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The impact of windfarms on winter navigation

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Contents of presentation

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- **Marine spatial planning – offshore wind farms (OWF)**
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Background and motivation of study

The cover of a report titled 'The impact of wind farms on winter navigation'. It features a photograph of three wind turbines in a misty, low-visibility environment. The Chalmers logo is in the top right corner. Below the image, the title is written in bold black text. At the bottom, there is a block of text providing project details.

The impact of wind farms on winter navigation

Project leader: Professor Jonas W. Ringsberg
Authors: Victor Ceder, Nils Helgesson, Basil P. Thomas, Jonas W. Ringsberg
Report date: 2024-10-22

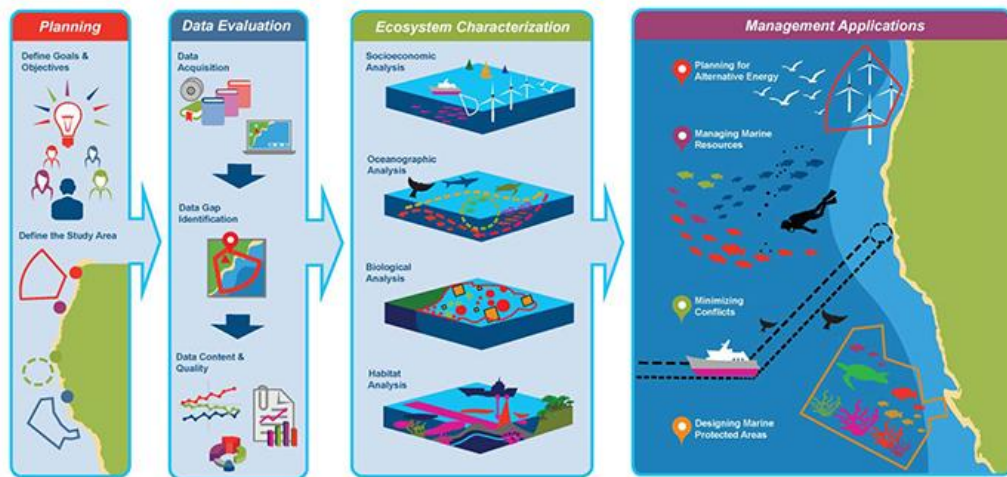
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https://research.chalmers.se/publication/543462/file/543462_Fulltext.pdf

- **Project 1, 2024: The impact of wind farms on winter navigation** (funded by SwAM)
 - Chalmers University of Technology, Swedish Agency for Marine and Water Management (SwAM), Swedish Maritime Administration
- **Project 2, 2025: Potential impacts of wind farms on shipping in the Bay of Bothnia** (funded by Lighthouse)
 - Uppsala University, Chalmers University of Technology, Swedish Maritime Administration, Skyborn Renewables, SwAM, Svea Wind Renewables, Swedish Shipowners' Association
- **Project 3, 2026-2027: AI-augmented ship traffic digital twin for optimal marine planning and assisting winter navigation in the Northern Baltic** (funded by Lighthouse)
 - Chalmers University of Technology, Uppsala University, SwAM, Swedish Maritime Administration, Marine Benchmark AB, RISÉ

Background and motivation of study

- Although the ocean covers 70% of the Earth's surface, many countries run out of space along and off their coasts
 - Examples: fisheries, aquaculture, shipping, tourism, and renewable energy production
 - Some cannot overlap



Source: <https://www.imbrsea.eu/product/40>

Each country has a strategic marine spatial plan (MSP) that contributes to long-term sustainable development by guiding the use of the sea

Background and motivation of study

Effective marine spatial planning must consider at least three essential attributes (UNESCO 2025)

1. **Multi-objective:** balance ecological, social, economic, and governance objectives. *The overriding objective should be increased sustainability.*
2. **Spatially focused:** the ocean area to be managed must be clearly defined, ideally at the ecosystem level, which is certainly large enough to incorporate relevant ecosystem processes
3. **Integrated:** the planning process should address the *interrelationships* and *interdependence* of each component within the defined management area, including natural processes, activities, and authorities



Source: <https://coastalscience.noaa.gov/>

Background and motivation of study

- **In 2022, the Swedish Government adopted its first Swedish marine spatial plans**
 - The Swedish Agency for Marine and Water Management (SwAM) was tasked with proposing amendments to these plans to meet the increased demand for electricity production
 - These plans identify several areas in the Gulf of Bothnia that could be suitable for offshore wind power installations, including dense wind farms
- **A literature review revealed a methodological gap**
 - Few studies in the literature present tools and methods related to UNESCO's **integrated** attribute, which can address both conceptual and practical challenges in, for example, the planning process of new marine infrastructure or changes to shipping routes.
- **This study presents a new methodology related to UNESCO's integrated attribute**
 - It can be utilised by administrators, planners, decision-makers at various political levels, engineers, stakeholders, and academic staff
 - The methodology is general: no-go zones designated by authorities, merchant ship traffic, bathymetry, metocean conditions, and ice conditions.
 - It is exemplified with a real case: the installation of offshore wind farms (OWF) in the Gulf of Bothnia

Marine spatial planning

Offshore wind farms (OWF) in the Gulf of Bothnia

- **Risk perspective**

- Emphasis on safe ship navigation:
shipping routes, ship traffic management, distance between neighbouring OWF areas
- Risks related to collisions or other wind tower structural integrity concerns

