulu – 1 north of the project area. However, this route adjustment means a longer journey for these vessels. The number of vessels that choose this route during a year today is few, so the effect is expected to be marginal.

Vessel traffic, such as in the Raahe-Oulu-Kemi/Tornio NW fairway south of the area, seems to have margins to position itself slightly further south and thus create a greater distance to the OWF. Furthermore, it should be emphasized that the traffic is very limited in the Oulu – 1 fairway, in general less than 1 vessel/week.

The pilotage route is one of the traffic routes that make up most of the traffic that takes place within the Halla project area during months with sea ice. Traficom highlights how this route functions as a water-depth-secured area (2022a) for vessels that require a greater draught. The fact that the pilotage route runs here may therefore be because it is too shallow to the east of the project area. To the west of the project area, in the deeper parts, drift ice occurs during the winter months, which results in difficult navigation conditions for shipping. The use of this pilotage route during the ice winter of 2022 might be due to icebreakers choosing to break up ice and create a passage for traffic in areas where the ice is stuck so that the route does not risk being blocked immediately afterwards by drift ice. The icebreakers also tend to choose the shortest possible route since icebreaker operations are costly.

It may be that there is an opportunity for icebreakers and traffic of a certain draught to position themselves both east and west of the Halla project area during months with sea ice depending on prevailing ice conditions and draught. It is notable that the development of the ice differs from year to year. In a future scenario, the proportion of drift ice is expected to increase, and for several years in the last decade drift ice has spread over most of the Gulf of Bothnia during maximum ice extent (see Appendix 1). This results in situations where the icebreakers are forced to create waterways for traffic through drift ice regardless.

Establishment of several OWF, shipping would need to be more regulated in more narrow routes and navigate in more limited areas. This would lead to a higher concentration of vessels in shipping areas. Vessels being more regulated could lead to more predictable shipping patterns and facilitate navigation. Furthermore, by moderating passages on the open sea to a greater extent, it could mean that the work is facilitated for icebreakers as well in the sense that they are concentrated to limited channels rather than a case-by-case basis. However, even though vessels being more regulated could facilitate navigation, such as the functioning of a TSS, the icebreakers might not always be able to operate in the area. Icebreaker operations are dependent upon the ice conditions such as thickness, concentration, and ice type. Given harsh circumstances icebreakers might not be able to operate, thus relocating the operations.

In summary, it should be possible for maritime traffic in the vicinity of Halla OWF to choose alternative routes after the establishment of a OWF. The shipping area Nordvalen – Kemi/Ajos/Tornio is estimated to be the shipping area most affected by the operation. Ensuring safe navigation in a future scenario due to (PIANC) guidelines, the outermost WTG in the north-western corner of Halla OWF will have to be either removed or relocated. Some vessels will be forced to choose somewhat longer routes, which may entail higher transport costs and greater emissions from the vessels. At the same time, Halla OWF will contribute with renewable energy production as well as economic and environmental benefits. The ratio between positive and negative effects of Halla OWF could be further studied in an in-depth analysis.

7 Conclusion

The number of vessel passages in the vicinity of Halla OWF is low in comparison with other areas further south in the Bothnian Bay and the Baltic Sea. This means that the vessels in general can be assumed to have room to position themselves in the lane in such a way that sufficient space can be created between the lane and the OWF so that evasive manoeuvres can be carried out, if necessary, without hampering other traffic.

The project area for Halla is not conflicting with vessel traffic on fairways used for public passages. During months without sea ice, Halla does not have significant impact on the routes used by shipping (Oulu-1 fairway, Raahe-Oulu-Kemi/Tornio coastal fairway, and the Raahe-Oulu-Kemi/Tornio north-west fairway).

The shipping area Nordvalen – Kemi/Tornio is estimated to be affected by establishment of the OWF. This is the busiest route adjacent to Halla. The recommended safety distances have been calculated and presented according to PIANC (2018). The recommended safety distance is not fulfilled; however, this can be done by removing the outermost WTG in the north-western corner of Halla OWF. By doing so, Traficom's (2022a) as well as PIANC (2018) recommendation regarding safety distance is met. This is also valid concerning future traffic volumes and vessel sizes. Note that the recommended safety distance is presented in this report are for open water. There are no guidelines for safety distances in ice conditions.

The unofficial pilotage route that runs through Halla project area, is considered the route being most affected. Piloting will have to be moved if Halla is established, either east or west of Halla, depending on draught for instance.

Establishment of several OWFs may result in some cumulative effects on traffic. This mainly applies to the possible commissioning of Polargrund and Omega OWF, west and south-west of Halla OWF. Together, these three OWFs will result in more concentrated traffic in the shipping lane Nordvalen – Kemi/Tornio.

In summary, the analysis indicates that there should be enough room around Halla OWF in general for certain traffic diversions as a result of the OWF establishment. This also applies if the traffic flow increases or if the ships become larger in the future.

The given recommendations regarding safety distances should not be considered a risk mitigating measure, but rather as a prerequisite for shipping. The risks that may arise after the OWF establishment is analysed and evaluated in a separate nautical risk assessment.

