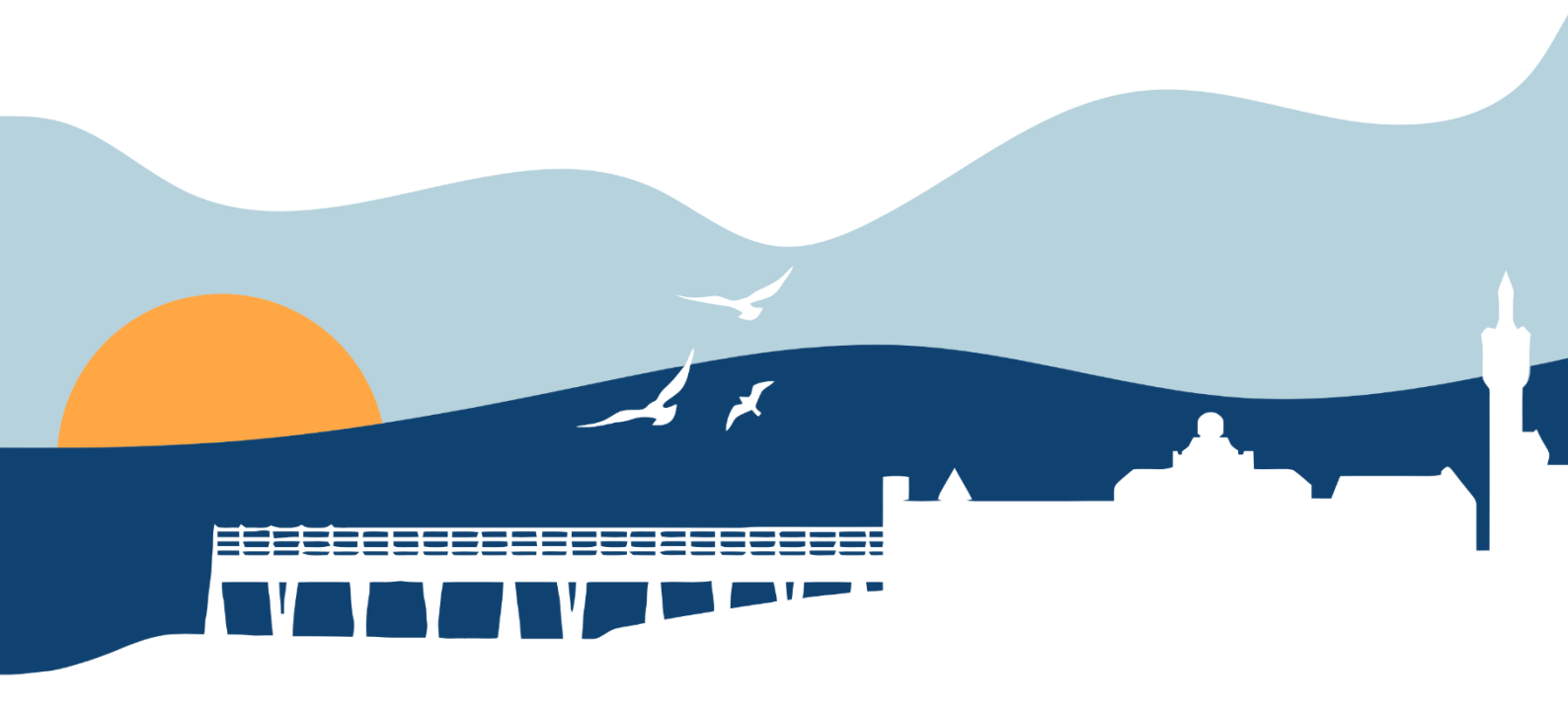
BALTIC SEA SCIENCE CONGRESS

FROM THE PIER OF KNOWLEDGE TO THE HORIZON OF DISCOVERY

26-30 MAY 2025 | SOPOT, POLAND

BOOK OF ABSTRACTS



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2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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Conference Summary

The Baltic Sea Science Congress 2025, held in Sopot, Poland, from 26 to 30 May 2025, brought together over 250 participants, including researchers, early-career scientists, policymakers, and stakeholders. The event offered a unique opportunity to explore the complex and evolving dynamics of the Baltic Sea and its catchment, focusing on its historical development, current functioning, and future outlook.

As the largest scientific forum dedicated to the Baltic Sea region, the Congress provided a vital platform for interdisciplinary exchange and international collaboration. Over the course of five days, participants engaged in seven thematic sessions, each addressing critical scientific and environmental issues across a broad spectrum of disciplines. The scientific programme featured 13 plenary talks, a panel discussion, 124 oral presentations, and 109 poster presentations, reflecting the diversity and depth of ongoing research in the region.

A strong presence of early-career scientists and the active involvement of policy representatives and organizations such as HELCOM highlighted the importance of connecting science with decision-making processes to address the region's growing environmental challenges – from eutrophication and climate change to biodiversity loss and hazardous substances.

By fostering cross-disciplinary dialogue and collaboration across national borders, BSSC2025 aimed to generate innovative, science-based solutions for the long-term protection and sustainable management of the Baltic Sea ecosystem.

This Book of Abstracts presents the full range of research and ideas shared during the Congress and serves as both a reference and an inspiration for continued cooperation in ensuring a sustainable future for the Baltic Sea region.


Photo: Kuba Witek

Thematic Sessions

Physical and Biogeochemical Changes in the Baltic Sea
Ecosystem Health and Biodiversity
Geological Processes and Coastal Erosion
Land-Ocean-Atmosphere Interactions and Catchment Processes
Marine Pollution: Sources, Trends, Effects and Solutions
Exploitation of Ecosystem Services and Its Impact on the Baltic Sea Ecosystem
Emerging Technologies for Research and Monitoring

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Plenary Talks

Abstract ID: 3

The ESA Ocean Science Cluster and regional EO activities in the Baltic Sea

Roberto Sabia[1], Marie-Hélène Rio[1], Jérôme Benveniste[2], Diego Fernández-Prieto[1]

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Within the broader scope of scientific exploitation of satellite assets, the European Space Agency (ESA) is funding a critical mass of R&D studies aimed at enhancing the observation and understanding of the Oceans from space. The ESA Ocean Science Cluster consists of a portfolio of several projects and networking actions promoting synergistic research within an Earth System science focus. More than 30 projects are currently belonging to the Ocean Science Cluster, further regrouped into six main topics, namely: Ocean Health, Ocean Extremes, Coastal Ocean including Land-Sea interactions, Ocean Carbon, Upper-ocean Dynamics including air-sea interactions, and the Ocean' s role in the Earth and Climate System.

This presentation will showcase results and outcomes of a sub-selection of the Cluster projects, with special emphasis on the EC-ESA joint Earth System Science Initiative (ESSI) and their collaborative ocean projects. In the context of the BSSC-25 conference, a further zoom will showcase highlights of a set of specific ESA projects focusing on the Baltic region, as part of a former ESA dedicated regional initiative. Within that, the 4D-BaltDyn project that is currently ongoing is attempting to generate a 4D data-driven reconstruction of the Baltic Seas encompassing an ample set of physical and biogeochemical variables. Lastly, and in a wider perspective, a subset of activities within the frame of the ESA Climate Change Initiative (CCI) programme will also be described, debriefing specifically on the ocean Essential Climate Variables (ECVs) that are monitored within CCI. The projects' products are all freely and openly available to the community, providing a unique dataset allowing to further monitor open/coastal oceans and semi-enclosed seas in a changing environment.

Abstract ID: 4

Baltic in evolution, active or passive approach?

Jan Marcin Węsławski, Karol Kuliński, Sławomir Sagan

Institute of Oceanology Polish Academy of Sciences, Sopot, Poland

The short and dynamic history of the Baltic Sea is far from being completed. Nowadays, it belongs to the fastest warming marine areas. At the same time, the coordinated international effort of HELCOM brings visible improvement to environmental conditions – especially reduction of nutrient loads and lower industrial contamination. On one hand, the societal expectations for ecological health are very high, on the other hand, the collapse of the cod fishery and the increase of hypoxic areas are widely commented on as failures.

With the increasing temperature, the cascade of side effects follows – North Sea inflows, once regarded as lifesaving events, are now also seen as having negative aspects – like increased stratification of the Baltic – as in the warmer water less oxygen is transported, and prolonged problem with elevated nutrient concentration is caused by the increasing anoxic conditions.

The future projections show an increase in river runoff from the northern catchment, but also an increase in saltwater import from the North Sea as a consequence of sea level rise. The net effect remains uncertain both for future salinity as well as for haline stratification, and thus also for ecosystem functioning and biodiversity.

The challenge is to identify processes that humans can modify, from those we have to adapt to, and finally, to convert the scientists' opinion to the acceptable communication for society.

Abstract ID: 5

Co-creation for advancing ocean observations of marine life – connecting the Baltic Sea to the global ocean

Lina Mtwana Nordlund[1], Artur Palacz[2], Florian Lüskow[1], Dominik Krzymiński[2]

[1]Uppsala University, Visby, Sweden. [2]Institute of Oceanology Polish Academy of Sciences, Sopot, Poland

The Baltic Sea region, with its rich legacy of some of the world's longest records of environmental and marine life observations, cutting-edge research in climate and ecosystem modelling, and reliable delivery of scientific advice for policy, stands at the forefront of ocean observation innovation. Yet the full potential of Baltic Sea science—particularly in marine biology and ecosystem research—remains underutilized in global contexts.

This session invites researchers, data managers, and science-policy actors to reimagine the ocean observing value chain—from individual observations to global impact. How can we collectively maximize the value of every single data point? How do we make Baltic research more globally interoperable and relevant, while learning from broader ocean science advances? And how can collaboration—across nations, disciplines, and sectors—amplify the influence of regional assessments in shaping global solutions?

Framed by a keynote presentation and followed by a dynamic panel discussion with expert voices, this interactive session will also include questions and engagement with the audience. We will explore these questions through the lens of the climate–biodiversity nexus, with the Baltic Sea as both a living laboratory and a testbed for scalable innovation. Drawing on initiatives such as BioEcoOcean's novel use of communication and co-creation to transform marine life observations, the session aims to inspire integrated thinking, catalyse dialogue, and promote systemic transformation—from individual practice to collective impact.

Join us to reflect, connect, and challenge yourself to think bigger about your role in the ocean science system.

Abstract ID: 6

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

Kari Hyytiäinen[1], Jamie Jenkins[1], Susa Niiranen[2], Vilma Sandström[1]

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Wild card events are low-probability, high-impact occurrences that are difficult or impossible to predict but can cause significant and potentially disruptive consequences when they happen. These events can trigger major changes in society, the economy, or ecosystems — or in all three consecutively or simultaneously. Their impacts may be either positive or negative. For example, a rapid surprise breakthrough in an environmentally friendly technology could generate economic value, job opportunities, and ecological benefits. Conversely, sudden geopolitical upheaval or an unforeseen crossing of an ecological tipping point could have devastating consequences for both human and natural systems.

This session invites participants to engage in a shared thought experiment to identify plausible but currently unexpected “wild cards” that could significantly impact the Baltic Sea ecosystem — either positively or negatively. These impacts may be direct (affecting the marine environment itself) or indirect (originating in human society and impacting terrestrial ecosystems within the Baltic Sea catchment and then cascading into the marine system).

Participants are encouraged to bring a mobile phone or laptop with internet access to take part in an interactive, co-creation exercise. The collected input will be immediately visualized and discussed during the session.

The session is organized by the Baltic Earth Network's working group on ‘Multiple Drivers of Earth System Changes’. The resulting data will contribute to ongoing research on how existing modeling frameworks can account for the effects of wild card events on the ecological state of the Baltic Sea.

Abstract ID: 7

Magnitude and fate of methane released from the Nord Stream pipeline ruptures and the state of knowledge of the environmental impact

Gregor Rehder[1], and a large number of scientists who will be recognized during the presentation[2]

[1]Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany. [2]affiliations acknowledged in the presentation

On the 26th of September 2022, damage to the Nord Stream pipelines Nord Stream 1 and Nord Stream 2 occurred in a series of underwater explosions, resulting in the abrupt release of large quantities of natural gas from three of the four pipelines, changing Europe`s gas and energy system dramatically.

Within only a few days after the events, a series of estimates of the amount of gas released were launched, using both bottom up (estimating the release based on pipeline characteristics and pressure considerations) and top down (using inverse modelling based on atmospheric monitoring data) approaches. Other contributions very quickly assessed the potential environmental harm to the environment.

More than two years later, three publications in Nature (1) and Nature communications (2, 3) gathered and re-processed all available information to achieve the best possible knowledge of the magnitude and timing of the gas release, and the fate of the fraction of gas that remained in Baltic Sea waters.

This presentation will present our state of knowledge based on earlier and these last results, also attempting to put the amount of methane released in the context of global sources and sinks. It will highlight the role of integration of data and knowledge from different observational data sources and scientific expertise. It will also briefly reflect the experience of interaction with the media when working on a politically “hot topic”, and try to give some simple recommendations.

References:
(1) Harris et al., Nature, Doi: 10.1038/s41586-024-08396-8 (2025)
(2) Mohrmann et al., Nature communications, Doi: 10.1038/s41467-024-53779-0 (2025)
(3) Reum et al., Nature communications, Doi: 10.1038/s41467-024-53780-7 (2025)

Abstract ID: 18

High-resolution sampling reveals a considerable year-round risk potential for aquatic organisms in an urban estuary of the Baltic Sea due to anthropogenic pollution mixture

Lukas Vogel[1], Kathrin Fisch[2], Theodor Sperlea[1], Conor Christopher Glackin[1], Erik Zschaubitz[1], Detlef Schulz-Bull[1], Matthias Labrenz[1], Marion Kanwischer[1]

[1]Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Rostock, Germany. [2]Julius Kühn-Institut (JKI), Berlin, Germany

Anthropogenic pollution in estuaries and coastal waters is an increasing problem worldwide. Risk assessment is challenging as, depending on the purpose and chemical properties of the pollutants, unique temporal and spatial patterns can emerge but potentially be overlooked with short time or low-resolution sampling. We performed a one-year high-resolution sampling campaign of a typical Baltic Sea urban estuary and its adjacent areas and analyzed water samples for 35 compounds, including pharmaceuticals, pesticides, UV filters. As main risk driver, pharmaceuticals such as diclofenac, carbamazepine, and sulfamethoxazole were identified, each of it showing distinct seasonal trends. In contrast, seasonal variation of the overall risk pattern was low, revealing that aquatic organisms in the estuary were under constantly high anthropogenic pressure throughout the year. Thus, risk-free periods were absent for aquatic organisms, especially for those living year-round in the estuarial habitat. However, our results also indicate that risks could be significantly reduced if discharges to environmental waters of only a limited number of contaminants could be reduced; urban point sources such as waste water treatment plants seem efficient mitigation targets. We conclude that it is important for less resolved sampling approaches to design strategies tailored to the pollutant type to be assessed, i.e., considering their ecotoxic potential or application patterns.

Abstract ID: 33

ROPEWALK (Rescuing Old data with People's Efforts: Weather and climate Archives from LogbooK records) – a digitization project for three centuries of weather observations on board of Danish ships

Martin Stendel[1], Adam Jon Kronegh[2], Esben Haubro Skov[2]

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ROPEWALK, funded by the AP Møller Mærsk Fund, is a joint initiative of the Danish National Archive and the Danish Meteorological Institute, which aims at digitizing and transcribing all weather observations in Danish ship journals and logbooks stored in the Danish National Archive, consisting of more than 750 shelf metres beginning as early as the 1680s. With the exception of the Napoleonic wars and Danish state bankruptcy in 1814, the data is complete.

Ship journals over large parts of the Northern Hemisphere are kept in the archive, with two regions of particular interest, Greenland and the Øresund.

The Greenlandic Trade Company had a monopoly for commerce with the colony of Greenland for nearly 200 years, and foreign ships would not be allowed to call a port. The company conducted these "Greenland Voyages" to western Greenland several times per year, starting as early as 1721 and through the 1930s. Weather observations from these voyages often include detailed sea ice observations.

Every ship passing the sound or belts in Denmark had to pay for passage between 1426 and 1857. To ensure payment, Danish war ships were placed at strategic locations near Copenhagen, Helsingør and Nyborg. Weather observations on board of these ships go back to the end of the Little Ice Age. In several cases, observations were conducted every time the ship bell was struck, resulting in as many as 48 observations in the course of a single day.

The scanning of the original logbooks and ship journals by the National Archive in highest possible resolution took 13 person-years, resulting in 2.1 million images covering more than 2.5 TB of data. Up to roughly 1750, the data consists of diary-like daily note in free text. Starting in the 1710s, observations are recorded as numbers in preprinted tables. We have transcribed this latter dataset, constructed a data model, trained a machine learning algorithm and conducted quality control. Free text data will be considered later.

First results will be presented. All transcribed data will be made publicly available and can be used for future research or as input for reanalysis projects.

Abstract ID: 46

Assessment and prediction of spatio-temporal dynamics of Vibrio vulnificus in the coastal Baltic Sea

Conor Christopher Glackin, David Riedinger, Erik Zschaubitz, Lukas Vogel, Theodor Sperlea, Matthias Labrenz, Heike Benterbusch, Clara Nietz

Leibniz Institute for Baltic Sea Research, Rostock, Germany

With rising infection rates in recent years *Vibrio vulnificus* pose an increasing threat to public safety in the coastal brackish Baltic Sea. *V. vulnificus*, associated with high mortality, can thrive in the Baltic Sea during summer months due to optimal conditions and can cause severe infections to humans through open-wound infections. Pinpointing a timeframe of increased risk of infection is the next step in curbing the increasing numbers of infections and also has wide-ranging ecological and economic effects. Routine monitoring of this bacterium in the Baltic Sea is critical to provide a warning system for the public when the risk of infection is potentially high. As part of an extensive twice weekly sampling campaign that included 14 locations in the coastal Baltic Sea across a one-year period between 2022-2023, we investigated the abundance of *V. vulnificus* using a multi-method approach, including droplet digital PCR (ddPCR) results targeting the *vvhA* gene region, agar cultivation, and species level classification of 16S rRNA gene sequencing. Physico-, biological- and hydrochemical parameters were measured concurrently and variables explaining *V. vulnificus* occurrence were identified by machine learning. In addition, numerous machine learning techniques were applied in order to predict *V. vulnificus* gene concentrations using ddPCR, with the objective of establishing models that accurately predict when *V. vulnificus* is most abundant in the coastal Baltic Sea. Time-series analysis was performed using variables from previous timepoints as predictors, with the goal of pinpointing the most important markers for creating an early warning system and highlighting the importance of improved coastal monitoring.

Abstract ID: 56

Microbially enhanced growth and metal capture by ferromanganese concretions in laboratory experiment

Renata Majamäki[1], Joonas Wasiljeff[1], Lotta Purkamo[1], Jenni Hultman[2,3], Eero Asmala[1], Pirjo Yli-Hemminki[2], Kirsten Jørgensen[4], Karoliina Koho[1], Jukka Kuva[1], Joonas Virtasalo[1]

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The ferromanganese (Fe-Mn) concretions are accumulations of iron and manganese hydroxides that form at the sediment-water interface on the seafloor. It has been estimated that more than 11% of the Finnish coastal sea areas are covered by concretion fields. The concretions have high contents of Fe and Mn and contain various other metals, such as Co, Ni, V and Zn which make them potential resources of critical minerals Furthermore, the concretions are hosted by diverse microbial communities with oxidative and reductive metabolism, influencing metal cycling. In this study, we collected Fe-Mn concretions from the Baltic Sea to assess the microbial influence on the concretion growth and trace metal accumulation and dissolution through laboratory experiments. We studied three concretion morphotypes: crust, discoidal, and spheroidal, with biotic and abiotic treatments. The concretion samples were collected into bottles containing artificial brackish seawater from the Gulf of Finland, incubated in-situ simulating conditions for 12 weeks, and sampled at the beginning and end of the experiment. Microscale X-ray-computed tomography confirmed the local growth of up to 10 µm thick patches on the concretion surface during the 12-week incubation period, corresponding to a growth rate of 0.04 mm/year. Scanning electron microscopy revealed freshly precipitated cauliflower-like grains, typical for freshly formed Fe-and Mn-hydroxides. Decreased concentrations of dissolved trace metals (Mn, Fe, Co, V, Ni, Zn, and Mo) in the incubation solutions indicated the capture of these elements into concretions in the biotic microcosms in 12 weeks. In contrast, the dissolution of concretions was observed in abiotic microcosms. These results demonstrated that microbial activity enhanced the accumulation of trace metals into Fe-Mn concretions from ambient solution. Microbial activity was furthermore confirmed by a decrease in headspace methane concentrations in the biotic microcosms, suggesting the presence of methanotrophs within the concretion communities.

Abstract ID: 61

From Waste to Resource: Unlocking the Role of Beachwrack in Supporting Dune Stability and Coastal Habitat Health

Daniela Glück, Hendrik Schubert

University Rostock, Rostock, Germany

Beachwrack, a natural accumulation of macroalgae, seagrass and other organic matter on beaches, is often perceived as waste that disrupts tourism and incurs high disposal costs. However, beachwrack plays a vital role in coastal ecosystems by providing nutrients, supporting biodiversity and stabilizing sediments. This study investigates the potential of beachwrack as a sustainable growth substrate for enhancing coastal vegetation and promoting ecosystem resilience. We conducted a 12-week growth experiment using different substrates—beachwrack, compost and only beach sand—to cultivate marram grass (*Ammophila arenaria*), a key dune-stabilizing plant species. Plant performance indicators (height, shoot number, pigment concentration and photosynthesis efficiency) and sediment samples (moisture and nutrient availability) were measured biweekly. Preliminary results demonstrate that marram grass exhibited the fastest growth rates and highest moisture retention when grown in beachwrack substrate. While isotopic analyses to trace nutrient uptake from decaying macroalgae are still ongoing, our findings suggest that beachwrack can enhance nutrient supply for coastal vegetation promoting vegetation establishment. However, potential risks from contaminants must be considered, as well as the composition of the beachwrack. To assess seasonal variability and potential risks, beachwrack composition was analyzed across multiple locations along the Baltic Sea coast (e.g. Germany and Sweden). With climate change potentially increasing macroalgal dominance in beachwrack composition, repurposing beachwrack as a substrate could offer a nature-based solution to support biodiversity, strengthen dune vegetation, and promote ecosystem resilience in the face of environmental change.

Abstract ID: 87

Turbulent oxygen transport across the halocline in the Gotland Basin: Identification of key physical processes

Oliver Thiele, Peter Holtermann, Lars Umlauf

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Anoxia in the central Baltic Sea arises from the imbalance between high oxygen demand below the halocline and limited oxygen supply from the upper, well-oxygenated water column through the strong halocline. Although the region below the halocline often remains anoxic, there is growing evidence that turbulent mixing at basin boundaries - where the halocline meets the seafloor - can facilitate notable oxygen transport to deeper layers.

In this study, we deployed both moored velocity measurements and ship-based velocity shear microstructure observations (using a shear microstructrure profiler) during three cruises/seasonal campaigns in the Eastern Gotland Basin. The shear microstructrure profiler was equipped with a fast-response oxygen sensor, allowing us to directly measure vertical oxygen fluxes. We focused on specific events driving oxygen mixing events across the strong halocline, with inertial waves, topographic waves, and mean currents as major dominating processes.

We analyzed the interplay between vertical shear, stratification, and oxygen fluxes during distinct periods dominated by these different processes. Our findings indicate that inertial waves contribute relatively little to the overall oxygen flux. In contrast, topographic waves significantly enhance oxygen transport across the halocline. In addition, under certain shear and stratification conditions, the mean current leads to appreciable oxygen fluxes. These results underscore the importance of low-frequency mechanisms in maintaining oxygen transport across the halocline and highlight the need for further investigation into these processes.

Abstract ID: 180

Are foundation models sufficient for plankton recognition? An evaluation of DINOv2 for FlowCam and IFCB imagery

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Deep learning (DL) AI approaches have been used to automate the classification and recognition of plankton at a species level to deal with the ever-increasing volume of plankton digital image data. There are several significant bottlenecks for robust DL classifiers, which include the dependency on high-quality labelled data from taxonomic experts and the poor transferability of classifiers across imaging platforms (domain shifting). Furthermore, species distribution in the natural world is long-tailed, with few representative images for rarer species, making classifier training difficult. AI foundation models, models pre-trained on large and varied datasets, have demonstrated impressive generalisability and robustness in a variety of image analysis tasks however, the transferability of this performance to plankton image analysis has not been explored. In this work, we evaluate the performance of DINOv2, an open-source foundation model pre-trained in a self-supervised manner on 142 million curated natural images for plankton classification. Using imagery from FlowCam and Imaging FlowCytobot (IFCB), we examine and present the generalisability of the model's features under settings relevant to marine monitoring: unsupervised classification in the case of rare/invasive species, end-to-end finetuning for device-specific models and explore the lower limit on annotated image numbers for accurate classification and compare it to models trained on plankton imagery only.

Abstract ID: 185

Baltic Earth 2.0

H. E. Markus Meier[1], Juris Aigars[2], Inga Dailidiene[3], Georgia Destouni[4], Matthias Gröger[1], Kari Hyytiäinen[5], Karol Kulinski[6], Urmas Lips[7], Kai Myrberg[8], Kevin Parnell[7], Piia Post[9], Gregor Rehder[1], Anna Rutgersson[10], Tarmo Soomere[7], Martin Stendel[11], Laura Tuomi[12], Ralf Weisse[13], Tamara Zalewska[14]

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The regional Earth system science program Baltic Earth (https://baltic.earth), founded in 2013 as the successor program to the well-known Baltic Sea Experiment program (BALTEX), is entering a new phase, henceforth called Baltic Earth 2.0. Over the years, a very active network of scientists from all Baltic Sea countries has formed, which has its own infrastructure, including a secretariat and a publication series. With a new International Baltic Earth Secretariat hosted by two research institutes located in two different countries, Poland and Germany, an updated science plan with new research topics and new members of the science steering group, Baltic Earth is preparing itself for the challenges ahead.

Baltic Earth, as part of the international GEWEX program, emphasizes and develops a holistic view of the Earth system, which includes processes in the atmosphere, the land, the sea and the anthroposphere. The aim is to understand the entire Earth system in the Baltic Sea region, including its internal dynamics and linkages, and to analyze the effects of all relevant influencing factors on the system. Successful research areas will continue to be worked on and new research areas will be addressed by additional or reorganized working groups, e.g. on climate variability and teleconnections, small-scale processes and their impact on the large-scale circulation, a comparison of coastal seas worldwide, various human impacts and philosophical aspects.

