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2nd International Baltic Earth Workshop on

Multiple Drivers of Earth system changes in the Baltic Sea region

Helsinki, 4 - 5 December 2024

Programme, Abstracts, Participants

Edited by
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Cover image:
Large, small and very small vessels share the Warnow river mouth, Rostock, Germany, southern Baltic Sea (Marcus Reckermann)

Multiple drivers for Earth system changes in the Baltic Sea

Helsinki, 4 - 5 December 2024

Preface

After the completion of the first phase of Baltic Earth and with the onset of a new phase, we are now revisiting the Baltic Earth Working Group on "Multiple drivers for Earth system changes in the Baltic Sea". This international Workshop shall set the scope for the new phase of this updated Baltic Earth Research Topic (RT) and bring together scientists and managers who are interested in collaborating in this continued Baltic Earth activity.

Background

The industrial revolution and the subsequent developments have dramatically changed the world, with massive benefits for humans and concomitant detrimental effects like anthropogenic climate change, eutrophication, overfishing, pollution, and others. It is now widely accepted that the connections between these intertwined factors must be addressed. Many publications have dealt with this complex issue on a general scale (differently termed multiple or cumulative effects, stressors, pressures, drivers), mostly using statistical analysis or modelling approaches to better describe the problem, or management procedures to cope with it.

The Baltic Earth Working Group on "Multiple drivers for Earth system changes in the Baltic Sea" has intended to provide an overview over the different human drivers and interrelations between then in the Baltic Sea region. The first Baltic Earth Workshop on this topic in Tallinn in 2018 set the stage and established a group of interested scientists which culminated in a writing team for the comprehensive Baltic Earth Assessment Report (BEAR) paper in Earth System Dynamics: "Human impacts and their interactions in the Baltic Sea region."

Scope of the Workshop

The outcome of the above-mentioned paper was the description of a number of human drivers for environmental changes and how they potentially interact with each other. We would now like take this to a new, more concrete level, and we are inviting interested scientists and managers to come together for the second Workshop to discuss how Baltic Earth can contribute to improving the scientific backup to the necessary management solutions. We would like to initiate an open discussion with the interested scientific and management community on how Baltic Earth can help to find the scientific foundation for best management practices to manage the different, often intertwined human pressures on the environment, while acknowledging human needs. The goal would be to provide knowledge as far as possible to help establish management options for policy makers.

The workshop should discuss how we as Baltic Earth scientific community can contribute to reaching this goal. A concrete outcome of this workshop should be the establishment of a group of interested and dedicated scientists to develop concrete and feasible plans for this updated Baltic Earth Research Topic (RT) for the next 3 years.

The Workshop Committee

***Kari Hyytiäinen**, Department of Economics and Management, Helsinki Institute of Sustainability Science (HELSUS), University of Helsinki, Finland*
***Markus Meier**, Leibniz Institute of Baltic Sea Research Warnemünde and University of Rostock, Germany*
***Kai Myrberg**, Finnish Environment Institute (Syke), Helsinki, Finland*
***Susa Niiranen**, Stockholm Resilience Centre, Stockholm University, Sweden*
***Marcus Reckermann**, International Baltic Earth Secretariat, Helmholtz-Zentrum Hereon, Geesthacht, Germany*
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2nd Baltic Earth Workshop on Multiple Drivers for Earth system changes in the Baltic Sea region

4-5 December 2024, Helsinki, Finland

Draft Programme

(details and presentation titles may change)

Day 1 (Afternoon, Wednesday 4 December 2024)

12:00-12:05 **Introduction**
Markus Meier and Marcus Reckermann

Invited Presentations (15+5)

First Block: Assessment of Drivers and Impacts
Chair: Kari Hyttiäinen

12:05-12:25 **Land-based food production: Land use, eutrophication and impacts**
Bärbel Müller Karulis

12:25-12:45 **Non-indigenous species and biodiversity in the Baltic Sea**
Maiju Lehtiniemi

12:45-13:05 **Coastal management options in the Baltic Sea, with particular reference to coastal infrastructure**
Kevin Parnell

13:05-13:25 **Maritime transport and safety**
Jukka-Pekka Jalkanen

13:25-13:45 **Renewable energy production: Wind power generation**
Xiaoli Guo Larsén

13:45-14:05 **The HELCOM Holistic Assessments (HOLAS)**
Owen Rowe

Second Block: Assessment of Management options (7+3)
Chair: Kai Myrberg

14:05-14:25 **Environmental management options and policy instruments**
Kari Hyytiäinen

14:25-14:45 Break

14:45-15:05 **Ecosystem-Based Management and Baltic Health Index**
Thorsten Blenckner

15:05-15:25 **ICES Integrated Environmental Assessment of the Baltic Sea**
Riikka Puntila