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Appendix 1

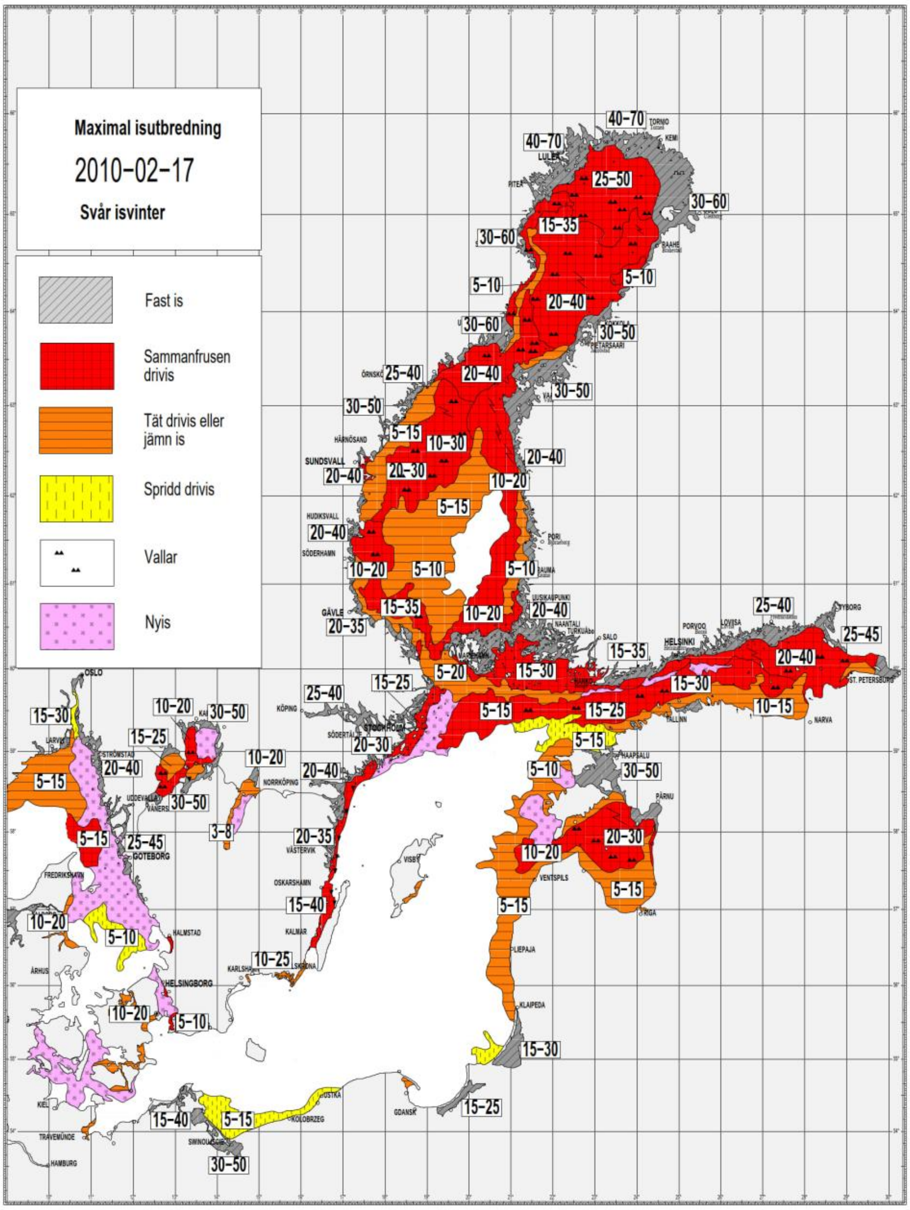

Figure 22. Maximum ice extent 2010. Map taken from smhi.se (SMHI, 2023)

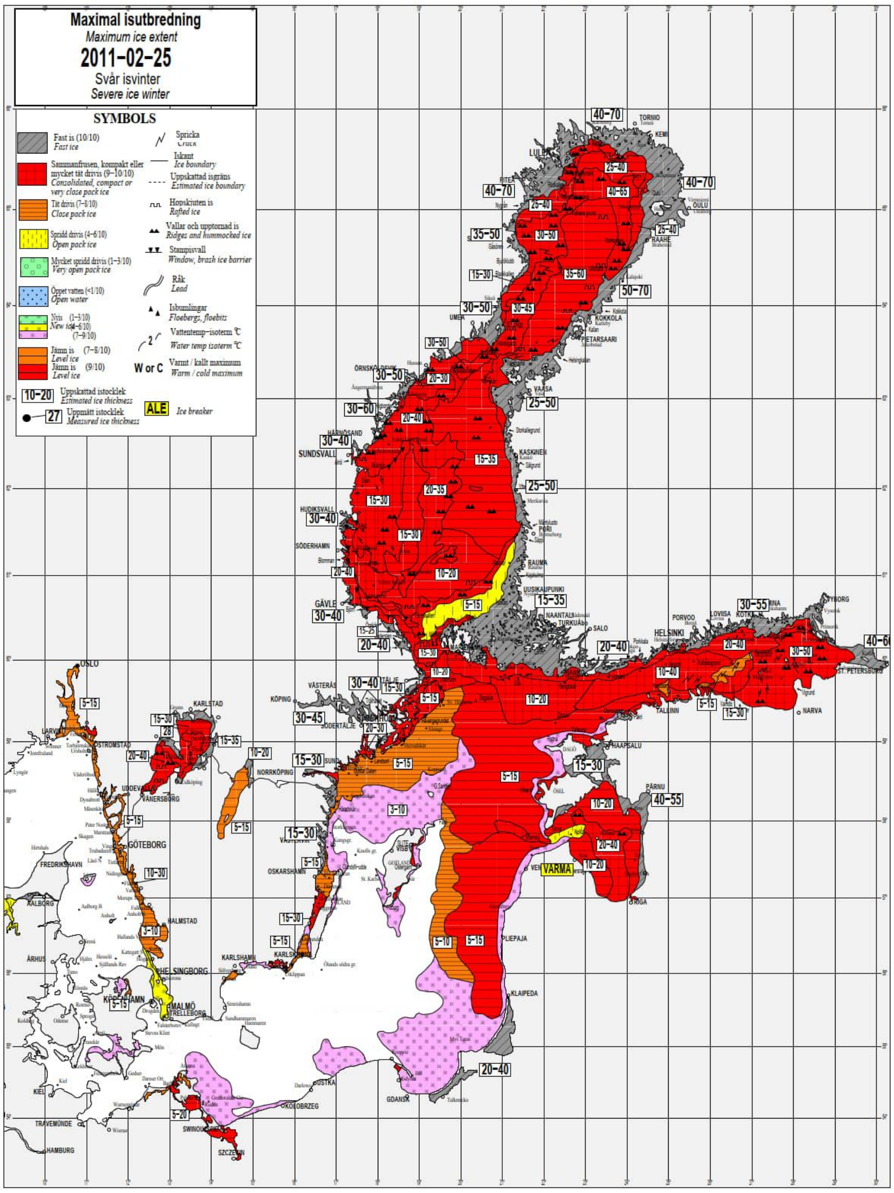

Figure 23. Maximum ice extent 2011. Map taken from smhi.se (SMHI, 2023)