Today's activities within Baltic Earth include 1) scientific networking at conferences, workshops, colloquia and working group meetings on selected scientific topics; 2) exchange with other scientific networks at Baltic, European and global level; 3) preparation of assessment reports on past and future climate and environmental changes in the Baltic Sea region; 4) co-operation with major stakeholders such as HELCOM, e.g. within the joint HELCOM/Baltic Earth Expert Network on Climate Change, EN Clime; and 5) training of students and graduates in summer and winter schools. In this presentation, we will introduce the recently started new activities and the future plans of Baltic Earth 2.0 for the next 10 years.

Oral Presentations

Thematic Session: Physical and Biogeochemical Changes in the Baltic Sea

Abstract ID: 13

Sea surface temperatures of the Baltic Sea: trends, variability, and links to the North Atlantic

Leonie Barghorn, Florian Börgel, Matthias Gröger, Markus Meier

Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany

During the last decades, the Baltic Sea has warmed more strongly than most other marginal seas around the world. This was partly attributed to remote effects from the Atlantic Multidecadal Variability (AMV), i.e., low-frequency sea surface temperature fluctuations in the North Atlantic. Various studies have shown that the AMV affects the European climate. However, they have a crucial shortcoming as they do not precisely separate internal variability and externally forced climate responses. This can be achieved by working with so-called Single-Model Initial-condition Large Ensembles (SMILEs). Such ensembles contain multiple runs of a (global) climate model which use the same forcing, but start from different initial conditions. Hence, each ensemble member evolves with a different realization of internal variability whereas the response to external forcing is similar and can be extracted by computing the ensemble mean.

In our study, we employ two different SMILEs including historical runs (1850-2014) and different shared socioeconomic pathway (SSP) scenarios (2015-2100) to analyze externally forced and internal components of the Baltic Sea's sea surface temperatures (SSTs), how they develop under future climate change scenarios, and how they are affected by the North Atlantic. We find that the presumed impact of the AMV on the Baltic SSTs is rather a large-scale response to external forcing while the internal variability of the Baltic SSTs is predominantly linked to the North Atlantic Oscillation. This is true for the historical period but also for all SSP scenarios considered. However, the AMV impact varies strongly between the different ensemble members, reflecting the pronounced internal variability of the Baltic Sea climate. In the future, the Baltic Sea will continue to experience strong warming, likely reaching 2 °C more at the end of the 21st century compared to 1950. Nevertheless, on a decadal scale, AMV-related SST fluctuations in the Baltic Sea will stay important.

Abstract ID: 21

Vertical mixing and benthic silicate fluxes in Baltic Sea bottom waters: a radium isotopic approach

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Benthic fluxes are critical sources of nutrients to the water column, often amplifying hypoxic and eutrophic conditions. However, most approaches for quantifying benthic fluxes require disturbing the sediment-water interface and cover relatively small areas. Here, we use short-lived radium isotopes (^{224}Ra and ^{223}Ra) to quantify vertical mixing across the Baltic Sea bottom waters. We collected radium and dissolved silicate (DSi) bottom water profiles from 50 stations spanning from the Skagerrak Sea to the Bothnian Bay in September 2023. Bottom water radium activities reached up to 45 and 0.98 dpm/100L for ^{224}Ra and ^{223}Ra, respectively, where the highest concentrations were found in the deep anoxic basins. DSi concentrations followed a similar trend to radium, where the highest concentrations (>80 µM) were in the deep waters of the Western and Eastern Gotland Basins. 52% of stations met the required criteria for the radium-based vertical mixing model, resulting in vertical mixing rates ranging from 10^{-6} to 10^{-3} m^2/s and median DSi fluxes of 5.9 mmol/m^2/day. Both vertical mixing rates and DSi fluxes agreed with previous local scale estimates using other methods. Extrapolated benthic DSi fluxes were ~190% of the total river DSi flux to the Baltic Sea, further demonstrating the importance of benthic sources to the water column.

Abstract ID: 28

A multi-model approach to estimate historical oxygen deficiency in the western Baltic Sea

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In the semi-enclosed Baltic Sea one of the most harmful effects of eutrophication is deoxygenation. In addition to the well-known permanent hypoxic areas (defined as <2 mg/l) in the deep basins of the central Baltic Sea, seasonal oxygen deficiency is also common in the western sub-basins (from Kattegat to Arkona Basin). Depending on the intensity and duration of the oxygen deficiency (defined as <6 mg/l), this can have far-reaching consequences for organisms and, in the worst case, lead to mass mortality events in affected areas. Management plans are needed to restore good environmental status in the Baltic Sea. These require thresholds that define good environmental status, which are often based on historical conditions without significant human influence. However, historical oxygen measurements are rare and cannot provide a comprehensive spatial picture of near-bottom oxygen deficiency alone. Modelling is therefore required to integrate these few point observations to estimate spatial distributions. We applied a multi-model approach that can provide more robust results. Specifically, we used a statistical (GAM) and a machine learning model (GPBoost), utilizing historic oxygen measurements as basis, as well as a mechanistic model (MOM-ERGOM) to assess the spatial extent of oxygen deficiency from 1949 to 1969 in the western Baltic Sea. Even though hypoxia was occasionally measured, it was not a common feature according to our combined approach with 0.04 % to 3 % of the near-bottom area being predicted as hypoxic with a high to low confidence, respectively. Nevertheless, oxygen deficiency with oxygen concentrations <6 mg/l were predicted for a near-bottom area of 11 % to 37 % with a high to low confidence, respectively. The statistical model generally predicted the smallest areas of oxygen deficiency, while the mechanistic model predicted the largest areas. A major uncertainty discovered by the application of our approach relates to the estimation of oxygen concentrations in the bottom boundary layer, as this is estimated differently by our three methods and observational data for model tuning is lacking. Thus, the use of our multi-model approach provides a more reliable estimate of the historical extent of near-bottom oxygen deficiency than any individual approach. To assess the consequences of oxygen deficiency on organisms and biodiversity, it would nevertheless be important to consider the temporal dynamics of oxygen deficiency in the future.

Abstract ID: 34

The legacy effect of changing nutrient inputs to Danish coastal ecosystems

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Nutrient management plans have been successful in reducing nutrient inputs to many coastal ecosystems, but ecosystem responses have been unanticipatedly weak. This lack of recovery has been attributed to a legacy effect of past nutrient inputs, possibly sustaining sediment nutrient release and eutrophication over longer periods. We analyzed sediment pools of carbon (measured as Loss-of-Ignition, LoI), total nitrogen (TN) and total phosphorus (TP) sampled over 25 years in two separate periods (1999-2003 and 2017-2023) across 14 Danish estuaries and coastal ecosystems, following substantial reductions in inputs of nitrogen (>50%) and phosphorus (>90%) from land, the majority of these occurring from 1985 to 1997. Sediment properties were not connected with water properties at station level, whereas LoI, TN and TP increased with water column depth and decreased with physical exposure, suggesting that sedimentation properties governed the overall concentrations. Sediment pools of LoI, TN and TP decreased by 6-8% between the two periods, although these changes were not significant. Variability among sediment cores was high, particularly spatial variability but also temporal variability, although variability could be reduced by normalizing TN and TP to LoI. Only TP changed significantly with sediment depth, but there was no significant difference in the shape of the profiles over time. Given the relatively large sampling effort (>130 cores), we estimated that it should be possible to detect changes of 15-20% with a probability of 80%. The changes in sediment pools are consistent with other studies, when considering the relative reductions in nutrient inputs. The trends also suggest that the legacy effect of nutrient reductions was within a few years rather than decades or that the legacy effect is small. Hence, the lack of coastal ecosystem recovery is most likely due to other factors.

Abstract ID: 51

Spatial and seasonal variability of dissolved dinitrogen gas (ΔN_2) below halocline: microbial insights and implications for nitrogen cycling

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Excess dissolved dinitrogen gas (ΔN_2) serves as an indicator of bioavailable nitrogen loss via primarily denitrification and anammox in marine environment. These processes are essential for regulating nitrogen cycling and have significant impacts on marine ecosystem functioning. To assess the spatial and seasonal variability of ΔN_2 in the Baltic Proper, we measured N_2/Ar ratios from the saturation conditions at 19 stations below the halocline during multiple field campaigns between 2017 and 2021. In addition, we investigated the seasonal and spatial structure of microbial community abundance in the Baltic Proper (Bornholm Deep, Gdańsk Deep, and Gotland Deep). Specifically, we focused on waters below the halocline at depths ranging from 75 to 135 m, characterized by variable oxygen conditions.

ΔN_2 concentrations below the halocline ranged from 1.0 to 32.6 μmol L^{-1}, with the highest values observed in the Gotland Deep ($p < 0.0001$) and peak concentrations occurring in winter ($p < 0.005$). These findings provide the first large-scale assessment of ΔN_2 variability in the Baltic Proper, highlighting the spatial and temporal heterogeneity of the N cycling and significant accumulated effect of N loss.

Additionally, microbial community revealed a stable nitrogen-processing capacity across locations, with nitrification, dissimilatory nitrate reduction, and denitrification predominantly linked to Thaumarchaeota and Proteobacteria. Seasonal shifts in nutrient and oxygen availability significantly influenced microbial activity, shaping nitrogen cycling dynamics. Notably, the absence of anammox-related genes in the water column suggests that nitrogen loss in the Baltic Proper is primarily driven by denitrification. The partitioning of this process is also suggested, with different microorganisms capable either producing or consuming key intermediates.

The results emphasize the necessity of further research to quantify denitrification rates and evaluate their climate change implications, including their influence on oceanic nitrogen inventories, and N_2O and CO_2 fluxes. Additionally, this calls for standardization of the methodologies to better quantify process-specific nitrogen removal rates and nitrogen cycling in stratified marine systems. Furthermore, understanding microbial responses to environmental variability is crucial for predicting future shifts in nitrogen cycling and developing effective management strategies for eutrophication control in the Baltic Sea.

Funding for this study was provided by NCN project no. 2019/34/EST10/00217.

Abstract ID: 67

How can activity of deepwater pockmarks modify benthic environmental conditions? – a case study from the Gulf of Gdańsk

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Sea-bottom pockmarks are shallow depressions associated with gas seepage or submarine groundwater discharge (SGD). Previous studies have indicated that such forms are also present at the bottom of the Gdańsk Basin. They occur in the areas of the Puck Bay, central Gulf of Gdańsk, southern and northern Gdańsk Deep. Our interdisciplinary studies (biogeochemical, geophysical and hydroacousic) conducted in 2019-2024 in the central Gulf of Gdańsk (MET1 area – 8 pockmarks of different type), at water depths of 75-90 m showed that the activity of deepwater pockmarks may have significant impact on benthic environmental conditions, especially in regions with strong stratification in the water column. Due to their specific morphology, pockmarks can act as a trap for different micro and macro pollutants. Gas emission may enhance the release of different substances, including nutrients, from sediments into near-bottom water whereas freshwater seepage (deepwater SGD) clearly influence mineral precipitation in surface sediments. In addition, microbial community composition in sediments of active pockmarks is significantly altered (more methanogenic and methanotrofic organisms), the sulfate-methane transition zone (SMTZ) is located very shallow, in surface sediments, which leads to lower efficiency of anaerobic methane oxidation (AOM). Moreover, the conducted studies revealed that sea bottom in the central Gulf of Gdańsk is morphologically diversified, with different types of pockmarks of different activity (constant point emission in the form of a gas flare, scattered emission of single gas bubbles from large surface area, freshwater infiltration, freshwater seepage).

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Abstract ID: 71

Improving storm surge forecasting by coupling ocean circulation and wave models, a case study on storm Babet, October 2023

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Storms with prevailing easterlies in the southwest Baltic Sea have the potential to generate record high sea levels, strong waves and wave induced coastal erosion due to the relative long fetches. In October 2023, storm Babet hit the coastline of Denmark and Germany, broke dikes, destroyed harbors and generated severe property damage of about a billion euro. The measured significant wave height reached values of up to 6 meters at Kriegers Flak wind farm. The operational storm surge model of the Danish Meteorological Institute (DMI) significantly under-predicted the values of the maximum sea level in regions with high waves in the southwest Baltic Sea. One potential reason can be that the operational ocean model does not resolve sufficiently the impact of the waves on the sea levels. This leads to a joint effort by the Danish Meteorological Institute (DMI) and the Finnish Meteorological Institute (FMI) investigating different coupling processes implemented in their operational ocean circulation and wave models, DMI HBM-WAM and FMI NEMO-WaveWatch3. The study includes: (1) the momentum input into the ocean model by implementing Stokes-Coriolis forcing and wave induced surface force (divergence of the radiation stress), (2) wave affected atmospheric momentum flux into the ocean and (3) surface drag parameterizations in the momentum solver and the turbulence model. Our presentation demonstrates the positive impacts of the model coupling processes on the forecasting quality of sea level. The coupled model system was used successfully to predict the near-shore ocean dynamics using high-resolution model grids with horizontal resolution of up to 185 meter (0.1 nmi). At this grid resolution, the model is able to represent the complex coastlines in the study area, which covers the southwest Baltic Sea. The presentation finalizes with an outlook on future developments and applications, like coastal erosion modelling using XBeach sediment transport model, which has greatly benefitted from the high resolution coupled modelling.

Abstract ID: 76

The changes in the water temperature parameter in the Baltic cod spawning grounds

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Studies of changes in water parameters occurring in the Baltic Sea frequently focus on the impact of climate change on the surface water and changes in conditions above the bottom. This is understandable due to two factors. In the case of surface water, the advancement of methods related to the remote sensing imaging, particularly satellite imaging, have made it possible to record various parameters as a whole and simultaneously tracking their changes over vast areas. Interest in conditions in the immediate vicinity of the bottom is understandable because of the organisms living there. Benthic biota elements are important in the trophic network of marine ecosystems, therefore, this is crucial for the management of marine living resources. A good understanding of both the changes occurring on the surface and above the seabed is essential for estimating the natural and economic potential of the study basins. However, knowing the life cycles of individual species, it is easy to realize that the changes in the sea between surface and bottom are also of vital significance. Cod is an example of such a species of economic importance. To successfully spawn, it requires the appropriate conditions. Cod eggs develop while floating in water with the right parameters, specifically with a dissolved oxygen value exceeding 2 ml/l and water salinity of more than 11. These are the two limiting parameters that determine the “cod water” layer in the water column. Studies on the success of cod spawning in the Southern Baltic which have been conducted at the National Marine Fisheries Research Institute since 2006 indicate that long-term temperature changes occur not only in surface or above the bottom but also in “cod water layer”, so they may impact its condition. The proposed presentation will present preliminary results of the temperature analysis in this layer.

Abstract ID: 77

Long-term development of Baltic Sea nutrient cycling driven by Major Baltic Inflows, frequent oxic water supply by intrusions in the halocline range and changing anthropogenic influence

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The development of the Baltic Sea since 1960 with regard to eutrophication and its abatement measures as well as the additional anthropogenic threat of climate change poses questions about its current state. What can be seen in the past observations and how do the trends look like. We aimed to summarize and actualize the state of knowledge about the nutrient cycle and its driving forces by physical transport processes in the Baltic Sea. A number of contradicting processes determined major nutrient cycling and availability of nitrate and phosphate for primary production in surface water. A load reduction that was almost successful for phosphorus but less efficient for nitrogen characterized the last decades. On the other side, processes reacted with delay, and legacy importantly contributed to eutrophication. The huge amount of phytoplankton is mainly degraded below the euphotic layer. In the pycnocline range oxygen demand is partly compensated by laterally intruded oxygen, whereas in bottom waters a serious oxygen deficit is caused during several years of stagnation. Alternating oxic and euxinic phases of deep water triggered by intermittent major Baltic Inflows had strong impact on the deep water nutrient cycle of phosphate. Phosphate is kept in solution in euxinic waters, but is scavenged by iron and manganese oxy-hydroxide particles during re-oxygenation by an inflow, and thus phosphate is at least temporally removed from the water column. As the surface water nitrate to phosphate concentration ratio is already low in winter and clearly below the optimal proportion (Redfield) in the central Baltic Sea, nitrate is limiting the spring bloom and favours diazotrophic cyanobacteria in the surface water during summer. This imbalance is likely fostered by longer lasting stagnation periods as phosphate is mobilized and nitrogen is lost during redox changes as gaseous compounds. However, the supply of surface water with phosphate is hindered by temporal removal of phosphate via microbially mediated processes within the redoxcline. The long-term development of the nutrient dynamics is analysed with regard to new findings in small scale process. Thereby, physical transport determines microbially mediated biogeochemical processes, which together with a changing oxygen state of Baltic Sea Deep waters result in an ultimate feedback to nutrients concentration distribution.

Abstract ID: 96

Drivers and impacts of severe deoxygenation during latest stagnation period in the Central Baltic Sea

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The properties of deep water in the Baltic Sea are significantly influenced by the alternation between Major Baltic Inflows (MBIs) and the stagnation periods that occur between these events. In addition to this natural variability, anthropogenic pressure from the surrounding catchment area and climate change have further altered conditions in the deep layer. This observation-based study examines developments in the Central Baltic Sea during the most recent stagnation period from 2016 to 2024, within the context of data collected since the 1960s.

The peaks of volume-averaged oxygen deficiency below 100 m depth in the Eastern Gotland Basin (EGB) in the end of stagnation periods have increased almost linearly from the late 1960s to 2013. The extent of deoxygenation during the latest stagnation period significantly deviates from this trend towards more severe deficiency. As of 2024, about 2.5 million tons of oxygen are required to neutralize anoxia in water below 100 meters in the EGB. It is unlikely that even very large MBIs can import the needed amount of oxygen. We propose that, in addition to long-term eutrophication, a combination of factors is responsible for the high level of deoxygenation: a dense bottom layer, strong stratification, weak vertical and horizontal oxygen transport, low oxygen solubility, and high rates of organic matter mineralization. The latter three factors are likely connected to the overall warming of the Baltic and North Seas. Our findings suggest that, under current human pressure from land and with warmer water due to climate change, it is highly unlikely that deoxygenation in the Baltic Sea will significantly relax in the coming years.

Abstract ID: 99

The Role of Saltwater Inflows and Mean Circulation in Baltic Sea Eutrophication

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The Baltic Sea, a semi-enclosed brackish system, suffers from persistent eutrophication driven by anthropogenic nutrient inputs, biogeochemical processes, and physical factors such as stratification, saltwater inflows, mean circulation, upwellings and ice cover. While nutrient enrichment exacerbates bottom-water anoxia, physical processes critically influence oxygen dynamics, nutrient distribution, and primary production. Major Baltic Inflows (MBIs) episodically ventilate deep waters, yet their long-term capacity to alleviate hypoxia remains limited. This modeling study (2010–2021) explores the interplay between hydrographic conditions (saltwater inflows and mean circulation) and ecosystem responses using the novel Trophic Transfer Index (TTI) alongside traditional indicators like chlorophyll-a. Results indicate that limited saltwater inflows in 2014 altered TTI by -5% to +3% in certain basins, while changes in mean circulation caused TTI variations of -3% to +2%. Both factors exhibited spatially heterogeneous effects on nutrient retention and primary production. Although secondary to anthropogenic drivers, physical processes significantly modulate eutrophication outcomes. Consequently, effective management strategies must integrate physical, biogeochemical, and anthropogenic factors to holistically address Baltic Sea eutrophication.

Abstract ID: 106

Coastal Vulnerability Evaluation Based on Non-Stationarity in GEV parameters in the Baltic Sea

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Extreme water levels (EWLs) can substantially contribute to coastal hazards such as erosion and flooding in low-lying coastal areas. In the Baltic Sea, EWLs result from the combined impact of the water volume of the sea (preconditioning) and local storm surges. In some locations, wave-driven processes, such as wave set-up or run-up, further elevate local water levels. These contributors act on varying spatial and temporal scales. The complex coastline of the Baltic Sea and varying orientations expose different coastal segments to distinct combinations of these factors.

We estimate EWLs along the Baltic Sea coast using the Generalized Extreme Value distribution (GEV), characterized by shape, location, and scale parameter. The shape parameter determines the tail behaviour of the distribution: a negative value suggests limited growth of future extremes, a near-zero value indicates moderate growth, and a positive value signals potentially rapid growth. Alongshore variations in the shape parameter reflect variations in the likelihood of extreme events, making it a useful indicator of coastal vulnerability. Traditional extreme value analysis assumes that all these parameters remain constant over time. However, climate change challenges this assumption. Rising sea levels, changing storm frequencies, and shifts in storm tracks can modify projections of future extremes.

We analyse temporal and spatial changes in all three GEV parameters along the coastline of the Baltic Sea. To account for the different drivers of EWLs, we also examine the potential non-stationarity in preconditioning and storm surges separately. Our analysis is based on simulated water levels from the General Estuarine Model (GETM) driven by Uncertainties in Ensembles of Regional ReAnalysis (UERRA) wind data for 1961–2018 (Lorenz and Gräwe, 2023), complemented by observational data from several Baltic stations. The results reveal significant variability in the GEV parameters for total water level and its components. Most coastal segments exhibit a decrease in the shape parameter, indicating reduced vulnerability. However, some areas exhibit increasing values, suggesting shifts toward fundamentally different extreme-value behaviours in the future. The dominant driver of increasing and decreasing trends (preconditioning or storm surges) varies across different parts of the sea.

Abstract ID: 107

Wind Extremes in the Gulf of Riga: A Comparison of Modelled and Observed Data

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The Gulf of Riga in the Baltic Sea is a shallow basin exposed to predominant southwestern (SW) winds, making it a prospective area for wind farm development (Barzehkar et al., 2024). A comprehensive understanding of wind conditions in this region is therefore essential. Existing measurement sites are sparsely located on the mainland and may not accurately reflect offshore conditions relevant to wind farms. While modelled data offer broader spatial coverage, we aim to evaluate its applicability and limitation through comparison with measurements. Our analysis relies on hourly wind speed and direction data at 10 m height from 2004–2022 at Ruhnu, Kihnu, Vilsandi, Sõrve, and Kolka, supplemented with ERA5 reanalysis wind information (Hersbach et al., 2020).

To identify prevailing wind patterns, we analyze the directional distribution of moderate (>5–10 m/s) and strong (>10 m/s) wind events. Overall and directional wind speed distributions are characterized using Weibull parameters, offering insights into the probability of occurrence of wind speeds suitable for energy production. Additionally, we assess extreme wind events using the Generalized Extreme Value (GEV) method, providing information on the most intense wind conditions relevant for structural design and risk assessment, considering both total and directional wind speeds.

Among the analyzed locations, correlations between ERA5 wind speeds and measurements range from 0.79 to 0.86. While ERA5 generally overestimates the frequency of moderate to strong winds (5–15 m/s), it underestimates the frequency of calm conditions and weak winds (below 5 m/s) and also the tail of the distribution representing extreme winds. The Weibull shape parameter is relatively close to 2 for both modelled (2.35–2.49) and measured data (1.7–1.96), resembling a Rayleigh-like distribution typical of open-sea winds. The strongest observed winds reached 28 m/s during a severe SW storm, whereas ERA5 data capture winds up to 21 m/s. Mean wind speeds range from 4–5 m/s for measured data and approximately 7 m/s for modelled data. For a 50-year return period, return values differ by about 16% in single stations, with even greater variability observed in directional return levels. Part of these differences may reflect deviations of local wind conditions from the modelled ones in partially sheltered measurement locations. However, fairly large differences in the values of the modelled and observed Weibull shape parameter and in the parameters of very strong wind events signal the necessity of upgrading the underlying wind model.

Abstract ID: 117

The chancing wave climate in the Baltic Sea

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The Baltic Sea wave climate is changing under the influence of multiple factors. Climate change affects the wave conditions through changes in seasonal ice cover and possible changes in wind fields and extreme storm events. Offshore structures, such as offshore wind farms (OWFs) interact with the surrounding environment and change the atmospheric and marine conditions. Providing information about the prevailing conditions and projecting the future changes in the wave climate is of interest to several blue economy sectors. In addition, planning of operations requires presenting the information in an adequate way and available statistics of wave conditions typically expressed in mean and maximum values and percentiles are not fit for purpose.

We present wave statistics for the Baltic Sea in a form tailored to the user's need. This includes utilising event-based statistics and extreme value analysis. We base our analysis on the 45-year Baltic Sea Wave Hindcast product from Copernicus Marine Service, wave climate projections and model runs planned to assess the effects of OWFs. Latter is based on modified wind fields accounting for the wind wake effect utilising the PyWake module developed by the Technical University of Denmark. We also evaluate how the changes in the wave field induced by OWFs compare to those projected by climate change and present

Abstract ID: 118

Simulating the consequences of bottom-trawling on organic matter dynamics and hypoxia in the Baltic Sea

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Continental shelves account for 70-90% of the global ocean organic matter (OM) burial but are exposed to bottom-trawling, which causes sediment resuspension. This may enhance OM mineralization, thereby releasing nutrients that could contribute to eutrophication.

The ERGOM ecosystem model simulates OM resuspension caused by bottom currents and surface waves and the settling of suspended material. We added trawling-induced resuspension to the model. The bottom-trawling activity was estimated by combining AIS ship-tracking data from the Global Fishing Watch with ICES reports about fishing activity in the Baltic Sea. The ship data, combined with OM and sediment-type maps of the Baltic Sea, allowed estimates of trawling-induced sediment erosion and OM resuspension fluxes.

We compare three scenarios to assess the impact of bottom-trawling on OM transport and mineralization: 1) a baseline simulation without trawling-induced resuspension, 2) a simulation with trawling-induced resuspension and subsequent relocation of OM, but without enhanced mineralization, and 3) a simulation with both trawling-induced resuspension and enhanced mineralization of suspended matter. By comparing simulations 1 and 2, we find that bottom-trawling can have a large impact on the spatial distribution of OM, which strongly depends on trawling activity and bathymetric slopes. However, OM suspended in shallow coastal areas does not reach the deepest basins, limiting its long-term contribution to eutrophication and hypoxia. In the third scenario, we simulate increased mineralization by allowing trawling to mobilize deeper buried OM.