15:25-15:45 **Combining numbers with expert knowledge: piecing together a holistic understanding of marine social-ecological systems**
Susa Niiranen

15:45-16:05 Panel discussion of presentations

Third Block: Short presentations (7+3)
Chair: Susa Niiranen

16:05-16:15 **Control of pathogenic vibrios via reduction of algal blooms in the Baltic Sea**
David Riedinger and Matthias Labrenz

16:15-16:25 **Comparison of Baltic Sea mesozooplankton and terrestrial mountain birch moth biomasses in relation to climatic factors**
Heta E.J. Rousi, Julia J.J. Fält-Nardmann, Betty Marjamäki, Ilmari Juutilainen, Tommi Andersson, Juhani Itämies, Pekka Niemelä and Jari Hänninen

16:25-16:35 **Baltic Sea coastline change under climate and human impacts – classification and quantification**
Wenyan Zhang, Peter Arlinghaus and David Pogorzelski

16:35-16:45 **Impact of bottom trawling on benthic ecosystem and sedimentary carbon storage**
Wenyan Zhang and Lucas Porz

16:45-16:55 **Impacts of Offshore Wind Farms on the Baltic Sea**
Andrew Twelves, Aleksi Nummelin and Pedro Bourdin

16:55-17:05 **Investigating the Impact of Offshore Wind Farms on Ocean Circulation and Turbulence in the North Sea and Baltic Sea**
Sonaljit Mukherjee, Vilnis Frisfelds, Jens Murawski and Jun She

17:05-17:15 **Marine heatwaves in the Gulf of Bothnia from historical measurements to future projections**
V. Haapaniemi, S-M. Siiriä, A. Nummelin and J. Haapala

17:15-17:25 **The combined impact of eutrophication, climate warming and marine structures on the water properties in the Baltic Sea**
Taavi Liblik

17:25-17:35 **Understanding the Complex Interplay of Climate and Oceanographic Drivers Shaping Long-Period Waves and Coastal Resilience in the Baltic Sea Region**
Loreta Kelpšaitė-Rimkienė

17:35-17:45 **Interaction of climate change with other drivers**
Markus Meier

17:45-17:55 **Socially optimal agriculture and forestry for improved water quality in the Baltic Sea**
Jenni Miettinen and Sanna Lötjönen

17:55-18:15 Panel discussion of presentations

18:15 Open Discussion and Wrap-up of Day 1
Outlook on Day 2

18:30 End of Day 1

Day 2 (Morning, Thursday 5 December 2024)

9:00 Recap Day 1 and Open Discussion

10:00 Establishment of Breakout Groups
Discussions within Breakout Groups

11:00 – 11:30 Break

12:00 Reporting by Group Rapporteurs and the way forward

12:45 Wrap-Up and Farewell

13:00 End of Workshop

Abstracts
Invited talks

1st author sorted alphabetically

Ecosystem-based management and the Baltic Health Index

Thorsten Blenckner, Stockholm Resilience Centre, Stockholm University, Sweden

Improving coastal and open sea marine ecosystem health is crucial for ecosystem-based management (EBM). A primary challenge of EBM is balancing the protection of ecological structure and functioning with the sustainable production of ecosystem services and societal benefits. Additionally, assessing cumulative effects on marine ecosystems remains difficult. The Baltic Health Index (BHI) addresses these challenges as a transparent, collaborative, and repeatable assessment tool that complements existing approaches by incorporating human dimensions in evaluating the Baltic Sea's status. Using extensive social-ecological data, we assessed nine goals representing progress towards set targets, including clean waters, biodiversity, food provision, natural products extraction, and tourism. Our results indicate suboptimal overall health of the Baltic Sea (76 out of 100), with substantial effort required to reach management objectives. The lowest scores were observed for carbon storage, contaminants, and marine protected areas, with significant spatial variation. Future projections suggest a positive trend towards a healthier Baltic Sea, although some basins show decreasing trends for specific goals. The BHI outcomes can identify management priorities at pan-Baltic and sub-regional scales, illustrating the interconnectedness of goals linked by cumulative pressures. This tool provides valuable information for policymakers and stakeholders in marine ecosystem management, supporting more effective implementation of EBM strategies.

Environmental management options and policy instruments

Kari Hyytiäinen, University of Helsinki Helsinki, Finland

I use the DPSIR framework to analyze the interactions between drivers and policy actions in the management of environmental problems in coastal and marine environments. The DPSIR framework is a conceptual model that provides a structured approach to understanding the relationships between human activities and the environment. This framework facilitates the development of effective policies and management strategies. Within the DPSIR framework drivers represent the underlying social, economic, or environmental trends and processes that indirectly cause environmental changes. These are broad, systemic factors originating from human values or natural processes. Drivers often reflect socio-economic or cultural trends and are linked to the overarching needs or aspirations of humanity. Responses refer to the actions taken by individuals, governments, organizations, or society at large to address the impacts of environmental issues. These responses may aim to indirectly impact drivers or directly reduce pressures, improve environmental state, or mitigate negative. Responses include: (1) regulations and legislation (laws, policies); (2) economic instruments (taxes, subsidies, trading schemes); (3) management actions (e.g. best practices or developing infrastructure for pollution control or restoration); (4) technological innovations; (5) awareness campaigns and education; (6) monitoring and research, and (7) international Cooperation. The challenging task for policymakers is to select the most appropriate policies based on various criteria, including expected effectiveness, economic efficiency, administrative burden, cross-sectoral impacts, equity and fairness considerations, and uncertainties.