- **Shipping routes and ice management perspective**

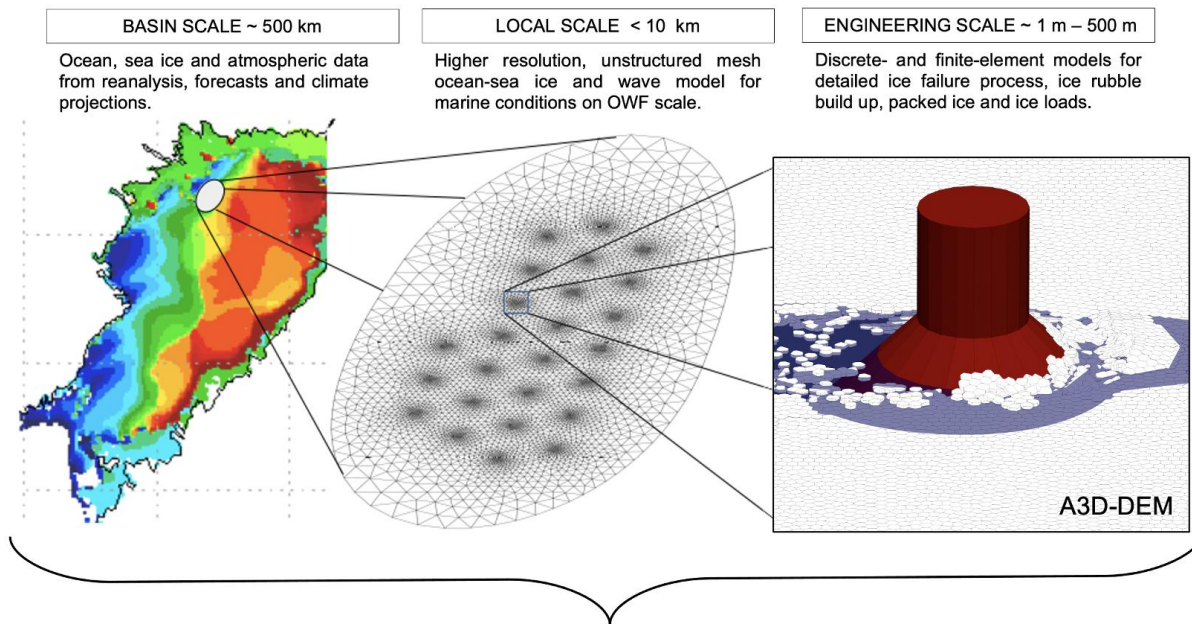
- Summer and winter seasons affect shipping routes
- Safe winter navigation requires ice breaker assistance in different areas and weeks in the Gulf of Bothnia

- **Ice formation perspective – need for increased ice breaker assistance**

- Wind turbines affect the surrounding conditions and the ice formation process
- “Local” ice failure caused by OWF installations
- Ice ridges, characteristics of re-frozen ice, drifting ice, etc ...

Marine spatial planning

Offshore wind farms (OWF) in the Gulf of Bothnia



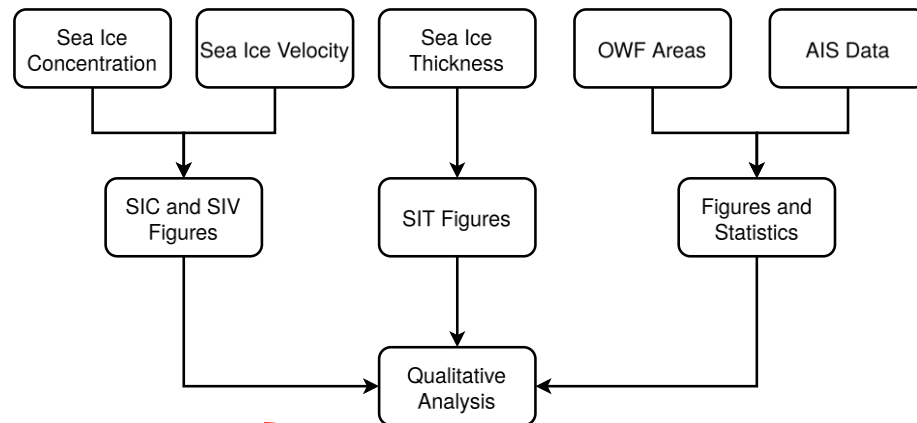
DIGITAL TWIN TO DESIGN, CONDUCT ENVIRONMENTAL IMPACT ASSESMENT AND OPERATE OWF

Project WindySea: <https://research.fi/en/results/funding/68675>

Methodology developed in Project 1

- **Uses historical data and statistics to evaluate trends**

- Sea ice concentration (SIC)
- Sea ice velocity (SIV)
- Sea ice thickness (SIT)
- OWF areas or other no-go zones
- AIS data
- *For ship performance analysis: bathymetry and metocean conditions*



- **New structures or areas with farms of structures can easily be introduced as new objects**