Abstract ID: 119

Using gliders to study complex transport and mixing dynamics in the Åland Sea

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In recent years, we have observed changes in the state of the Bothnian Sea. The factors inducing these changes are not yet well understood. One of the factors affecting this region is the water exchange between the Bothnian Sea and the Baltic Proper. This occurs through complex and dynamic areas: the Åland Sea and the Archipelago Sea. Modelling studies have shown high variability in currents and transport in these areas. As a deeper basin with a larger volume, the Åland Sea has a greater contribution in the water exchange compared to the role of the Archipelago Sea.

Until recently, there has been a limited number of observations available from the Åland Sea, mainly data from monitoring cruises a few times a year. Since November 2023, the Voice of the Ocean foundation has conducted glider measurements in the Åland Sea, resulting in more than a year of continuous data from this region. This results in more than 12500 profiles of temperature, salinity, and oxygen, among other variables. Combining this data with Finnish Meteorological Institute's measurements from the Åland Sea, the Archipelago Sea, the Bothnian Sea and the Baltic Proper (including e.g. ADCP, Argo and glider data) makes a unique dataset enabling detailed studies of the complex dynamics of water exchange through the Åland Sea.

We present results from the Åland Sea glider measurements showing high temporal variability in temperature, salinity and oxygen especially in the mid and deep layers. For a more detailed study of the transport and mixing processes we focus on a few events where ADCP data showed high current speeds in the deeper layers near the sills at the southern Åland Sea. Combining the Åland Sea measurements with data from the surrounding basins we evaluate the water exchange processes between the Baltic Proper and the Bothnian Sea.

Abstract ID: 120

Dynamics of the Carbonate System in the Coastal Waters of the Southern Baltic Sea

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Ocean acidification, driven by rising atmospheric CO_2, threatens marine ecosystems, particularly in shelf sea regions. These areas experience high carbonate system variability, mainly due to freshwater inflows, high biological activity, and direct impacts of sedimentary processes. One such example is the Baltic Sea, where the combination of these factors leads to pronounced spatial and temporal variability in the carbonate system, which has been recognized mostly in open waters. The lack of detailed data from the coastal zone creates a gap that this research aims to fill by analyzing the seasonal and long-term variability of the carbonate system structure in the Gulf of Gdansk (southern Baltic Sea).

Since 2016, weekly measurements at the Sopot pier (located about 55 km NW of the Vistula River mouth) have included carbonate system parameters such as dissolved inorganic carbon (DIC), total alkalinity (TA), and pH, along with sampling to determine concentrations of dissolved organic carbon, particulate organic and inorganic carbon, chlorophyll a, nutrients, temperature, and salinity. The results indicate strong seasonal temperature changes and relatively stable salinity levels (5.9–7.9), with occasional decreases due to Vistula River inflows, the second-largest river draining into the Baltic Sea. Observed DIC and TA values exhibited significant variability, distinguishing them from the clear seasonal patterns observed in the open Baltic Sea and highlighting riverine influence. The highest TA concentrations were recorded in spring (2119 µmol/kg), while the lowest occurred in winter (1581 µmol/kg), further implying seasonal variability in TA within river waters affecting this region. DIC seasonality closely resembled that of TA; however, distinct discrepancies were noted in spring and summer, likely due to primary production, as confirmed by a nutrient drop and chlorophyll a increase, which reduce DIC and increase TA. It was also shown that TA and DIC concentrations at the Sopot pier were generally much higher than in the central Baltic Sea (1674–1700 µmol/kg) but lower than in Vistula River water (2800–3600 µmol/kg), emphasizing the significant role of riverine inflows as a source of TA and DIC for the Gulf of Gdansk.

The large TA and DIC variabilities, often without clear interdependencies, suggest the influence of numerous biogeochemical processes. Further studies will identify and quantify these interactions. First, we plan to apply the two-end member approach—mixing open Baltic Sea water with freshwater from the Vistula River—to verify the influence of riverine input on observed carbonate system variability.

Abstract ID: 125

Bottom Trawling Enhances Bottom-Water Oxygen Depletion in Muddy Shelf Sediments

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Bottom trawling is known to disturb vast areas of the seafloor every year, resuspending sediments and altering benthic habitats. This practice is particularly common on continental shelves, which play a crucial role in the biological carbon pump and serve as major carbon sinks. While the physical impacts on benthic fauna and sediment resuspension are well-documented, the broader biogeochemical consequences on long-term carbon sequestration are still unclear.

In this study, we investigated the biogeochemical effects of bottom trawling on carbon sequestration and nutrient dynamics on a muddy seabed in the western Baltic Sea. We conducted two trawling experiments to disturb the seafloor and suspend sediment while monitoring the changes in major nutrient concentrations, inorganic carbon, suspended particles, and oxygen dynamics. In the first experiment, a commercial bottom trawler conducted an artificial trawl to create a sediment disturbance, while concurrent CTD profiling and water sampling was performed at selected locations in the disturbed area up to a day after the trawl. In the second experiment, a stationary benthic observatory was positioned on the seafloor prior to nearby disturbance with a benthic sled to collect continuous data over a 24-hour period after the trawl.

Our findings show that within the first hour after the trawling event, concentrations of combined inorganic nitrogen, phosphate, and silicate increased in a non-Redfield stoichiometry, but returned to baseline levels after three hours. Oxygen concentrations in the lower water column continued to decline over a 24-h period, suggesting the presence of a longer-term oxygen sink. We propose that sediment suspension by bottom trawling mobilizes and re-exposes anoxic sediment particles to oxygen leading to oxidation of sediment sulfide, as well as dissolved ammonium, sulfide, manganese, and iron. Suspension of sediment at the scale of our experiments also had a small, but discernible effect on the dissolved inorganic carbon inventory, presumably due to higher microbial respiration. The observed effects of this artificial sediment disturbance are close to the analytical precision limit of our nutrient and inorganic carbon data.

Abstract ID: 129

Decoding Sedimentological Changes in the Baltic Proper: The Role of the AD 1951 Giant Saltwater Inflow

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A significant sedimentological change in subsurface sediments across the entire Baltic Proper has been previously observed. We studied this change using acoustic profiling, hydrographic instrumental monitoring data, and sediment cores including artificial radionuclides and organic carbon content data. Past saline water inflows were identified by benthic foraminifera counting.

Our studies of sediment cores from basin-wide water depths transects (Moros et al. 2024) indicate that this sedimentological change was triggered by significant hydrographic and environmental shifts that began at the end of the Little Ice Age (LIA,~AD 1850) and were accelerated by a rapid change in water column stratification in AD 1951, caused by a giant saline water inflow. We argue that on a longer timescale, winter-time deep-water convection gradually weakened due to the winter-time atmospheric and ocean warming after the end of the LIA, but still contributed to the ventilation of bottom water of the entire Baltic Proper. Currents prevented sediment accumulation and even eroded the seabed above water depths of approximately 150-160 m. The hydrographic conditions changed markedly with the saline water inflow in AD 1951. The accompanying increase in stratification caused a collapse of the already weakened winter-time convection, leading to hypoxia in the bottom waters, which in turn forced a sudden phosphate release from the sediments and increased primary production in the late 1950s.

The sharp sedimentological boundary reflects this sudden environmental change. With the convection collapse, the delivery of fine-grained re-worked material to the subbasins stopped and the base (depth) of sediment re-suspension shifted upwards. This enabled the accumulation of organic carbon-rich sediments from the late 1950s onwards also at shallower water depths, to approximately 60–70 m (the modern winter-time mixing depth). The speed (<10 years) of the seabed change triggered by external forcing and accelerated by internal processes is remarkable. The combined effect of stratification and winter-time temperature changes seem to have played a stronger role in bottom-water ventilation than previously thought. There is a need to improve the resemblance of these processes in ecosystem models because such changes seem to have frequently forced environmental shifts during the last 7,000 years of the Baltic Sea´s history. Moreover, on a hemispheric scale, new results indicate that a similar winter-time temperature warming after the LIA, affected markedly the depositional environment in semi-enclosed subarctic Eastern Canadian coastal basins.

Reference:
Moros et al., 2024. Giant saltwater inflow in AD 1951 triggered Baltic Sea hypoxia. Boreas. https://doi.org/10.1111/bor.12643

Abstract ID: 135

Constructing nutrient budgets of coastal waterbodies (applied in the Estonian coastal areas)

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The Baltic Sea is strongly affected by eutrophication due to historical excessive nutrient inputs. Despite extensive measures and reduced loads, its overall environmental status has not improved. The Baltic Sea consists of several sub-basins and coastal areas with differing natural conditions and anthropogenic pressures. To better manage these waterbodies, defining the input limits needed to maintain a healthy ecosystem is crucial. For this, we must quantify nutrient inputs from land and atmosphere, exchanges with adjacent basins, and fluxes between the water column and sediments and the water column and atmosphere. Water-borne nutrient inputs were estimated using monitoring data (inputs from rivers and direct sources) and atmospheric deposition using the EMEP model. A numerical biogeochemical model system based on GETM-ERGOM is applied to analyze nitrogen and phosphorus cycles in the Baltic Sea. The used ERGOM version has 15 state variables: three phytoplankton classes, zooplankton, detritus, oxygen, hydrogen sulfide, nutrients and sedimented material. The following amounts and fluxes of nutrients are additionally stored in the daily model output: amount of nutrients in the active layer of sediments, burial of nutrients and nitrogen fixation. To validate the model regarding the internal load of phosphorus, water samples from the near-bottom layer and sediment samples in different sea areas were collected and analyzed for phosphorus fractions. As a result of the study, nutrient budgets for all coastal water bodies in the Estonian sea area were constructed. It is shown that the major sources of nutrients for different waterbodies differ, and the water bodies act variably in terms of the accumulation or release of nutrients. The results indicate whether a water body is more influenced by changes in a larger area, e.g. in the Baltic Sea, or whether local changes have a more significant effect. This approach is useful for suggesting potential land-based measures to reduce human-induced pressures (locally and/or regionally) and mitigate eutrophication. We discuss ways to improve the estimates of nutrient fluxes and budgets. For instance, a very rough assumption is applied to calculate the total nutrient concentrations in the water column in the present study since the ERGOM version did not include DOM as a state variable. DOM must be included to improve the model performance because it contains a large fraction of nutrients, is a significant component of nutrient cycles and is used for remineralization.

Abstract ID: 155

Linking benthic communities and biogeochemical cycling in the southern Baltic Sea

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In order to understand marine biogeochemical cycles and marine ecosystem functioning we need to understand the benthic functioning, including benthic trophic relations and faunal activities within the sediment (bioturbation). Here we present results of the 'COmEBACk' project, funded by the Polish National Science Centre, that aimed to study the complexity and functioning of benthic communities and their role in biogeochemical processes in coastal areas affected by different anthropogenic impacts. Sampling was carried out in shallow parts of the southern Baltic Sea, along the Polish coast, and covered shallow brackish lagoons (Szczecin Lagoon), open coast, Puck Bay and Vistula river prodelta. Samples were taken during winter, spring and autumn, from late 2018 to early 2020, from the shore (0.5m), and from the r/v Oceania along the depth gradient from about 10 m to 35 m depth, and 60 m in case of Vistula river prodelta. We sampled macrozoobenthic communities and benthic food webs, and measured a wide range of environmental parameters. During three campaigns, *ex situ* core incubations were conducted in controlled conditions at selected stations and seasons to determine the sediment mixing rates and the role of benthic communities in biogeochemical processes, *i.e.* benthic fluxes of oxygen, dissolved organic and inorganic carbon (DOC, DIC), silica, phosphates, nitrate + nitrite, and ammonium. We show temporal and spatial patterns of benthic food-web structures and bioturbation activities. We demonstrate that shallow benthic communities are resilient to changes in seasonal organic matter variability, and utilize various organic matter sources, including river derived organic matter. We further show that benthic communities, in addition to sediment properties, can play a dominant role in shaping benthic fluxes. However, benthic role is different depending on the type of flux: *e.g.* it is crucial in shaping O_2 and DIC fluxes, but not in DOC flux. Its role also varies depending on the area sampled and environmental settings – *e.g.* benthic organisms are important in shaping dissolved silica fluxes in shallow enclosed areas, while environmental factors, such as organic matter properties, are key drivers in open coasts. Finally, we discuss how the role of benthic organisms in ecosystem functioning may change with accelerating climate change.

Abstract ID: 159

The evolution of the medium size MBI in December 2023 along its pathway from the western Baltic to the Eastern Gotland Basin.

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The properties and strength of the estuarine circulation controls crucially the general stratification in the Baltic and thus, particularly the vertical connectivity between the upper layer and the deep water. Major Baltic Inflows (MBI) are an important component of the Baltic overturn circulation. Till today, there is no robust long-term trend in the MBI frequency, but it depicts a high variability on decadal time scale. In December 2023 a medium size MBI was observed in the western Baltic, that transported 87 km³ saline water containing 1.6 Gt salt over the Darss Sill and the Drogden Sill. This is about 20% of the mean annual salt import of the Baltic.

Multiple observations covered the saline inflow from its origin to the central Baltic. In March/April 2024 the inflow plume reached the eastern Gotland Basin (EGB). Here the structure of the saline plume and its mixing with the ambient deep water was investigated with high resolution towed CTD (ScanFish) measurements and a microstructure probe (MSS). The mixing with ambient waters occurred mainly near bottom at the front of the plume and along the eastern rim of the inflowing water, where it interacts with the slope of the basin. The most important process that forces the mixing seems to be the shear stress between the moving plume and the sea bed.

The inflow waters were not dense enough to reach the bottom layer of the EGB. Instead, the inflow was sandwiched below the halocline and 130m depth in the upper deep water. After it detaches from the bottom the inflow water spread in separate plumes into the EGB and was further advected with the general cyclonic circulation in the basin. The inflow process into the EGB was finished in late summer 2024. At that time the dissolved oxygen of inflow plumes was nearly depleted. Between August 2024 and February 2025 the changing salinity and temperature in the Fårö Deep indicate that part of the inflow water has left the EGB northwards and reached the bottom layer of the Fårö Deep. However, no ventilation was detected here since the oxygen was completely consumed upstream. The observations reveal the evolution and fate of a medium size inflow event which was not able to renew the EGB bottom water.

Abstract ID: 162

Uncovering seasonal scales in marine CO_2 dynamics – The bridging role of OneArgo in Baltic Sea monitoring

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To properly observe and document changes in marine CO_2 or other parameters in the Baltic Sea or beyond, a combined approach between observation and modelling, but also the combination of different observation approaches is needed.

The OneArgo programme and its autonomous float measurements can help to fill temporal and spatial gaps of traditional, surface or research-vessel based monitoring programmes. Argo floats have been successfully operated in the Baltic Sea for more than a decade. OneArgo observations not only cover temperature and salinity, but also oxygen, sulfide, chlorophyll *a* and suspended particles as well as light regime and nitrate through its BGC-mission. Thus, OneArgo is full on scope to support assessments of the current state of the Baltic Sea, e.g., with established HELCOM indicators.

Here, we expand the observations of OneArgo to marine pCO_2: (1) surface carbon measurements by a ship of opportunity (SOOP), (2) research-vessel based water sampling of the water column, and (3) vertical profiling Argo float data of pCO_2 as the crucial link build the foundation for a comprehensive CO_2 observation network. By cross-validating data across the different research infrastructures, we ensure that data are interoperable. Combined, the three different research infrastructures provide highly complementary information to quantify CO_2 uptake, on the seasonal cycling and fate of CO_2 in the water column, and on timescales of CO_2 sequestration. Next steps are to integrate data from the different sources into a comprehensive 4D BGC product of Baltic Sea CO_2.

To further expand OneArgo's bridging role, future float deployments in the Baltic Sea will more frequently involve sensors for pCO_2, nitrate, oxygen debt, and hyperspectral radiometry, e.g., to link up with satellite remote sensing products. Thus, OneArgo profiling floats can also play a role in an updated HELCOM monitoring strategy.

Abstract ID: 172

Long term trends and variability of the mixed layer depth in the Baltic Sea

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The mixed layer in the Baltic Sea is a dynamic and critical component of the region's oceanographic system. Its variability is driven by wind, ice cover, freshwater inflow, and stratification, with significant seasonal and spatial differences. Understanding these patterns is essential for predicting the impacts of climate change on the Baltic Sea's physical and ecological systems. The study focuses on analyzing the mixed layer depth (MLD) in the Baltic Sea, highlighting spatial and seasonal variability, key patterns, and influencing factors.

The MLD is deeper in the offshore areas of the Baltic Sea, where it reaches long-term mean values between 20 and 25 m. Analysis reveals significant spatial variability in MLD trends across the Baltic Sea. In the northern and eastern regions, the MLD shows a deepening trend over time, with a maximum slope of approximately 1.3 m per decade. The deepening of the MLD in the northern and eastern areas may be attributed to reduced ice coverage in winter. The absence of ice cover allows wind mixing to penetrate deeper into the water column. Conversely, in the southern and central regions, the MLD exhibits a shoaling trend, with the strongest negative slope around -1.5 m per decade. The shoaling of the MLD in the central and southern Baltic Sea may be related to increased stratification within the halocline and its upward shift observed in recent decades. These trends are statistically significant in the eastern Baltic subbasins and offshore central/southern Baltic Proper. Despite opposing trends between the northern-eastern and central-southern regions, the MLD spatial pattern remains stable over 30 years.

There is strong seasonal variability in the MLD across the Baltic Sea. The mixed layer is thicker in winter compared to summer, with spatially averaged MLD values ranging from 23 to 28 m in different winters, reducing to around 10m during summers.

K-means clustering of annual mean and variance of MLD identifies three distinct zones. The deep central areas of the Bothnian Bay, Bothnian Sea, Gulf of Riga, and southern/eastern Baltic Proper have higher MLD and larger variance. Narrow coastal zones feature a thinner mixed layer with low variance. A transition zone, varying geographically, spans the entire Gulf of Finland and most of the western/southwestern Baltic Proper.

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Abstract ID: 182

Shore to Basin (S^2B): An interdisciplinary initiative to understand shallow water coastal dynamics with an example from the coast of Nienhagen

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The Shore to Basin (S^2B) research initiative at the IOW aims to develop an in-depth understanding of the shallow (approx. 15 m depth and less) water bodies in marine systems. We are a group of technicians and scientists who have focused their work in an interdisciplinary way to study the dynamics of shallow water and the exchange with the open Baltic Sea in a changing environment. As a first result we would like to present data from the coast of Nienhagen, situated about 5 km west of the city of Rostock. At Nienhagen an in-house developed long-term mooring chain with sensors at 4 levels measuring temperature, salinity, oxygen, turbidity and Chl-a was deployed in 12 m depth. The mooring is capable to send the data on-line to the IOW, where they can be immediately used and processed in-house. The mooring is designed to be modular and is planned to be extended by current measurements, an eDNA-sampler and a FlowCytobot device. In addition to the mooring, regular campaign based measurements of nitrogen cycling processes in the sediment, particle size and distributions in the water column, oxygen microprofiles in the sediment together with near bottom oxygen fluxes based on eddy-covariance measurements have been performed. This interdisciplinary dataset is accompanied by campaign based cross-shore transects of water currents, CTD profiles as well as the dissipation rate of turbulent kinetic energy. The Results of measurements in autumn 2024 depict a pronounced salinity stratification with decreased oxygen concentrations of 40% air saturation in the deeper water column at about 10 m. This water mass is transported upslope to less than 5 m water depth during an upwelling event. We discuss the consequences of such rapid oxygen changes in the water column on the oxygen dynamics in the sediment and the consequences for the nitrogen cycle in coastal shallow waters. We expect that such dynamics in oxygen concentrations will become more frequent as a result of climate change. Our results from the field measurements will be incorporated into numerical models, which will be used to study the exchange processes of nutrients between the shallow water and the open Baltic Sea and to what degree they change in the future.

Abstract ID: 190

Submesoscale dynamics in the Baltic Sea

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Submesoscale (SMS) processes in the ocean occupy spatial scales between mesoscale processes and 3D isotropic turbulence. They drive energy transfer towards microscale dissipation and diapycnal mixing and contribute significantly to ocean dynamics and biogeochemistry. In the Baltic Sea, the corresponding horizontal scales range from a few km to 100 m. Due to their limited extent in space and time, SMS processes are difficult to describe by conventional ship-borne measurements and autonomous platforms must be applied. Numerical models with SMS permitting resolutions have revealed high variability and richness of features in the respective wavenumber range. Lack of data with required resolution and coverage hinders proper validation of these high-resolution model runs.

We summarize the results of our studies focused on SMS processes in the Baltic Sea. Pronounced variability at the submesoscale has been revealed using ferryboxes, profiling stations, scanfish and glider observations in the presence of active mesoscale processes. Horizontal wavenumber spectra of density variance in the upper mixed layer have shapes suggesting a significant role of SMS processes in the energy cascade. Similarly, the spice variance spectra at isopycnal surfaces in the subsurface layers indicate the impact of local stirring at the submesoscale. Recorded intense SMS variability at the base of the upper mixed layer suggests the release of potential energy close to the density interface. An analysis of temperature variability at a profiling station showed that approximately 50% of the observed high-frequency fluctuations can be explained by SMS processes. Patterns corresponding to ageostrophic secondary circulation at the mesoscale front were mapped by a glider mission when forcing ceased to support the frontal dynamics. Results from continuous glider sections and high-resolution modelling suggest that topography-related instabilities of frontal currents can create favourable conditions for SMS subduction and intense coastal-offshore exchange. Phytoplankton patches in the thermocline further indicate the impact of such a circulation pattern – fast subduction in narrow zones and slow upward motion in wider areas – on the biogeochemistry in stratified environments.

All these observational results confirm the significant role of SMS processes in the dynamics of the Baltic Sea. They appear in many different forms yet remain neither geostrophically balanced (2D) nor 3D isotropic. It is a major challenge to describe such sub-grid processes in large-scale numerical models where the unrelated description of horizontal and vertical mixing probably does not work at scales close to the submesoscale.

Abstract ID: 191

Summer heatwaves on the Baltic Sea seabed may cause episodic hypoxia in shallow areas

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The water temperature in the Baltic Sea, which is a semi-enclosed, permanently stratified body of water, has warmed more than other coastal seas as a result of global change. Therefore, the Baltic Sea is prone to marine heat waves (MHWs), which are defined as discrete, anomalously warm water events lasting from days to weeks. During the last century, MHWs have become more frequent and widespread not only in the Baltic Sea but also globally. In general, MHWs are associated with damage to marine ecosystems, such as the death of marine species through direct (e.g. thermal stress) and indirect effects (e.g. oxygen depletion).

We investigated and described the spatial and temporal variability of MHWs longer than 10 days in the Baltic Sea using two three-dimensional ocean reanalysis datasets covering the periods 1970-1999 and 1993-2020, giving a total time series of 51 years. Due to the interest in the ecological application of the results, a fixed-threshold approach as well as the climatological baseline approach were used. We investigated how summer MHWs (June-September) affect bottom water oxygen concentrations, including the effects of reduced oxygen solubility in seawater.

We found that with both approaches, MHWs have occurred everywhere at the sea surface since the early 1990s. Periods with sea surface temperatures of more than 20 °C were particularly numerous in the shallow coastal zone of the southern and eastern Baltic Sea. The extent of MHWs reaching the sea floor has increased since the 1990s, while the trends in the MHW extent at the sea surface are not statistically significant. This applies to both approaches. MHWs occurred mainly in water depths of less than 20 meters, where they led to a decrease in oxygen concentration. Hence, the increasing number of marine heatwaves increases the risk of hypoxia events in the coastal zone.

Abstract ID: 199

Performance of modeled winds for offshore wind farms in the Baltic Sea

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Successful development of offshore wind farms is contingent upon a solid understanding of the local wind and wave conditions, which directly impact the energy yield and the structural resilience of the wind turbines. In the Baltic Sea region, extensive measurements of wind information are often limited in time and space (Björkvist et al., 2018), compelling stakeholders to rely on models, that are typically validated by means of short-term and localized measurements. Accounting for these limitations, this study proposes an evaluation of prominent modeled wind information (ERA5, COSMO-REA6, MERRA-2, NCEP-NCAR), across several offshore sites in the Baltic Sea, over a 60-year period. The methods employed involve a detailed analysis of seasonal variations, diurnal cycles, inter-model comparisons, with a focus on the performance of the models during extreme storm events. Model outputs are compared to assess discrepancies and overall performance during both moderate and high-intensity events, during which variations in wind speed and directional shifts critically affect wave generation and overall marine conditions (Giudici et al., 2023). The results highlight the importance of tuning multiple model sources together with available measurement campaigns to mitigate the uncertainties tied with the use of purely modeled data. This approach provides more relevant information for risk assessment and energy yield estimation, as well as offers insights for design optimization and policy making, which are critical for the development of offshore wind energy in the region.

Abstract ID: 200

Sea ice in the Baltic Sea during 1993/94–2020/21 ice seasons from satellite observations and model reanalysis

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The study investigates the sea ice characteristics of the Baltic Sea using Copernicus satellite and model reanalysis data products from 1993 onward. Our primary focus was on assessing the performance of the latest Copernicus model reanalysis product in estimating the ice season evolution compared to the satellite dataset. The model estimates an earlier start to the ice season; it generally matches satellite data regarding the season's end. In addition, the model ice thickness is compared with the ice chart-based data. Across the Baltic Sea, declining trends for sea ice were observed. The sea ice characteristics during the recent period (2007/08–2020/21) showed decreased sea ice fraction and thickness compared to the preceding period (1993/94–2006/07) of the study. The decrease in sea ice thickness was greater than 50 % in some areas during the spring season. The trend analysis in the study revealed a uniform pattern toward shorter ice seasons (the most prominent being in Bothnian Bay with a range of approximately 1–3 days/year of decline in ice season), reduced sea ice extent (SIE) and reduced mean ice thickness (reaching up to -0.7 cm/year).

