ECONNECT 2120

EUROPEAN UNION

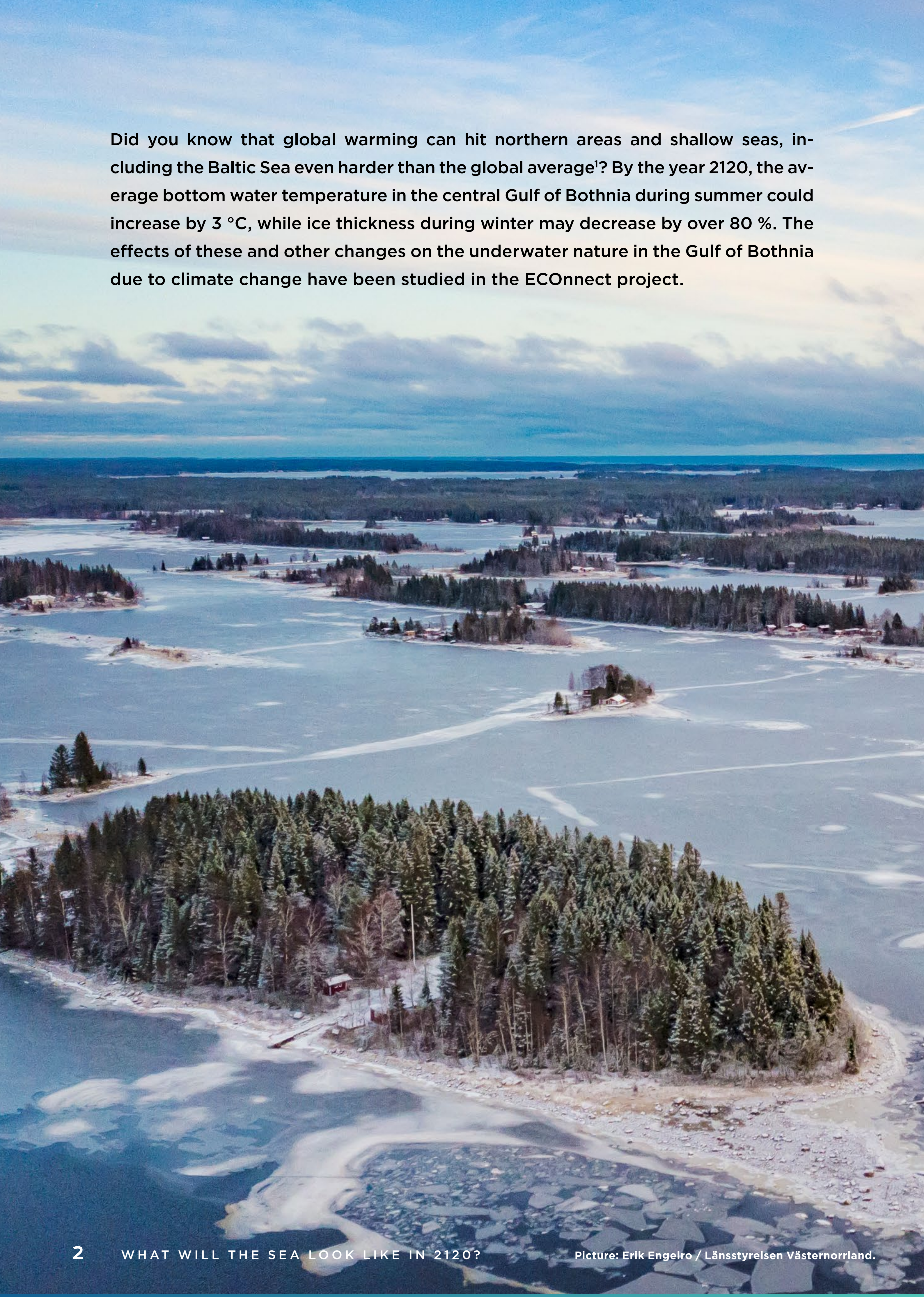
Interreg Botnia-Atlantica

European Regional Development Fund

What will the sea look like in 2120?