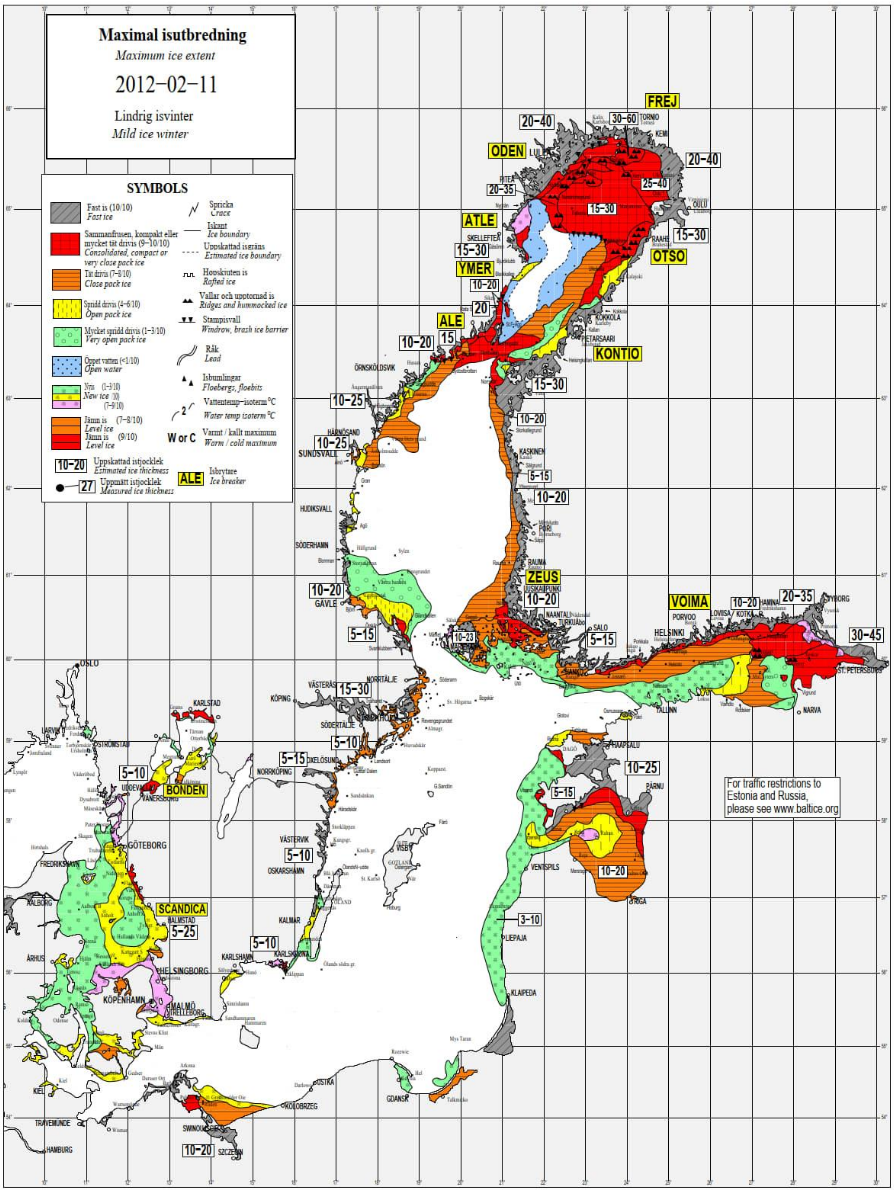

Figure 24. Maximum ice extent 2012. Map taken from smhi.se (SMHI, 2023)

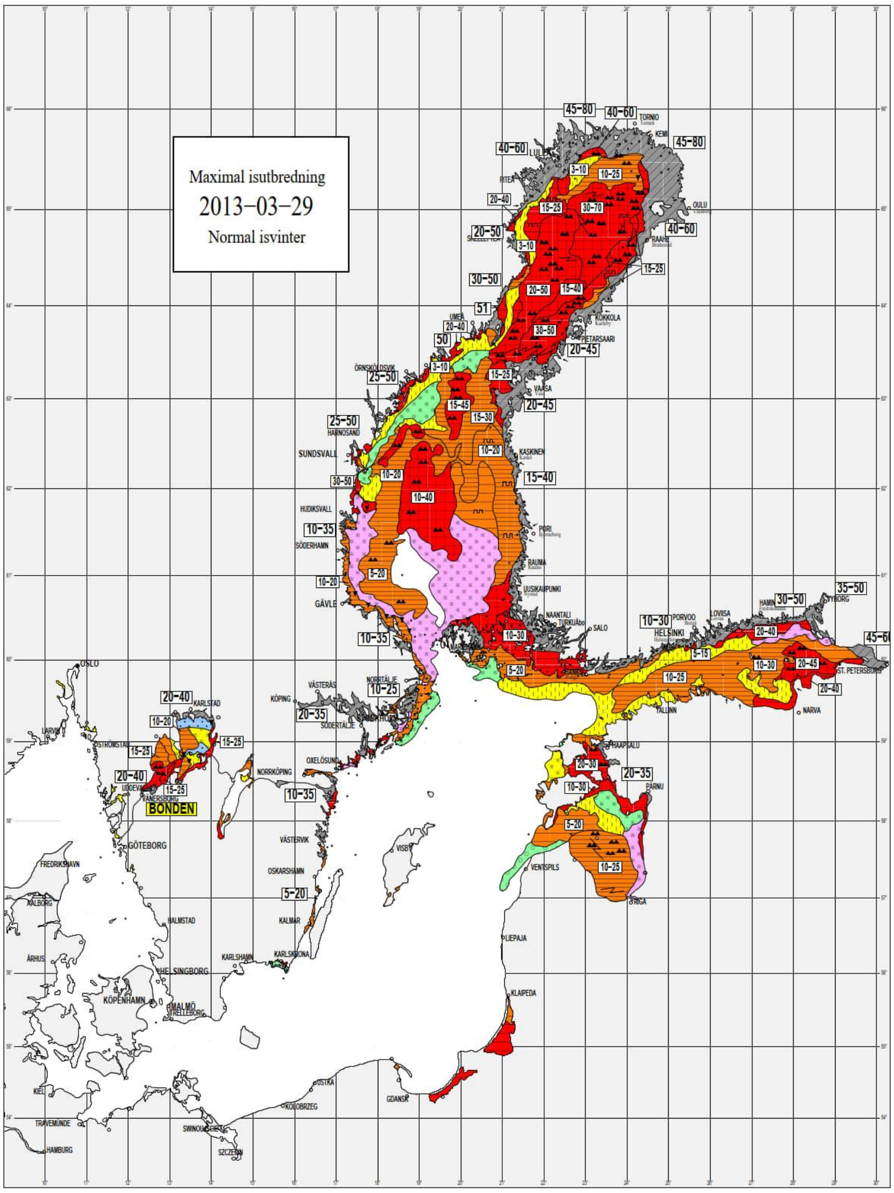

Figure 25. Maximum ice extent 2013. Map taken from smhi.se (SMHI, 2023)

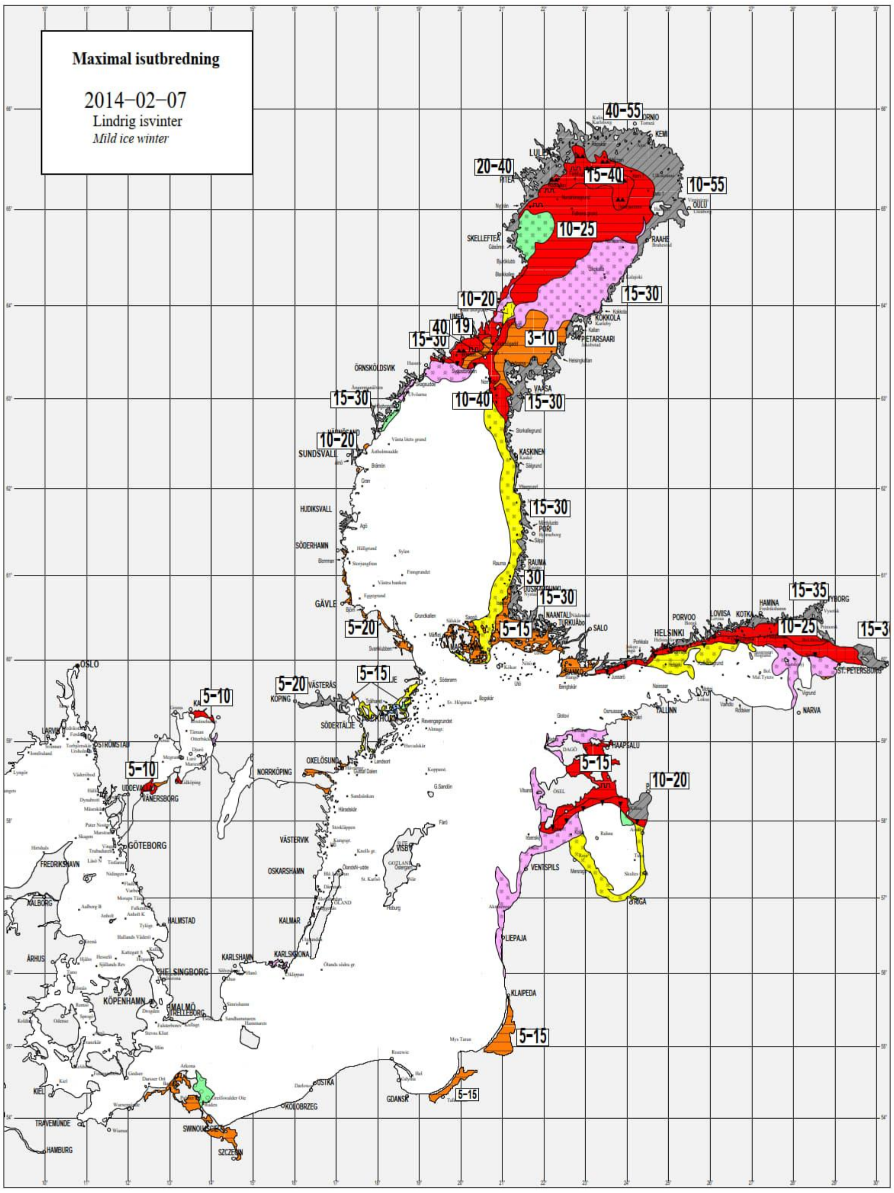

Figure 26. Maximum ice extent 2014. Map taken from smhi.se (SMHI, 2023)