Abstract ID: 201

Marine Cold Spells in the Baltic Sea

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Marine cold spells (MCSs), characterized by anomalously low sea surface temperatures, play a crucial role in shaping marine ecosystems and have significant socioeconomic implications. While numerous studies have examined the increasing frequency and intensity of marine heatwaves (MHWs), research on MCSs remains limited, particularly in the Baltic Sea. This study analyzes MCS trends in the Baltic Sea from 1982 to 2023, focusing on their frequency, duration, intensity, and spatial extent during the extended summer–autumn period (June–November). Over this period, MCS occurrences have significantly declined, with total events across the Baltic Sea ranging from approximately 20 to 45. Coastal MCS events were more intense, with mean intensities reaching around 4°C, while offshore regions averaged just over 3°C. MCS duration has also decreased across the Baltic Sea, with a more pronounced decline in the western part. To provide a comprehensive assessment, an activity parameter is used to integrate all MCS indices into a single measure. The observed decline in MCS activity is then decomposed into contributions from long-term warming and interannual variability, revealing that the primary driver is a sustained SST warming trend of ~0.05°C per year, with interannual variability playing a secondary role. MCS parameters are also derived from detrended sea surface temperature data to remove the long-term warming signal and assess cold spell variability. In recent years, coastal regions associated with upwelling zones have experienced fewer and shorter cold spells, consistent with other regions, but their intensity has significantly increased.

Abstract ID: 219

Changes in Gulf of Bothnia – implications for the future and management

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The eutrophication status of the Bothnian Sea has significantly deteriorated over the past decades, with increasing phosphate concentrations leading to intensified nitrogen limitation and more frequent cyanobacterial blooms. These changes have recently gained additional management significance, as the updated EU Urban Wastewater Directive requires a renewed justification for the current exemption from stringent nitrogen removal requirements in wastewater treatment plants around the Gulf of Bothnia. Neither the magnitude nor the temporal trends of nutrient loads within the Gulf of Bothnia fully explain the deterioration of the eutrophication state, suggesting a dominant influence from phosphorus influx from the Baltic Proper. However, the trends in phosphorus concentrations in both basins indicate a complex interaction. Additionally, altered physical conditions as consequence of rising air temperatures and reduced ice cover in recent decades have potentially had effects on the biogeochemical cycles in the Gulf of Bothnia. To investigate the causes of these changes and assess future developments, we use simulations from the physical-biogeochemical model BALTSEM. Furthermore, we quantify and evaluate the potential impact of enhanced nitrogen removal in sewage treatment based on our model simulations.

Abstract ID: 238

An Efficient Ecological Modeling Framework Aiding Robust Decision-Making for Estuarine Ecosystems: The Curonian Lagoon Case

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The Curonian Lagoon is a highly dynamic, hypereutrophic estuarine system that functions as a biogeochemical reactor between the land and the Baltic Sea. Its primary driver is riverine input, particularly during spring and autumn, bringing a large nutrient load into the lagoon and consequently into the Baltic Sea. Therefore, an ecological model is required to represent this continuum system to propose and support efficient eutrophication mitigation strategies. However, such studies should be conducted with caution. First, an appropriate model must be selected or developed with sufficient ecological and spatial complexity and configured for long-term simulations. Subsequently, the model requires several analyses to ensure reliable results, including calibration, validation, and uncertainty quantification. Mostly rigorous and often subjective trial-and-error calibration method has been commonly applied by ecological modelers. However, a wide range of automated calibration tools, such as the Parameter Estimation (PEST) software, have been successfully used for ecological model calibration and uncertainty analysis.

For our case study, we employed the Curonian Lagoon ecological box model in Python (CuLPy) and the SHYFEM hydrodynamic finite element model to estimate eutrophication-related processes. Essential biogeochemical processes and physical forcing, such as nutrient cycles, saltwater intrusion, and light availability, are considered by the CuLPy model, which has 10 abiotic state variables and one biotic state variable (phytoplankton). The use of Python enabled us to achieve significant improvements in computational time through Just-in-Time (JIT) compilation. In conjunction with gradient and ensemble-based methods for parameter optimization, it can enhance ecological model calibration and nutrient estimations while using fewer resources. To our consideration, this methodology is particularly well-suited for highly complex biogeochemical models. The construction of an ecological model and its calibration/validation with long-term monitoring data enabled us to understand the lagoon's complexity regarding the nutrient dynamics and its current state. Our preliminary results and in-situ measurements show that the lagoon does not effectively act as a sink for riverine nutrient loading. Therefore, follow-up studies, such as scenario analyses, could be conducted to examine possible conservation strategies for the Curonian Lagoon and subsequently the southeastern Baltic Sea coast.

Abstract ID: 246

Reconstruction of dynamic processes in the Baltic Sea using the synergy of satellite images and in situ data supported by numerical modeling and AI methods – first outcomes from 4DBaltDyn project

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Gaining in-depth knowledge of the marine environment requires high-resolution data, which can be difficult to obtain through traditional observation methods. Modern satellite data provide powerful and unprecedented tools for monitoring the marine environment at both local and global scales. However, these observations are typically limited to the sea surface or the nearest subsurface layers, making it challenging to achieve a comprehensive understanding of environmental conditions, assess their state with precision, and track changes over time and space. A truly holistic perspective requires data that encompass the entire water column.

Mathematical modeling offers a means to generate such data, but even the most advanced models struggle to fully reproduce all environmental parameters with high accuracy. Alternatively, modern statistical techniques, including artificial intelligence (AI) and machine learning (ML), can provide valuable insights into the water column. However, neither mathematical modeling nor AI/ML methods alone can yield fully reliable results without the integration of real-world environmental data. The synergy of these approaches with satellite observations is essential for delivering a comprehensive and reliable picture of the marine environment, enabling continuous monitoring of changes and improving the ability to forecast their impacts on ecosystems and human activities.

This integrated approach is at the core of the Baltic Sea Dynamics through 4D Modeling and Integrated Earth Observation (4DBALTDYN) project, launched in 2024. The project aims to enhance our understanding of the physical and biogeochemical states of the Baltic Sea by combining modern statistical methods, advanced modeling, in situ measurements, and satellite imagery. Its primary outcome will be a high-resolution 4D reconstruction of the Baltic Sea's physical and biogeochemical conditions over recent decades.

The project’s potential will be demonstrated through four case studies, showcasing how this 4D reconstruction can improve our understanding of the complex interactions between physical, biological, and biogeochemical processes in the Baltic Sea. The preliminary results of the project, highlighting key findings and the potential applications of this innovative approach will be presented and discussed.

Abstract ID: 247

New insights into the sources of alkalinity in the Baltic Sea

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Total alkalinity (A_T) is one of the measurable parameters of the carbonate system. It is a measure of the ability of natural waters to neutralize acids and thus, of the resilience against pH-changes due to e.g. acidification. In the Baltic Sea, the distribution of A_T is complex. The central Baltic Sea acts as a mixing bowl of A_T -rich saline water from the North Sea and freshwater endmembers, which have a low A_T content in the northern basins with granite-dominated bedrock in the catchment area, but a high A_T content in the south, where a bedrock with a high $CaCO_3$ content is weathered. In addition, internal sources and sinks affect the A_T signature.

Despite the importance of A_T related to carbon storage and the regulation of the acid-base characteristics of Baltic Sea waters, there are two major shortcomings in our current understanding: 1- While the distribution of A_T is well reflected by most Baltic Sea biogeochemical models, they uniformly underestimate the A_T content of the Baltic; 2- there is clear evidence that A_T in the Baltic Sea has substantially increased over the last century, and, in a very traceable way due to improved analytics, continues to do so over the last 30 years, but the reasons are currently still unclear.

We shed new light on these scientific questions, based on new results on the freshwater endmember characteristics and A_T -S relationships from a coastal-near pan-Baltic research expedition and additional $A_T$data of riverine endmembers retrieved from land, including data from the currently not-well constrained southern drainage basin. We also re-investigate historical trends of A_T in deep waters over the past 30 years in the context of potential internal alkalinity sources. We will use these data to reason on the relative importance of internal sources and changes of external runoff, in particular in the southern drainage basin (Gulf of Riga, Bay of Gdansk), for the observed A_T changes in the Baltic Sea.

The inorganic carbon system is a key variable in understanding biogeochemical cycles. Understanding the inventory, patterns, and trends of A_T in particular is a pre-requisite to constrain the Baltic Sea carbon inventory, to assess future trends of acidification in the context of the HELCOM strategic approach to ocean acidification for the Baltic Sea currently under development, and to set a baseline for marine carbon dioxide removal (mCDR) actions in the Baltic Sea, including Blue carbon and ocean alkalinity enhancement.

Abstract ID: 252

Causes of multidecadal variability of the Baltic Sea system

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Long-term observations of the salinity of the Baltic Sea show a pronounced variability on a time scale of around 30 years. These variations are also found in the precipitation over the Baltic Sea region, the freshwater inflow from land and in the saltwater inflows from the North Sea. The Baltic Sea is characterised by a very large catchment area, which is about four times larger than the sea surface. It is therefore not surprising that the fluctuations in the atmospheric water cycle over the Baltic Sea region are reflected in the salinity of the Baltic Sea. We propose that teleconnections between the North Atlantic and the Baltic Sea region are the cause of these fluctuations. Using model simulations, we show that a large fraction of the outflowing brackish Baltic Sea water is connected to the incoming saline water by mixing in the Baltic Sea entrance area and that this process represents a positive feedback that amplifies the multidecadal salinity fluctuations. The strength of this feedback is considerable, as the atmospheric influences have almost the same periodicity as the response time of the freshwater content to external freshwater inputs. The long-term behaviour of the stratification in the Baltic Sea, which is characterised by the frequency of large saltwater inflows, is different. The frequency of the large saltwater inflows is not subject to systematic changes. In this review lecture, various publications on this topic are summarised and the effects on the marine ecosystem are discussed.

Thematic Session: Ecosystem Health and Biodiversity

Abstract ID: 1

Marine Biodiversity Management: from a Social-Ecological System to a Decision Support System

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The management of biodiversity within Social-Ecological Systems (SES) frameworks has become increasingly vital for promoting ecosystem health and resilience. SES approaches integrate ecological and social dimensions, recognising the interconnectedness between human activities and natural processes (Paolisso et al., 2019). This perspective is essential as biodiversity supports ecosystem services that benefit humanity, including food production, climate regulation, and recreational opportunities (Zhang et al., 2022; Isbell et al., 2017). Managing biodiversity through an SES lens provides a comprehensive approach incorporating ecological integrity, stakeholder engagement, and adaptive governance. It highlights the necessity for interdisciplinary research and integrated strategies that address both ecological and socioeconomic challenges, fostering sustainable coexistence between human societies and natural ecosystems.

Two major European biodiversity research and innovation projects, MarineSABRES and MARBEFES, employed SES approaches as key tools in biodiversity management. Across extensive European marine areas, initial quantitative and qualitative SES models were developed through structured stakeholder interviews, subsequently validated, refined, and compiled into computer-based network systems. Various network analytical methods (including loop analysis and leverage point detection) were applied to reveal intrinsic properties of each SES and provide insights for biodiversity management and sustainable use decisions. The final phase involved developing an interactive tool that integrated visNetwork, igraph, and LoopAnalyst R packages into a Shiny web application. The tool's interface and functions were validated through stakeholder and expert consultations.

To facilitate tool usage, a comprehensive guidance document with Standard Operating Procedures (SOPs) was created, covering all necessary steps from SES construction to analysis and decision support. A tutorial showcasing biodiversity management complexity in the Tuscan Archipelago (Tyrrhenian Sea, Italy) was provided as a practical application example.

This research is funded by the MARBEFES and MarineSABRES projects.

Abstract ID: 27

Spatiotemporal change of depth effects on macrozoobenthic communities in the Gulf of Gdansk

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Depth gradients are of utmost relevance in marine ecology, encompassing strong changes in environmental conditions, and thus playing a primary role in community organization and ecosystem functioning. In this study, we used the publicly available eCUDO database to evaluate depth effects on the presence/absence structuring of macrozoobenthic communities in the coastal waters of the Gulf of Gdańsk. We compared depth effects across different subareas with varying exposure to open waters, at different time periods in the 20th and 21st centuries, and assessed the extent to which depth elicits varying responses across organismal groups. We found evidence of interaction between space, time, and depth in explaining community shifts, with underlying responses being variable when different organismal groups were compared. Overall, our results suggest that exposure to open waters plays a role in shaping the distribution of benthic organisms across marine depth gradients, and more generally, that environmental changes through time may have uneven effects on ecological communities across space within a given area. Our results also support the notion of distinct responses across different organismal groups in front of environmental changes, with potential implications for ecosystem functioning.

Abstract ID: 29

Ontogeny of horizontal movement patterns of rehabilitated grey seal juveniles (*Halichoerus grypus*) in the Baltic Sea.

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The ethical considerations over the ecological benefits have fuelled debate about the rehabilitation of wildlife. Although there is evidence that many rehabilitated species are able to survive after rehabilitation, there is a paucity of research on the behaviour of rehabilitated pinnipeds, including grey seals (*Halichoerus grypus*). In this study, 14 juvenile grey seals were rehabilitated at the Baltic Sea Animal Rehabilitation Center in Lithuania and fitted with biotelemetry devices to enable remote post-release monitoring and investigate the ontogeny of their movement patterns in the Baltic Sea. The study revealed that their movements were similar to wild, non-rehabilitated grey seal pups when leaving their natal site: at first, they exhibited highly exploratory behaviour with largely transient movements, then switched into a resident movement pattern, while maximising foraging and minimising travelling time. Neither sex nor year of release, which varied in terms of rehabilitation time and body mass, had a significant effect on the ontogeny of these movements. Movements were significantly influenced by the time after release, suggesting that rehabilitated juveniles have gained experience and developed their movements over time in order to survive in the wild.

Abstract ID: 42

The Status of Anadromous Lampreys in Poland

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In Poland, two species of anadromous lampreys are recognized: the sea lamprey *Petromyzon marinus* and the river lamprey *Lampetra fluviatilis*. While the sea lamprey has always been observed only occasionally in rivers and coastal waters of the southern Baltic, the river lamprey population was historically numerous enough to be subject to commercial fishing, particularly in the Szczecin Lagoon, Vistula Lagoon, and the Lower Vistula region. Due to hydraulic engineering projects and river pollution in the 20th century, a significant decline in the spawning populations of lampreys in Polish rivers has been observed. Since 2004, anadromous lampreys have been legally protected in Poland, effectively ending commercial fishing. Since then, fish passes have been built on many rivers in Pomerania, significantly extending the migratory range of salmonids, such as the sea trout. However, monitoring of the status and range of anadromous lampreys has only been carried out since 2016. In 2020-2021, subsequent monitoring of the spawning populations of anadromous lampreys was conducted in 13 selected rivers in northern Poland. The study included catches during the autumn and spring migrations using dedicated traps, as well as electrofishing for larvae in potential spawning areas. Throughout the study period, a total of only 462 river lamprey individuals were caught, ranging from 19 to 45.5 cm in length (mean = 35.6 cm), and their presence was recorded in most of the studied rivers. No sea lampreys were found. Lampreys migrating from the sea were only found in the lower sections of rivers, below the first dam, regardless of the presence of fish passes. Electrofishing revealed the presence of lamprey larvae only from the genus Lampetra. However, their relative abundance in the main riverbed and its lower reaches was very low or not detected (0-3.6 indiv./m²), compared to habitats located in the upper sections or in smaller tributaries (0.3-42 indiv./m²). The results of the monitoring survey indicate that river lampreys are still migrating from the Baltic Sea to most rivers in northern Poland. However, despite the implementation of various projects aimed at restoring ecological connectivity for migratory fish, the range of their migration is limited solely to the lower river sections, and access to suitable spawning and larval growth habitats is severely restricted. This results in limited prospects for an increase in the population of anadromous lampreys in the southern Baltic region and may contribute to their continued decline in this area.

Abstract ID: 69

Impacts of chemical pollution on biodiversity and biological responses in the Archipelago Sea (Baltic Sea)

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Biodiversity is vital for the structure and function of marine ecosystems, and is increasingly threatened by chemical pollution, a major driver of global biodiversity loss. Under the framework of the BIODIVERSA+ funded project Detect2Protect, the current study focused on the effects of chemical pollutants on Baltic Sea biota by combining sediment contamination analysis with various biomarkers in the soft-bottom bivalve *Macoma balthica* as well as biodiversity indicators including species community composition and environmental DNA (eDNA) analysis.

In August 2024, a field sampling campaign was conducted targeting on a well-characterized pollution gradient in the Archipelago Sea (northern Baltic Sea). Sediment samples were collected from five stations ranging from a reference site in the outer archipelago to highly polluted stations in the inner archipelago. Biodiversity was assessed through benthic fauna surveys and eDNA analysis of sediment samples. Stable isotope analysis of carbon and nitrogen was performed to investigate trophic interactions and potential shifts in food web structure along the pollution gradient. Sediment samples were analyzed for selected chemical contaminants and physicochemical properties. Specimens of *M. balthica* were collected for the analysis of biomarkers of oxidative stress, neurotoxicity, genotoxicity, cytotoxicity, and a condition index.

Macrofaunal diversity declined along the pollution gradient, with sensitive species such as *Monoporeia affinis* mostly restricted to the reference site, while more tolerant species such as *M. balthica* persisting across all study stations. eDNA analysis is expected to show reduced genetic diversity and shifts in meiofaunal communities at polluted sites, highlighting ecosystem-level impacts. Stable isotope analysis is anticipated to reveal altered trophic structures and disrupted energy transfer in contaminated areas, while markedly increased biological effects are expected in *M. balthica* from the most polluted sites.

The integration of biomarker responses, contaminant levels, stable isotope data, and biodiversity indicators is expected to demonstrate clear links between chemical pollution and changes in biodiversity. These findings will highlight the need for multistressor approaches to better understand and address the complex impacts of pollution on marine ecosystems.

Abstract ID: 72

Carbon stocks, secondary production and diversity of benthic macroinvertebrates in littoral ecosystems

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Littoral ecosystems cover a large area in the shallow Baltic Sea, yet the ecology and functioning of these habitats are poorly understood. Littoral ecosystems differ from deeper coastal habitats, as they have higher light availability, stronger sediment movement due to wave action, ice scouring in the winter, and they are more intensively used for human recreation. These unique characteristics of the littoral zone shape the ecosystem services provided by these habitats, such as carbon recycling and storage. In this study, we compared the secondary production, biomass-bound carbon stocks, and diversity of infauna at 1.5 m and 3.5 m depths at 20 sites across large environmental gradients along Hanko peninsula, Gulf of Finland. We focused on the infauna community due to the large area covered by bare sediment ecosystems, and because the animals have a key role in the carbon cycle in consuming, storing, and recycling carbon. We sampled the infauna communities by SCUBA and calculated the carbon stocks and secondary production from measured abundances and biomasses. We found that the both the carbon stocks and secondary production by infauna, as well as the species richness were lower at the very shallow depth (1.5 m) in the most pristine and exposed areas in the outer archipelago, but conversely, the carbon stocks at the very shallow depth were higher than those at 3.5 m in the most sheltered and eutrophied bays in the inner archipelago. Our results highlight the uniqueness of the very shallow littoral habitats and link the carbon dynamics of infauna to both natural ecosystem characteristics and ecosystem health.

Abstract ID: 82

Diet composition of herring (*Clupea harengus*) larvae in the Vistula Lagoon

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Understanding the feeding ecology of fish larvae is crucial for predicting recruitment success and population dynamics, particularly in fluctuating estuarine environments. This study investigates the feeding selectivity and dietary shifts of Atlantic herring (*Clupea harengus*) larvae in the Vistula Lagoon, a shallow brackish ecosystem characterized by strong seasonal and hydrological variability. The main objective was to assess how changes in zooplankton composition and abundance influence larval diet composition and growth rates. Field sampling was conducted from April to June 2022–2024, covering the peak spawning and early development period of herring. Zooplankton and larval fish were collected at 5 stations and analyzed for species composition and biomass. Larval stomach contents were examined to determine prey preferences, and selectivity indices were calculated. Results revealed that first-feeding larvae (about 8 mm SL) exhibited a strong preference for rotifers and nauplii of *Eurytemora affinis*, comprising over 70% of ingested prey items. As larvae grew (15–19 mm SL), their diet shifted towards larger copepodites and adult copepods, with *E. affinis* and Cyclopoida dominating stomach contents (90% of total prey biomass). However, in late spring, as the zooplankton community structure changes, marked by a decline in larger copepod species and an increase in rotifer abundance, herring larvae shift to feeding on less favorable prey, resulting in a decrease in the mean biomass of their diet. These findings highlight the importance of seasonal prey dynamics in shaping larval feeding strategies and growth efficiency. The observed dietary shifts suggest that recruitment success may be highly sensitive to fluctuations in copepod availability, which are influenced by temperature, salinity, and eutrophication-driven changes in plankton communities. Given the ongoing climate-induced modifications in estuarine ecosystems, our study underscores the need for continuous monitoring of trophic interactions to improve predictions of herring population dynamics. Further research should focus on the potential mismatch between larval demand and zooplankton production, which may have profound consequences for herring stock sustainability in the region.

Abstract ID: 98

Zooplankton in ballast water of ships serviced at a shipyard situated in the southern Baltic Sea estuarine system

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Untreated ballast water (BW), gravity-drained from ships dry-docked at repair yards, may constitute a means of introducing non-indigenous species into an area. With this idea on mind, we studied zooplankton assemblages in BW of 11 ships brought to a repair shipyard in the River Oder estuarine system (southern Baltic Sea) in 2009-2011. We found the zooplankton, taxonomic richness (1–26 taxa/ship), dominance structure and abundance to depend more on the season (cold vs. warm) when a ship arrived than on the BW type (salinity). The copepod-dominated BW zooplankton in warm seasons was largely dissimilar from that occurring in the adjacent river area, dominated by rotifers. Non-indigenous marine and brackish water taxa (*Calanus finmarchicus*, *Paracalanus* sp., *Saphirella* spp., *Oncaea* sp.) were identified in BW, but occurred mostly at low abundances; this and their habitat preferences did not qualify them as potential invaders. However, the study could not entirely dispel the concern related to alien species' introduction with BW of the ships to be serviced, as the BW zooplankton during warm season occurred occasionally at very high (> 640,000 inds m^{-3}) densities, higher than allowed by the international regulations. Moreover, larvae of benthic organisms that could not be identified to the genus or species level might include additional and potentially viable non-indigenous taxa.

Abstract ID: 100

Interannual Variability of Meroplankton Communities: Insights from the Baltic Sea and a Norwegian Fjord

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Meroplankton, the pelagic larvae of benthic invertebrates, is an essential yet understudied component of zooplankton communities. Their abundance and composition vary between years, partly reflecting environmental and climatic drivers acting either on the adult benthic communities or directly on meroplankton in the water column. This study identifies similarities and regional differences in interannual variability in two data sets of meroplankton from the southern Baltic Sea (2005–2021) and a northern Norwegian fjord (Saltfjord; 2014–2024). Baltic Sea samples were collected at 11 stations during typically two annual cruises between April and August, while Saltfjord samples were collected at a single station at higher frequencies (up to six sampling events in spring) from March to May.

In the Baltic Sea, meroplankton showed significant temporal shifts in composition and biomass, with three distinct periods. Initially, Polychaeta and Bivalvia co-dominated, but after 2014, Bivalvia became numerically and biomass-dominant. A striking increase in overall abundance and biomass occurred during 2019, potentially linked to rising water temperatures. Saltfjord's meroplankton community was numerically dominated by Cirripedia, followed by Echinodermata, Bivalvia, and Polychaeta. Also, in Northern Norway a community shift occurred in 2018/19, but in contrast to the southern Baltic Sea, meroplankton abundance was lower post-2018 than in the years prior. Despite regional differences, both systems showed a correlation between seasonal succession of meroplankton and surface water temperature, while the identified community shifts in 2019 appear to be best explained by changes in bottom water temperature.

While both regions experienced significant post-2018 shifts in meroplankton abundance and composition, the magnitude and direction of change varied. These findings highlight the sensitivity of meroplankton communities to environmental change and emphasize the importance of continued monitoring to assess the broader implications for benthic-pelagic coupling in the Baltic Sea and beyond.

Abstract ID: 114

Knowns and unknowns of gelatinous zooplankton in the Central Baltic Sea – a comprehensive overview

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This study investigates the diversity and spatiotemporal distribution of gelatinous zooplankton (GZ) in the Central Baltic Sea (coastal waters of Gotland and the adjacent Eastern and Western Gotland Basins), a region characterised by low salinity and ecological sensitivity. Despite the Baltic Sea being the largest brackish water body globally, knowledge about its GZ, specifically medusae and ctenophores, remains sparse in the central part. Our research synthesises existing literature, open-access data, and local reports. Three to five GZ species occur within the studied area, with the common jellyfish *Aurelia aurita* dominating. Peak sightings of *A. aurita* happen between July and October, whereas the ctenophore *Mertensia ovum* and scyphozoan *Cyanea capillata* display sporadic occurrences. We pinpoint notable gaps in understanding GZ phenology and food web impacts due to historical neglect and insufficient monitoring, particularly under low salinity conditions (salinity between 5 and 8) that restrict species richness. Jellyfish and ctenophores fall under the Essential Ocean Variable (EOV) “Zooplankton Biomass and Diversity” governed by the Global Ocean Observing System, IOC-UNESCO. The EOVs are an approach for globally interoperable data and adhere to Findable, Accessible, Interoperable, and Reusable (FAIR) data principles. Including the EOV in routine collection and reporting would significantly enhance regional and global understanding and contribute to a holistic ecosystem view. Thus, we advocate for enhanced global ocean observation frameworks to comprehensively monitor GZ populations and their ecological, biogeochemical, and socioeconomic roles. Our findings serve as a crucial step towards understanding the implications of climate change on GZ assemblages in the Baltic Sea, promoting a holistic approach to marine ecosystem management.

Abstract ID: 121

Investigation the effectiveness of stocking using a genetic approach - the case of sea trout (*Salmo trutta* m. *trutta*) from Rega River.

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Sea trout (*Salmo trutta* m. *trutta*) is of significant economic importance for coastal fisheries and play a crucial role in tourism and recreation, especially angling, in Poland and the many European countries around Baltic Sea. The continued pressure on this species, leading to a decrease of sea trout resources, necessitates the intensive stocking activities on this anadromous species. The goal of this study is to control the effectiveness of this action. Popular in aquaculture husbandry practices parentage assignment methods are engaged to investigate the effectiveness of fish stock enhancement. Microsatellite-based genetic genotyping of sea trout spawners, participating in artificial spawning on the Rega River, and fish returning to the river in subsequent years combined with the use of FAP, COLONY and SOLOMON programs allows to assign family of origin to progeny and estimate the proportion of artificial breeding sea trout from spawning season. The results obtained from the research conducted between 2016 and 2021 will be presented and discussed.