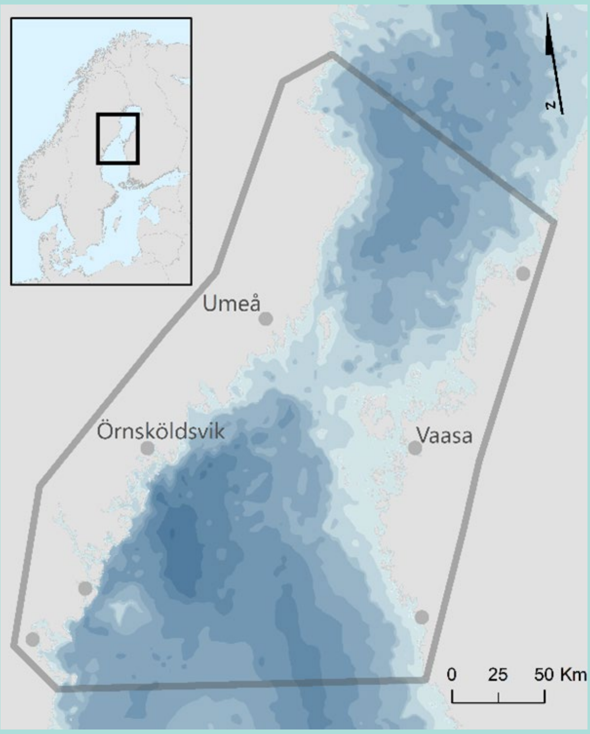
ECOnnect Summary Report

Did you know that global warming can hit northern areas and shallow seas, including the Baltic Sea even harder than the global average[1]? By the year 2120, the average bottom water temperature in the central Gulf of Bothnia during summer could increase by 3 °C, while ice thickness during winter may decrease by over 80 %. The effects of these and other changes on the underwater nature in the Gulf of Bothnia due to climate change have been studied in the ECOnnect project.



Picture: Erik Engelro / Länsstyrelsen Västernorrland.

Reducing the emissions of greenhouse gases is key to minimising the effects of climate change in the sea. At the same time, we need to be ready to take action to adapt to the changes. But how do we know how to act if we lack knowledge about how climate change might affect our sea area? This document contains the latest data on possible future changes in the central Gulf of Bothnia. Where can we see the biggest change in water temperature, how might salinity change, and how will key species cope in the changing climate?



The ECOnnect project area (grey line) lies in the central Gulf of Bothnia in the Baltic Sea between Sweden and Finland. The narrow middle part, known as the Kvarken, is very shallow (lighter blue), whereas the sea areas to the north and south are deeper (darker blue).

The ECOnnect project

ECOnnect was a collaboration project between Sweden and Finland with the aim to study how climate change might affect species distribution, ecosystem services, and the connectivity of habitats in the central Gulf of Bothnia in 100 years.

This summary report highlights and summarizes some key findings of the project. For materials, methods and more detailed results, the reader is advised to study the main reports. These reports, as well as other material can be found on the project's website, **econnect2120.com.**

The unique Gulf of Bothnia

The central Gulf of Bothnia is home to a mixture of species of both marine and freshwater origin. The salinity in the area is low and about 80 % of the water in the Gulf of Bothnia originates from the many rivers flowing into it. Marine species such as the blue mussel (*Mytilus trossulus x edulis*) are living at the limit of their tolerance due to the low salinity. In addition, some of the species are adapted to cold water or are dependent on sea ice, such as the ringed seal (*Pusa hispida botnica*). Therefore, this is the place where the predicted effects of climate change can have especially profound effects on marine life. Making predictions of what the future might hold is useful when preparing for these changes.

Also, it is not too late to take action to minimize the impacts of global warming. The future changes presented here are based on the worst-case climate models, and if rigorous measures are taken, they might still be avoided.

The ringed seal is one of the iconic species that occurs within the project area. It gives birth in snow caves on the ice and is therefore expected to suffer from climate warming and the loss of sea ice. Picture: Peter Lilja / Länsstyrelsen Västerbotten.

Warmer water and thinner ice

The most recent climate models suggest that by the end of the century, the mean bottom water temperature during the growing season could increase by 3 °C on average in the central Gulf of Bothnia. Warming will be stronger in shallow areas than in deeper waters. As the mean temperature during the growing season increases, maximum temperatures are likely to increase. Marine heatwaves can therefore pose a severe threat to underwater life in the future.

Winters are also expected to become warmer, and sea ice is predicted to be over 80 % thinner by the end of this century (Fig. 1, 2). This modelled decrease concerns the mean ice thickness during winters over a period of 30 years. Nevertheless, even in the future, there will likely be variation in the extent and thickness of the ice cover between different years.

These changes in water temperature and ice conditions, together with other projected changes taking place in the sea, could have a profound effect on marine ecosystems. The distribution of species may change, causing cascading effects, even on human wellbeing and the economy. The physical and biological components of nature are the basis of ecosystem services that we are dependent on, such as oxygen, food from the sea, and clean water.

Models

The climate models used in this project were based on a worst-case climate scenario (RCP8.5) and the nutrient reduction schemes of the HELCOM Baltic Sea Action Plan (BSAP). The climate models were run by the Swedish Meteorological and Hydrological Institute, SMHI, and the Finnish Meteorological Institute, FMI.

In other words, this is the kind of future we may face if we manage to address the more local eutrophication problem in the Baltic Sea but fail to reduce the emissions of greenhouse gases globally.