Environmental pressures of shipping and their trends in the Baltic Sea area during 2006-2023

Jukka-Pekka Jalkanen, Atmospheric Composition Research, Finnish Meteorological Institute

In the Baltic Sea area, the trend of GHG emissions from ships has some worrying features. Emissions from international shipping are decreasing, but they are decreasing at a rate which leads to -50% in 2050 when compared to 2008 situation, as is stated in the original IMO GHG strategy. Domestic shipping emissions are not decreasing. This falls short of the revised strategy target of making international shipping carbon neutral by 2050.

To comply with the gradually tightening air pollution requirements in the Baltic Sea area, over 800 ships are using an Exhaust Gas Cleaning System (SOx scrubber). This has created a new pollution stream from ships directly to the sea, dwarfed only by the ballast water discharge.

Impact studies show that the effects of scrubber discharges are detrimental to many marine species, especially at early development stage. Polyaromatic carbon components and metals are commonly found in the effluent, which are harmful to many organisms. Whole effluent toxicity testing shows that some species suffer even at 1 ppm levels of scrubber effluent, and coastal and archipelago areas are at risk of contamination.

These discharges can be regulated by countries themselves, in their territorial seas inside the 12 nm zone, but any extension beyond this would require a decision at the IMO. Currently, IMO has not agreed to ban scrubbers, but countries like Denmark, Sweden and Finland already have, or will soon, ban the effluent discharges from scrubbers.

Non-indigenous species and biodiversity in the Baltic Sea

Maiju Lehtiniemi, Finnish Environment Institute, Finland

Non-indigenous species are one of the largest threats to biodiversity globally. New species are mostly introduced via shipping (ballast water and hull fouling) also to the Baltic Sea. International agreements in place and in development will hopefully decrease the rate of new introductions in the future. As eradication of established non-indigenous species is mostly impossible, species already introduced are spreading and increasing in abundance causing changes in the habitats and food webs. Changes are often shown only as negative ones but some species may also have positive impacts on the ecosystem or humans. Although non-indigenous species have been studied a few decades in the Baltic Sea evidence base on the effects they cause is still very limited even for the most widespread species. To meet the requirements of international legislation countries and regional sea conventions need to assess the number of introduced species, their abundance and impacts, requirements depending on the legislative act. Gathering the needed data and knowledge continuous monitoring in various habitats is of utmost importance with the ultimate aim of managing non-indigenous species and their negative effects. Monitoring covering well different habitats and taxonomic groups serve both non-indigenous species management and biodiversity assessments.

Land-based food production: Land-use, eutrophication and impacts

Bärbel Muller-Karulis, Michelle McCrackin, Benoit Dessirier, Bo Gustafsson, Christoph Humborg

Roughly half of the present nitrogen and phosphorus loads to the Baltic Sea originate from diffuse sources, with agriculture as the main contributor. Agriculture is the dominant land use in the catchments of the Danish Straits and the Baltic Proper, whereas boreal forest cover much of the northern catchments. Today about 21% of the total catchment area of the Baltic Sea drainage is used for agriculture today, a decline from 33% since 1910.

Fuelled by technological advances and access to mineral fertilizers agricultural production increased despite the decline in agricultural area. In particular the growing mineral fertilizer consumption after WWII led to increasing net anthropogenic inputs of nitrogen and phosphorus to the drainage basin. Compared to pre-WWII, these inputs had roughly tripled until the 1980s, before declining in Denmark, Sweden, and Finland. In the former East Bloc countries net inputs grew until the collapse of the Soviet Union. After 2000, net nitrogen inputs stabilized at 64% and phosphorus inputs at 30% of 1980s levels.

Soils and inland waters temporally store nitrogen and phosphorus inputs to the catchment, forming active legacy pools that contribute to riverine nutrient loads. A simple storage model suggests that these legacy pools delayed the response of riverine loads to changes in nitrogen and phosphorus inputs to the catchment with response times of approximately 4 years for nitrogen and 6 – 18 years for phosphorus. Given the relatively low present NAPI inputs to the Baltic Sea catchment, we expect a continued decline in riverine phosphorus loads, whereas nitrogen loads are in balance with inputs to the catchment.