Abstract ID: 138

Ambitious environmental monitoring programs – key for successful, cost-efficient management of natural resources in a rapidly changing world

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Systematic monitoring is not only essential for ecosystem assessments. It also provides the foundation for mitigation measures tailored to specific problems like fish stock collapses, accumulation of contaminants or spread of invasive species, and for the evaluation of their effectiveness and hence of the return of economical investment. These benefits are often overlooked and not sufficiently included in cost-benefit analyses of investments in management actions. With tight public budgets in many countries, funding for monitoring programs is increasingly under pressure, and policymakers need to be better informed about the critical importance of sustaining and expanding monitoring programs to understand and address the inevitable changes that will develop as human pressures continue to grow. We provide a Pan-Baltic ecologists' perspective on the importance of ambitious, long-term, improved and expanded marine environmental monitoring as foundation for successful and cost-efficient resource management in an era of rapid change. We review the trends in monetary investments, present successful case studies and discuss the relationship between (mandate-driven) monitoring and (question-driven) basic science and the potential for synergies and mutual benefits among the two domains, as well as risks and opportunities of introducing new monitoring methods and of funding opportunities.

This contribution is submitted by the Björn Carlson Baltic Fellows, a network of 20 exclusively selected researchers around the Baltic Sea, striving to promote a healthier Baltic Sea ecosystem.

Abstract ID: 145

Artificial reefs as a tool for Baltic cod recovery: A Study from the Hanö cod reef

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This study explores the use of artificial reefs as an innovative tool to support fish stock recovery, with a particular focus on Baltic cod (*Gadus morhua*) in the southwestern Baltic Sea. Artificial reefs provide essential habitat, offering shelter from predators such as seals and cormorants, potentially enhancing the survival of larger individuals. The research is conducted at Hanö, where 35 artificial reefs have been deployed within the Hanö Torskrev Association initiative, inspired by similar projects on Sweden's west coast. These reefs, among the first in the Baltic Sea, hold significant potential for improving ecological balance and advancing knowledge on cod behavior and marine ecosystem restoration.

Baltic cod populations have declined drastically due to overfishing, eutrophication, and hypoxia, leading to reduced stock sizes, poor growth, and deteriorating health. Despite a fishing ban since 2019, no recovery has been observed. The loss of large benthic invertebrates, essential for juvenile cod before they shift to piscivory, has likely worsened the situation, compounded by hypoxic conditions. Predation by seals and cormorants may further hamper recovery, increasing mortality and triggering behavioral changes that reduce growth and fitness. Studies suggest that predation may counteract the benefits of marine protected areas, limiting their role in stock regeneration.

Artificial reefs, integrated within no-take zones, have demonstrated enhanced conservation outcomes, as complex reef structures attract fish by providing refuge and foraging opportunities, ultimately improving energy conservation and survival.

The Hanö reef project investigates how artificial reefs can create vital habitats for the most valuable stock components—large, mature cod—thereby accelerating recovery, enhancing resilience, and supporting sustainable fisheries beyond reef areas. Established in 2023, the Hanö reefs present a unique opportunity to study cod behavior and interactions with predators in a controlled field setting. By utilizing advanced video monitoring, hydrographic measurements, the project aims to identify key factors influencing these interactions.

Since March 2023, reef activity has been systematically documented using underwater drones and stationary cameras, alongside a reference site without reefs for comparison. Preliminary findings indicate higher activity of larger cod (>30 cm) at the reefs, whereas smaller individuals (<20 cm) dominate surrounding areas. Additionally, continuous data collection on water chemistry and physical conditions using a SeaGuard Single Point Platform provides valuable insights into environmental influences on cod behavior and reef functionality.

Abstract ID: 165

Snail responses to invasion of a novel predator: Do shell traits show adaptive plasticity?

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Previous studies on interactions between native and invasive species have focused mainly on the invasive species, while studies on adaptive responses in native species are sparse. Thus, we study the responses of the native snail *Theodoxus fluviatilis* to the ongoing invasion of the novel mud crab *Rhithropanopeus harrisii* in the Baltic Sea. Our hypothesis is that the novel predator poses strong selection on prey traits and provokes adaptive responses that influence the outcome of the predator-prey interaction. Native prey may show various adaptive responses to novel invasive predators. These include evolutionary responses to selection and adaptive plasticity to alarm cues from conspecifics or even to cues from the predator itself if the prey has evolutionary experience with that type of predator. Adaptive plasticity in phenotypic traits can be alterations in behaviour or morphology as a response to such cues. As genetic variation may form the basis of expression and magnitude of such plasticity, it can be acted on by natural selection and in long-term may become an evolutionary adaptation. Consequently, we sampled snails from several populations that either had or had not been exposed to the invasion of the mud crab. Moreover, we conducted predation experiments to investigate selection by the novel predator for prey traits and long-term rearing experiments of the snail with crab cues and alarm cues of injured conspecifics to study potential adaptive plasticity of the prey. The focal prey traits included body-size, body-shape, shell thickness, and shell strength. We found significant differences in shell traits among *T. fluviatilis* populations, partly attributable to coexistence with the crab. The populations sampled from the field demonstrated a significant increase of strength with increasing shell length, which is varying depending on the invasion history. The predation experiment demonstrated that crabs chose significantly larger snails. Furthermore, we found a significant decrease in body-size with snails reared with alarm cues. These results demonstrate that generic plastic responses to alarm cues can work as antipredation adaptations also against novel predators. Therefore, it is important to consider the evolutionary consequences of invasions to fully understand the impacts of invasions and their temporal progression.

Abstract ID: 187

Uncovering the biology and ecosystemic roles of the southern Baltic Sea cnidarians

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Cnidarians are extremely diverse and ubiquitous members of marine ecosystems. Their metagenetic life cycle (sedentary polyps – pelagic jellyfish) tightly links them within marine food webs, both in plankton and benthos. Cnidarians also have pronounced habitat-forming capacity (e.g., marine animal forests) and are characterized by a boom-bust population dynamics with locally and temporally important contributions to carbon cycling. Despite their relevance, cnidarians have remained poorly studied in many marine regions, including the Baltic Sea. This particular ecosystem experiences several challenges, for instance, high concentration of pollutants and low salinity, both stemming from its semi-enclosed nature. This geographic constraint has also affected cnidarian communities, justifying their overall low diversity with large proportion of non-native taxa, and explaining intraspecific physiological distinctiveness between Baltic Sea populations and those inhabiting oceanic waters. To provide more thorough understanding of cnidarian diversity and ecosystemic roles within the Baltic Sea, we report on several contributions resulting from our work on cnidarians from the Gulf of Gdańsk. We start by documenting a novel case of biological invasion by an anthoathecate hydrozoan, native to American estuaries, using integrative morphological and molecular approach. We then use experimental data to describe how brackish nature of the Baltic Sea affects asexual reproduction of the polyps of the widely distributed moon jellyfish – *Aurelia aurita*, hence providing insights its population dynamics. We also assess the role of *A. aurita* in the transfer of anthropogenically derived pollutants, by documenting the first case of elemental carbon detection in tissues of marine fauna. We then report results of experimental assessment of the dynamics and load of nutrients released from decomposing jellyfish, to better understand their contributions to local biogeochemical cycles. Overall, our work highlights the complex and important roles of cnidarians in the Baltic Sea coastal ecosystems and provides directions for future research.

Abstract ID: 227

Following the Baltic seawater outflow: international and interdisciplinary research cruise of Oceanograf and Oceania

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Two Polish research vessels, OCEANOGRAF (University of Gdańsk) and OCEANIA (Institute of Oceanology PAN), followed the Baltic seawater outflow along the Scandinavian Peninsula, working together in international and interdisciplinary teams. Twenty surface drifters launched during the cruise remained on the continental shelf, distinguishing the Norwegian Coastal Current from the offshore Norwegian Atlantic Slope Current; some ended up in the Barents Sea, confirming a northward path of Baltic seawater outflow reaching high latitudes, as predicted by the numerical Regional Arctic System Model of high horizontal resolution.

The chemical analysis of seawater revealed differences between offshore and coastal zones, and along the transect. Elevated concentrations of phosphate and nitrate in coastal waters suggest the land-based runoff, while variations in conductivity and total organic carbon reflect the mixing of waters from different origins. We observed decrease of stable carbon isotopes ($\delta^{13}C_{POC}$) values northwards and variable stable nitrogen isotopes ($\delta^{15}N_{POC}$). Results also showed the marygenic origin of chromophoric dissolved organic matter in all samples, with a sharp decrease in aromaticity northwards. Additionally, a net output of perfluoroalkyl and polyfluoroalkyl substances, a group of persistent, toxic, synthetic chemicals, from the Baltic towards the North Sea, was detected at low levels in all samples, and at higher concentrations in surface waters. The highest total mercury concentration in suspended particulate matter was measured near Bodø, while in zooplankton and phytoplankton at the Baltic Sea–North Sea section. The sea surface microlayer was enriched with heavy metals, polycyclic aromatic hydrocarbons and elemental carbon, related to the combustion of fossil fuels.

Gradual decrease in chlorophyll *a* concentration in surface waters was observed northwards; and marker pigments analysis showed the occurrence of diatoms, prochlorophytes, prasinophytes, cryptophytes, chlorophytes, and cyanobacteria in varying proportions along the transect. $\Delta N_2/Ar$, a tracer for N_2 fixation, indicated similar variable trends. Consequently, we observed a shift in phytoplankton communities: from the predominance of cyanobacteria in the Baltic Sea, a bloom of diatoms in Kattegat, to dinoflagellates- and diatoms-abundant waters further north. Interestingly, in the coastal waters of the Norwegian Sea, single trichomes of poor-conditioned cyanobacteria *Nodularia* and *Aphanizomenon* were observed,

possibly transported from the Baltic Sea. Underwater Vision Profiler revealed changes in the concentration of zooplankton and marine snow, with decreasing amounts of detritus towards the north. Additionally, hydroacoustic data, collected using split beam echosounder, demonstrated northward acoustic biomass growth, patchy horizontal distribution of biological objects, and the impact of thermohaline on their vertical distribution.

Abstract ID: 228

The HELCOM regional approach to achieving a healthy Baltic Sea – science-driven holistic assessments and actions

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The third, and latest, HELCOM regional holistic assessment, HOLAS 3, was published in 2023. Coordinated by the Secretariat, it reflects the work of around 1000 regional experts (scientists, managers, and policy makers) and consists of a summary report, five thematic assessments, fifty-nine indicators, and millions of data points.

The latest holistic assessment addresses key components of biodiversity (mammals, fish, waterbirds, zooplankton, zoobenthos and phytoplankton) and food webs, as well as major pressures, such as hazardous substances, eutrophication, marine litter, underwater noise, and non-indigenous species. It also addresses spatial cumulative effects, and their impacts, as well as examining economic and social aspects. HOLAS 3 applies a conceptual management framework, DAPSIM. Linking Drivers-Activities-Pressures-Status-Impact-Measures, where impact equally represents an impact on the ecosystem or society, in order to help inform decision makers.

These holistic assessments are science and data driven, utilising the best available knowledge to achieve regional assessments that are optimised to the scale, data, and management needs in the region. These holistic assessments are also used as a benchmark to understand the health of the Baltic Sea marine environment. In doing this they offer an evaluation of progress made towards the vision of the Baltic Sea Action Plan (BSAP 2021). Additionally, in many cases these assessments are also utilised by member countries to support other policy obligations, such as the Marine Strategy Framework Directive (MSFD) or Sustainable Development Goals (SDGs).

The most recent holistic assessment indicates that many biodiversity components are in poor health and that the overall ecosystem is heavily impacted. It also highlights the fact that pressures, derived from human activities, exceed levels that would offer the possibility of achieving a healthy and sustainably used Baltic Sea ecosystem. Moreover, it also showed that the cumulative effects of these are significant and that climate change is an overarching pressure across the entire region.

The combination of science and policy, each highlighting key issues to the other, as well as the application of tools such as the DAPSIM conceptual management framework, allow for progress to be triggered and for an increased understanding of the appropriate action needed (or placement of that action). The 2021 BSAP, covering 199 actions, targeted at various pressures or activities, aims to implement the best available knowledge towards its vision of a healthy Baltic Sea. To identify key knowledge gaps preventing better decision making, HELCOM also has a science agenda.

Abstract ID: 229

Investigating Climate Change-Driven Biogeochemical Variability in Estuaries as a Potential Component in the Aetiology of UDN in Salmonid Fish – The HealthyRiver Project Development

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Ulcerative dermal necrosis (UDN) is a skin condition affecting wild and farmed salmonids that was first documented in Europe in 1820. Its origin remains unknown. It affects the epidermal and dermal layers and initially appears as small grey lesions on the heads of migratory adult salmonids when they enter freshwater for upstream migration. UDN can affect up to 75% of wild spawners and is associated with high mortality, posing a significant threat to salmonid populations. Although its aetiology remains unclear, our research suggests that environmental factors may contribute to its occurrence.

Estuaries, where UDN typically first appears, are highly dynamic environments with steep acid-base gradients due to the mixing of marine and riverine waters. This variability is further intensified by fluctuations in the carbonate system. These fluctuations result from the net effect of mineralization and primary production, processes driven by inputs of terrestrial nutrients and organic matter. Moreover, higher temperatures accelerate chemical weathering in soils, thus further modifying the acid-base properties of riverine and, consequently, estuarine waters. Our study shows a significant positive correlation between local temperature anomalies along the Polish coast and the occurrence of UDN in sea trout (*Salmo trutta m. trutta*) spawners in the Słupia River. Specifically, we observed a Pearson correlation coefficient of 0.70 over the period 2014-2022. These findings suggest that estuarine biogeochemical variability, driven by climate change, may be a contributing factor in the development of UDN.

To investigate this hypothesis, we have established an observational system in the Słupia River estuary - a key migration route for sea trout where UDN symptoms are commonly observed. The system is equipped with state-of-the-art biogeochemical sensors that provide real-time data on the chemical and physical properties of water, including temperature, salinity, pH, partial pressure of CO_2, and oxygen content. These data will be integrated with ichthyological observations from underwater fish scanners. The scanners quantify the percentage of migrating spawners affected by UDN, providing insight into the disease's severity over time. Additionally, we are conducting controlled laboratory experiments to assess the physiological stress response of fish exposed to altered water acid-base conditions.

Our research highlights the need for systematic monitoring of estuarine biogeochemistry and UDN occurrence to better understand how climate change influences this disease and impacts salmonid fish populations. Given the ecological and economic significance of salmonids, understanding the mechanisms underlying UDN is crucial for fisheries management and coastal ecosystem sustainability.

Abstract ID: 230

Are the Baltic Sea conditions favourable for the Atlantic rangia?

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The issue of alien species, benthic species particularly, is visible in the ecosystem of the Baltic Sea. Especially in the context of increasing human pressure and ongoing climate change. The species that has been noted mainly in lagoons and estuaries is the bivalve *Rangia cuneata* (G. B. Sowerby I, 1832). This North American origin species has been present in the Baltic Sea (Vistula Lagoon) since at least 2010 and continues to be recorded in further areas of the sea.

Atlantic rangia is a species with a wide tolerance to changes in salinity, occurring in its native region at relatively high water temperatures. The ecology of this species is described scarcely outside its native areas. Studies of rangia from Vistula Lagoon indicate large inter-annual fluctuations. The distribution and density of this species, with high mortality in the winter season, is explained by oxygen deficiencies in the bottom zone during this period or high energy expenditure for osmoregulatory processes in low temperature and salinity. The population in the Vistula River Delta is more stable and during the decade of research, we observed mass mortality of that clam once.

Water temperatures increase in the coastal zone of the southern Baltic Sea as predicted by modelling and currently observed potentially promotes the spread and establishment of stable populations of warm-water species. To indicate the favourability of environmental conditions or the availability of food both morphological and biochemical indicators can be used. These indicators may change according to the seasonal cycle of activity typical of marine invertebrates.

Our study aimed to determine the seasonal variation in fitness and biochemical composition of *R. cuneata* in the coastal zone of the southern Baltic Sea. In the study, we compared populations in the river delta region and the coastal waters.

The results indicate the occurrence of seasonal variability in the condition of *R. cuneata* both in the Wisła Śmiała and in the coastal zone of the Gulf of Gdańsk. In both study areas, individuals had similar energy reserves. Still, the fitness of individuals from the Bay of Puck in winter and spring was lower than those from the Wisła Śmiała. *R. cuneata* is a permanent component of the macrozoobenthos in the Wisła Śmiała. During periods of favourable conditions, rangia may become the dominant species in the macrozoobenthos biomass.

Abstract ID: 254

Long & low; or high & short; photoperiods and light differential growth yields of PC-rich and PE-rich picocyanobacteria

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Picocyanobacteria are important primary producers in marine, freshwater, and brackish ecosystems, contributing to trophic networks, biomass production and oxygen generation. They are also capable of creating massive blooms and production of harmful secondary metabolites. Future scenarios now forecast range expansions of marine *Synechococcus* into new photic regimes, making the recognition of the mechanisms responsible for the expansion of these organisms an important issue for a better understanding of the functioning of the Baltic Sea ecosystem.

We found that Baltic picocyanobacteria show differing growth responses to photoperiod and light level, even under conditions with equivalent cumulative diel Photosynthetically Usable Radiant (PUR). Both phycoerythrin(PE)-rich and phycocyanin(PC)-rich phenotypes of *Synechococcus*, grew fastest under moderate light and a 24-h (continuous) photoperiod. Moreover, in optimal conditions (24-h of photoperiod and a peak PAR of 180 µmol photons m^{-2} s^{-1}), one of the PE-rich *Synechococcus*, reached a chlorophyll-specific exponential growth rate of 4.5 d^{-1} (3.7-h doubling time), a record for a cyanobacteria. PE-rich strains in the exponential phase of growth demonstrated high ability to modulate their PUR/PAR ratio by adjusting pigment composition, giving them an advantage in the competition for light. Based on an analysis of environmental samples, we have also shown that the PE-rich *Synechococcus* was the dominant picocyanobacteria in the southern Baltic Sea during spring, summer, and fall.

Our results suggest possible expansion of the range of picocyanobacteria to new photic regimes in a warmed future and indicate that PE-rich *Synechococcus* may be a dominant component of picophytoplankton in nutrient-rich environments.

Thematic Session: Geological Processes and Coastal Erosion

Abstract ID: 9

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 their coastal morphology is subject to impacts of not only multiple natural drivers (e.g. tides, waves, winds, storm surges, sea level change) but also extensive human activities (e.g. land reclamation, tourism, harbor construction, coastal protection measures). 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 high-resolution 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 introduce our work on the coastline change of the Baltic Sea based on analysis of multispectral satellite images for the period of 2015-2024 (sentinel-2). We firstly classified the coastline into different types including marshlands, soft and hard cliffs, sandy beaches and human constructions (e.g. piers, seawalls, dykes) using an active learning pipeline which integrates unsupervised, semi-supervised and supervised learning techniques. Based on the validated classified dataset with high accuracy, we then quantified the area change of each coastline type and identified hotspots of changes. Coastline erosion and accretion are quantified based on a transect system at 100 m intervals along the entire Baltic Sea coast. The derived dataset (10 × 10 m resolution, with time series covering the period of 2015-2024) provides an invaluable base that can serve for practical use in coastal management and planning.

Abstract ID: 23

Postglacial weathering inputs and their role in boosting primary production in the Northern Baltic Sea: Insights from sedimentary Si phase separation

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Dissolved silica (DSi), originating from the dissolution of biogenic silica (BSi) and lithogenic silicate minerals (LSi), is a vital nutrient to sustain primary production in marine ecosystems. The BSi and DSi inputs from rivers are a major source to the oceanic Si budget and promote the formation of amorphous secondary silica phases (ASSi). This latter process is called reverse weathering, which, in contrast to so called forward silicate weathering, consumes cations and alkalinity, and releases CO_2 to the water column. The connection between terrestrial to marine processes and reverse to forward weathering is described as a silicate weathering continuum. However, this continuum has never been explicitly investigated in the Baltic Sea. We hypothesize that the increased input of weathering products after the retreat of the Fennoscandian ice sheet might have boosted primary production and subsequent accumulation of particulate organic carbon (POC) and BSi in the Baltic Sea.

We apply wet-chemical sequential leaching (modified after [1]) on a sediment core from the Bothnian Bay (Northern Baltic Sea). Downcore sediment samples were sequentially treated with HCl, Na_2CO_3, and NaOH to extract and quantify silicate phases (ASSi, BSi, and LSi). Distinct BSi and POC peaks at 30 cm below seafloor (cmbsf) suggests a high accumulation of organic carbon due to elevated primary production. Around the same depth (20-60 cmbsf), the leached ASSi and LSi phases reveal high metal concentrations (Fe, Mn, Mg, and K). Based on these findings, we propose that, over this period, increased weathering of Fe-rich bedrock and subsequent riverine transport of these critical nutrients boosted primary production and the burial of POC.

Our results highlight how the silicate weathering continuum tightly links terrestrial weathering (e.g., nutrient transport via rivers) and marine silicate alteration processes (e.g., nutrient release and burial of ASSi and BSi on the seafloor). To further quantify Fe and Si input and availability, we aim to conduct targeted analyses of dissolved, particulate, and mineral phases of weathering products in the Baltic Sea catchment area.

Reference:
[1] Huang, Tzu-Hao, et al. "Separating Si phases from diagenetically-modified sediments through sequential leaching." Chemical Geology 637 (2023): 121681.

Abstract ID: 64

Coastal setback and coastal erosion prevention and mitigation in the Baltic Sea, with emphasis on physical and human drivers in Estonia.

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Coastal setback, the provision of a buffer area along the shoreline where infrastructure is prohibited or significantly restricted, is an effective strategy to prevent, mitigate or reduce the negative impacts of coastal erosion. The value of setback, at least in the short to medium term, is rarely debated. Its provision, however, even when mandated in legislation or policy, frequently does not occur due to historical factors, traditions, necessity, cost (including the cost of alternatives), economics, property rights, political reality and illegal actions. Most states have setback policies, but the meaning, width, implementation and enforcement vary considerably. While often expressed in policy as a simple distance, its location-specific determination should take into account a variety of factors, such as the geomorphology and ground level, even before existing use is considered. Simple application of distance, while easy to enforce, leads to accusations of oversimplification and provides arguments for those promoting exemptions. Implementation of setback in Baltic Sea countries is reviewed and assessed based on Baltic Sea specific erosion processes, primarily the coincidence of high waves and extreme water levels during storms and the importance of wind direction to coastal processes and sedimentation. In Estonia, much of the country has a large setback, partly the result of the generally rural nature of society and tradition, but also due to the existence of restricted areas along the coast during the 1940-1991 soviet occupation. This history made the provision of adequate setback in the Nature Conservation Act (2004), ranging from 50-200m, relatively simple. However, in 2021 there was an attempt by some members of the Riigikogu (parliament) to reduce the legislated setback to 20m, which local government could expand if desired. With little community support and much opposition, the attempt was soundly defeated. The importance of not relenting on coastal setback where historical advantages exist is emphasized. There are, however, many cases where setbacks (for both legal and illegal constructions) are not enforced. The reasons for non-enforcement and the consequence for coastal processes and management are considered, and a case for implementation of best practice based on international experience is made.

Abstract ID: 65

Changing environments and human settlement during the late Holocene in Central Europe through Baltic Sea sediment

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The Vistula River covers much of the Polish landscape, including mountains and lowlands. This river supplies a huge amount of sediment to the Baltic Sea. As a record of the past, the sediments transported by the Vistula are an extremely valuable source of information about the surrounding environment and thus contain a lot of information about environmental fluctuations to which sediments bear witness. Moreover, these sediments keep the associated changes in the character of the vegetation, indicating the changes in human settlement, their impact on the land, and the natural variability of climate on a regional scale. However, such studies remain rare in the Baltic marine sediments and are almost absent, especially in the Gulf of Gdansk. In this study, we aim to reconstruct past environmental changes and ancient human activities using radiocarbon and ^{210}Pb-dated marine sediment core retrieved from the Gulf of Gdańsk (southern Baltic Sea), located in close proximity to the Vistula River mouth. This approach provides a unique opportunity to understand how human activities, particularly the emergence and evolution of ancient communities in modern Polish territories, influenced their surrounding environment within the Vistula catchment area. The depositional processes influenced by climate shifts and human impact were reconstructed based on the sedimentological and geochemical proxies as well as stable isotopes measured on the shells of benthic foraminifera. Pollen and microcharcoal records will be used to track deforestation and agricultural activities, both linked to human settlements. Altogether, these proxies will allow us to understand how human activity (e.g., agriculture, deforestation), climatic shifts, and other factors have influenced the region's evolution over the past few thousand years. By delving into these sedimentary archives, we seek to provide insights that could improve our understanding of broader environmental patterns and guide future research on climate change and history on a regional scale.

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Abstract ID: 68

Numerical modeling of marginal seas paleogeographic evolution – Baltic Sea case study

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Paleogeographic evolution of marginal seas is being driven by various global, regional and local driving forces. Application of conceptual Relative Sea Level (RSL) equation allowed to generate a set of paleogeographic scenarios; corresponding to evolution of Baltic Sea throughout Holocene with 500 years time interval; by combination of global eustatic sea level changes, vertical crust movements (GIA - glacio-isostatic adjustment) as well as regional sediment thickness model and performing grid-based calculations on present-day Digital Elevation Model (DEM). Obtained paleo-DEMs were positively validated by comparison with field-based reconstructions of RSL and successfully reproduced the connection/disconnection events between the Baltic Sea and the North Sea during the transitions between lake and sea phases. The comparison improved the reconstruction of the hydrographic connection between the Baltic Sea and the North Sea in the marginal zone of the former Fennoscandian Ice Sheet. This study required generation of regional Holocene sediment thickness map, which was obtained by synthesis of various local datasets and application of 2 different extrapolation methods to cover the undersampled areas. Noteworthy is, that eustatic water level curve considered the disconnection of paleo-North Sea and the Baltic freshwater body during the Ancylus Lake stage, inferring independent water level from the global data. This study represents a further step towards a consistent methodology to reconstruct the formation of marginal seas during transgression/regression cycles including not only tropic and subtropic climate zones but also polar and subpolar marginal seas impacted by the regional dynamics of ice sheets.