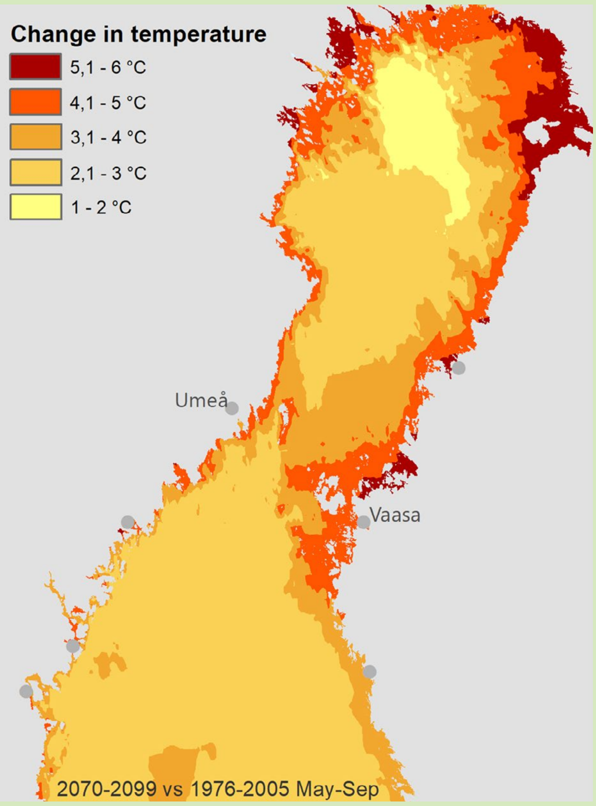


Figure 1. Changes in bottom water temperatures based on the climate models produced by SMHI and FMI.

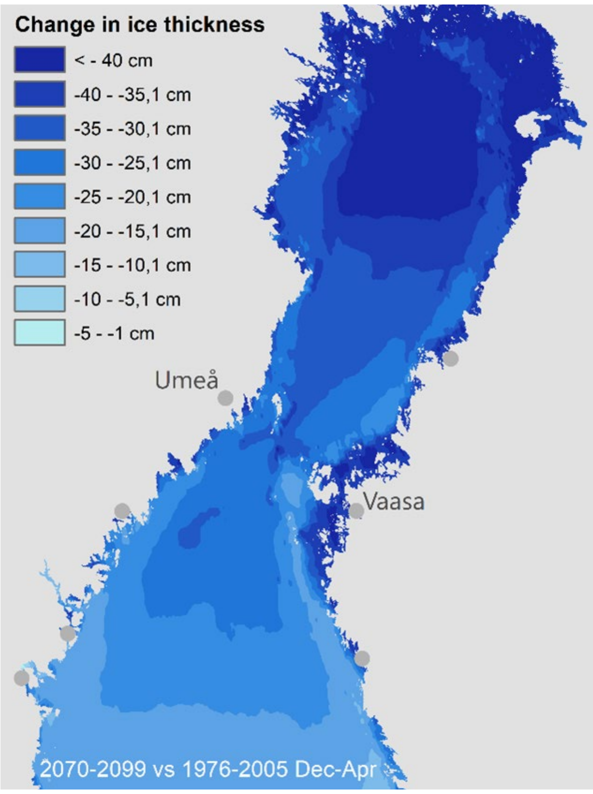
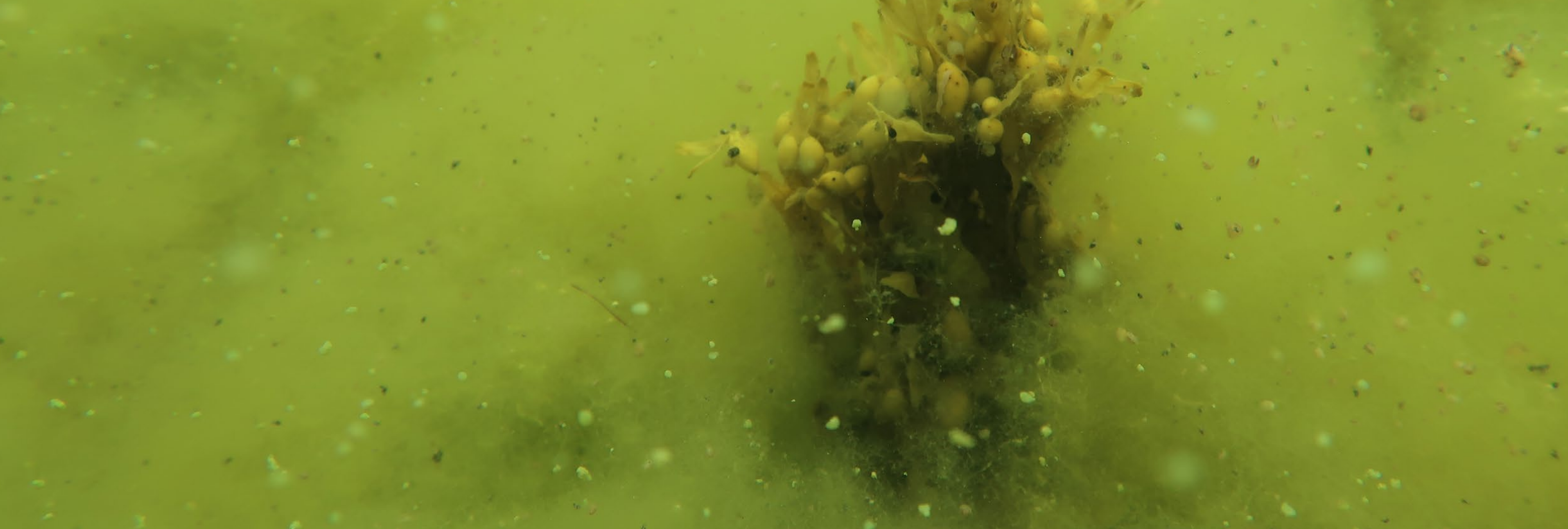


Figure 2. Mean change in ice thickness based on the climate models from SMHI and FMI.

