

Process description: Wild cards in the Baltic Sea – are we ready for the unexpected?

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Project Aim

The aim of this work is to assess the capacities of currently available modelling tools to assess the potential consequences and mitigation possibilities of various *wild card events*. Wild card events are low-probability, high-impact occurrences that are difficult to predict but can have disruptive and lasting consequences for ecosystems, societies, or economies. Their effects may be beneficial, such as a rapid technological breakthrough, or harmful, such as geopolitical instability or crossing of ecological tipping points.

This research addresses three research questions:

1. What is the spectrum of potential wild card events that may threaten the ecosystem services in the Baltic Sea region?
2. Are the current modelling tools able to predict their potential consequences and give management guidance to mitigate and adapt to these changes?
3. How could the existing tools be developed to better account for possible wild card events?

Our focus is on the Baltic Sea, and the drivers that affect the state of the sea, the marine ecosystem, and/or the drainage basin of the Baltic Sea. We are interested in collecting a range of plausible wild card events, and how such discontinuities could be meaningfully accounted for in mitigation scenarios. We aim to assess how capable the available modeling tools and integrated assessment models are at predicting the ecological and social consequences of these events when they occur.

The collected information will be used for research purposes. **All participants in the process are invited to become co-authors of the research article** if they take part in the assessment of the modelling capabilities including: 1) filling in the pre-workshop questionnaire, 2) participating in the expert workshop (online), 3) fill in the post-workshop feedback survey and, 4) participate in commenting and/or editing the research article. Participation in the study is voluntary. You are free to withdraw at any stage of the process by contacting the leading author and you are free to join for separate parts.

Research Process

The research process has been divided into the three main steps described below (figure 1).

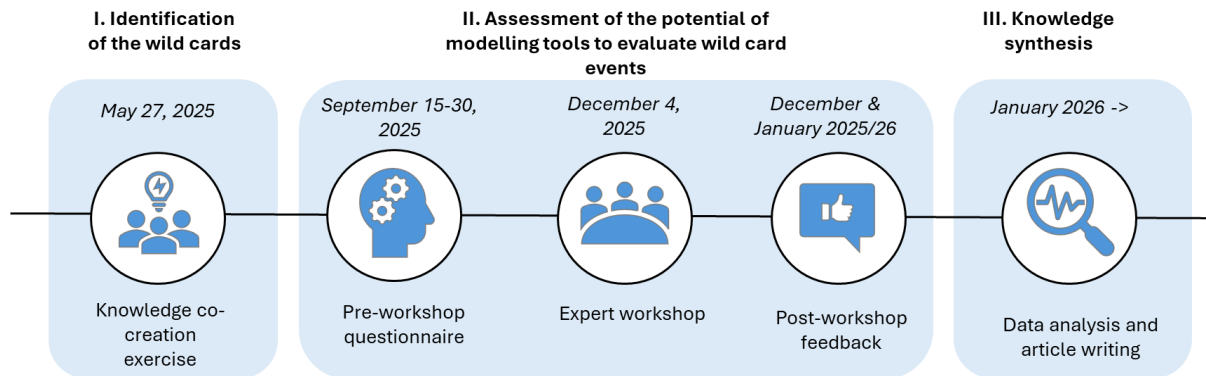


Figure 1. Main steps of the research process

I. Identification of the wild cards

As a first step, the aim was to identify plausible wild card events in the Baltic Sea region. For this, we organized a knowledge co-creation process during a plenary session of the Baltic Sea Science congress in Sopot, Poland, on May 27th, 2025. During the keynote speech, we asked: *What are possible wild card events that could impact the Baltic Sea?* We obtained in total 340 responses from more than 100 individual respondents collected and visualised in real-time during the session. Results are in the below section.