Abstract ID: 80

Quantifying Organic Carbon Storage and Sequestration in Baltic Sea Sediments

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The Baltic Sea represents a remarkable long-term carbon sink in the Earth system, hosting several muddy basins rich in organic matter that has been accumulating throughout the Holocene. However, the Baltic Sea's natural capacity for carbon sequestration may be compromised by human activities that disturb its sediments, leading to excess remineralization of previously buried organic carbon. In this contribution, we estimate the total stocks and sequestration rates of organic carbon in the Baltic Sea by combining Holocene mud thickness maps, organic carbon content and accumulation rate data. We find that sequestration rates are considerably higher compared to other shelf seas, but that the relationship between stocks and accumulation rate is not straight-forward, as sedimentation rates between different basins have varied over time. We tally the results per Exclusive Economic Zone of each riparian nation and discuss potential implications for Blue Carbon management strategies.

Abstract ID: 143

Wave Climate, Longshore Sediment Transport, and Coastal Stability: Implications for the Planned Nuclear Power Plant in Lubiatowo

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This study examines the wave climate in front of the planned nuclear power plant construction site from 1958 to 2022. Using measured data from a directional wave buoy in the Lubiatowo area and wave modeling, an analysis of wave conditions has been conducted. Measurement data were analyzed for a three-kilometer-long, natural, undeveloped segment of the coastal dune system along the southern Baltic Sea, including shoreline profiles and multi-year shoreline position changes. Furthermore, longshore sediment transport was analyzed, and the obtained results were compared with existing literature. Historical data were used to assess differences in beach and dune evolution under similar storm wave and water level conditions. Based on this analysis, conclusions were drawn regarding the impact of wave conditions on coastal stability.

In this study, a methodology for assessing coastal sandy dissipative segments was developed, which are crucial for planning power plant construction. It evaluates hydrodynamic, lithodynamic, and morphodynamic processes in the shore section where a jetty and pipelines for the nuclear power plant are to be built. By integrating field measurements with theoretical methods, including mathematical modeling, this approach ensures a comprehensive understanding of environmental processes.

The results highlight the necessity of implementing coastal protection measures at the construction site.

Abstract ID: 147

Beach Evolution and Wave-Induced Dune Erosion from Extreme Hydrodynamic Events in the Southern Baltic Sea: Implementation of a Run-Up Flume Model

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The shoreline is the primary morphological element of the coastal zone, undergoing continuous changes due to fluctuations in sea level, erosion, beach accretion, or a combination of these factors. The description of shoreline variability depends on the adopted spatio-temporal scales and applied simplifications. Along the coast, a diverse range of coastal formations is observed, exhibiting varying spatial scales and temporal stability. The most significant include beach ridges, cyclic accumulation-erosion patterns, beach cusps, and bays, ranging in scale from hundreds of meters to several kilometers.

Dune coasts along the southern Baltic Sea account for approximately 450 km of the coastline. Around 80% of the South Baltic coast consists of sandy, dissipative, multi-bar coastal segments with well-developed dunes. Wide beaches and sufficiently high dunes serve as natural protection for the hinterland against both erosion and marine flooding. However, during storms, dunes undergo erosion, contributing sand to the shore and nearshore zones. Previous studies indicate that dune erosion is primarily caused by the undermining of the dune base, leading to landslides. At the turn of the 21st century, the average rate of shoreline recession along the Polish coast was estimated at 1–2 m/year, with a growing trend observed in recent years.

As part of the expansion of the IBW PAN hydraulic laboratory, a new wave flume model was constructed in 2023. The primary motivation for developing this model was the need to verify existing formulas describing wave run-up on beaches and to better understand the impact of waves on dunes under the specific conditions of the Baltic Sea. These conditions include storm surges, varying sediment properties, distinct beach geometries, and the presence of ice. To address these factors, full-scale (1:1) measurements were conducted. These experiments aimed to provide a detailed analysis of dune erosion processes resulting from extreme hydrodynamic events.

Abstract ID: 178

Distributions of wave heights and directions extracted from properties of wave-driven water speeds in the eastern Gulf of Riga

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Many features of wave-driven effects in the nearshore, such as the probability of entrainment of fine sediment into water column or direction and magnitude of wave-driven sediment transport are governed by properties of wave heights and approach directions in the nearshore. We make an attempt to identify the basic shape and parameters of the distributions of wave heights and approach directions of most energetic waves in the eastern nearshore of the Gulf of Riga near Skulte in Latvia. This done in terms of near-bed water speed in approximately 4 m deep water measured approximately 700 m from the shore. The experiment in August–September 2022 employed nine so-called hydromast devices for recording water velocity mounted at a distance of 10 m from each other on a rectangular frame of 20×20 m, complemented by an acoustic Doppler velocimeter.

The empirical distributions of velocity components are symmetric. This signals that waves were far from breaking in this location and thus had mostly linear nature. The shapes of the distributions of velocity components greatly deviate from the expected Gaussian distribution; possibly because of frequent presence of relatively weak waves. The empirical distributions of water speeds (equivalently, wave heights) follow almost exactly an exponential distribution in the range of 0.2–0.7 m/s (and up to 0.85 m/s for some devices). This shape deviates from the common Rayleigh or Forristall distribution for ocean waves and seems to be characteristic for coastal areas of semi-sheltered seas, such as the Baltic Sea or the Caspian Sea.

The distribution of propagation direction of all waves is almost isotropic, with slight prevalence of waves approaching from the north and south-south-west. However, waves with appreciable height (that is, driving water speed >0.1 m/s) approached the measurement location from two directions: south-west and north-north-west. These directions match the well-known two-peak directional distribution of predominant moderate and strong waves in the Gulf of Riga and north-eastern Baltic Sea. Even higher waves approached from an even narrower range of directions. Consequently, waves with appreciable height from the south-west approach the shoreline at an angle of about 40° with respect to the shore normal and waves from the north-north-west even at an angle of about 60°. Such waves create much stronger alongshore sediment transport than waves of comparable height that approach the shore at a small angle.

Abstract ID: 195

Alongshore sediment transport patterns under varying sea level conditions in the microtidal Baltic Sea

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This study systematically examines the magnitude and directional patterns of wave-driven alongshore sediment transport in the eastern Baltic Sea under varying sea level conditions. The interaction between wave properties and water levels can influence the depth of closure, potentially stabilizing certain coastal areas. Conversely, the alignment of predominant wave fields with high water level events may result in significantly increased sediment transport rates.

For this analysis, we examine a ~700 km stretch of sedimentary shores in the eastern Baltic Sea, extending from the entrance to the Gulf of Finland in Estonia to Cape Taran, Kaliningrad District, Russia. Wave properties are simulated using a nested SWAN model with a spatial resolution of 1–3 nautical miles, forced by ERA5 winds at an hourly resolution for the period 1993–2021. Wave-driven potential alongshore sediment transport is assessed using the Coastal Engineering Research Centre (CERC) approach and linked to modeled sea level data. Sea level variations are simulated with a spatial resolution of 2 nautical miles using the NEMO 4.0 ice-ocean model, combined with the SI3 sea ice and thermodynamic model, and forced by ERA5 winds.

Results indicate that 30–40% of the annual alongshore sediment transport occurs when sea level exceeds the 90th percentile. The study area consists of three structurally different segments in terms of wave-driven sediment transport balance and direction under varying sea level.

The dominant transport pattern in the study area is unidirectional. In these segments, waves from other directions have a limited effect on transport, and the highest and most severe waves seem to occur during high sea level conditions. These waves approach the shore at relatively large angles (35–40°) at the breaking point, which may contribute to shoreline instability.

Some coastal systems appear to be stabilized by the combined impact of storm waves from one direction during high sea levels and lower waves from the opposite direction. Other coastal areas seem to develop under a balance of wave systems from two dominant directions, SW and NNW. This is evident in many coastal sections in Latvia and Lithuania, where net sediment transport is close to zero, experience wave approach from two dominant directions, even during high sea level.

Abstract ID: 218

Temporal Variability of Alongshore Sediment Transport in the Eastern Baltic Sea

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Understanding alongshore sediment transport is a crucial step for analysing the coastal dynamics, particularly in the eastern Baltic Sea, where wave-driven processes dominantly shape extensive sedimentary coastlines. This study examines the temporal variability in sediment transport rates along the coastline extending from the Sambian Peninsula in Kaliningrad to Pärnu Bay in the Gulf of Riga, incorporating multiple segments established based on regional coastal orientation. This highlights the importance of both wave height and wave direction to coastal morphology. By applying the Coastal Engineering Research Centre (CERC) sediment transport formula to a high-resolution dataset derived from a triple-nested SWAN wave model, this analysis provides insights into sediment transport patterns over more than 30 years (1990–2022), using wind-driven wave data to estimate transport at approximately beach profile closure depth.

The results indicate complex spatiotemporal variability in sediment transport rates across the study area. While certain years exhibit increasing or decreasing trends in bulk sediment transport, the relationship between adjacent coastal segments is not uniform. Some areas, particularly within the Gulf of Riga, display an inverse response for sediment flux, where an increase in net transport in one segment appears to suppress transport in a neighbouring section. This effect is likely due to regional-scale variations in coastal orientation, where changes in net transport direction align with shifts in the dominant wave approach angles. The importance of segmentation within the broader transport system is underscored by the stark contrast in sediment flux magnitudes: while transport rates reach 700,000–1,000,000 m^3/yr along the northwestern Latvian coast near Cape Kolka, just east of the Cape in the Gulf of Riga, transport rates drop dramatically to around 50,000 m^3/yr, despite being part of the same general sediment transport system.

This study highlights the importance of long-term sediment transport modelling in identifying persistent trends and potential climate-driven modifications to the coastal system. By integrating high-resolution modelling with extended datasets and performing a statistical analysis of the sediment transport variability over the covered years, this research contributes to a more comprehensive understanding of the factors driving longshore sediment transport along the eastern Baltic coast and provides a strong foundation for future work assessing the resilience of these coastal environments under changing climatic conditions.

Thematic Session: Land-Ocean-Atmosphere Interactions and Catchment Processes

Abstract ID: 108

Modelling the effectiveness of Natural/Small Water Retention Measures in Hungary and Lithuania: Influencing downstream water bodies.

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Natural/Small Water Retention Measures (NSWRM) can play a crucial role in agricultural catchments, enhancing water and nutrient management to ensure sustainable agricultural production. Such measures help to balance agricultural water use with other human and environmental demands, such as drinking water supply and maintaining environmental flows, extending their benefits from the source to downstream water bodies like lakes, lagoons, or seas. Within the H2020 OPTAIN project, we analysed several catchments across diverse biogeographical regions of Europe using environmental models. The project aims to deepen the understanding of the multiple benefits of spatially targeted combinations of NSWRMs on the management of small agricultural catchments across Europe, and the conditions under which they perform most effectively.

In this presentation we will compare the results of case studies in Hungary and Lithuania, representing two different biogeographical regions (Pannonian vs. Boreal). Riparian forest buffers and cover crops were investigated in both case studies. We hypothesize that the effectiveness of these NSWRMs will vary due to differences in climatic conditions and soil properties. Additionally, wetlands/ponds and reduced tillage were applied in the Lithuanian case study due to its hydrological conditions and current management practices. Conversely, in the Hungarian case study, no-tillage, buffer strips, and afforestation were considered and included in the modelling process.

To model the effects of NSWRMs, we used the SWAT+ modelling tool to evaluate their current and projected effectiveness following the developed modelling protocol and utilizing a suite of scripted workflows in R for building the model setup, verification, calibration, validation, and running scenarios. Our investigation focuses on the effects of NSWRMs on hydrology (water yields), nutrients (nitrogen and phosphorus), transported sediments, and crop yields.

We will present the effectiveness of these measures in each case study, highlighting how upstream land management practices influence downstream water bodies. The transition to sustainable water management and farming practices can lead to significant cumulative benefits for downstream environments, ultimately contributing to healthier rivers, lakes, lagoons, and seas. By comparing the effectiveness of these measures in both countries, we aim to identify the main sources of any observed differences in performance and underscore the long-term environmental benefits of widespread adoption of NSWRMs.

Abstract ID: 127

Impact of Land Use Change on the Optical Properties of the Gulf of Riga

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The optical properties of aquatic systems are essential indicators of ecosystem health, influencing primary production, habitat conditions, and overall water quality. This study examines the key factors driving changes in the optical properties of the Gulf of Riga, with a particular focus on the effects of land use changes in the River Daugava catchment. The research is part of the AquaINFRA project, which aims to develop a research infrastructure that facilitates seamless data discovery and processing across marine and freshwater domains.

The Gulf of Riga is an optically complex system where light absorption and scattering are primarily influenced by chlorophyll-a, suspended particulate matter (SPM), and colored dissolved organic matter (CDOM). Long-term observations indicate a decline in water transparency, with Secchi depth measurements showing a consistent decreasing trend over the past five decades. The River Daugava, the main freshwater inflow into the Gulf, plays a crucial role in shaping water quality, contributing significant loads of nutrients, dissolved organic carbon (DOC), and suspended matter.

This research aims to: (1) identify the drivers influencing the optical properties of the Gulf of Riga, (2) assess the role of land-use activities and climate-induced changes in shaping water quality trends, and (3) evaluate the socio-economic drivers that modify these environmental pressures. By integrating in situ biogeochemical measurements with Earth Observation data, we analyze the relationships between satellite-derived products and in situ water transparency and color metrics.

This study contributes to the broader understanding of land-sea interactions in the Baltic region, providing a knowledge base for sustainable coastal management and policy development.

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Abstract ID: 128

Uncertainty Analysis in Direct and Indirect CO_2 Flux Measurements: The Role of Organic Matter Enrichment

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Measurements of carbon dioxide (CO_2) fluxes between the ocean and atmosphere can be conducted using direct methods, such as eddy covariance (EC), and indirect methods, which rely on the difference in CO_2 fugacity between water and air (ΔfCO_2) combined with gas transfer velocity parameterizations (k). Each of these approaches carries distinct levels of uncertainty.

Studies have shown that the uncertainty (1 standard deviation) in hourly averaged EC air–sea CO_2 flux measurements ranges from 1.4 to 3.2 mmol m^{-2} d^{-1}, corresponding to a relative uncertainty of approximately 20% during Arctic cruises with high CO_2 flux values. For smaller fluxes, this uncertainty can increase to around 50% Dong et al. (2021). In contrast, indirect methods often exhibit lower uncertainty; however, this depends on the accuracy of ΔfCO_2 measurements and the applied gas transfer velocity parameterization.

In our studies conducted in the Baltic Sea from our research vessel, we found that when using wind speed data in the direct EC method, uncertainties were approximately 28%, whereas in the indirect method, utilizing the same wind speed data, the uncertainty was around 5%. This significant discrepancy may stem from the fact that the EC method is more susceptible to random errors caused by turbulence and atmospheric variability, while indirect methods rely on averaged values and gas transfer models, which can reduce uncertainty but may introduce potential systematic errors associated with the parameterization of k.

Our research aimed to determine the contribution of organic matter enrichment in the Baltic Sea waters to the observed 28% uncertainty in the EC method. Increased presence of organic matter can influence local biogeochemical processes, such as production and decomposition of organic material, leading to greater variability in CO_2 fluxes and increasing the uncertainty of EC measurements. Understanding these relationships is crucial for improving the accuracy of CO_2 exchange estimates between the sea and atmosphere and for better modeling the carbon cycle in the Baltic Sea region.

Abstract ID: 132

Meteotsunami as saline water intrusion driver to the Curonian Lagoon

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Meteotsunamis are long-period waves generated by atmospheric disturbances. They exhibit characteristics similar to seismic tsunamis but originate from meteorological phenomena rather than tectonic activity. These events are primarily driven by abrupt changes in atmospheric pressure and wind patterns, leading to significant water level fluctuations along coastlines and within enclosed water bodies. The unique dynamics of meteotsunamis are a significantly concern for coastal communities, as climate change may influence their frequency and intensity.

Predicting long-period waves and rapid saline water intrusions into the Curonian Lagoon via the Klaipeda Strait remains challenging, as not all contributing factors are fully understood. This study examines significant saline water intrusion events into the Curonian Lagoon during the years 2023 and 2024, focusing on the potential impact of meteotsunamis on these occurrences.

Previous research by Dailidienė and Davulienė (2007) reported that between 1993 and 2005, the average salinity in the Klaipeda Strait was 2.6 PSU; in Juodkrantė, 1.2 PSU; and in Ventė, 0.1 PSU. Maximum salinity levels reached 7.72 PSU, 7.24 PSU, and 2.43 PSU, respectively. In the 2023–2024 period, these values in the northern part of the lagoon remained comparable: the mean salinity in the Klaipeda Strait was 2.74 PSU, and in Juodkrantė, 1.25 PSU. Maximum values were also similar in 1993 – 2005: 7.54 PSU in the Klaipėda Strait and 7.42 PSU in Juodkrantė. However, saline water began intruding into the lagoon more rapidly, increasing salinity over time and space. The mean salinity in Ventė rose to 0.24 PSU, with a maximum value of 4.4 PSU in 2024.

In 2023–2024, at Juodkrantė's monitoring station it was recorded that salinity levels exceeding 0.5 PSU for 314 days. Salinity levels above 1.8 PSU were observed on 44 days, with a maximum salinity of 7.4 PSU and an average of 5 PSU. The highest salinity in Juodkrantė was recorded on October 9, 2023.

Observations preceding saline water inflow events into the Curonian Lagoon indicate a characteristic sequence of atmospheric pressure and wind pattern changes. Initially, a pressure drop accompanied by northeast winds is observed, followed by a sudden pressure increase and a shift in wind direction to north-northwest. This sequence facilitates the transport of saline water into the lagoon. These pressure changes also drive meteotsunami waves, which amplify the intrusion of saline water into the Curonian Lagoon.

Abstract ID: 202

The Impact of Large-Scale and Regional-Scale Atmospheric Circulation on Water Mass Exchange and Circulation in the Baltic Sea

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The climate of the North Atlantic–European sector is driven by the variability of large-scale pressure systems, known as climate regimes, which control large-scale airflow. The Baltic Sea is a semi-enclosed, brackish water body that is highly sensitive to atmospheric forcing. These atmospheric influences affect the exchange of water masses, salinity levels, and overall circulation dynamics, playing a crucial role in shaping the sea's physical environment. The four primary climate regimes include the positive and negative phases of the North Atlantic Oscillation (NAO+ and NAO-), Scandinavian Blocking (SCAND), and the Atlantic Ridge. These regimes are identified from pressure fields using k-means clustering, with each occurring approximately 25% of the time over multi-decadal periods. However, interannual variability is high, and in some months, a single pattern can dominate for more than 80% of the days. The positive phase of the North Atlantic Oscillation (NAO+) is characterized by a strong meridional pressure gradient, which drives intense westerly airflow, bringing mild and moist air to the Baltic Sea region. In contrast, during the negative phase (NAO-), a weaker meridional pressure gradient allows easterly or meridional winds to dominate, resulting in the advection of cold, dry air. Another climate regime, the Atlantic Ridge, features a dipole pressure system with a strong high over the North Atlantic and a low-pressure system farther east. The fourth dominant mode, the SCAND pattern, has an opposite pressure configuration to the Atlantic Ridge, with high-pressure conditions prevailing over Scandinavia. In winter, this pattern is typically associated with dry, cold weather and predominantly weak easterly winds.

The weather in the Baltic Sea region is closely linked to large-scale climate regimes. However, the atmospheric impact on the sea's circulation can vary in different ways. For example, severe winters with extensive ice cover can result not only from NAO- conditions but also from prolonged SCAND patterns. Therefore, regional atmospheric circulation patterns should also be considered. Our main objective can be summarized as follows: What are the spatial and temporal scales of atmospheric forcing on water mass exchange and circulation in the Baltic Sea? To answer this question, we conduct a series of sensitivity studies using various COST733 atmospheric circulation classifications, adjusting the position and size of the classified area, the altitude of the pressure field, and the classification period. These analyses help us better understand the variability of water circulation and move us toward detecting them based on atmospheric parameters.

Abstract ID: 209

Circulation of the Central Baltic: combining data from an array of current meters and numerical simulations

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Currents and circulation patterns are important for redistributing heat, salt and other substances, thereby shaping the environmental conditions in the Baltic Sea. In 2022, a measurement campaign was carried out as part of the Central Baltic Circulation Experiment (CABLE), during which an array of acoustic current meters was deployed for half a year. Simultaneously, an eddy-resolving numerical experiment using GETM was carried out from 2010 until 2023. The model grid had a horizontal resolution of 926 m and 60 vertically adaptive coordinates. Atmospheric forcing was taken from ERA5 re-analysis, and the open boundary was set in the Kattegat.

Initial results show stronger and more persistent currents near the coasts, while weaker currents with lower persistency were observed in the upper layer in the offshore area. The former are attributed to the local sea level gradient, whereas the latter are consistent with the wind-driven Ekman transport. A strong current in the deep layer at the Fårö sill was observed. By integrating the observations from CABLE with high-resolution numerical simulations, we explore the current structure, circulation and transport of the Central Baltic in synoptic, seasonal and interannual timescales. Our work advances the knowledge of regional circulation, its dynamics and environmental impacts.

Abstract ID: 233

The evolution of freshwater discharges to the Baltic Sea and their extremes: Deciphered from a Baltic multi catchment and multi dataset synthesis

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Essential Baltic Sea conditions, such as salinity levels, nutrient loads, eutrophication and ecosystem health states, depend on the discharges of freshwater from land to sea. Different science disciplines relate to these Baltic Sea conditions and thus have to account for the freshwater discharges to the sea. Consistent comparisons and validations, however, are largely lacking for the freshwater flow data, concepts, and models used by various research communities. Here, we present a Baltic synthesis of four comparative (observation and model-based) datasets for the seaward freshwater fluxes in 69 non-overlapping hydrological catchments around the Baltic Sea Drainage Basin (BSDB) over a 30-year study period 1980–2010; the Baltic data are extracted and synthesized from the global datasets recently reported and provided with open access by Zarei and Destouni (2024a,b). The dataset comparison identifies key agreements for robust (and disagreements for more highly uncertain) assessment of the freshwater flux variations and changes (including in flood and drought extremes) and their interplay with climate variability and change around the BSDB. The comparative datasets agree on that average runoff to the sea has decreased (decelerated) while average precipitation has instead increased (accelerated) over the study period in the BSDB. Robustly across the datasets it thus emerges that changes in average precipitation do not directly determine even the directions of changes in average freshwater discharges to the Baltic Sea. The same applies to the occurrence and severity of extreme drought and flood events. For example, the datasets mostly imply less severe – i.e., smaller water input deficits in – low-precipitation (meteorological) drought events but more severe – i.e., greater water flow deficits in – low-runoff (hydrological) drought events during summer. Another example is increased intensity of high-precipitation events but decreased intensity of high-runoff (flood) events in springtime. Overall, these robust dataset implications call for enhanced focus and strengthening of Baltic Sea research on the complex flow processes and heterogeneous change drivers and propagation pathways taking place and interplaying with climate, societal and environmental changes on land to determine the resulting freshwater discharges to the sea.

References:

Zarei M. & Destouni G. (2024a). A global multi catchment and multi dataset synthesis for water fluxes and storage changes on land, *Scientific Data*, 11, 1333. https://doi.org/10.1038/s41597-024-04203-1

Zarei M. & Destouni G. (2024b). Global Hydro-Climatic Data (GHCD), Version v3, Zenodo Repository [Dataset]. https://doi.org/10.5281/zenodo.10932898

Abstract ID: 235

Investigating of air-sea coupling on diurnal time scale with UAS measurements

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An exchange of energy and momentum through an air-sea interface has broad implications for both atmospheric and oceanic environments across scales. Physical processes responsible for variations in energy and momentum fluxes are not limited to the interface, but span across boundary layers on both sides of the surface. Unfortunately, coupled observations across an air-sea interference, covering both atmospheric and oceanic environments, are challenging to conduct and therefore sparse. One of the unknowns is an impact of a short-term temperature variations of the sea surface temperature (SST) on the surface fluxes and stratification of the lower troposphere. Under certain conditions (low wind speed, high insolation) warm layer may form at the sea surface, which not only temporarily increases SST but via increased stability results in a decoupling of the surface temperature from the rest of the mixed layer as well. Increased SST may result in larger upward energy fluxes, while stronger stratification near ocean surface can damp downward momentum transfer. While diurnal variations in the SST are smaller than diurnal temperature variations over land, they may have impact on the lower troposphere.

For the assessment of an effect of a warm layer on surface fluxes and stability of the atmosphere above it, frequent vertical profiles of temperature, pressure, humidity, wind speed, and wind direction are required. To that end, frequent profiling with Uncrewed Aerial Systems (UAS) in lower PBL and upper sea was performed in the coastal zone of Baltic Sea as well as over open sea and tropical Atlantic ocean. During the daily evolution of PBL, flights were performed more frequently, especially at night-to-day and day-to-night transition times, to capture the change of stability within PBL. Those observations were paired with simultaneous measurements of temperature in the first 5m beneath the sea surface for the purpose of observing the presence or absence of an oceanic warm layer. Bulk and gradient Richardson number methods are employed to investigate observed changes in n atmospheric stability and temperature in the context of diurnal evolution of SST

This approach demonstrates that UAS can be utilized to monitor conditions across air-sea interface on a diurnal time scale. Results show typical daily evolution of PBL paired with interesting cases where inversion doesn’t completely vanish from first 120m or starts to form from up to down, which is more interesting when compared with evolution of SST.

Thematic Session: Marine Pollution: Sources, Trends, Effects and Solutions

Abstract ID: 19

The scientific landscape of the Baltic Sea: From basic research to assessing environmental risks stemming from tense geopolitics

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Traditionally, Baltic Sea research has focused on challenges such as eutrophication, harmful substances, climate change, and biodiversity loss, with strong cooperation between researchers from Baltic riparian countries. However, the Russian war in Ukraine has brought changes to this research landscape. Cooperation with Russia has ceased, leading to significant data gaps. A conflicted geopolitical situation has emerged, bringing new environmental threats to the Baltic Sea, stemming from accidents, intentional damage, infrastructure deterioration, and even changes in land use. This has created an urgent need to address the heightened risks of environmental damage. We combine state-of the-art research with stakeholder knowledge to identify, analyze, quantify, and evaluate risks caused by the changed geopolitical situation to the marine environment of the Gulf of Finland (GoF). The work is centered around four questions: 1) How does the changed geopolitical context influence the environmental risks in the GoF? We hypothesize that new threats will emerge, both due to Russia's conventional war in Ukraine and its hybrid war against the West. 2) How can we understand the risks, and anticipate the impacts of realized risks? We presume that integrating knowledge and expertise from various sources and perspectives enables us to structure risks into cause-effect relationships and to identify risk control options. 3) How can we assess the environmental damage and degradation caused by adverse events, compensate for missing data, detect disinformation, and quantify uncertainties? We expect that the combination of numerical and statistical modelling, together with remotely sensed and in situ data and experimentation provides adequate information of water properties to allow for the monitoring of risks and prediction of impacts. 4) What can we learn from the GoF risk assessments to protect vulnerable coastal marine systems in other regions? We consider that the GoF as a well-studied sea area, is ideal for developing and testing new risk analysis and control methods. The project's results can thus enhance emergency preparedness also in other coastal seas.