The chances for ice fishing will become rarer if the sea ice becomes too thin or even absent in the future. Picture: Seger Marketing.

Bladderwrack (*Fucus vesiculosus*) surrounded by filamentous algae. Although both bladderwrack and narrow wrack (*F. radicans*) may benefit from less ice, they suffer from heatwaves in the summer. Filamentous algae, that can outgrow and even smother *Fucus* spp., may also increase in the future due to warmer water. Picture: Johnny Berglund / Länsstyrelsen Västerbotten.



Possible changes in salinity

The climate models used in this project suggest that the mean bottom salinity could decline by approximately 10 % (Fig. 3). This change could be highly stressful for some of the marine species in the Kvarken area that already live close to the limit of their tolerance for low salinity. However, there is a lot of uncertainty in the projections for precipitation, evaporation, river flow, sea level rise, and the frequency of pulses of salty water through the Danish straits, all of which can affect salinity[2, 3]. Therefore, also the predictions for future salinity are very uncertain, and several kinds of futures seem possible[4, 5].

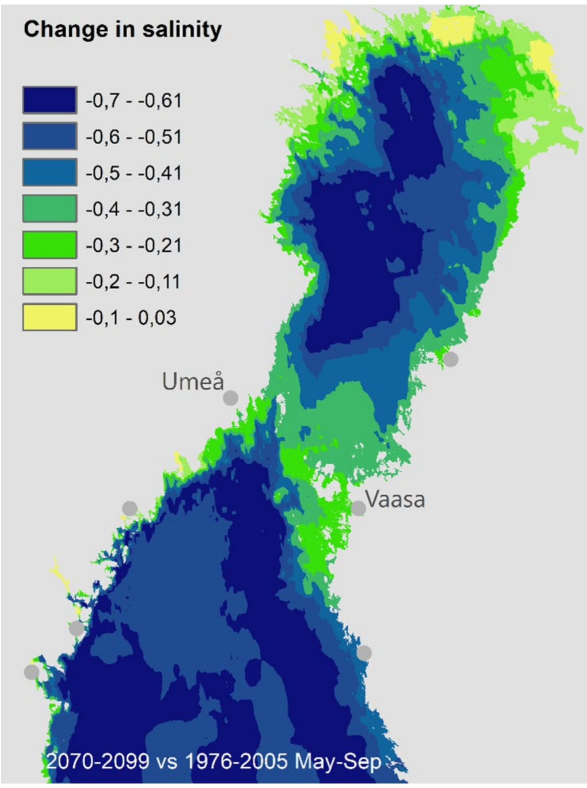


Figure 3. Changes in bottom salinity predicted by the climate models from SMHI and FMI. Unit for salinity is PSU.

Picture: Heidi Arponen / Metsähallitus.

Species react to changes in their environment

As global warming changes the environmental conditions in the sea, some species will benefit from the new situation, while others may decline or show no significant response. The species that most probably will thrive in the future are those aquatic plants and algae that benefit from warmer water and ice-free shores and the assumed successful application of the BSAP. In contrast, species that prefer cool and saline water are among the ones expected to react negatively to the changes.

The blue mussel is a key species in the Baltic Sea. It provides food and habitat for several other species, therefore changes in blue mussel communities can affect the entire ecosystem[6, 7]. Blue mussels also filter the water from nutrients and harmful substances, and it is estimated that the entire blue mussel community of the Baltic Sea filters all of the water in the basin each year[8]. The combined stress from low salinity and drastically increasing water temperature in the future may prove detrimental for mussels, which have already suffered from excessively high water temperatures during particularly warm summers[9, 10]. Based on species distribution models, the suitable areas for blue mussels within the project area might decrease drastically by the end of the century. It is possible that dense blue mussel populations will only occur in areas with higher salinity and in deeper areas where the water is colder (Fig. 4). However, mussels require rock or stones on which to attach, and in deeper areas, there is often soft sediment. Therefore, the future does not look good for the blue mussel, or those species that are dependent on it.

Changing nature

There are both winners and losers when conditions change. Visit **econnect2120.com** to see how the distribution of different species is expected to change in the future due to climate change.

Picture: Juuso Haapaniemi.