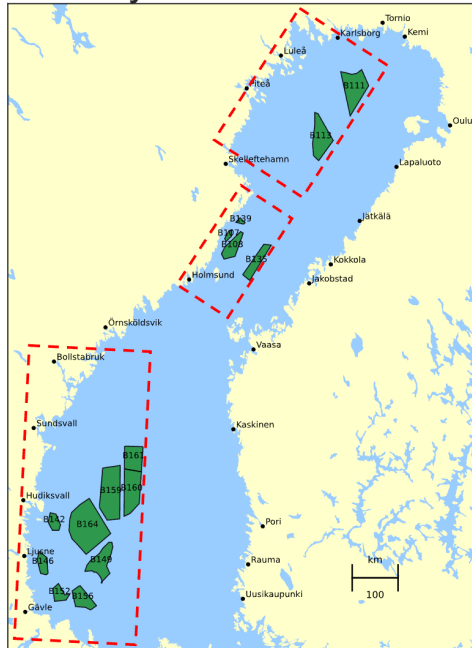
- **A re-analysis of historical trends can be used to:**

- determine whether mitigation actions are necessary
- analyse if the new installations will have no negative consequences, e.g., on shipping routes

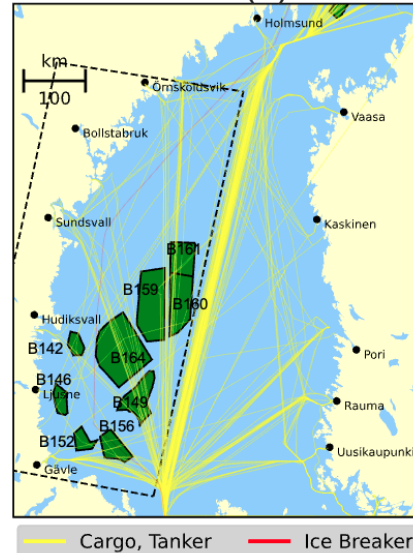
**UNESCO's
integrated attribute**

Methodology developed in Project 1

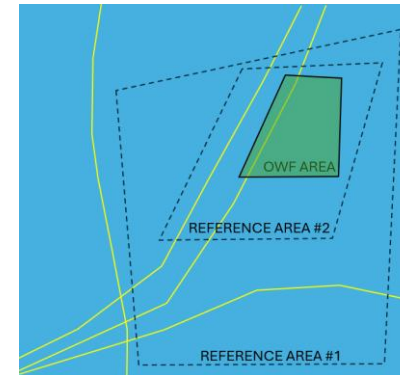
1. Define the boundaries of study areas



2. Project selected AIS data onto the area(s)



3. Define local go/no-go zone boundaries by defining the size of the reference area

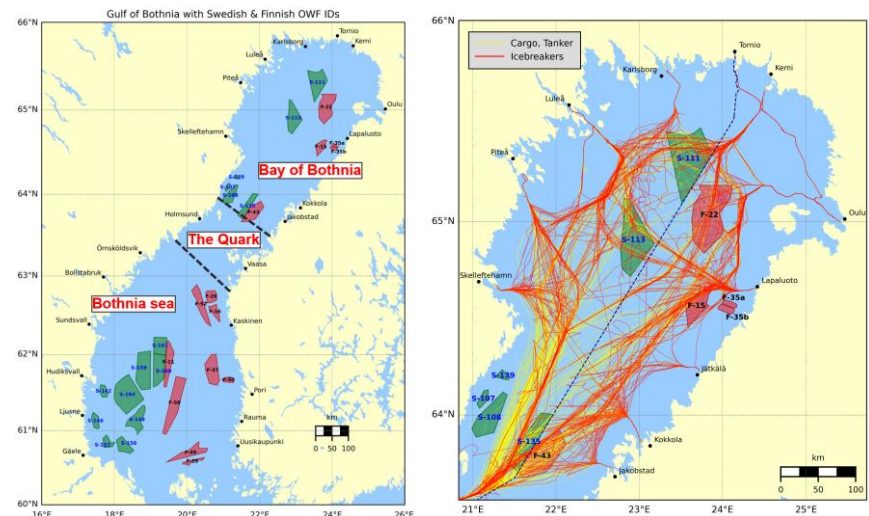
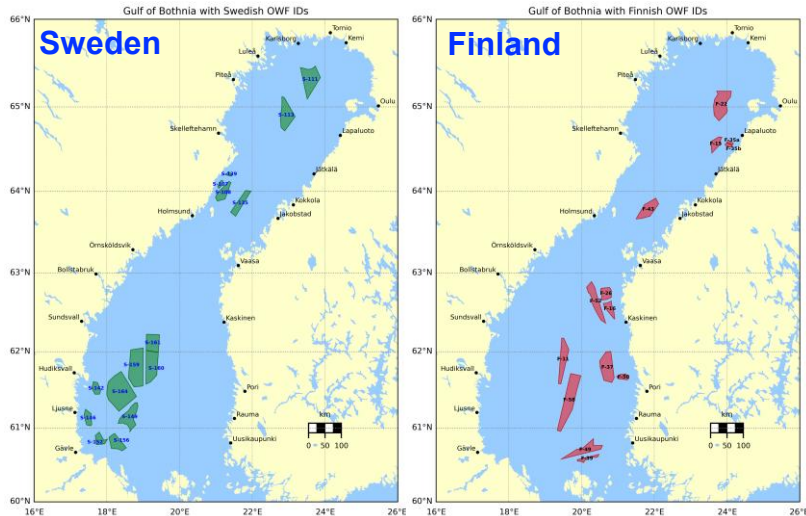


4. Ratio crossing:

$$\frac{\text{AIS tracks in an OWF area}}{\text{AIS tracks in a reference area}}$$

Methodology developed in Project 1

- The same methodology has been used in Project 2 and will be used in the new Project 3
 - Additional simulations of more winters, both Swedish and Finnish OWF installations, joint icebreaker tactics for ice-breaking