Funding: Coastal waters under pressure – safeguarding a healthy Gulf of Finland in a changing geopolitical and environmental landscape (CoWup), funded by the Strategic Research Council of Finland.

Abstract ID: 47

Baltic Sea case study: Port biofouling assessment using SERC method

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The International Maritime Organization (IMO) addresses a significant issue of policy importance through the implementation of the Biofouling Guidelines and the IMO Biofouling Guidance for leisure boats (IMO, 2011; 2023). The issue of biofouling has many aspects and encompasses various study topics. The examples include the involvement of bacterial biofilms in the early stages of biofouling, the occurrence of biofouling in freshwater, estuarine, or marine environments, the spread of invasive species, the effects of antifouling technologies on biofouling and the surrounding environment. These examples are supported by studies conducted by Davidson et al. (2016), Zabin et al. (2014), Floerl et al. (2005). One of the challenges in biofouling management and prevention is to evaluate the rate of biofouling in various regions using standardized methodologies. This approach is needed in order to establish compliance measures that can be applied to the International Maritime Organization (IMO) biofouling guidelines.

In this paper, we will present results of the experiment elaborated within the workshop “Assessment of fouling alien species in ports with the SERC protocol and experimental applications” guidelines, organized by the University of Pavia (UNIPV) and the Smithsonian Environmental Research Center (SERC). The SERC method was utilized in the Baltic Sea, port of Klaipėda, to evaluate biological invasions, considering biofouling species in the port. The experiment lasted for six months and aimed to quantify the rate of biofouling using PVC plates.

Abstract ID: 49

Heavy metals in host-parasite system: salmon *Salmo salar* - tapeworm *Eubothrium* sp. from the southern Baltic Sea

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Salmon (*Salmo salar*) it is valuable fish species intended for human consumption. It is predator, feeds intensively, and as a consequence it might be exposed to the accumulation of harmful factors such as parasites or heavy metals. Salmon were collected during standard ichthyological analysis in spring 2023 in the southern Baltic Sea. All 40 specimens has been found highly infected with intestinal tapeworm parasite *Eubothrium* sp. The aim of this study was to evaluate concentrations of toxic metals (As, Cd, Hg, Pb), macroelements (Ca, K, Na, Mg, P) and microelements (Cr, Cu, Fe, Mn, Sr, Zn) in the tissues of salmon (liver and muscle) and its parasites *Eubothrium* sp. The relationships between metal concentrations in parasite and salmon tissues were expressed as a bioconcentration factors (BCF). In the parasite - host (muscles) system: salmon parasites mainly accumulate microelements, which negatively affects the condition of fish. A high parasite - host (muscles) BCF ratio for Cd content should be considered as a positive factor protecting the fish against the toxic effects of this metal. In the parasite - host (liver) system: parasites absorb microelements (Sr, Zn, Mn) and macroelements and accumulate highly toxic Hg.

Abstract ID: 57

Microbes as indicators of Hg polluted sediments

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Chemical pollution resulting from human activities is a significant global concern for environmental authorities. Pollutants released into aquatic ecosystems often accumulate at levels far exceeding natural background concentrations, leading to harmful effects on local organisms and the overall functioning of these ecosystems. Bioindication plays a critical role in the implementation of environmental legislation, particularly within the European Union, for assessing the quality of various natural environments. Microbes are found in a wide array of habitats, which would make them particularly valuable as rapid and sensitive indicators of environmental disturbances caused by pollutants, for example mercury (Hg).

The overall aim of this study was to elucidate if bacteria can be used as indicators of Hg contaminated sediments. Three fiber bank gradients in the Gulf of Bothnia were studied; Bureå (Bothnian Bay), Köpmanholmen and Sundsvall (Bothnian Sea). The bacterial community composition was determined from 16S sequencing and compared with the level of Hg pollution. We found that some groups of bacteria were enriched at the Hg polluted sites, for example, the phyla Campylobacterota (Class Campylobacteria) and Desulfobacterota (Class Desulfobaccia). The results were relatively similar in response to total Hg and MeHg. At the unpolluted “control” sites, the phylum Proteobacteria was more prominent. Presently, the gene composition and their link to taxonomic groups are being analysed, focusing on mercury methylation genes (*hgcAB*) and tolerance genes (*mer*). A separate toxicity experiment showed that bacterial communities from contaminated areas were more tolerant to Hg addition than those from un-contaminated areas. The results imply that high abundance of the phyla Campylobacterota and Desulfobacterota could be used as indicators of mercury pollution, and that bacterial communities can become adapted to Hg pollution. Taken together, our study contributes with a framework on bacterial community structure and function as a response to Hg pollution in sediments, which can be useful in ecosystem monitoring.

Abstract ID: 62

The impact of fuel pollution in the s/s Stuttgart shipwreck site area on nearby benthic habitats

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Located approximately 2 nautical miles from Gdynia harbor, in an ecologically valuable area of the Puck Bay, the s/s Stuttgart shipwreck has become a focal point for studying the long-term impacts of oil pollution on benthic habitats in the southern Baltic Sea. The area surrounding the wreck was contaminated due to the fuel release, leading to environmental degradation at the site. In this study samples were collected from eight stations, within 500 meters of the wreck to examine the impact of an oil spill on benthic habitat and community structure within the pollution zone. To evaluate the structure of the meiofauna communities, 5-centimeter surface sediment cores were collected and divided into three layers of 0-1 cm, 1-2 cm, and 2-5 cm at all stations. Macrofauna samples were collected from three stations located on the western edges of the oil spill. To determine the concentration of 12 polycyclic aromatic hydrocarbons (PAHs), 7 polychlorinated biphenyls (PCBs), and hexachlorobenzene (HCB), surface sediment samples were collected at all stations. The analyses revealed elevated levels of PAHs at all the studied stations, with maximum values recorded at two stations located closest to the left side of the wreck. Increased concentrations of PCBs and HCB were detected at several stations, at levels that could cause toxic effects due to chronic exposure. Interestingly, despite the high contamination of the sediments, the meiofauna communities were diverse and a total of 12 taxa were found, with Nematoda dominating at all research stations. Maximum abundance was recorded at the station farthest from the wreck in the northeast direction (1429 individuals/10cm^2) and minimum at the station closest to the bow of the wreck (12 individuals/10cm^2), where life was present only in the top 2 cm of the sediment. The stations located at the edge of the contaminated area were characterized by macrofauna diversity typical for Puck Bay, with Gastropoda dominating in abundance and mussels of the species *Mytilus edulis* dominating in biomass.

Abstract ID: 103

Breaking forever bonds – electrochemical oxidation for PFAS removal from runoff water

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Per- and polyfluoroalkyl substances – PFAS – is a group of synthetic organic compounds used for pans (Teflon), straws or paper cups as coating, or in waterproof clothes. They are called “forever chemicals” because of their high durability and persistence in the environment. They are almost indestructible because of containing the strong C-F bonds (488 kJ/mol). PFAS may bioaccumulate and transfer on long distances via different pathways (e.g. hydrosphere, atmosphere), hence now they are ubiquitous in the environment. Selected PFASs are included in the Stockholm Convention on the Persistent Organic Pollutants list and in the EU Directive 2020/2184. Given the fact that PFAS are being found almost everywhere, there is a need to monitor their concentrations and mitigate their presence in the environment. Therefore, identifying an effective method for its removal from contaminated environments is of critical importance.

Under this study the runoff water samples from Port of Gdynia (Poland) and Former Korsør Fire Academy (Korsør, Denmark) area were analyzed for 24 different PFAS where range was from 3.36 to 473 ng/L and from 140 to 153 000 ng/L, respectively. PFAS determination was based on targeted high-performance liquid chromatography tandem mass spectrometry (HPLC-MS/MS). Next, samples from both contaminated areas were subjected to the electrochemical oxidation treatment. The electrochemical oxidation (EO) was conducted using a boron-doped diamond (BDD) anode and a stainless-steel mesh cathode under galvanostatic conditions (2h-6h). Removal efficiencies in contaminated concentrated runoff water from Korsør were up to 52% for sulphonic acids (e.g., PFHxS) and 51% for carboxylic acids (e.g., PFOA). Moreover, some compounds are showing re-formation during treatment (e.g. PFNS, PFNA).

The efficiency of PFAS removal is highly dependent on electrooxidation (EO) conditions and the matrix composition, indicating that there is still potential for enhancement. Further research is essential to optimize experimental parameters and minimize associated costs. However, based on preliminary results, it is a promising technique for mitigating the negative consequences of PFAS presence in the environment.

Funding: This work was funded by the project “Innovative concepts for sustainable water treatment targeting PFAS and other critical micropollutants from point sources in the South Baltic Sea area” (LIMIT) co-financed by Interreg South Baltic 2021-2027 through the European Regional Development Fund. Agreement STHB.02.02-IP.01-0001/23 from 2023-09-01.

Abstract ID: 112

Beach litter on the southern Baltic coast – status after 10 years of studies – SUP directive and pandemic signs

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Marine litter, including collected on beaches, poses a significant threat to the marine environment. Growing awareness in this area makes it necessary to take action to reduce their number. The basis is to recognise the scale of the problem, which is why studies of marine litter on beaches are carried out, which is also part of the provisions of the Marine Strategy Framework Directive (MSFD). From 2020 to 2024, research on litter on the southern Baltic Sea coast, which started in 2015, was continued. The study covered the pandemic time and the implementation of the 'single-use plastics' (SUP) directive. The research was carried out on 15 sections of 1 km, four times a year and included counting all litter items and assigning them to nine categories. Litter items were also linked to sources and divided into SUPs, fishing gear, other plastics and other categories. The total number of litter items was 51011, which means a decrease compared to the previous 5 years (85086). The highest numbers were recorded in autumn (31%) and summer (26%), and the lowest in winter (19%). The share of litter on urban beaches (54%) was only slightly higher than on rural beaches (46%). The most numerous category was plastics (64.3%), wood occurred with the share of 13.4%, metal – 6.4%, glass and ceramics – 5.4%, paper/cardboard – 4.1% and rubber -1.2%. The share of food waste and chemicals did not exceed 1%. The remaining litter items were classified as undefined. Tourism and recreational activities (53%) were the primary source of beach litter. The pandemic state in Poland lasted from March 2020 to May 2022. In 2020, the number of litter items (12298) decreased by 27.7% compared to the 2015-2019 average, while 2021 and 2022 were characterised by the lowest numbers, 7447 and 5518, respectively, which could be associated with the pandemic. Still, the 2022 tourist season was no longer covered by it. In 2023 and 2024, the number of litter items increased again to 1287 and 13661, respectively. The average share of SUPs in 2020-2024 was 39% and decreased compared to 2015-2019 (47%). The share of other plastics was 25%, and fishing gear accounted for only 0.6%. The lowest number of SUPs and thus the lowest percentage share were in 2021 (22%) and 2022 (27%), mainly due to the reduction in tourist traffic, as the share of SUP increased again to 39% in the following years.

Abstract ID: 148

Microplastics Disrupt Microbial Communities: A Dual Threat of Toxicity and Physical Presence

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Microplastic (MP) pollution poses a significant threat to aquatic environments. While most research focuses on animals, key ecological processes are driven by microorganisms. Microbial food webs process nearly half of primary production, substantially influencing pelagic ecosystems. Bacteria consume dissolved organic matter and serve as food for small protists, meaning any disruption to their activity can profoundly impact the entire ecosystem. However, little is known about the effects of MP pollution on microbial community activity and composition.

Small MP particles may reduce bacteria-bacterivore encounter rates, lowering food capture efficiency and grazing rates. Additionally, bacterivores may mistake MPs, which offer poor nutritional quality, for bacteria, reducing their growth. Conversely, plastic-derived compounds may serve as a carbon source for bacteria, potentially stimulating their growth. This study investigated how bacteria-sized (1–5 µm) MP particles affect bacterial and bacterivorous protist activity, growth rates, and community composition. We conducted two whole-community experiments: (i) assessing the effects of increasing polystyrene (PS) concentrations and (ii) comparing the effects of PS and polyethylene (PE). Glass spheres and unamended treatments served as controls.

Increasing concentrations of spheres—both glass and PS—negatively impacted bacterivore abundance. The effects on bacteria were less pronounced, with a potentially positive impact on bacterial abundance toward the experiment's end. This suggests that bacterivore decline resulted from inedible particle presence rather than MP's toxicity. No significant differences in microbial respiration or community composition were observed between treatments. A follow-up experiment on a natural microbial community, sampled two weeks later, also showed negative effects of PS, PE, and glass particles on bacterivores. However, in this case, the heterotrophic nanoflagellate (HNF) community recovered after three days in the presence of glass but not MPs. Both MPs increased bacterial abundance compared to unamended and glass controls, and microbial respiration was significantly higher in PE treatments.

These findings suggest that MP impacts on microbial communities depend on particle type and initial community composition. Overall, our results highlight the complexity of MP pollution effects on microbial food webs, emphasizing the need for further research to predict long-term ecological consequences accurately.

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Abstract ID: 151

Finnish-Estonian Collaborative Research Project: Utilizing Passive Samplers in Pharmaceutical Research in the Gulf of Finland

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Pharmaceuticals in the environment may have adverse effects on organisms at very low concentration levels. Although most pharmaceuticals are not persistent, they are constantly present in the environment due to their continuous release from e.g. WWTPs. Oceans act as a sink for pharmaceutical loading but low and biologically significant concentrations may be challenging to detect using only traditional sampling methods.

Grab water sampling is used in regulatory monitoring of chemicals. However, it's vulnerability has been recognized as the timing of the sampling effects if chemical concentration peak is detected or if the concentration remains undiscovered. Hence the concentration below the detection limit does not automatically mean that the chemical is not present. Therefore, an instant grab water sample cannot necessarily be considered as representative to describe the chemical status of the watercourse. With passive sampling, the chemicals are accumulated into the sampler over a time period up to several weeks. This can help to enrich the trace concentrations to measurable level. Thus, passive sampling can bring different information and new insight to this issue.

POCIS passive samplers were deployed at differently polluted marine sites in front of Helsinki and Tallinn and in the open sea of the Gulf of Finland. The aim was to determine baseline concentration level for pharmaceuticals monitored with passive sampling technique at sites. Almost 150 pharmaceuticals were analysed from passive samplers and grab water samplers and 32 substances were discovered. Number of pharmaceuticals detected in passive samplers (27) was higher than in grab samples (20). However, the study revealed several pharmaceuticals even from expected background sites implying their ubiquitous presence at the study area.

Passive sampler results are converted to time-weighted average concentrations (ng/L) with sampling rate, which is characteristic to sampler type and studied compound. Sampling rates are generally determined in controlled laboratory conditions which can differ from the environmental conditions prevailing at the study site and providing uncertainty on occurrence and levels of some pharmaceuticals. We assessed the suitability and differences of sampling rates collected from literature, calculated from $\text{Log}K_{OW}$ values and estimated from field deployment results. Instant grab sampling and long-term passive sampling techniques indicate different things as one gives total concentration and the other the dissolved part of chemical. Additionally, both sampling methods have pros and cons. There are open questions how to reconcile the passive sampling results with regulatory monitoring obligations based on grab water sampling and existing reference concentrations.

Abstract ID: 152

Effects of underwater noise on behavior and physiological stress responses in Baltic Sea mussels (*Mytilus* spp.)

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The physiology and behavior of marine organisms may be impacted by underwater noise pollution, which is an increasing concern in the marine environment. Filter-feeding mussels belonging to the genus *Mytilus* are key species in the Baltic Sea and may be adversely affected by underwater noise. With an emphasis on simulated traffic situations, this study aimed at determining how vessel noise affects the behavior and physiological stress reactions of mussels.

The mussels were kept in controlled aquaria and subjected to 3 and 7 days of exposure with moderate and intense vessel traffic noise. A 7 days of recovery period was included for mussels exposed for 7 days. Field-recorded vessel passage noise was played to mussels at randomized intervals, interrupted by the ambient laboratory soundscape. Real-world data, including hydrophone recordings from the Archipelago Sea and AIS-based vessel monitoring, were used to estimate traffic rates. Valve gape activity was continuously monitored to assess behavioral reactions of the mussels. Biomarkers of oxidative stress were measured from the mussels to record physiological alterations caused by noise exposure.

Valve gape behavior was significantly altered in mussels exposed to noise treatments. Prolonged valve gape closure was observed during exposure periods with frequent boat passages, while periods containing less frequent occurring boat passages induced more variable gape patterns, suggesting differential responses to noise type. When compared to control, the intense noise level significantly decreased the valve gape activity during the treatment period and the decreased activity continued even during the recovery period.

Biomarker analyses showed a significant decrease in glutathione content (GSH) in all the treatments, indicating potential impacts of oxidative stress. Furthermore, a decrease in lipid peroxidation at 3 and 7 days of intense noise exposure but and increase during the 7 days recovery period was observed. This may indicate a fasting effect, in which, in response to noise, mussels filter less and may also show less lipid peroxidation linked with a decreased amount of reactive oxygen species due to decreased metabolism.

The documented behavioral and physiological reactions indicate that underwater noise, regardless of its intensity and pattern, generates stress in mussels, potentially impacting their health and ecological functioning. These findings highlight the necessity of acknowledging noise pollution as a substantial stressor in the Baltic Sea ecosystems and improve our understanding of how noise can lead to cumulative effects that may jeopardize ecosystem stability.

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Abstract ID: 161

Microplastic in the Southern Baltic Sea: what's new to explore?

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Eliminating plastic from everyday life is an unrealistic goal as the widespread use of multiple types of plastic concerns various areas including the textile industry, food packaging, electronics, furniture and many others.

The fact that the production of plastic items is ongoing and demand for new products is constantly increasing, the importance of recycling and waste management has become a significant part of the economy. From a scientific point of view, the fate of plastic released (accidentally or due to negligence) into the environment and its impact on biota is the main interest.

Estimation of the amount and identification of the pieces in a few centimeters size is well-researched, whereas analysis of microplastic (<5 mm) is still more complex. Multiple stages and numerous technical activities pose a risk of contamination/cross-contamination or loss of the smallest particles causing underestimation. Furthermore, the variable concentration and diverse polymer composition of plastic in environmental samples make the assessment very challenging. Unified sampling and sample preparation procedures paired with modern tools and up-to-date knowledge enhance the reliability of the results. One of the techniques gaining interest is the FT-IR Mid-infrared (MIR) spectroscopy microscope.

This technique enables the tracking of the samples and analysis with a non-destructive method, which is a crucial feature when working on delicate and unique samples. The fact that the identification of a single particle is possible, a greater understanding and a more complete picture of the microplastic presence in the environment.

Our studies concentrate on the Baltic Sea as the relatively small size of the water area and the major impact of river flow and transport, compared with reduced water exchange with other sea basins makes this scientific issue particularly relevant. The samples of seawater, sediments, algae and zooplankton are to be tested with FT-IR MIR spectroscopy to create a database with spectra of degraded plastic particles exposed to environmental factors and image collection presenting examples (with spectral verification) of organic and non-organic particles mistaken for microplastic.

Abstract ID: 167

Post-Spill Analysis: Assessing the Ecological Damage from the Macro Polo oil spill in Hanö bay

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On October 22, 2023, the passenger ferry *Marco Polo* caused a spill of 150,000 liters of oil in Hanö bay, Blekinge Sweden. Cleanup efforts have been ongoing since then, as a significant portion of the oil sank to the seabed and oil resurfaced on shorelines, necessitating repeated cleanups and highlighting the long-term impact of oil spills on coastal ecosystems. The increased traffic of substandard vessels in the southern Baltic Sea, particularly since the large-scale invasion of Ukraine, underscores the need for greater preparedness and understanding of oil spill consequences. Oil pollution in marine environments can have immediate toxic effects and prolonged ecological damage, depending on the type and quantity of oil, location, and environmental conditions. A key concern is the presence of Polycyclic Aromatic Hydrocarbons (PAHs), which are highly toxic, bioaccumulative, and include known carcinogens. In August 2024, the County Administrative Board of Blekinge and IVL Swedish Environmental Institute conducted sampling of seawater, sediments, blue mussels (*Mytilus edulis trossulus*), and stranded oil. Results revealed significantly elevated PAH levels in affected areas, surpassing ecotoxicological thresholds. Chemical analysis identified a unique PAH "fingerprint" matching *Marco Polo*'s spill, with high concentrations of alkyled PAHs. These contaminants likely pose physiological risks to mussels and may transfer to higher trophic levels, affecting fish and seabirds.

This study aims to assess the impact of the oil spill from Marco Polo in blue mussels using traditional and innovative methods. We are analyzing both the soft and hard parts of mussels, conducting morphological assessments of the shells using microcomputed tomography and testing their structural integrity. Additionally, we are performing geochemical analyses of the shells using laser ablation ICP-MS to assess potential heavy metal incorporation. The project can generate new insights into how marine environments and ecosystems respond to oil contamination, providing essential knowledge to inform effective mitigation and restoration strategies and contribute to scientific advancements in understanding the prolonged consequences of oil spill.

Abstract ID: 203

Is it possible to remotely detect dispersed oil in seawater? Results of modeling and experiment in the Baltic Sea

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Dispersed oil droplets place high among the most harmful micropollutants in seawater. They may be crude oil droplets floating in the surface mixed layer after an oil spill, ship engine oil droplets discharged in waste-water, or land-based oils from industrial and agricultural sources that are carried into the sea. For years oil slicks spilled on sea surface have been the main focus of remote detection and monitoring of oil pollution, however there are reasons to move the way forward - toward the detection of dispersed forms of oil. Research teams from Gdynia Maritime University and the Institute of Oceanology of Polish Academy of Sciences jointly conducted a four-stage series of experiments to test the possibility of remote detection of dispersed oil droplets. These experiments included 1) laboratory measurements of physical properties of pure and dispersed oils; 2) mathematical modeling of the inherent optical properties (IOPs) of oil droplets; 3) field experiment in the Baltic Sea, and 4) series of radiative transfer modeling to simulate the field conditions. Laboratory measurements included temperature-dependent density and viscosity, absorption coefficient, and refractive index of pure oils, as well as droplet size distributions of dispersed oils. The results were applied in Lorenz-Mie modeling to obtain the IOPs of dispersed oils, which next served as inputs to the radiative transfer model. The main field experiment was conducted from the *r/vOceania* in the coastal zone of the southern Baltic Sea. Remote sensing reflectance was measured in a specially designed floating transparent tank with a volume of about 1 m^3. Three types of oil were dispersed in our experiment tank: crude, biodiesel, and mineral in five consecutive concentrations, from 1 ppm to 15 ppm, the concentration range permitted for the effluent and drainage of vessels under the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). As a result we observed, that all oil types noticeably increased the water-leaving radiance. Maximal increase of the remote sensing reflectance R_{rs} varied from about 40% for lubricant oil Cyliten N460 droplets to over three-fold for biodiesel BIO-100 droplets. The effect depended on oil type and on natural seawater composition. Additionally, we evaluated the impact of dispersed oils on R_{rs} band ratios that are commonly used in ocean color and other bio-optical models. Some “blue-to-green” ratios increased by up to 40%, while other ratios specific for each oil indicated over a 50% increase.

Abstract ID: 224

Measuring biological effects as a tool in linking biodiversity loss and chemical contamination in the Baltic Sea

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Biodiversity loss is one of the main threats to the stability of the Earth system. It is driven by several factors within the framework of planetary boundaries, with “novel entities” – particularly chemical pollution – playing a major role. Research linking biodiversity loss to chemical pollution has, however, been limited in comparison with other pressures such as climate change, habitat loss, overexploitation and invasive species. Despite the complexities arising from interconnections between pollution and these other drivers, it is becoming increasingly clear that greater attention is needed to address this issue.

One specific concern regarding chemical contamination is the dramatic rise in the number of different synthetic chemicals in the environment. While various environmental protection measures and regulations have helped to reduce the concentrations of hazardous or potentially harmful chemicals in some regions, the overwhelming diversity of substances currently in the environment poses a unique challenge. Many of these chemicals are present at levels below defined environmental threshold values, but their cumulative effects, particularly in mixtures, remain poorly understood. Recent research has highlighted that assessing the toxicity of chemical mixtures in the environment is best approached through biological effects measurements, utilizing biomarkers that reflect changes in biological functions at molecular to individual levels.

The current presentation covers issues related to the use of biological effects measurement methodologies and their potential in investigating the role of biodiversity loss, with an emphasis on the Baltic Sea marine environment but also from a more general perspective, including some previous research. It also introduces the ongoing project “New approaches in determining the impacts of chemical pollution to protect the biodiversity of the Baltic Sea” (Detect2Protect), funded by BIODIVERSA+ with co-funding from national agencies and partner institutions.

Thematic Session: Exploitation of Ecosystem Services and Its Impact on the Baltic Sea Ecosystem

Abstract ID: 17

Ecology of beach wrack at the Baltic Sea coast and its economic utilization

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Beach wrack, defined as any material washed ashore by wind and waves, is a common problem at the Baltic Sea coast. In order to gain knowledge on its ecology, amount and seasonality were monitored and decay characteristics investigated, both, at the beach and in the water.

It turned out that beach wrack underlies a strong seasonality with respect to composition and amounts but also a strong weather dependency. On the German Baltic Sea coast shares of algae were subject to seasonal changes. Red algae had main shares with 14.3 % whereas brown (5.6 %) and green algae (7 %) had similar amounts. Seagrass (*Zostera marina*) dominated the beach wrack with over 73 % throughout the year. The overall amounts were the highest with 0.96 kg m^{-2} dw during summer, followed by autumn with 0.74 kg m^{-2} dw. Beach wrack landings reached highest amounts after storm events. In order to evaluate decay times of beach wrack, litterbag experiments were performed in and outside the water. On average, beach wrack in the water had a decay time of around 140 days when decay started in summer and over 210 days when decay started in winter. Beach wrack was not fully disintegrated after 365 days at land.