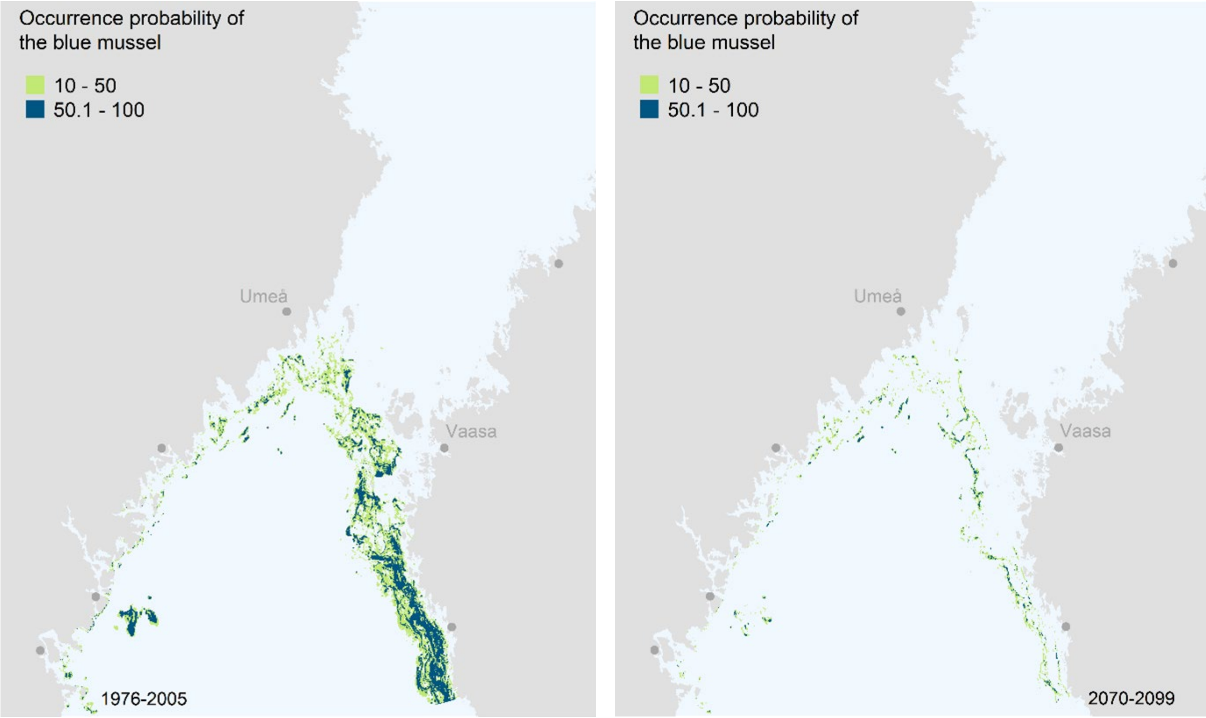


Figure 4. Suitable areas for the blue mussel in the reference period (left) and in the future (right) based on species distribution models made by the ECOnnect project. NB! The bottom substrate is not considered, so the areas predicted suitable by the models are only suitable if there is a hard substrate on which the mussels can attach. The green colour represents moderately suitable areas, and the blue colour represents the most suitable areas for the species. Modelling is based on the worst-case climate scenario RCP8.5 and nutrient reduction schemes by BSAP.

Changes in Ecosystem services

Species and ecosystems provide us with free benefits known as ecosystem services (Fig. 5). These services can be something we can use directly like fish or berries, which are considered as provisioning services. Indirect ecosystem services are often forgotten because they are harder to see. These include vital regulating and maintenance services e.g., where living organisms neutralize toxins or where both benthic fauna and bacteria recycle nutrients. Various plants forming under water meadows also help to provide ecosystem services. As well as photosynthesizing, plants provide food, habitats, and hiding places for fish. The sea itself also regulates climate by absorbing a large proportion of the excessive heat and carbon dioxide from the atmosphere. In addition, ecosystems provide cultural services like swimming and boating, as well as ice skating in winter.

Climate change is expected to have both positive and negative effects on the ecosystem services that the sea provides. Warmer water may lead to an increased probability of algal blooms in the summer, which reduces the value of the sea for recreational purposes, among other issues. On the other hand, warmer water will improve the living conditions of warm water fish (e.g., perch, pike, and cyprinids), leading to a possible increase in catches of those fish species[11, 12, 13]. At the same time, fish that are adapted to colder water (e.g., white fish and salmon) are expected to decline, meaning that there could be possible changes taking place in the fishing industry in the future. Species in the Gulf of Bothnia also have to deal with other possible effects of climate change in the future like e.g., changes in pH, and the spread of alien species, which can affect the provision of ecosystem services.

The thinning or disappearance of sea ice will reduce the much-appreciated cultural services related to it: ice fishing, ice skating, and skiing. Ice also calms water under it during winter and the loss of this protective cover can have several consequences. In general, although the changes in the physical parameters are hard to predict, climate change can lead to an increased risk of storms and higher waves in winter, which can cause damage to infrastructure built near or within the sea[2].