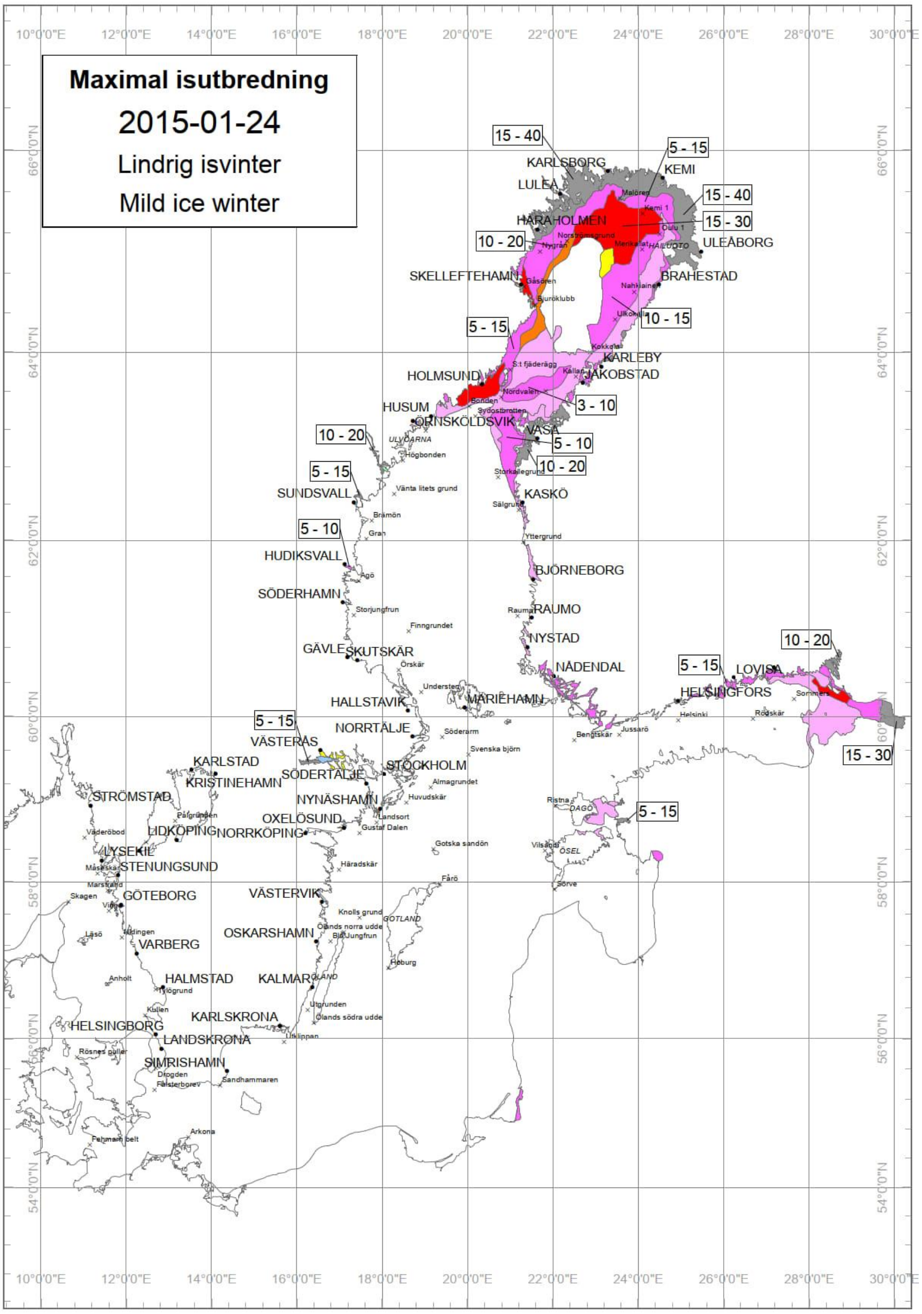

Figure 27. Maximum ice extent 2015. Map taken from smhi.se (SMHI, 2023)