Methodology developed in Project 1

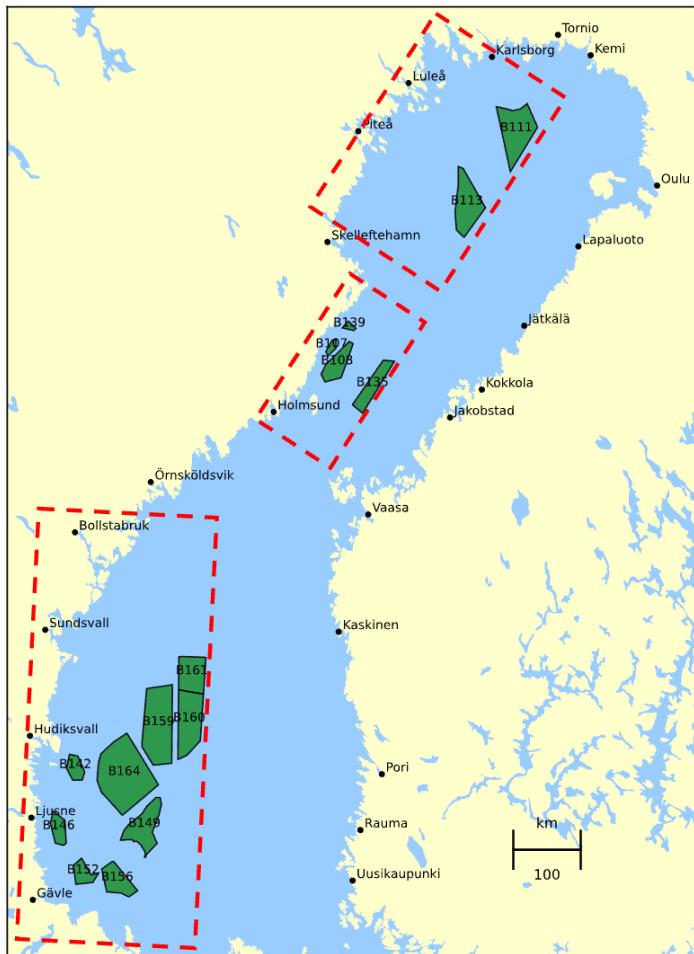
- **Data sources for sea ice, bathymetry and other metocean data**
 - **CMEMS**: Copernicus Marine Environment Monitoring Service
 - **FMI**: Finnish Meteorological Institute
 - **Mercator Océan International**
 - **SMHI**: Swedish Meteorological and Hydrological Institute

Data	Dataset	Source	DOI
Sea ice thickness and concentration	Baltic Sea - sea ice concentration and thickness charts	FMI	https://doi.org/10.48670/moi-00132
Sea ice velocity (1993-01-01 to 2021-06-01)	Global ocean physics reanalysis	Mercator	https://doi.org/10.48670/moi-00021
Sea ice velocity (From 2021-06-01)	Global ocean physics analysis and forecast	Mercator	https://doi.org/10.48670/moi-00016
Bathymetry	Baltic Sea physics analysis and forecast	SMHI	https://doi.org/10.48670/moi-00010



Selection of results from case studies

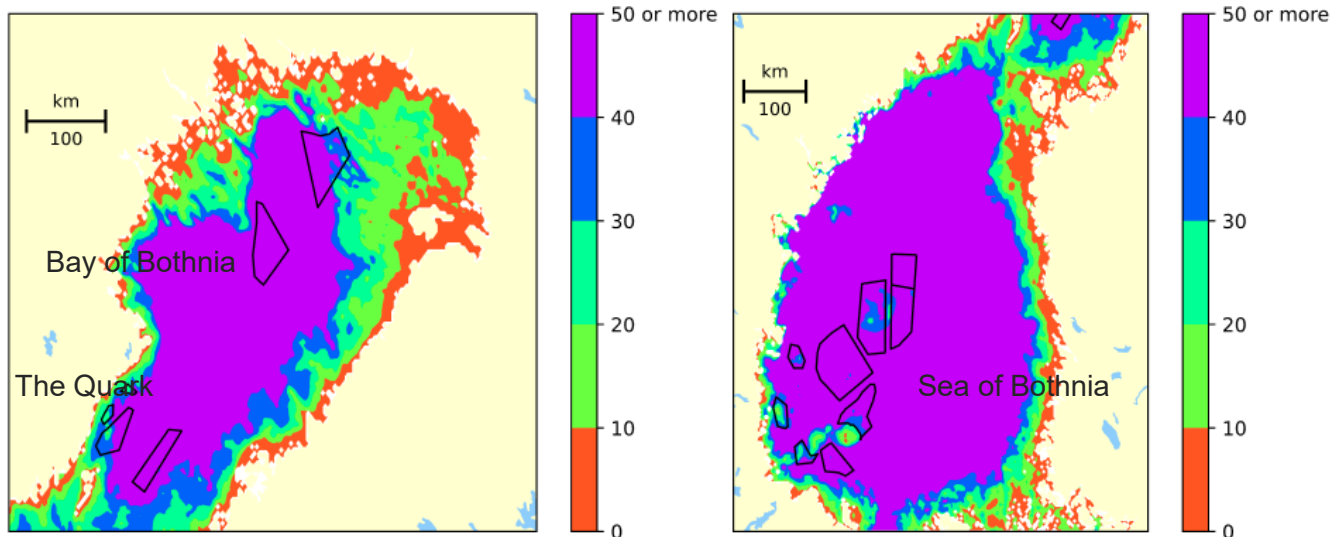
- **The analysis of shipping traffic was divided into three regions**
 - Bay of Bothnia (north)
 - The Quark (center)
 - Sea of Bothnia (south)
- **Three winters**
 - 2017-2018: normal ice winter (SMHI)
 - 2021-2022; 2022-2023: mild ice winter (SMHI)
- **Ship types (filtering using IMO numbers)**
 - Cargo ships, tankers, icebreakers