The ecosystem services index (ESI) created in the project displays where ecosystem services may decline or increase in the future (Fig. 6). The ESI is based on the most important plant, algae, and benthic animal species in the area, and it describes the ecosystem services related to those species. The net change in the ESI over the whole project area is +3 %, which in practice, means no remarkable change, considering the uncertainties. There are, however, some interesting and locally important spatial patterns in how the ESI is predicted to change. The map shows that in general, deeper areas will be negatively affected but that the shallow areas closer to the coast might be positively affected by climate change in the future (Fig. 6). The decline in ecosystem services provision in deeper areas is due to a decline in important key species of the deeper waters (the benthic amphipod *Monoporeia affinis*, the blue mussel, and the Baltic

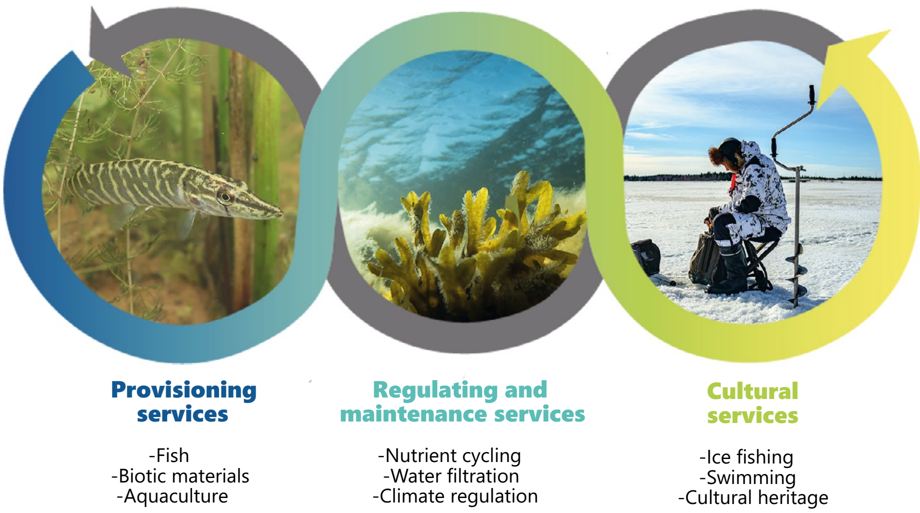


Figure 5. Ecosystem services are often grouped into three main categories: provisioning services, regulating and maintenance services, and cultural services. Further, although supporting services form the fourth group, they are often omitted when talking about service outputs as they form the underlying processes and functions in ecosystems that maintain other services. Pictures: Anniina Saarinen / Länsstyrelsen Västerbotten, Juuso Haapaniemi / Metsähallitus, & Seger Marketing.

clam *Limecola balthica*). While the reasons for this decline vary between species, in all cases it is related to climate change and the subsequent salinity and temperature changes. These species have an important role in e.g., food web dynamics, nutrient recycling, and water purification[7, 14, 15].

The positive changes in many shallow areas are related to a predicted increase in several plants and algae, that will benefit from clearer waters and ice-free shores. These changes are not only a consequence of climate change, but the models also assume that the nutrient reduction targets according to BSAP are achieved, which means that the nutrient input into the sea will be reduced. If this is not achieved, the results would be different since excess eutrophication is harmful to species and ecosystems. Also, it is important to keep in mind that only certain groups of species were included in the evaluation of ecosystem services (see page 12) and several species (and thus, services) could not be included. For example, fish species could not be taken into account in the ESI calculation, and thus the ESI can only describe ecosystem services provision within a narrow context. However, the changes in the distribution of the index species can also reflect the distribution of other species. For example, perch and pike could benefit from the expected increase of shallow water plant and algal communities, which offer them habitats and hiding places.

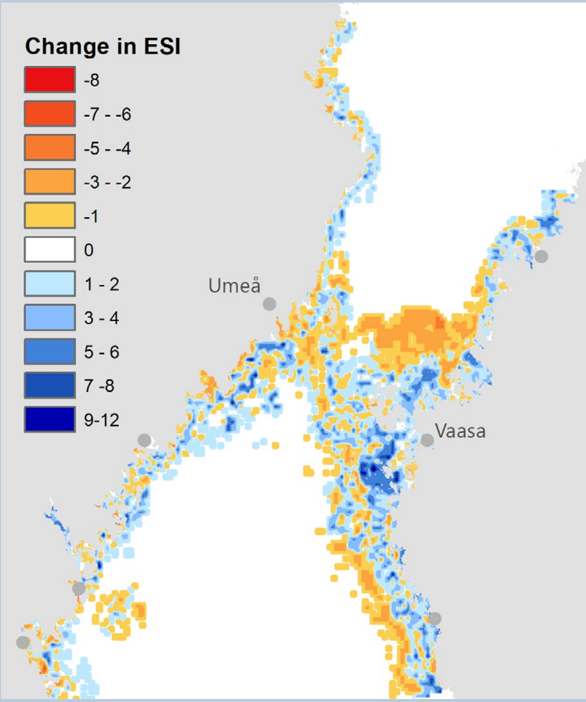
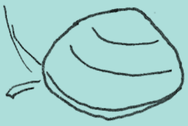


Figure 6. The difference in the provision of underwater ecosystem services today and in the future as measured by the Ecosystem Services Index (ESI) developed in the ECOnnect project. The unit is arbitrary and change in the index describes change in ES provision. The blue colour describes increasing ecosystem services, while the orange spectrum describes declining services. In total, ecosystem services produced by 11 species were included in the ESI calculation and the modelling of species distribution was based on the worst-case climate scenario RCP8.5 and nutrient reduction schemes by the BSAP.