Combining numbers with expert knowledge: piecing together a holistic understanding of marine social-ecological systems

Susa Niiranen

The exploitation of natural resources is moving from land to sea at unprecedented rates. Together with rapidly changing climate, the risks for the deterioration of coastal and ocean ecosystems are increasing, and trade-offs between the different uses of ocean space and resources are unavoidable. Such development is also evident in the Baltic Sea. With increasing claims, the challenge of sustainable ocean management is not only getting more complex, but also urgent, calling for assessment approaches that can make the best use of existing evidence of social-ecological system interactions and vulnerabilities even under conditions of imperfect or lacking data. This talk will introduce examples of different approaches to ecosystem resilience and risk assessment that build both on quantitative data and qualitative evidence including expert knowledge. The chosen examples are derived from ongoing research projects covering a range of different marine environments and social-ecological systems. The applicability of such approaches to Baltic Sea specific questions will be discussed.

The HELCOM Holistic Assessments (HOLAS)

Owen Rowe, HELCOM Secretariat, Finland

The third HELCOM regional holistic assessment of the health of the Baltic Sea, HOLAS 3, was published in 2023. The assessment is based on the input and review of over 1000 regional experts (scientists, managers, and policy makers), consists of a summary report, five thematic assessments, fifty-nine indicators, and millions of data points. The purpose of these assessments is to support achievement of the Baltic Sea Action Plan (BSAP, 2021) vision and support Contracting Parties (countries) that are also EU Member States with Marine Strategy Framework Directive (MSFD) reporting, in doing so also understanding if progress is being made via the measures that are implemented. The process relies on science at its core, addressing regional and policy requirements in the process.

In HOLAS 3 HELCOM applied a conceptual management framework, DAPSIM, to support the assessment. By linking Drivers-Activities-Pressures-Status-Impact-Measures, where impact equally represents an impact on the ecosystem or society, we aim to build towards a data driven assessment across all components. This can allow for a clear understanding of where the problems lie and where measures are most effectively placed to achieve a sustainably used and healthy Baltic Sea. A vast array of human activities have been identified as present in, or relevant for the Baltic Sea, leading to pressures of various kinds. In cases a single activity may also generate multiple pressures, though in others these connections may be more linear. Building from this is the potential for cumulative impacts to emerge from this mass of pressures generating significant impacts on the Baltic Sea ecosystem.

The most recent holistic assessment addresses the core topics of biodiversity status, including food webs, and key pressures such as hazardous substances, eutrophication, non-indigenous species, underwater noise, and marine litter, as well as exploring the cumulative effects of these in relation to the ecosystem and society.

Coastal management options in the Baltic Sea, with particular reference to coastal infrastructure

Kevin Parnell, Department of Cybernetics, School of Science, Tallinn University of Technology, Tallinn, Estonia

We often consider the Baltic Sea as a single entity, to be studied and managed in its entirety. We seek management solutions that transcend national borders, looking for wide applicability. The reality, of course, is quite different. From a coastal geomorphic perspective, considering coastal erosion and inundation as the most significant hazards, the situation around the Baltic Sea shores is hugely variable. For the northern shores, there is little that needs active management. The hard rocky coasts, with continued isostatic uplift and lower energy inputs, provide stability, with infrastructure design able to reflect these realities, and managers able to concentrate on non-physical problems. The southern and eastern shores of the Baltic reflect a different reality, with erosion, inundation, and infrastructure damage, being significant problems, due to the isostatic status of the coast, exposure to dominant winds and different sedimentary characteristics. In some areas alongshore sediment transport is massive. The management challenges and costs on these shores, particularly those with high-value infrastructure, are consequently also high. The situation is even more complicated by different drivers dominating the physical process regimes in different parts of the sea, even over relatively small distances. There must therefore be a range of management responses, reflecting the different drivers, even at the scale of a single country. Future challenges will reflect different driver/location combinations, which must be understood to avoid negative economic and social consequences.

Integrated ecosystem assessments in the Baltic Sea

Riikka Puntila-Dodd and the ICES WGAIB group

Most ecosystems in the world are susceptible for a variety of human pressures, while humans depend on the ecosystem services they provide. The Baltic Sea is no exception and the ecosystem functions in a tight connection with the human system making it a great example of a socioecological system (SES). Moving management of SESs towards Ecosystem Based Management (EBM) requires knowledge of all the dimensions of the ecosystem as well as integration of human perspectives. Integrated Ecosystem Assessments (IEAs) aim at synthesizing and evaluating information on physical, chemical, ecological, human and environmental processes affecting ecosystems. IEAs have been originally developed as a framework to implement and assess the progress of EBM. An IEA aims to be a dynamically evolving tool co-created product by experts in the relevant social, economic, and ecological areas, as well as stakeholders to capture the ecosystem status, and the adequacy of its management implementation process.