Selection of results from case studies

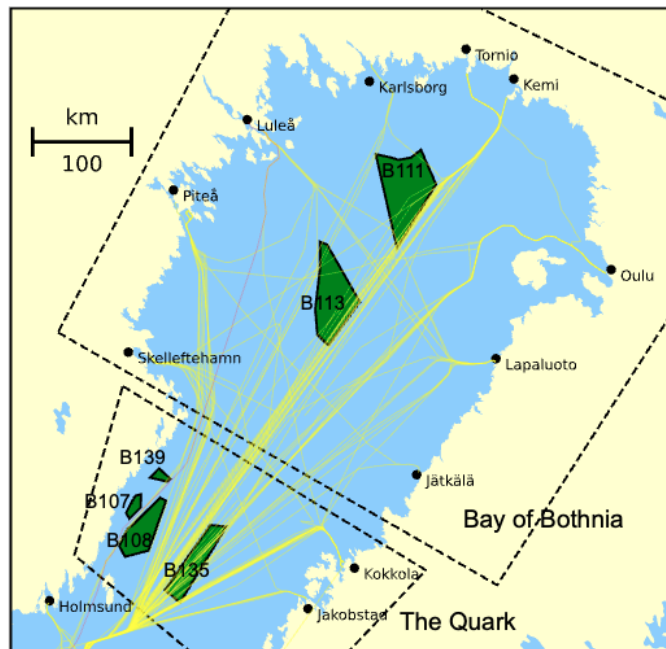
Bathymetry data [m]

- Affects the planned OWF areas
- Affects “possible” shipping routes and safe navigation

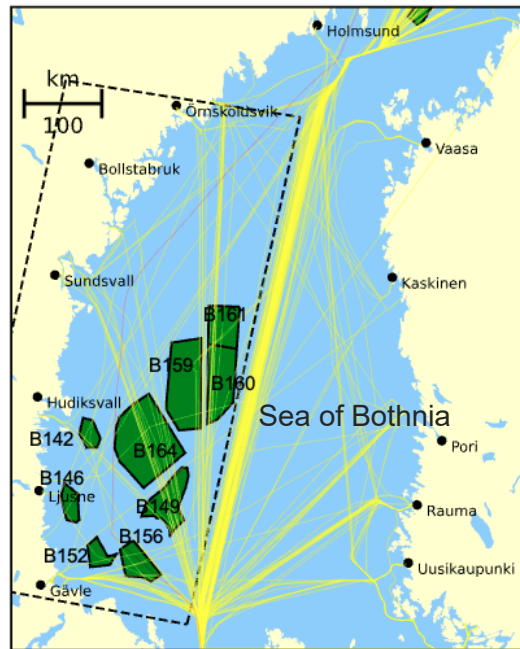


Selection of results from case studies

Ship tracks plotted for the period 2023-08-01 to 2023-08-07



— Cargo, Tanker — Ice Breaker



— Cargo, Tanker — Ice Breaker

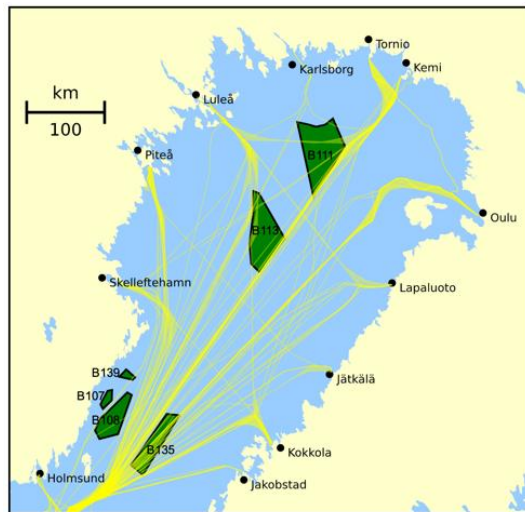
The results for one week of shipping traffic show many crossings of the planned OWF areas

The methodology offers the possibility to study an “unlimited” time period

It is recommended to study at least one year of shipping traffic (with weekly results)