II. Assessment of the capabilities of modelling tools to evaluate wild card events

In the second phase of the project, the objective is to evaluate the capacity of existing modelling frameworks (such as biogeochemical, ecological, bioeconomic and agent-based models) to assess the consequences of the wild card events on the state of the Baltic Sea ecosystem. We are interested in the following questions:

1. What are the existing modeling tools and what are their capabilities in predicting the consequences of different types of wild card events on the Baltic Sea?
2. What are the capabilities of the different models in giving management guidance to mitigate or adapt to the wild card events on the Baltic Sea?
3. How can the models be developed to better assess the consequences of wild card events? What are the most important knowledge gaps?

Figure 2. Results of the co-creation process visualized as a word cloud. The size of the word expresses the number of times the topic was mentioned in the responses.

The individual wildcard events mentioned in the responses were classified into the categories described below with both direct and indirect impacts to the Baltic Sea ecosystems.

1. Abrupt changes in pollution loads

Examples of wild cards include:

- Abrupt positive or negative changes in pollution loads of, for example, nutrients, microplastics, pharmaceuticals, toxic chemicals from munitions, oil
- Abrupt changes in yet unidentified or new chemicals and pesticides

2. Alterations in use of marine resources

Examples include wild cards such as:

- altered fishing effort (overfishing and extinctions vs. fishing bans as extremes)
- mining
- wind resources (new structures)

3. Altered biotic entrants and ecological processes

Examples include different types of:

- Species invasions (fauna or flora), sharks or highly deadly jellyfish populating the area
- Novel microbial strains (bacteria developed unique genetic adaptations or characteristics)
- Emergent pathogens (with impacts both on humans and local biota)
- Antibacterial resistant bacteria, pandemic on animals
- Possible consequences: mass mortality, species extinctions, crossing of ecological tipping points -> ecosystem collapses

4. Extreme natural disasters or system changes

Examples include climate extremes:

- climate change-induced: sudden heat currents, storms, floods, droughts, sea-level changes, extreme coastal upwelling
- Yet unexpected events (against current scientific understanding in the region): reduced rainfall, heavy tides

- Events taking place elsewhere with impacts on the Baltic Sea (e.g. earthquakes, volcanos, tsunamis, e.g. Yellowstone supervolcano)
- Broader earth system changes: AMOC-change, Ice age, Geomagnetic changes, pole flipping
- Solar system/outer space: Solar flares, asteroids
- Possible consequences: e.g. giant submarine landslides

5. Geopolitical conflicts and turmoil

Examples include:

- The conflicts between countries include different degrees ranging from disputes, sabotages and hostilities to wars – nuclear war and global peace as extremes
- Changes in power relations between countries (e.g. China's role) and coalitions (e.g. end of EU or UN)
- economic system: trade collapse
- military: restrictions for marine traffic (e.g. closed marine traffic between the Baltic Sea and other seas)
- new structures built on the seafloor or coastal zones
- Changes in numbers and spatial distribution of human population (migration, human extinction as an extreme)

6. Policy changes or changes in political systems

Examples include:

- Fishing policy extremes (relaxed regulation leading to overfishing or species extinctions / total fishing bans) -> impacts of species distribution
- Legislation enabling investments on geoengineering -> multiple risks
- Increases in research funding -> better understanding on natural and human processes impacting sea ecosystems
- Broader changes in political systems (e.g. end of capitalism)

7. Technological failures or accidents

Examples include:

- Wastewater treatment plant failure -> N,P, bacteria, harmful substances, what else?
- Nuclear power plants -> radiation, energy entering the sea, what else?
- Marine traffic, tanker accidents -> oil, harmful substances, what else?

8. Technological, economic and/or social innovations

Examples include:

- Wind energy expansion -> New structures on the sea -> changes in physical, biological and chemical processes and structures
- Fusion power -> less demand for oil transports, wind power
- Lifestyle changes (plant-based diets), public opinion change -> reduced/increased pollution or multiple other impacts depending on the nature of the value change

More information

If you have any further questions regarding the research process, please contact Jamie Jenkins (jamie.jenkins@helsinki.fi).