ICES WGIAB is aiming to produce science that promotes adaptive and holistic marine management strategies in the Baltic Sea. We develop tools for IEA, applied to the Baltic Sea but transferable to parallel situations in the other regional seas. We assess long-term trends in the ecosystem (e.g., Integrated Trend Analyses, ITA) and develop models for scenario-based management strategy evaluation. Our work builds on case studies to enhance understanding of the Baltic Sea ecosystem, particularly concerning food-web dynamics, management trade-offs, and ecosystem interactions over different temporal and spatial scales, and to identify key species and processes for sustainability.

Offshore Wind Energy in the Baltic Sea and its impacts

Xiaoli Guo Larsén, Department of Wind and Energy System, Technical University of Denmark

Wind energy is becoming an essential part of the energy system in the Baltic Sea region (BSR). This study provides an overview of the development of offshore wind energy in the BSR. It acknowledges the numerous relevant, good quality, pertinent studies on the subjects of resource, siting conditions (including winds, waves, seabed, icing, precipitation), maritime spatial planning, grid connection and integration, and social and political aspects. The overview demonstrates that in the wind energy sector, there are already technologies, methods, tools and data that are sufficiently mature, and many of them can be applied to support the urgent and extensive scale development of offshore wind in the region. This study also addresses the impacts of the offshore wind farms on a number of environmental factors.

Abstracts
Short talks

1st author sorted alphabetically

Marine heatwaves in the Gulf of Bothnia from historical measurements to future projections

Haapaniemi V[1], Siiriä S-M.[1], Nummelin A.[1,2], Haapala J.[1]

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[2]NORCE Norwegian Research Centre AS, Bergen, Norway

Marine heatwaves (MHWs), defined as extended periods of extremely high oceanic temperatures, are known to impact aquatic respiration and oxygen depletion in marine ecosystems. Understanding the frequency, intensity and regional extent of MHWs is crucial for predicting ecosystem health. We argue that understanding the spatio-temporal variability and long-term trends in MHWs is important for marine conservation planning in the Baltic Sea, as managing cumulative impacts would require reducing other environmental stressors from regions where higher impacts of MHWs are to be expected.

In this presentation the past MHW events in the Gulf of Bothnia are analyzed based on historical measurements from the Finnish coastal stations. The properties of these historical heatwave events are then compared to the heatwave events identified from modeled future projections between the present day and the end of this century. The future projections of the NEMO ocean circulation model are forced with dynamically downscaled atmospheric conditions following the RCP4.5 and RCP8.5 emission scenarios.

Understanding the Complex Interplay of Climate and Oceanographic Drivers Shaping Long-Period Waves and Coastal Resilience in the Baltic Sea Region

Loreta Kelpšaitė-Rimkienė, Marine Research Institute, Klaipėda University, Lithuania

The Baltic Sea region faces a complex interplay of drivers transforming the Earth system, for significant implications for long period waves. Climate change stands as a key driver, altering wind patterns and intensifying storms, leading to more frequent and powerful long waves of different origins. These waves disrupt port operations, as seen in Klaipeda, impacting maritime traffic and local economies. To increase the resilience of coastal zones to the effects of climate change, a balance between environmental health and human well-being needs to be considered. For successful management of coastal regions, controversial ideas must be considered, as the same management methods cannot be applied across the entire Baltic Sea. As a semi-enclosed and shallow marine environment, the Baltic Sea is highly dynamic, its behavior strongly governed by large-scale atmospheric circulation and hydrological processes (Lass & Matthäus, 2008). The region's wave climate is profoundly shaped by the interplay of these atmospheric and oceanographic drivers. The salinity dynamics of the Baltic Sea are a fundamental component, with major implications for the entire ecosystem (Lehmann et al., 2022).

Long waves driven by air pressure disturbances can trigger harbor resonance in the Port of Klaipeda and allow saline water intrusion through the Klaipeda channel into the Curonian lagoon. This single driver, long waves, can directly impact human well-being through economic factors and disrupt the fragile brackish ecosystem of the Curonian lagoon via saline water intrusion. Therefore, understanding these complex interactions and their potential consequences is crucial for developing effective adaptation and mitigation strategies to ensure the sustainable future of the Baltic Sea region.

References

1. Lass, U., H., and Wolfgang Matthäus. 2008. "General Oceanography of the Baltic Sea" : 5-43. https://doi.org/10.1002/9780470283134.ch2.
2. Lehmann, Andreas, Kai Myrberg, Piia Post, Irina Chubarenko, Inga Dailidienė, Hans-Harald Hinrichsen, Karin Hüssy, Taavi Liblik, H. E. Markus Meier, Urmas Lips, and Tatiana Bukanova. 2022. "Salinity dynamics of the Baltic Sea" Copernicus Publications 13 (1) : 373-392. https://doi.org/10.5194/esd-13-373-2022.