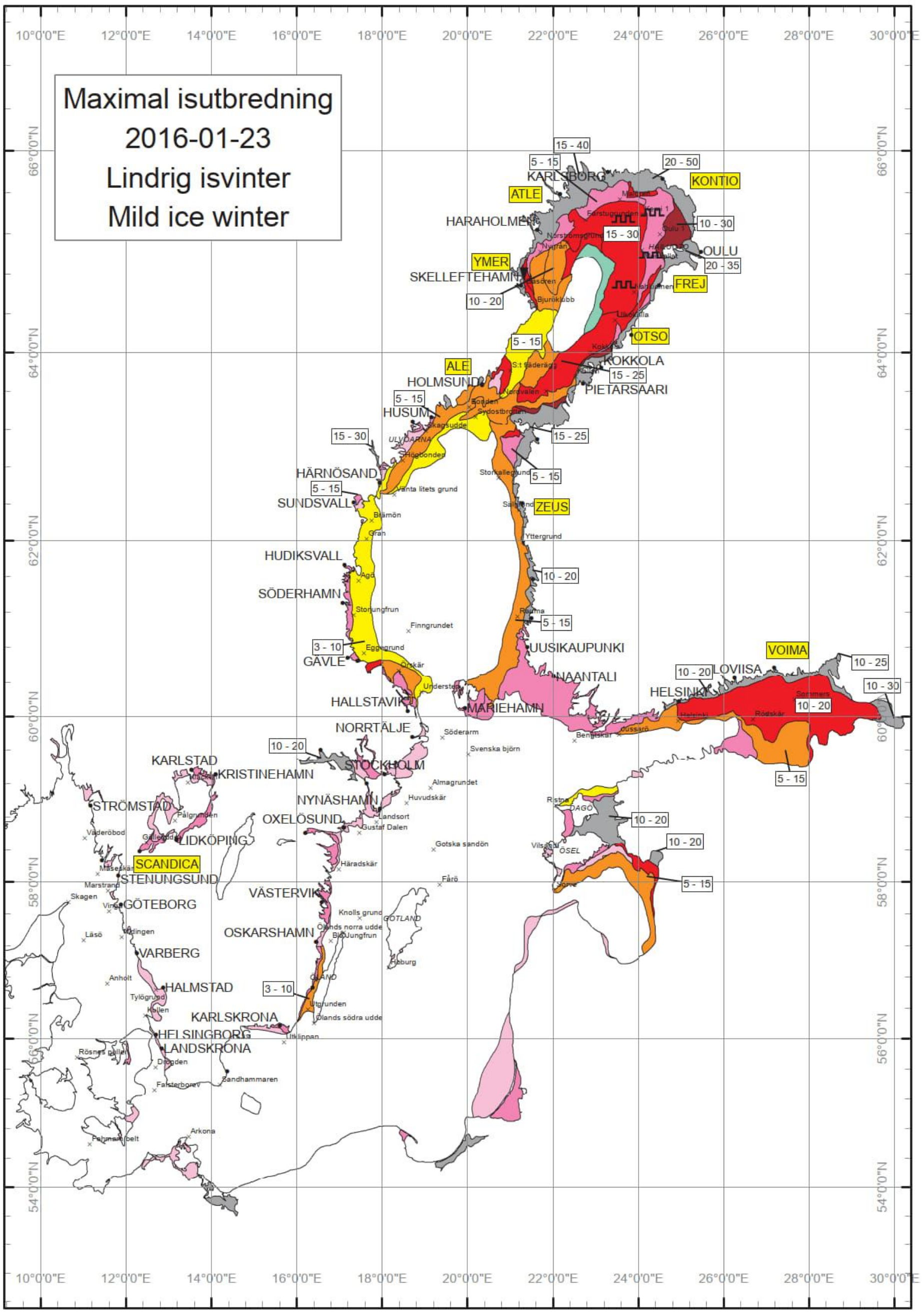

Figure 28. Maximum ice extent 2016. Map taken from smhi.se (SMHI, 2023)

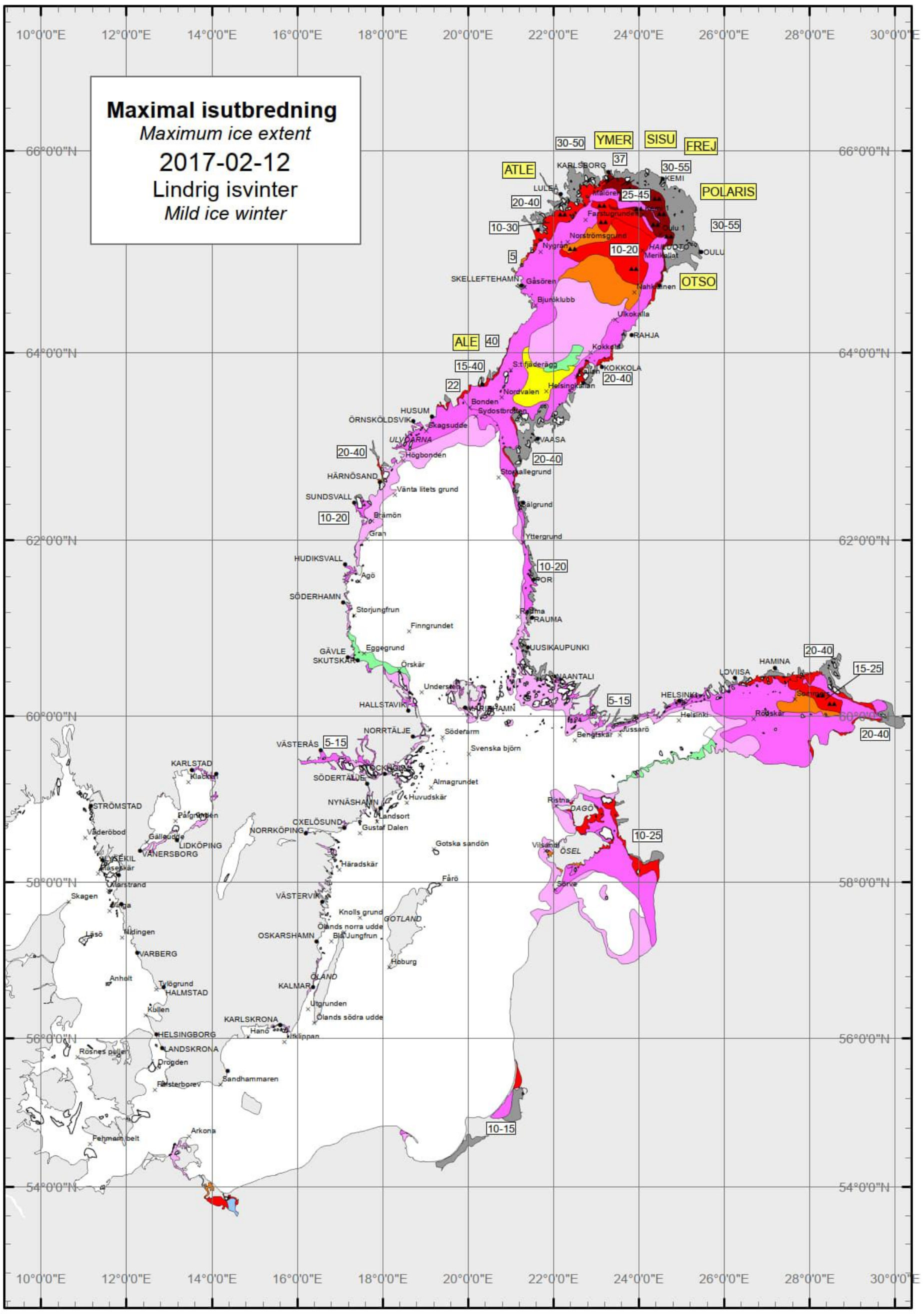

Figure 29. Maximum ice extent 2017. Map taken from smhi.se (SMHI, 2023)