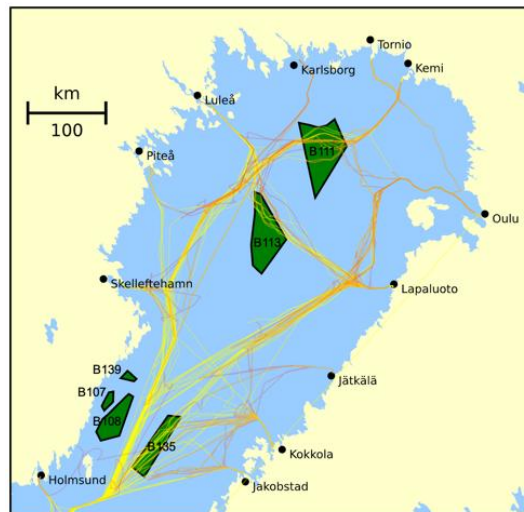
Selection of results from case studies

Navigation tracks in the Bay of Bothnia and The Quark



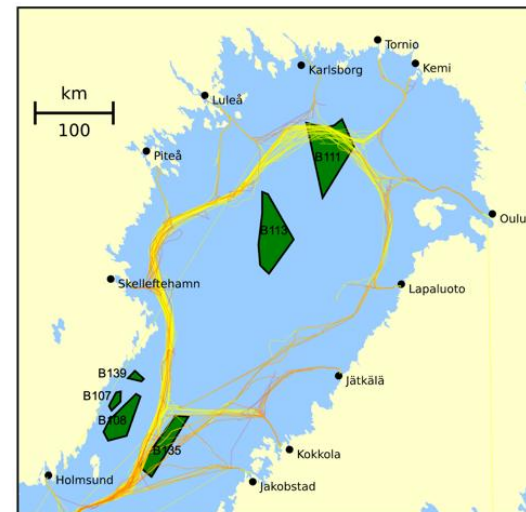
Summer

2023-07-15 to 2023-07-21



Winter

2023-03-08 to 2023-03-14

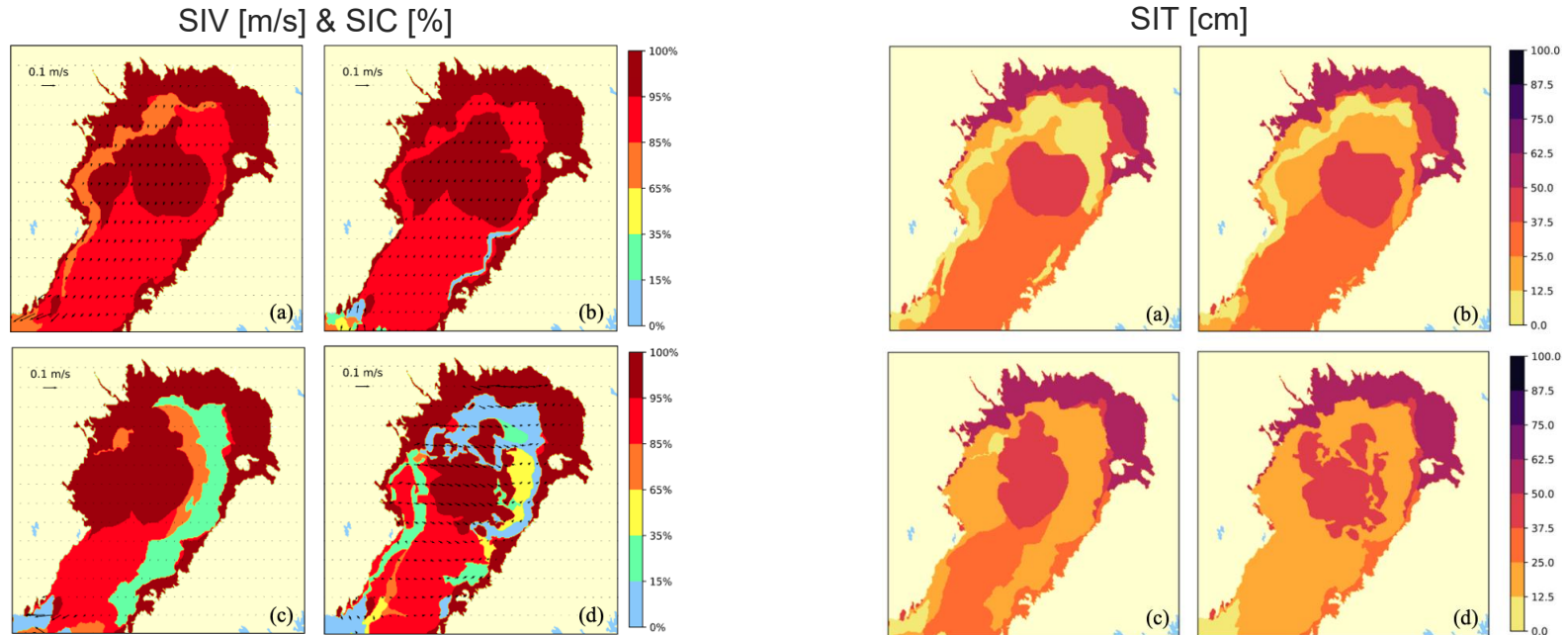


Winter

2023-04-01 to 2023-04-07

Selection of results from case studies

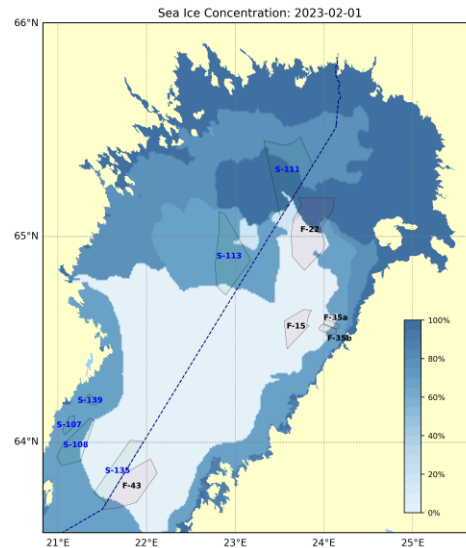
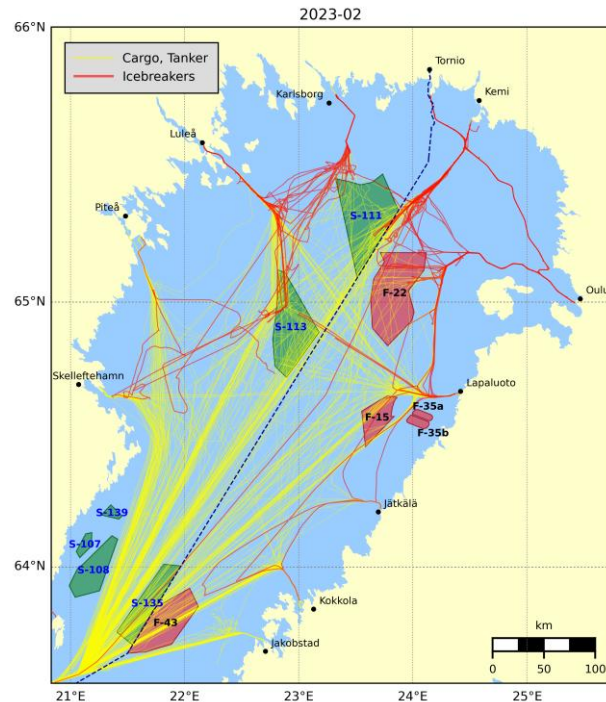
Sea ice velocity (SIV), concentration (SIC) and thickness (SIT)



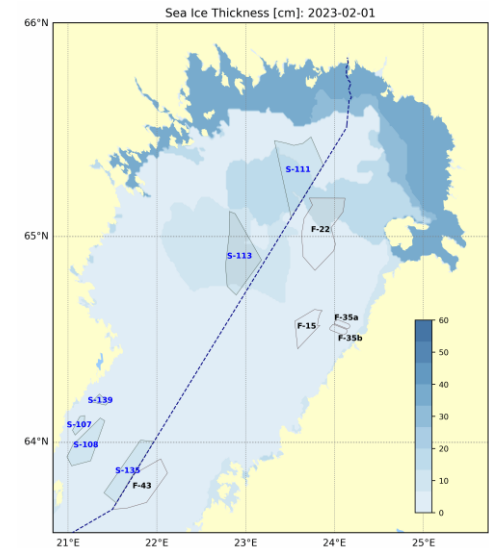
Bay of Bothnia and The Quark: (a) 2023-04-01, (b) 2023-04-07, (c) 2023-04-14, and (d) 2023-04-21

Selection of results from case studies

Normal winter 2022/2023: February ice concentration and thickness



Ice concentration



Ice thickness [cm]

Selection of results from case studies

- Number of cargo ships and tankers crossing the OWF areas, and the crossing ratios
 - One summer week 2023: 15 to 21 July