The combined impact of eutrophication, climate warming and marine structures on the water properties in the Baltic Sea

Taavi Liblik, Tallinn University of Technology, Tallinn, Estonia (taavi.liblik@taltech.ee)

Eutrophication leads to hypoxia and anoxia in the near-bottom layer of the Baltic Sea. Oxygen depletion could be further exacerbated by the long-term warming of the upper layer. The physical drivers impacting the oxygen conditions in the water column are water exchange and vertical mixing, which could be altered by marine structures. We show two examples of the impact of marine structures: a dam in a shallow strait and planned offshore wind farm.

Ecological conditions in the Väike Strait between Saaremaa and Muhumaa have been considerably impacted. Water exchange in the area close to the dam has decreased 10–12-fold. As a result, exchange with the atmosphere and sediments has a relatively greater role in shaping water characteristics. Consequently, occasional very high sea surface temperature, salinity, and total nitrogen, and strong diurnal cycles in water temperature (>4°C) and dissolved oxygen (>4 mg l^{-1}) were observed near the dam in summer.

Offhore wind farm foundations, on one hand, cause additional drag and impact the current field, increasing vertical mixing. On the other hand, the wind wake effect of offshore wind farms reduces vertical mixing. One could expect that this impact on horizontal advection and vertical transport reflects in physical and biogeochemical variables.

In conclusion, marine structures, particularly the planned numerous wind farm developments, could accumulate with the existing human pressures and impact the pelagic habitats.

Interaction of climate change with other drivers

Markus Meier, Institute of Baltic Sea Research Warnemünde, Rostock, Germany

According to the Baltic Earth Assessment Reports climate change is perhaps not the largest driver of societal changes in the Baltic Sea region but systematically affects many of the other drivers of the Earth system including the atmosphere, hydrosphere, cryosphere, biosphere, lithosphere and anthroposphere. Projections for the Baltic Sea region suggest that in the future mean air and water temperatures will increase, sea level will rise, snow and ice (on sea, lakes, and rivers) will melt, and acidification will increase , at least in the southern Baltic Sea. Other changes such as changes of the water cycle are less clear (precipitation, evaporation, river discharge, ocean salinity). In this presentation the current knowledge about climate change in the Baltic Sea will be summarized and its interaction with other drivers such as ocean hypoxia, fisheries, non-indigenous species, land use and nutrient loads, aquaculture, river regulation, offshore wind farms, shipping, chemical contaminants, dumped military material, marine litter, tourism, and coastal management will be discussed.

Socially optimal agriculture and forestry for improved water quality in the Baltic Sea

Jenni Miettinen and Sanna Lötjönen , University of Helsinki, Finland

In the land use sector, agriculture and forestry are significant sources of pollution, contributing to nutrient , sediment and organic carbon loads. These loads origin ate from inland catchment areas and reach the Baltic Sea through rivers Thus, these sectors are major drivers affecting the status of the sea In addition to their impacts on water quality, agriculture and forestry significantly affect climate change and biodiversity , highlighting their future role in preserving the Baltic Sea.

Economically negative environmental impacts from agriculture and forest management practices, such as nutrient loads, are considered negative externalities. These negative externalities can further be defined in monetary terms, which allows comparing them to the profit s from economic activities in the two sectors . Both the net revenues and the negative externalities can then be simultaneously evaluated in an economic framework, which describes the social welfare from agriculture and forestry.

The ways to decrease water quality impacts include both water protection measures and changes in agricultural and forest management practices (for example carbon farming and continuous cover forestry) forestry). In the social optimum framework, the costs of these water protection measures and required changes in management practices can be estimated. The social optimum framework enables the analysis of water policy instruments targeted at the land use sector. Currently, economic studies on these water policy instruments are found in agriculture but are missing in forestry. In the future there is an increasing need to jointly design the policy instruments used in agriculture and forestry to be applied in the catchment scale. Further, it is important to study and account for the possible coeffects of climate and biodiversity policies targeted at land use sector to avoid tradeoffs between different environmental goals.

Keywords

agricultural production, carbon farming, continuous cover forestry, economic instruments, forest management, nutrient load, organic carbon load, sediment load

Investigating the Impact of Offshore Wind Farms on Ocean Circulation and Turbulence in the North Sea and Baltic Sea.

Sonaljit Mukherjee, Vilnis Frisfelds, Jens Murawski and Jun She

With the expansion of offshore wind farms, multi-use platforms combining wind energy and aquaculture have emerged as promising tools to support sustainability and reduce carbon emissions. However, large-scale deployment of these structures raises questions about their cumulative impact on marine environments. As part of the OLAMUR project, this study investigates the effects of wind farms on ocean circulation and turbulence in the North Sea and Baltic Sea, both of which have high potential for sustainable energy and aquaculture.