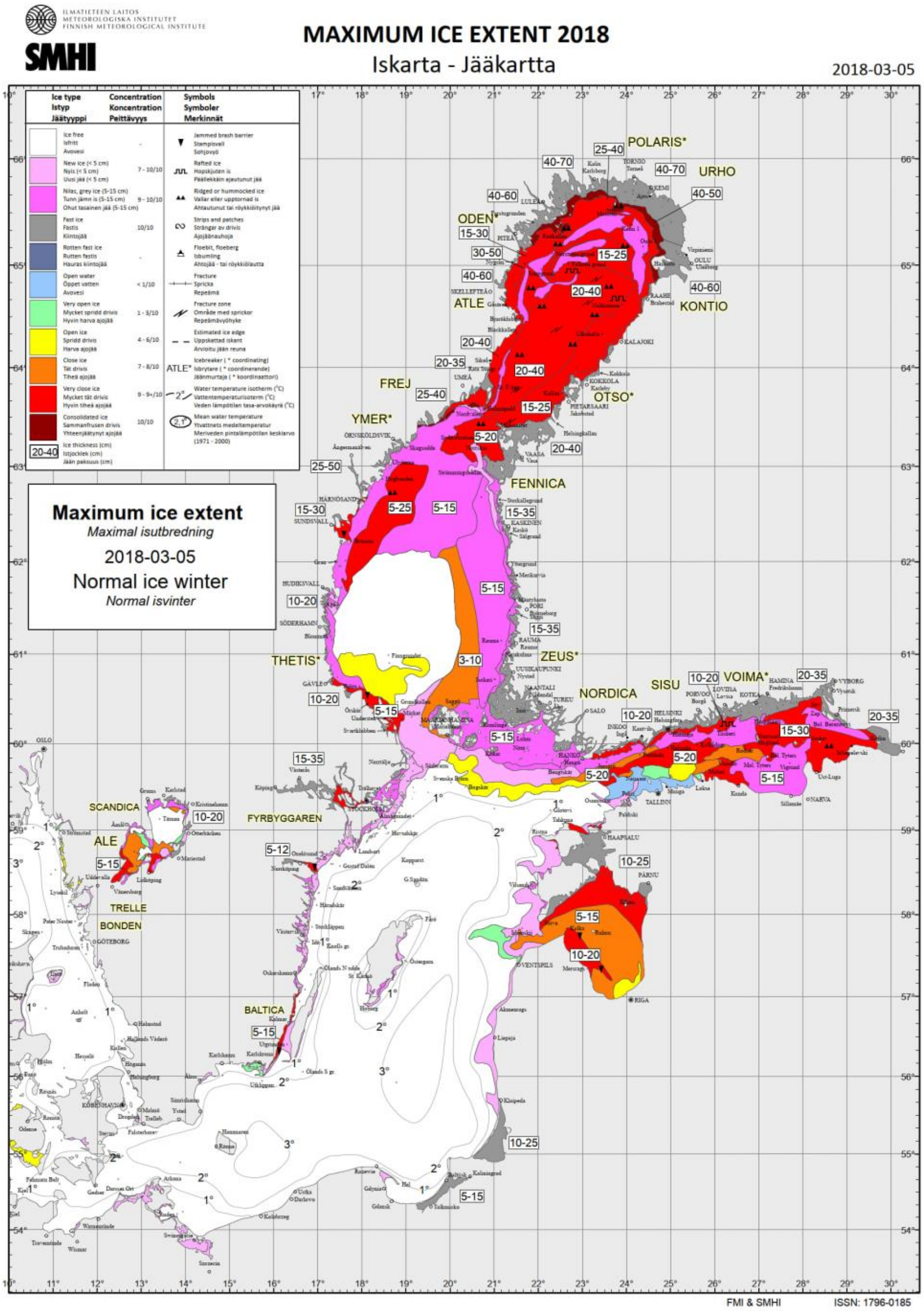

Figure 30. Maximum ice extent 2018. Map taken from smhi.se (SMHI, 2023)

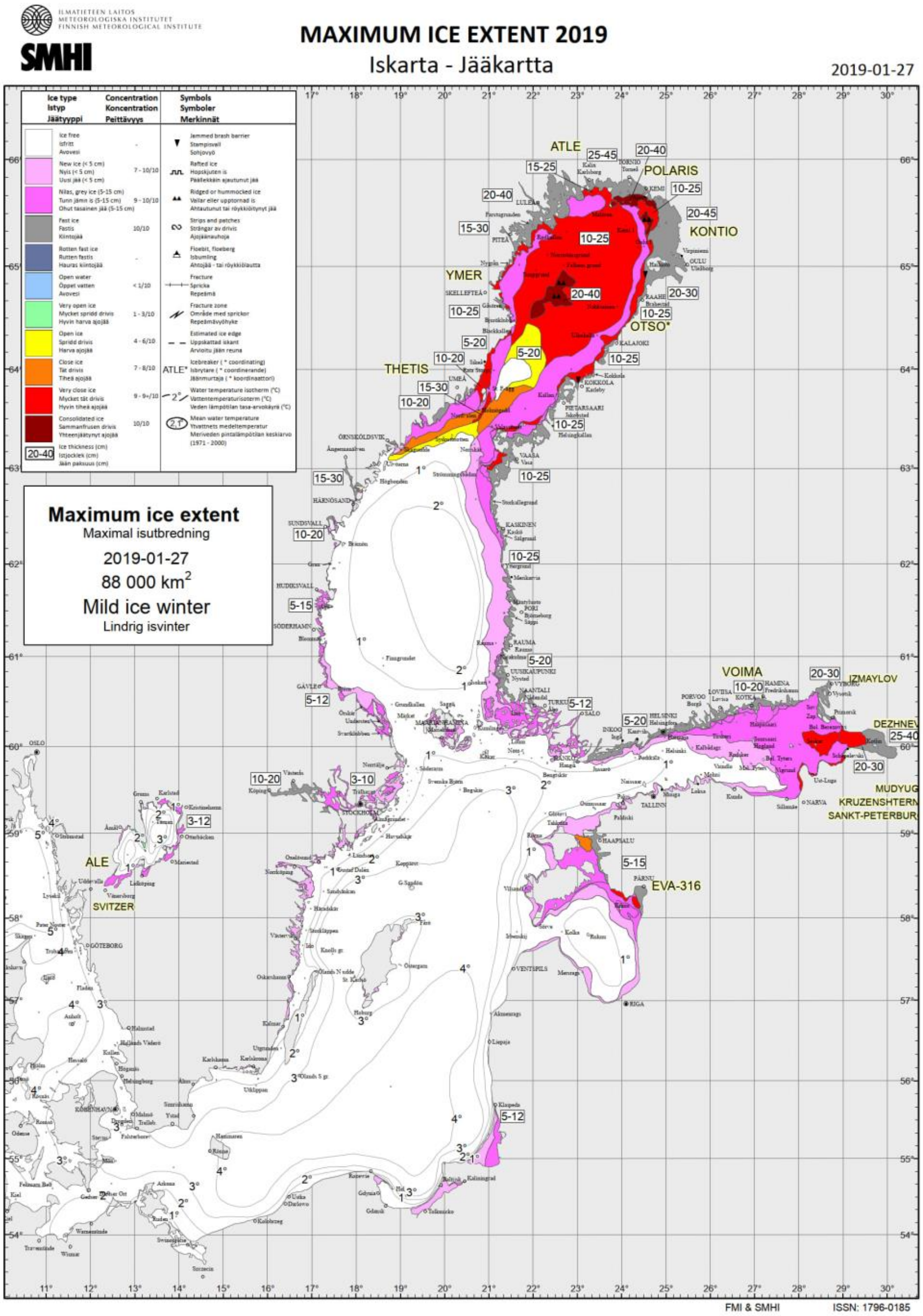

Figure 31. Maximum ice extent 2019. Map taken from smhi.se (SMHI, 2023)