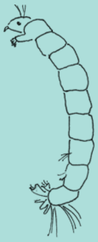
The importance of coastal areas

Many of the ecosystem services are concentrated in the shallow coastal areas. At the same time, this is where most human activities take place. It is therefore essential to use the coastal areas in a sustainable way without risking the provision of ecosystem services in the future.

Species and species groups included in the index



Baltic clam



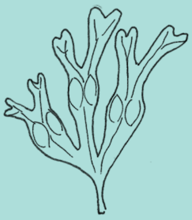
Filamentous annual algae

Monoporeia affinis

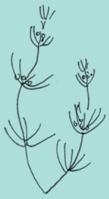
Chironomid larvae

Blue mussel

Furcellaria lumbricalis



Fucus spp.



Stoneworts

Aquatic mosses

Pondweeds

Common reed

Species illustrations: Anniina Saarinen.

Small image: Julia Nyström, Metsähallitus.

Big image: Juuso Haapaniemi, Metsähallitus.

Connectivity between habitats is vital for species

Species that live in the sea have adapted to specific environmental conditions over a long period. The species in the central Gulf of Bothnia, including the Kvarken area, are used to a certain range of water temperatures, salinity levels, and thicknesses of ice-cover during the winter, etc. If these were to change rapidly in the future as an effect of climate change, it could be difficult for species to adapt to the new conditions. If a species cannot adapt to the new conditions, it must spread to another area with a more favourable environment.

Species can spread between different habitats if they are not too far apart and if there are no barriers in the way. In the sea, such barriers can arise from activities like construction and dredging as they fragment the landscape. Unfavourable temperature and salinity can also work as barriers to movement. Marine protected areas are undisturbed areas for marine life and a way to fill in the gaps between disturbed habitats far away from each other. The better the protected areas are placed, the better habitat network they create for species. Thus, marine species have better chances to spread and better conditions for survival in the future. It is important to remember that not all species can spread the same distance or in the same way. Some species groups such as vegetation or mussels are immobile for a large part of their lifespan and mainly spread as spores or larvae. Other species groups such as fish can move actively for most of their lives. Some species also need a denser network of habitats than others. Species such as salmon can migrate long distances (several hundred kilometres), whereas other species such as perch move only short distances (10 km). There are also species that barely move at all, such as bladderwrack (usually around 10 m, and 1 km at most)[16].

Picture: Anniina Saarinen / Länsstyrelsen Västerbotten.

Also, some species can actively move from one habitat to another, whereas others must rely on passive transport with currents.

One aim of the project was to investigate how well marine nature is connected for species movement. One method of analysis for this focuses on the depth variable and highlights shallow areas as important for species movement (Fig. 7). The analysis visualizes the long-term spreading of species that prefer shallow environments and experience deeper areas as more difficult for their movement. The currents are not taken into consideration in the analysis. The results suggest that the Kvarken area in the central Gulf of Bothnia is an important route for species to spread between Sweden and Finland. The Finnish side of the gulf promotes spreading because the coastline is shallow and thus fosters lush ecosystems for many species to occur. Conversely, the Swedish side of the gulf along the High Coast is naturally very steep. This means that due to the light availability, in particular plant and algae species are limited to quite a narrow zone along the coastline. This limits the number of ecosystems in a specific area and thus also affects their connectivity. The connecting route in Kvarken also highlights the importance of collaboration between Finland and Sweden. The species living in our waters do not recognize national borders, and it is the countries' shared responsibility to provide a barrier-free connection over the Kvarken area.