Using the Hiromb-Boos Model (HBM) with a modified $k-\omega$ turbulence closure, we simulate the frictional drag generated by clusters of wind turbines, examining their impact on ocean properties like salinity, velocity, and turbulent kinetic energy. Our simulations compare outputs with and without wind-farm-induced drag across different horizontal resolutions (0.1 and 1 nautical mile), showing that the drag enhances submesoscale turbulence, particularly in densely populated wind-farm areas of the southern North Sea. Results indicate that frictional drag from internal tidal oscillations primarily drives submesoscale turbulence in these regions, while strong cross-exchange flows between the North Sea and Baltic Sea contribute to turbulence in the Danish Straits. Spectral analysis further highlights regional differences in submesoscale turbulence influenced by tides, stratification, and lateral shear. These findings offer insights into wind farm impact on ocean dynamics, and demonstrate a technical approach for modifying regional ocean models to account for drag induced by wind-farms with dimensions much smaller than the model's grid resolution.

Marine heatwaves in the Gulf of Bothnia from historical measurements to future projections

Riedinger, D.[1] and Matthias Labrenz[1,2]

[1]Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Germany
[2]Marine Research Institute, Klaipeda, Lithuania

Human pathogenic bacteria of the genus Vibrio are gaining significance in the Baltic Sea, with Vibrio vulnificus likely posing the greatest threat. This species can infect immunocompromised individuals during bathing or wading and can lead to death within a few days. Such infections pose risks to human health and aquaculture and attract considerable media attention as 'flesh-eating Baltic Sea bacteria', potentially harming tourism.

Previous studies have suggested a positive relationship between the abundance of V. vulnificus and water temperature, eutrophication, and algal blooms, and a negative relationship with the presence of seagrass. This allows for possible local or regional regulation measures of V. vulnificus; locally through restoration of seagrass meadows and regionally through reduction of eutrophication levels or consequential algal blooms. The potential of both these options for the Baltic Sea coastlines was explored in the Biodiversa project “BaltVib”.

We found that V. vulnificus abundance was indirectly influenced by eutrophication, as it was associated with algal blooms, with no observable effect from seagrass. In consequence, reducing eutrophication induced algal blooms may be the most effective strategy for limiting the proliferation of V. vulnificus along the Baltic coast. Thus, while abundances of pathogenic V. vulnificus can probably be influenced on regional level in the Baltic Sea, faster nature-based solutions acting at the local level seem to have little impact on pathogenic Vibrio spp. in coastal waters. This highlights the importance of adequate management solutions for good coastal water quality on the issue of human pathogenic bacteria.

Comparison of Baltic Sea mesozooplankton and terrestrial mountain birch moth biomasses in relation to climatic factors

Heta E.J. Rousi[1], Julia J.J. Fält-Nardmann[2], Betty Marjamäki[2], Ilmari Juutilainen[3], Tommi Andersson[2], Juhani Itämies[3], Pekka Niemelä[2,4], Jari Hänninen[1]

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As new research initial, we investigate the effects of NAO and observed marine regime shifts (RS) in two different ecosystems. Time series data were used to compare trends and changes in the biomasses of northern Baltic Sea mesozooplankton (1966–2019) and subarctic moths (1972–2017) and to analyse how both groups were affected by climate variables.

Biomasses of all mesozooplankton groups decreased. Decreases of total and marine copepods and cladocerans as well as brackish copepods were the most obvious, but also total rotifer biomasses decreased.

Concerning moths, some, especially generalist moth guilds as well as moths overwintering as eggs and imagines, increased, whereas specialist moth guilds and those overwintering as larvae, decreased in biomass.

RS, during 1975–76 positively correlated with total and marine copepods, as it was caused by a Major Baltic Inflow event. RS during1989–90, however, was the most significant factor for mesozooplankton, especially for marine and brackish water originating groups. Winter NAO negatively correlated with total and brackish cladoceran biomasses.

Moths hibernating as imagines and host plant generalists, were negatively correlated with autumn NAO. Host plant specialists were correlated negatively with RS in 1975–76. Total moths, moths overwintering as eggs and those feeding on at least three plant genera were positively correlated by the RS in 1989–90.

Our results indicate significant effects of climate change on mesozooplankton and moths, but the climatic regulation mechanisms affect these invertebrate groups differently, for instance due to phenological and ecosystem related differences.

Keywords

climate change, NAO, regime shifts, mesozooplankton, moths

Impacts of Offshore Wind Farms on the Baltic Sea

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Offshore wind farms (OWFs) have large potential as a source of electricity for countries surrounding the Baltic Sea. At present, OWFs are heavily concentrated in the southern Baltic, and in the transition zone to the North Sea. However future plans envisage substantial OWF development throughout the Baltic, including in the seasonally ice-dominated Gulf of Bothnia. It is important to understand how this distribution of wind farms, if constructed as planned, would impact upon sea surface wind fields, and thus upon the marine environment.