 - Three winter weeks 2023: 1 to 7 April, 8 to 15 March, 15 to 21 April

Area code		B111	B113	B108	B135	B107	B139	B156	B149	B164	B159	B160	B161
No. of cargo ships crossing	Summer week, in average	56			55			62					
	Winter week, in average	44			70			48					
No. of tankers crossing	Summer week, in average	8			12			8					
	Winter week, in average	6			12			6					
Ratio: cargo ships crossing	Summer week, in average	20.3%	23.4%	4.5%	29.9%	-	3.0%	5.7%	30%	28.6%	11.4%	15.7%	14.3%
	Winter week, in average	54.0%	2.0%	-	36.4%	-	-	9.4%	22.4%	22.6%	7.0%	15.4%	15.7%
Ratio: tankers crossing	Summer week, in average	-	-	-	11.9%	-	-	-	2.9%	2.9%	1.4%	5.7%	2.9%
	Winter week, in average	6.0%	-	-	8.6%	-	-	3.3%	1.4%	1.9%	1.9%	3.4%	2.0%

Selection of results from case studies

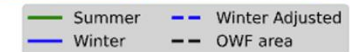
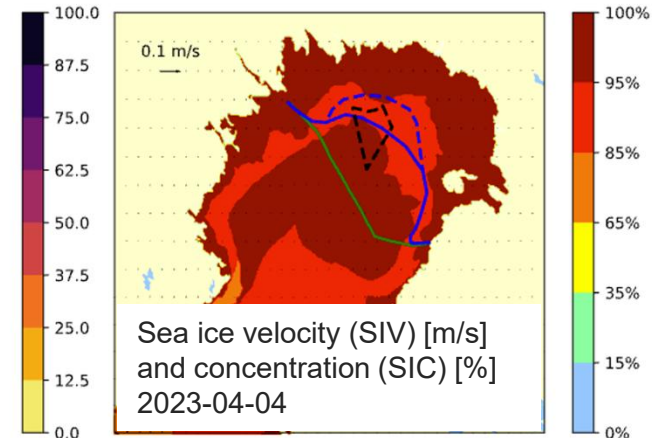
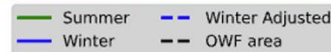
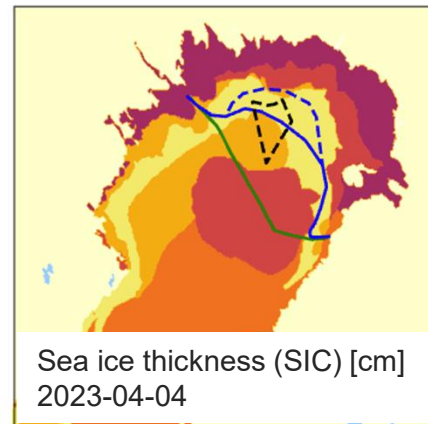
Mitigation study: re-routing of a ship crossing the OWF area B111