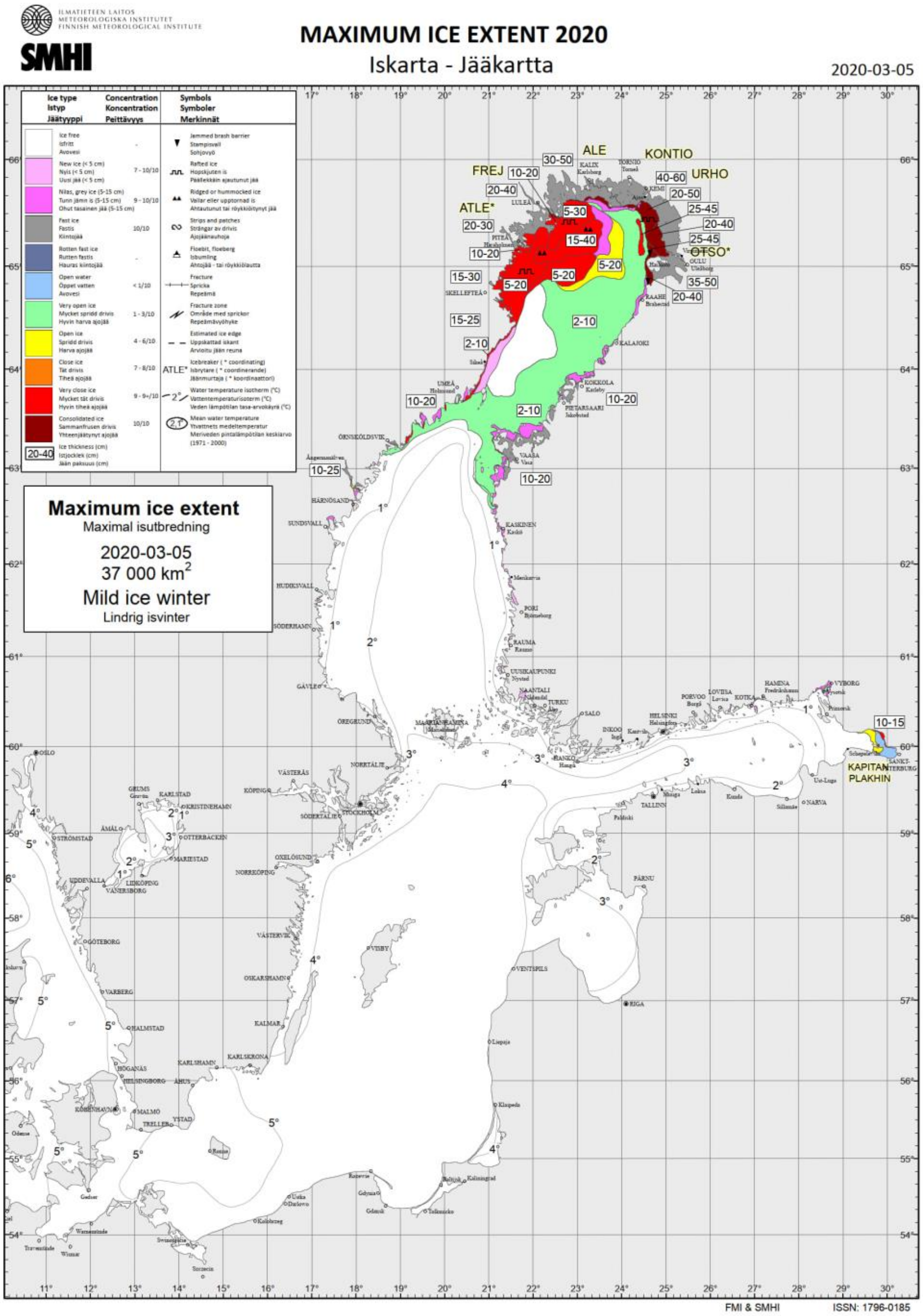

Figure 32. Maximum ice extent 2020. Map taken from smhi.se (SMHI, 2023)

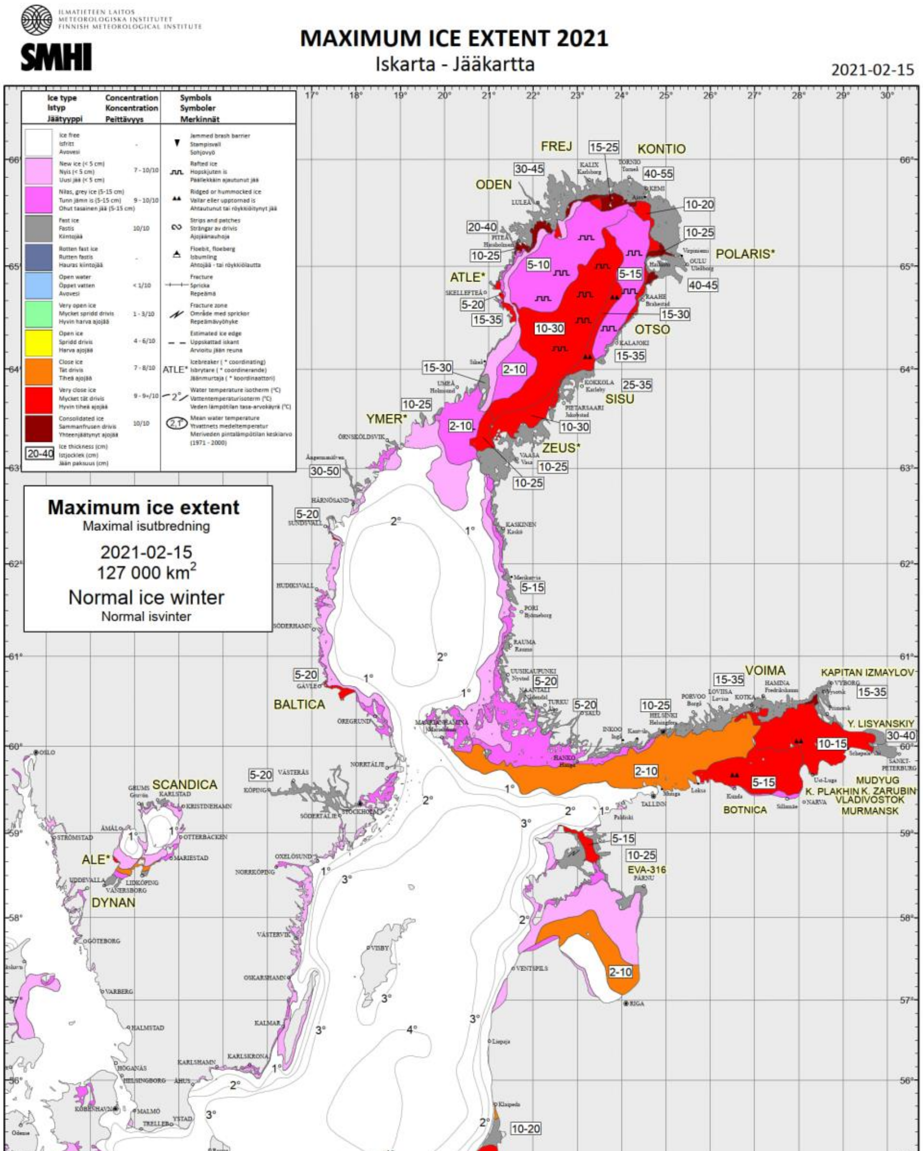

Figure 33. Maximum ice extent 2021. Map taken from smhi.se (SMHI, 2023)