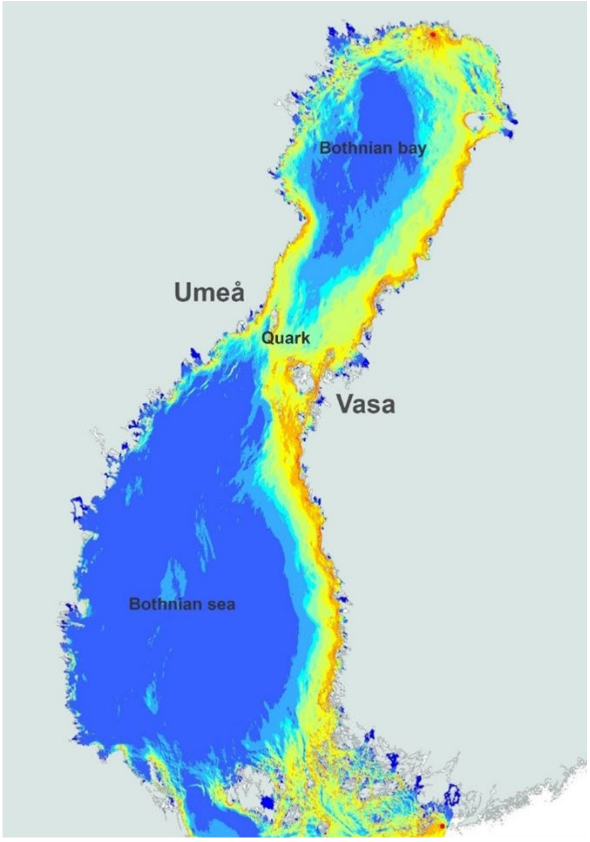


Figure 7. A model showing the possibility for large-scale species dispersal including probable geneflow across the coastline. The orange colour describes better conditions for spreading, yellow colour medium conditions, while turquoise describes weaker conditions for spreading. The shallow Kvarken area in the central Gulf of Bothnia is an important route for species to move between Sweden and Finland. On the Swedish coast, the movement of species is restricted in many places due to the very deep coastline, which limits the occurrence of many species to a rather narrow zone and weakens the possibilities for spreading. The Swedish coastline in the central Gulf of Bothnia thus becomes naturally fragmented and sensitive.

Shallow and undisturbed areas are important for species movement. Picture: Anniina Saarinen / Länsstyrelsen Västerbotten.

The future is uncertain

It is important to remember that the results presented in this summary report are based on certain assumptions and modelling methods, and like all models, they contain several sources of uncertainty and error. If the greenhouse gas (GHG) concentrations in the atmosphere would develop differently, or if the nutrient reductions according to BSAP are not successfully applied, as the models expect, the future will look different. Climate models also contain other potential sources of error and uncertainty in addition to the choice of future scenarios. Moreover, the complexity of nature and variation of possible futures makes predicting the future difficult. In conclusion, the results and predictions presented in this and other publications of the ECOnnect project are only one possible scenario of the future.

Act and adapt

Climate change is happening right now and cannot be reversed. What we can do is to act now and reduce the effects of climate change by reducing further GHG emissions and by enforcing carbon binding by protecting the environment. Further, it is important to make sure that the nutrient reduction targets of the BSAP are met on time in the entire Baltic Sea to ensure a healthier sea. Reducing eutrophication will also improve the ability of the Baltic Sea to better deal with the effects of climate change. Despite the efforts to minimize the effects of climate change, adaptation is also needed. Better marine spatial planning, nature conservation and restoration all help nature, as well as society to cope with future changes. The results of the ECOnnect project are meant to help in visualizing a possible future to which we may need to adapt. The project's species distribution models offer predictions on the possible future state of many important species in the area. With this knowledge, adequate means of conservation may be considered for the species that are expected to suffer from future changes in places that still will be suitable for them in the future. Society and its functions will have to adapt to future changes by modifying the ways they rely on certain ecosystem services, for example by investing in the utilization of new ones. A better understanding of the future changes in ecosystem services is needed for this purpose. For example, it could be profitable to create markets for and develop products of warm water fish species as they are expected to benefit from increasing water temperature. Further, by better acknowledging the need for habitat connectivity, we can concentrate on improving the connectivity across the whole coast with marine spatial planning. The actions and decisions we make today can have far-reaching effects and determine what kind of future the Baltic Sea will face, and nature and people with it.

How to reduce the impacts from climate change on the brackish water environment?

- Reducing greenhouse gas emissions
- Nature conservation
- Restoration of habitats
- Reducing coastal exploitation
- Reducing eutrophication and pollution
- Sustainable marine spatial planning

The central Gulf of Bothnia offers an interesting area for research as both marine and freshwater species co-occur there in abundance. Picture: Erik Engelro / Länsstyrelsen Västernorrland.

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What will the sea look like in 2120?

The ECOnnect project was an Interreg Botnia-Atlantica project that began in June 2018 and ended in May 2022. The project was a result of a long-time cross-border collaboration between Finland and Sweden in the central Gulf of Bothnia. Project partners included The County Administrative Board of Västerbotten, The County Administrative Board of Västernorrland, Metsähallitus Parks & Wildlife Finland, and South Ostrobothnia Centre for Economic Development, Transport, and the Environment. The project area was confined to Ostrobothnia and Central Ostrobothnia in Finland and the Counties of Västerbotten and Västernorrland in Sweden. The climate models used in the project are based on the modelling work done by SMHI and FMI. The models were originally made for the SmartSea project with projections to the year 2059, but for the ECOnnect project, the projections were further extended to the year 2099.

Additional information

For full reports, visit **econnect2120.com**

SeaGIS2.0 portal for GIS-layers of the future models produced in the ECOnnect project

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