- **Medium-range (MR) tanker**

- Overall length of 183 m, breadth of 32 m, and draught of 11 m

- **Ship performance prediction model, ShipCLEAN**

- Open-water conditions
- Ice resistance models are included for various ice conditions
- Calculation of fuel consumption and voyage durations
 - Ice conditions
 - Ship speed
 - Ship route lengths



Selection of results from case studies

Mitigation study: re-routing of a ship crossing the OWF area B111

- **All winter routes:**

- Broken ice channel by “virtual” icebreaker, SIC 20%; SIT and SIV according to data

- **Reference route: Winter**

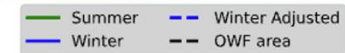
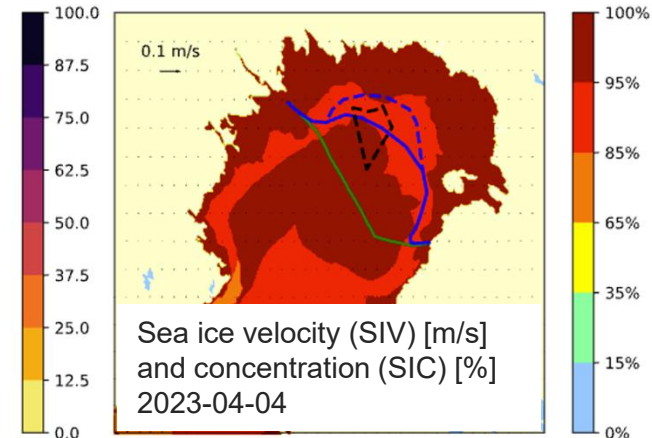
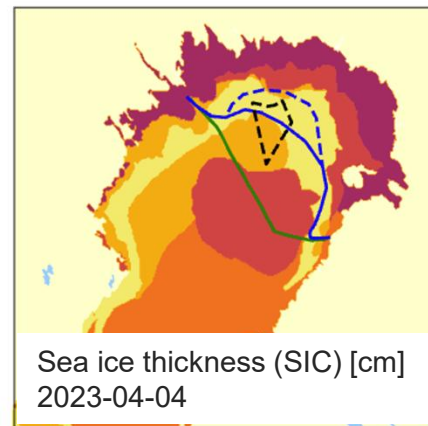
- 5 and 10 knots

- **Winter Adjusted**

- 5 knots: +3 hours, +25% FC
- 10 knots: +1 hour, +11% FC

- **Summer route**

- 5 knots: -3 hours, -13% FC
- 10 knots: -2 hours, -17% FC



Conclusions

- **This study developed a methodology to assess the impact of new marine structures on shipping**
 - Spatial planning for allocating marine structures can be determined based on ship traffic data, ship fuel consumption, bathymetry, metocean conditions, and ice conditions
- **The methodology was applied to evaluating areas for installing OWFs in the Gulf of Bothnia**
 - A direct consideration in marine spatial planning was that OWFs should be placed in areas without affecting heavy ship lanes (summer and winter)
 - It was found that some areas will require re-routing the current statistical ship traffic based on AIS data
 - The new routes will be longer and pass over shallower waters, which can increase the risk during winter conditions





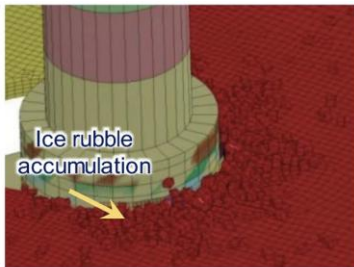
Conclusions

- **Winter navigation: ice movements and tactic icebreaker assistance were considered for the OWF areas**
 - Icebreaking tactics must be allowed to be dynamic to offer safe shipping conditions during winter
- **The installation of OWFs in ice-infested waters will likely make ice management more difficult, as they will limit options for ship route planning**
 - The need for re-routing ships around the areas will not only increase the voyage time for merchant traffic but also increase the demand for icebreaking capacity
 - A case study showed that fuel consumption also increases dramatically

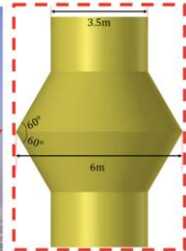
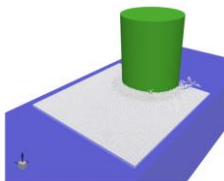
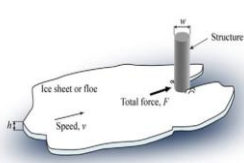
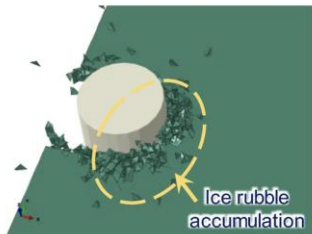




(a)



(b)



Ongoing and future work

- How will the formation of ice (e.g., thickness, hardness, movement, and growth of ice ridges) be changed if offshore wind farms are installed?
 - Effect of wind farm structures on ice formation
 - Higher ice loads on vessels?
- True cost analysis: shipping, OWF
- Systematic variation and definition of reference areas for intersection statistics
- Ship energy consumption analysis, including icebreaker assistance study
- Revised icebreaking strategy



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