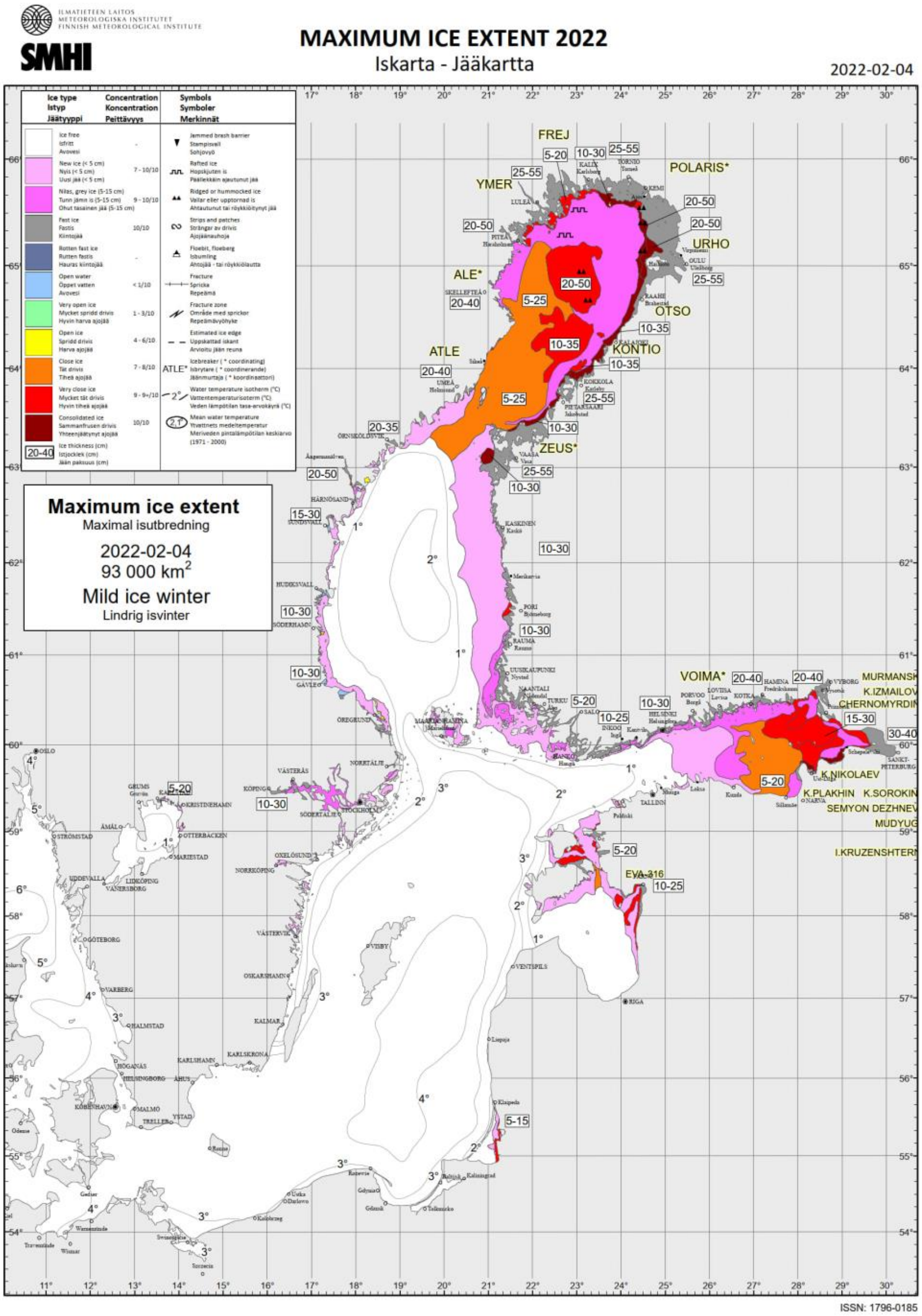

Figure 34. Maximum ice extent 2022. Map taken from smhi.se (SMHI, 2023)

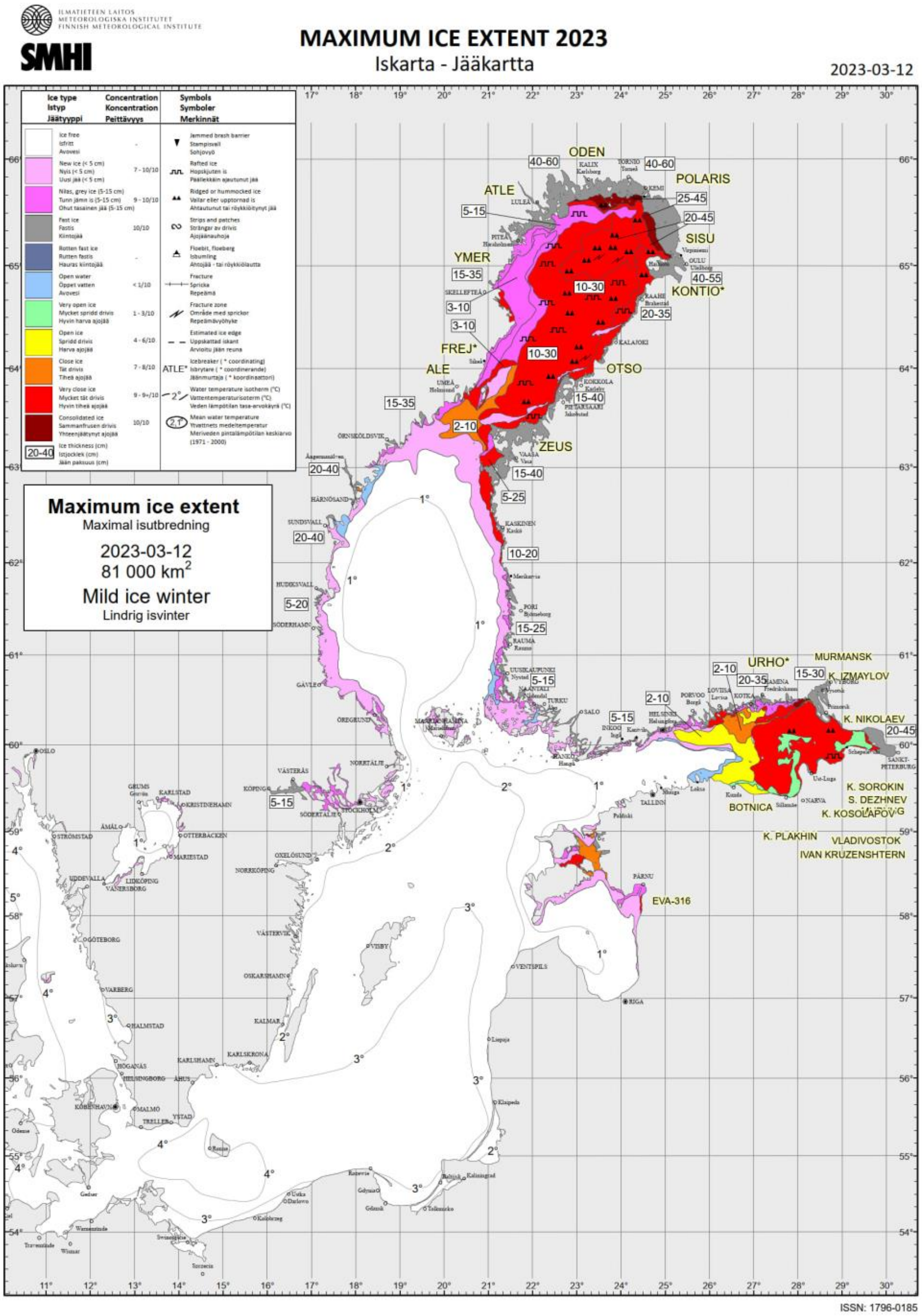

Figure 35. Maximum ice extent 2023. Map taken from smhi.se (SMHI, 2023)

Together with our clients and the collective knowledge of our 18,500 architects, engineers and other specialists, we co-create solutions that address urbanisation, capture the power of digitalization, and make our societies more sustainable.

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