Studies in the North Sea have shown wind wakes to impact both physical and biogeochemical processes, with effects propagating as far as the seafloor. The need to understand potential environmental impacts is likely even more acute in the Baltic Sea. Here ecosystems are already in a degraded state - especially regarding oxygen availability - so that even small changes in environmental conditions could drive large ecosystem changes.

We focus on the impact of OWF-induced wakes on ocean physics. We first use the wind-wake calculation tool PyWake, in conjunction with a map of existing and planned Baltic Sea OWFs from the EMODnet database, to derive reductions in the wind fields produced by the Copernicus Regional Reanalysis for Europe (CERRA). Then, using the Nucleus for European Modelling of the Ocean (NEMO), we conduct parallel simulations using the reduced and original CERRA winds, covering the 2010-2015 period. By comparing the two sets of model outputs, we investigate basin-scale changes in mixing, momentum transfer and heat fluxes in the Baltic Sea.

Impact of bottom trawling on benthic ecosystem and sedimentary carbon storage

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Whereas the consequences of human activities on land are readily observable, measuring underwater effects remains challenging. A notorious instance is bottom trawling, a controversial fishing practice that uses heavy nets to catch seafloor-dwellers such as shrimp and flatfish. Bottom trawls disturb the upper sediment layers and might depreciate seafloor habitats if poorly managed. Research has highlighted the potential of bottom trawls to release a large amount of organic carbon from sediments into the water, where it is partly metabolised by organisms to carbon dioxide. Part of the produced CO_2 outgasses to the atmosphere, enhancing anthropogenic climate change. The magnitude of this indirect emission has been heavily debated, with estimates spanning from negligibly small to climate-relevant. Thus, management of bottom trawling for climate protection is hindered by a lack of reliable data and insufficient process-based understanding.

In this talk, we present a case study in the North Sea. We found that sediment samples collected in intensely trawled areas contained a reduced amount of organic carbon, and we were able to attribute this effect to bottom trawling with high confidence. Meanwhile, we found no clear impact of bottom trawling in samples taken in weakly trawled areas. These results were confirmed by numerical simulations. We estimated that bottom trawling annually releases ~1 million tonnes of CO2 in the North Sea and 30 million tonnes globally, which is on the lower end of previous estimates.

We are also initiating research work on quantifying the bottom trawling impact on the Baltic Sea benthic ecosystem and sedimentary carbon and will present some preliminary results here.

Baltic Sea coastline change under climate and human impacts – classification and quantification

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Marginal Seas are lying at the transition zone between land and ocean and are thus subject to extensive human activities and stressor (pollution, land reclamation, tourism, shipping, fisheries, offshore wind farms) and multiple natural drivers (tides, waves, winds, storm surges, sea level change) which are impacting the marine environment and ecosystem. These drivers together with lithological configuration of the coastline determine the morphology of coastline which is unique for all marginal seas. Coastline change is highly dynamic and may react to regime shifts in climate or hydrodynamic conditions or changes in human activity by accretion or erosion of sediments, growth or decline of vegetation or composition change.

Acquiring data on coastline changes may serve as a proxy for regime shifts and may deepen the understanding of different drivers acting within marginal seas. Therefore, in this presentation we will present our analysis on the coastline of the Baltic Sea using multispectral satellite images (sentinel-2). We firstly classify the coastline into different types including marshlands, soft and hard cliffs, sandy beaches and human constructions (e.g. piers, seawalls, dykes). Then we quantify the area change of each coastline type and identify hotspots of changes. Erosion and accretion are quantified based on a transect system at 100 m intervals along the entire Baltic Sea coast.

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No. 9 Conference Proceedings. 1st Baltic Earth Conference. Multiple drivers for Earth system changes in the Baltic Sea region. Nida, Curonian Spit, Lithuania, 13 - 17 June 2016. International Baltic Earth Secretariat Publication No. 9, 222 pp, June 2016

No. 10 Programme, Abstracts, Participants. Baltic Earth Workshop on ”Coupled atmosphere-ocean modeling for the Baltic Sea and North Sea”, Leibniz Institute for Baltic Sea Research Warnemünde, Germany, 7- 8 February 2017. International Baltic Earth Secretariat Publication No. 10, 24 pp, February 2017

No. 11 Baltic Earth Science Plan 2017. International Baltic Earth Secretariat Publication No. 11, 28 pp, February 2017

No. 12 Programme, Abstracts, Participants. MedCORDEX-Baltic Earth-COST Workshop "Regional Climate System Modelling for the European Sea Regions". Universitat de les Illes Baleares, Palma de Mallorca, Spain, 14 - 16 March 2018, International Baltic Earth Secretariat Publication No. 12, 96 pp, March 2018

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