Additionally, beach wrack was tested for commercial use in an earlier project. In case studies in cooperation with economy aspects of beach wrack utilization were studied. For example, the usage as an additive to fertilizer, its role in carbonizing and the exploitation in biogas production were tested. Another idea for the utilization of beach wrack in circular economy derived within the Novafoodies project: Here, the first experiments and insights on the use of beach wrack as feed for marine invertebrates are presented. Gammarids (*Gammarus locusta* and *G. oceanicus*) are utilized after initial experiments to convert macrophyte biomass from beach wrack into animal biomass that is intended to be used as substitute for fish meal in fish feed for aquacultures.

Abstract ID: 60

Wakes from offshore wind farms reduce vertical mixing within a model of the Baltic Sea

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At present, offshore wind farms in the Baltic Sea are mostly limited to the southern Baltic and the Danish Straits. However substantial development throughout the Baltic is envisaged as part of the transition towards renewable energy networks, with wind farms planned as far north as the seasonally ice-covered Gulf of Bothnia.

Studies in the North Sea have already 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 with regards to oxygen availability – so that even small changes in environmental conditions could drive large ecosystem changes.

In this study we focus on the impact of turbine-induced wind wakes on ocean physics. We calculate these wakes by applying the PyWake python package to wind fields from the Copernicus Regional Reanalysis for Europe (CERRA), using the planned wind farm distribution in the Baltic Sea from the European Marine Observation and Data Network (EMODnet) database as an input. We then use the original CERRA wind fields and the PyWake-adjusted fields to run parallel simulations with the Nucleus for European Modelling of the Ocean (NEMO), over a ten-year period covering the years from 2010 to 2020.

Comparing the two sets of simulations allows us to show both localized and basin-scale changes in energy fluxes, mixing, and upper ocean properties. We find that although there is considerable year-to-year variability, robust signals emerge from the ten-year ensemble. The turbines reduce the wind work and buoyancy forcing in the wakes throughout the year, allowing shallow mixed layers to persist for longer during the summer. We hypothesize that the increased vertical stability in the vicinity of wind farms could promote stronger marine heatwaves, and more intense phytoplankton blooms.

Abstract ID: 86

Exploring the Prospects for a Shared Vision of Offshore Wind Energy at the Finnish National Level

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Interest in developing offshore wind is rapidly increasing but remains in its early stages in many countries. The aim of this paper is to understand the role (if any) that offshore wind may play in achieving Finland's 2035 carbon neutrality goal. We present a co-created vision of offshore wind, and the process of co-creation resulted in a shared vision, rather than multiple visions or a collective of partly opposing ideas. The results reveal five required pre-conditions to be satisfied before the vision can be attained, and five overarching processes encompassing concrete solutions to transition from the current state to the vision. The combined preconditions and processes describe a future where 1) the positive externalities of development must outweigh the negative externalities, and 2) a clear and reliable governance and political framework supporting renewable energy development, and 3) an availability of skilled labour from attracting international talent and developing education and training programmes to teach the next generation, and 4) development of a sustainable private sector, that provides local community opportunities, through innovation, investment and research in relevant technologies, and 5) development of a diverse and resilient energy system that contributes to national energy safety.

Abstract ID: 111

Impact of climate change on ecosystem services in the northeastern Baltic Sea

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The Baltic Sea is one of the marine areas most affected by climate change worldwide. Eutrophication and strong anthropogenic impact accelerate local changes and pose a challenge to marine life and human societies alike. Ecosystem services act as an informative link between humans and natural ecosystems. In order to evaluate possible negative outcomes, model projections serve as a valuable tool.

We will provide an overview of the most likely climate-driven changes in the local marine environment and their effects on the ecosystem services of the northeastern Baltic coast. The services are classified and quantified based on the Common International Classification of Ecosystem Services (CICES) framework. The impact of climate change on the bio-physical state of the focus area is assessed using the coupled model system GETM-ERGOM, driven by the downscaled IPCC future climate projection under scenario SSP2-4.5. The model output is used directly and indirectly to assess the quantitative change of a selected set of Baltic Sea ecosystem services in the future. We provide a map of focus area ecosystem services, their future status, determine key risk areas for different categories.

Our results indicate that the regulating and provisioning services are mostly negatively affected by climate change. Keeping the integrity and availability of these services forms the basis for mitigating the impact and adapting to changes in the environment. Changes in certain cultural ecosystem services, however, could also have a positive impact on human societies, e.g. elongated bathing season (tourism sector) and increased marine heat capacity (green energy sector) can be expected in a warmer climate.

Our results and analysis serve as a possible tool for decision makers around the Baltic Sea, from local to international scales.

Abstract ID: 205

SeaHeat: Baltic Sea's thermal energy potential

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The Baltic Sea presents a unique environment for thermal energy usage through heat pumps, an opportunity that has yet to be extensively explored. Its distinct characteristics, such as a strong vertical stratification dominated by salinity and relatively shallow depth, create a setting where, despite cold winters, the water beneath the halocline remains relatively warm. Identifying areas where temperatures remain sufficiently warm is the first step in utilising this resource for energy production. During winter, with water temperatures between 2-5 °C, the water flows required for viable power plants would be comparable to those of small rivers, necessitating a thorough assessment of the environmental impacts of both extracting warm water and the outflow of cooler water.

We will present the first results of a project SeaHeat in which we have used the existing Baltic Sea reanalysis from Copernicus Marine Services as well as scenario runs (RCP 4.5 and RCP 8.5) up to year 2100 to identify potential areas were seaheat could be reliable source of energy currently and in future decades. The methods of assessing the outflowing waters' impact area is also discussed. The results of the SeaHeat project can be applied both when assessing the heating, as well as cooling applications throughout the Baltic Sea shores.

The datasets developed are connected into a tool designed for end-users considering the implementation of sea-heat power plants. This tool provides a preliminary assessment of both the opportunities and risks associated with specific sites, offering a crucial first step in the decision-making process for potential sea-heat energy projects.

Abstract ID: 221

Research vessels and marine laboratories in the ecosystem service chain: recent policies and debates in the Baltic Sea region

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The proposed contribution discusses the role of long-term field research in reformulating chains of marine ecosystem services. With the recent ecopolitical tensions in the Baltic Sea region, arguments about marine policy and biodiversity are being radically reformulated. Both the militarisation of the area and the initiation of new renewable energy programmes reshape the existing patterns of ecosystem use. The crisis provides both opportunities and threads for Baltic biodiversity and eco-politics agenda. It also brings to the surface several unexpected political alliances and hitherto overlooked capacities. In this respect, a reliable and long-term activities underpinned by science become particularly relevant.

The proposed contribution focuses on research vessels operating in the Baltic Sea and neighbouring regions. It aims to critically assess current science funding policies by considering how the maintenance of micro-fleets in operation affects the balance of arguments in eco-political debates. To formulate a holistic insight into the impacts of long-term marine research engagement, I use the results of participatory observation conducted during the r/v Oceania AREX cruise in the summer of 2024. In order to reveal the changing points of view on ecosystem service chains, I refer to further analysis of media feeds in Poland, followed along the debates in 2024/2025.

The proposed study aims to provide arguments for effective management of frameworks that mitigate negative impacts on ecosystem services. The basis for the presented evaluation is derived from the legacy of a strong programme in the sociology of science (Hacking 1992, Latour 1983). It allows the assertion that operational fleets and active laboratories pursue more than neatly planned research projects. Each laboratory and research vessel, in addition to processing data and collecting samples, produces a range of know-how, site-specific techniques and social relations that accumulate in the form of unique expertise (Hutchins 1995). This practice-based expertise, I would claim, is of unprecedented value for the far-sighted management of ecosystem services and their politics in a state of crisis. Selected points on this expertise are therefore proposed to be voiced by policy advisors and research communities sharing their views on ecosystem service management.

References:

Hacking, Ian. "The self-vindication of the laboratory sciences." Science as practice and culture 30 (1992).
Hutchins, Edwin. Cognition in the Wild. MIT press, 1995.
Latour, Bruno. "Give me a laboratory and I will raise the world." Science observed: Perspectives on the social study of science (1983): 141-170.

Thematic Session: Emerging Technologies for Research and Monitoring

Abstract ID: 10

Micropollutants from Wastewater Treatment: Assessment of Environmental Risks in the Baltic Sea Region (APRIORA)

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In October 2022, the European Commission proposed an amendment to the 1991 Urban Wastewater Treatment Directive (UWWTD), marking a pivotal component of the EU action plan for pollution reduction and a circular economy. The updated directive introduces stricter nitrogen and phosphorus emission limits for wastewater treatment plants (WWTPs) serving populations exceeding 150,000 population equivalents (PE) by 2039 and those exceeding 10,000 PE by 2045.

Additionally, the directive mandates the implementation of a fourth treatment stage aimed at reducing micropollutant emissions in all WWTPs exceeding 150,000 PE by 2045. For smaller agglomerations exceeding 10,000 PE, the fourth treatment stage will be required only if environmental or public health risks are identified.

Environmental Protection Agencies (EPAs), in cooperation with wastewater treatment operators, will be responsible for conducting risk assessments (RAs) and developing appropriate mitigation measures. However, both stakeholder groups face a significant challenge due to insufficient data on micropollutant emissions and the lack of robust tools for consistent risk assessments and evaluation of mitigation strategies.

The primary objective of the APRIORA project is to develop and implement effective water resource management systems based on comprehensive monitoring, modeling, and multi-criteria assessment of environmental and public health risks. By employing an evidence-based risk assessment framework, the implementation of the fourth treatment stage can be targeted specifically to regions where it is genuinely necessary.

Funding: The APRIORA project is funded under the INTERREG Baltic Sea Region program for 2021–2027. Project partners include Rostock University (project lead) and the German Environment Agency (Germany), the Finnish Environment Institute and the Centre for Economic Development, Transport, and the Environment in South Ostrobothnia (Finland), the Latvian Institute of Aquatic Ecology and the Latvian Environment, Geology, and Meteorology Centre (Latvia), Kristianstad University (Sweden), and Gdańsk University of Technology (Poland).

Abstract ID: 20

Predictive Modelling of Benthic Habitats in the Polish Marine Areas

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This study presents the key findings of the large national project titled "Mapping benthic habitats of Polish Marine Areas (PMA) using the mosaic sonar method," initiated by the Chief Inspectorate of Environmental Protection, within the framework of the State Environmental Monitoring and financed by the Polish national budget. The project aimed to conduct the first high-resolution survey of PMA using side-scan sonar (SSS) and multibeam echosounders (MBES). The primary goal was to map all benthic habitats, fulfilling the obligations of the EU Marine Strategy Framework Directive (Directive 2008/56/EC).

The concept of predictive modelling of benthic habitats defines a habitat as a combination of environmental features, known as descriptors. For the Baltic Sea area, at the EUNIS level 3, the following descriptors were identified: biological zone, energy zone, salinity level, and sediment type. This study aimed to develop benthic habitat maps at the EUNIS level 5, requiring the creation of an additional descriptor for dominant habitats. Detailed modelling also involved refining the sediment descriptor and integrating all descriptors for the PMA obtaining comprehensive information on EUNIS 5 habitats.

Underwater acoustic data (from MBES and SSS) and ground-truth information from sediment and benthic samples were used to determine sediment and dominant species habitat descriptors. The bathymetric data were unified to generate an overall model for the entire PMA area in a resolution of 2 x 2 m. MBES backscatter and SSS data for high-confidence areas were also integrated and exported. These datasets were used to train a predictive model of benthic habitats, consisting data from all ground-truth sources in the PMA area. Bathymetry was utilised creating geomorphometric parameters of the seabed.

Supervised classification of the seabed was conducted using the Random Forest algorithm, with 1000 samples used for training and 427 for validation. Object-Based Image Analysis was employed for habitat delimitation, recommended for high-resolution spatial data. The highest accuracy predictive model was selected. The resulting sediment and dominant species habitat descriptors were integrated with biological zone, energy zone, and salinity descriptors provided by EMODnet. This task produced a predictive map of benthic habitats at EUNIS levels 3/4/5.

For high-confidence areas, predictions from a pre-trained model were used, adapted to high-confidence spatial data at the original resolution. Modelling was performed in separate research sheets, and descriptor integration was repeated for all sheets. The final map for the entire PMA area was created by integrating high-confidence model data with the overall model for PMA.

Abstract ID: 22

A Neural Network Approach to Eutrophication Assessment in the Baltic Sea

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Eutrophication poses a significant threat to the Baltic Sea, leading to algal blooms, oxygen depletion, and biodiversity loss. Traditional assessment methods often oversimplify the complex interplay of factors driving this process. This study explores the potential of artificial neural networks (ANNs) to predict the eutrophication status using the novel Trophic Transfer Index (TTI) and standard environmental data spanning the last 70 years. The TTI, which assesses the consistency of the carbon transfer efficiency between phytoplankton and zooplankton, offers a more holistic measure of ecosystem health than traditional indicators.

We trained a feedforward neural network using both simulated and measured data from the Baltic Sea, including nutrient concentrations, chlorophyll-a, oxygen levels, and physical parameters such as temperature, salinity, and depth. The model demonstrated high accuracy in predicting both TTI and Good Environmental Status (GES) as derived from high TTI values, exceeding 90% accuracy in GES classification. Notably, the inclusion of physical variables improved the model's performance, highlighting the importance of considering physical processes in eutrophication dynamics.

The predicted TTI and GES maps revealed distinct spatial and temporal patterns, including a regime shift around 1990, particularly in the deeper waters of the Central Baltic Sea, suggesting an abrupt worsening of the eutrophication status. This shift coincided with increased nutrient loading and changes in the physical environment, along with significant changes in the food web, including a decline in fish stocks. Our assessment reveals a similar temporal decline in GES regions to that observed with the well-known HEAT and TRIX indicators, but with a key distinction: our approach reveals an abrupt shift in GES following the regime change, a feature not apparent in traditional assessments. The study demonstrates the potential of ANNs as a tool for eutrophication assessment, offering advantages over traditional methods by capturing complex relationships and incorporating multiple environmental variables. This approach can aid in identifying vulnerable areas, evaluating management strategies, and contributing to the protection of the Baltic Sea ecosystem.

Abstract ID: 32

Advancing downwelling observations in the Baltic Sea using in-situ monitoring measurements

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Upwelling and downwelling are common phenomena in the Baltic Sea, significantly altering the thermal balance and surface and deep water conditions, influencing biological activity. While upwelling has been extensively studied using remote sensing and modelling, downwelling remains poorly documented, partly due to the challenges of direct measurements. However, understanding and predicting downwelling events is crucial for assessing their impact on biological processes and particle dynamics. This study presents novel in-situ observations of a coastal downwelling event using a benthic lander, complemented by vertical profile measurements.

A 41-day deployment (August–September 2024) was conducted in the South Coast of Finland, where a benthic lander recorded flow velocity and particle concentration throughout the bottom meter of the water column, along with salinity, temperature, and oxygen and chlorophyll concentrations. Data was collected at high temporal resolution, with instruments recording every 6 hours or more frequently. These benthic lander measurements were supplemented by nutrient sampling and full-depth vertical profiles of temperature and oxygen concentrations.

Under typical conditions, we measured a weak downward flow and low horizontal velocities (mean of 2 cm s-1), with minimal particle concentrations. Chlorophyll concentrations were low (<0.08 RFU), and oxygen concentration remained stable at approximately 190 µmol L-1. However, in September 2024, a distinct downwelling event was detected with the benthic lander measurements, as evidenced by temperature, salinity, oxygen, and velocity data, and further validated by the complementary vertical temperature profile measurements. This downwelling event was found to induce a meaningful increase in flow velocity (up to 7 cm s-1) and particle concentration. Additionally, both chlorophyll and oxygen showed an increase in the benthic layer, alongside notable variations in nutrient concentrations, such as nitrate. These changes, within an otherwise stable benthic environment, suggest potential impact on biogeochemical cycles and ecosystem functioning. The influx of warmer, nutrient-rich surface water to the seafloor may enhance oxygen consumption and greenhouse gas production.

The study highlights the potential of benthic landers as versatile tools for monitoring coastal oceanographic processes. Their adaptability and high-resolution capabilities make them ideal for integrated frameworks exploring the interplay between wind forcing, coastal circulation, particle transport, and nutrient fluxes. Understanding these processes is crucial in the context of climate change, where changes in wind patterns may modify upwelling and downwelling frequency and intensity, with cascading ecological consequences. Furthermore, the collected data can support and refine modelling efforts, including preliminary assessments of a wind-driven upwelling index to improve predictive capabilities.

Abstract ID: 37

Argo Floats at the Southern Baltic Sea – From Case Studies to Monitoring

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The Baltic Sea, a region characterized by complex hydrographic conditions and significant anthropogenic pressures, requires innovative approaches to monitor its dynamic ecosystem. Argo floats, autonomous profiling instruments traditionally used in open ocean research, have been adapted to the specific challenges of the Baltic Sea.

Finnish oceanographers deployed the first Argo floats in the Baltic Sea in 2012. Polish oceanographers, working within the Euro-Argo ERIC program, launched their first floats in 2016. The Baltic Sea's shallow depth, strong horizontal and vertical gradients in water properties, heavy ship traffic and intense fishing activity made these experimental deployments high-risk. However, despite initial challenges, Argo floats have proven effective in the Baltic Sea. This success required adjustments to float settings and even a shift in their operational philosophy. Shorter profiling cycles were introduced, and a "bottom parking" method was implemented to minimize float drift.

Over nine years of operations in the Baltic Sea, more than 8000 CTD profiles have been obtained by Argo-Poland. Most floats are equipped with oxygen sensors, resulting in more than 4000 dissolved oxygen profiles. In 2023, the first Polish biogeochemical float was deployed and has been continuously operating in the Gdansk Deep. The autonomous operation of Argo floats offers a cost-effective and reliable solution for continuous monitoring in this challenging environment. The small size of the Baltic Sea also allows for floats to be recovered, serviced, and their batteries replaced. These activities are in line with the new paradigm of using the Argo network, as set out in the OneArgo project.

Data from Argo and other observational platforms, such as research vessels, satellites, and gliders, can be used to create a comprehensive monitoring network. Large datasets helps to develop predictive models, supporting ecosystem management and decision-making.

A key strength of the Argo initiative in the Baltic Sea is its emphasis on international collaboration. By contributing to the global Argo network and European infrastructure Euro-Argo ERIC, the program may enhance the accuracy and reliability of monitoring in the Baltic Sea. Oceanographers from Germany and Denmark have also joined the effort, deploying Argo floats in the Baltic Sea.

This collaborative effort demonstrates the potential of Argo floats to understand the Baltic Sea. From case studies to long-term monitoring, Argo floats have proven to be a versatile tool for environmental research. The program highlights the importance of investing in innovative technologies to support sustainable management of the marine ecosystem.

Abstract ID: 48

Sea Surface Current Fields Prediction with a Surrogate Deep Learning Model Using CNN-UNET: A Case Study of the Gulf of Riga

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The precise forecasting of sea surface currents is essential for operational oceanography. Conventional high-resolution hydrodynamic models, provide detailed short-term forecasts; however, they are computationally intensive and resource-demanding. To overcome these challenges, we introduce sciCUN, a deep learning surrogate model that partially emulates hydrodynamic predictive processes for *s*urface *c*urrent *i*nference, utilizing a *C*NN-*U*-*N*et architecture.

sciCUN predicts daily high-resolution zonal and meridional sea surface current velocity fields using background sea surface currents fields and five key atmospheric variables: zonal and meridional wind components, mean sea level pressure, air temperature, and dew point temperature. As a case study, we applied sciCUN to the Gulf of Riga, training the model on 27 years (1993–2019) of high-resolution sea surface current data from the Copernicus Marine Service Baltic Sea Physics Reanalysis and atmospheric forcing data from ECMWF Reanalysis v5 (ERA5). The model learns the influence of atmospheric forcing fields at time step *t+1* on background sea surface currents at time step *t*, enabling robust next-day predictions of sea surface current fields at *t+1*.

A 4-year testing period (2020–2023) validated its daily predictions effectiveness. Results demonstrate that sciCUN delivers strong predictive performance, achieving an average component-wise mean absolute error (MAE) of 1.45 cm/s and a correlation coefficient of 0.92. The average Euclidean distance between predicted and reference data was 2.30 cm/s. While accuracy was slightly lower in complex coastal regions such as river mouths and the Irbe Strait—where hydrodynamic models typically depend on boundary conditions—the model's overall performance remained impressive.

sciCUN provides an efficient computational framework for ocean modeling, offering rapid and scalable predictions that approach the accuracy of traditional hydrodynamic models. This approach has the potential to significantly advance operational oceanography by enabling real-time applications such as marine navigation, oil spill tracking, and environmental monitoring. Additionally, sciCUN can improve data preprocessing for models that rely on ocean current inputs, such as wave simulations, or aiding in data assimilation.

Abstract ID: 54

Sea level maps obtained by fast processing of observations, based on big data patterns from models

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Emerging oceanographic applications require fast-track seamless data maps with minimum delay from the time of actual measurements. Sea level data are exchanged within BOOS (Baltic Operational Oceanographic System) over the entire Baltic Sea at hourly intervals. Good realism can be obtained using big data pattern extraction techniques from the Copernicus Marine Service (CMEMS).

We calculated the gridded maps E(x,y) of sea level using optimal superposition of precalculated statistically justified patterns Fk(x,y) where k is a sequence number of the pattern. Then the maps are calculated E(x,y) = sumk (Ak * Fk(x,y)) where the weight coefficients Ak are determined by least-squares minimization of the observation to reconstruction difference at observation locations (xi,yi).

In our specific Baltic Sea implementation, spatiotemporal statistics were calculated from the CMEMS operational hourly forecast with a resolution of 1 nautical mile. Averaging was done over different time steps of modeled maps. As the basic statistical pattern approach, EOF eigenvectors Fk(x,y) and eigenvalues were calculated. We also used patterns calculated using k-means cluster analysis. Then different patterns Fk(x,y) were found as the centroids of the identified clusters, iteratively refined by minimizing the within-cluster sum of squared differences to represent characteristic patterns.

For the diagnosis's input data, we used hourly sea level observations from 80 stations around the Baltic, of which 75 were selected for good coverage in 2024. Regarding the datum, mean model results were used as a reference for 2D reconstruction. At the coastal observation points, the mean observational values were reconverted.

Comparison with observed time series at coastal points revealed that diagnosis (based on observations !!!) is closer to the observations than the model forecast. Using patterns from EOF analysis and k-means clustering gives similarly good diagnosis performance: R2 > 0.95, cRMSE < 0.04 m. With the selected set of parameters (10 different patterns of Fk(x,y)), however, the EOF method gave slightly better results. Problem points were found on small islands (Dragor, Kronstadt) and small and narrow elongated bays (Juten, Stockholm).

Options for further developments:
- practical use of sea level maps with hourly updates for extreme situations;
- detailed sea level patterns for smaller target areas;
- online finding and eliminating of wrong data, imputation of missing observations;
- spatial forecast correction during post-processing, as an extension to the present point-wise correction;
- using reconstructed maps in data assimilation;
- extending pointwise HIDRA2 forecasts over 2D sea areas.

Abstract ID: 74

Advanced Model-Based Tools for Monitoring and Forecasting Biochemical Conditions in the Southern Baltic Sea

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This study presents newly developed computational tools designed for the monitoring and forecasting of biochemical conditions in the Southern Baltic Sea based on model-generated data. These tools are integrated within the three-dimensional ecohydrodynamic model CEMBS-PolSea, which combines hydrodynamic and biogeochemical components to provide a comprehensive simulation of the marine environment.

The biogeochemical module of the model represents key ecosystem parameters, including phytoplankton and zooplankton biomass, living and detrital organic matter, chlorophyll-a concentration, dissolved oxygen (O_2), and major chemical compounds such as nitrates (NO_3), phosphates (PO_4), and silicates (SiO_3). The implementation of these environmental variables is governed by the definition of source and sink functions within a second-order partial differential equation that describes turbulent diffusion with an advective term. This equation serves as the interface between the hydrodynamic and biogeochemical components, ensuring a realistic representation of ecosystem dynamics.

A major innovation of this study is the development of novel tools that enhance research capabilities in spatial analysis and predictive modeling. These include a habitat identification tool, which enables users to locate regions that meet specific hydrodynamic, physicochemical, and biological conditions based on numerical simulation outputs. Additionally, a particle trajectory tracking tool has been developed to simulate the transport of passive particles within the surface layer under varying hydrodynamic conditions. By leveraging numerical forecasts, this tool provides estimates of key transport metrics, including maximum displacement range, transit time, and predicted final location based on initial positions. These tools are designed for operational use and will be made available to end-users in an open-access format.

The integration of these technologies will significantly enhance the understanding of the spatiotemporal dynamics of marine ecosystems, particularly in coastal regions. By combining biogeochemical and hydrodynamic modeling within the CEMBS-PolSea framework, the system improves predictive capabilities and facilitates environmental analysis, thereby supporting both scientific research and environmental management efforts. Ultimately, the developed tools constitute a robust decision-support system that contributes to a more comprehensive understanding of the Southern Baltic Sea ecosystem.

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Abstract ID: 78

Silent Observers: Advancing underwater acoustic monitoring in the Baltic Sea using coastal gliders

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Coastal gliders equipped with Passive Acoustic Monitoring (PAM) systems offer a cost-effective, and non-invasive solution for studying underwater soundscapes and monitoring noise pollution. Their silent, buoyancy-driven nature allows for long-term deployments, collecting both acoustic and environmental data crucial for understanding sound propagation and its ecological impacts. Moreover, their versatility and autonomous operation make them valuable tools for continuous and remote monitoring in challenging marine environments. From our records, they have, however, never been used for PAM applications in the Baltic Sea.

This study evaluates the effectiveness of gliders for PAM applications through two deployments in the Baltic Sea (spring and summer 2024). Recordings were collected in a shallow coastal area (Tvärminne, May 2024) and a deep open-water region (Utö, June 2024) to assess how local bathymetry and thermocline influence sound transmission. Descent and ascent phases, comprising 72–80% of mission time, were identified as optimal for acoustic recording, while surface maneuvers generated self-noise, were considered as unsuitable for PAM purposes and removed from the analysis.

Our preliminary results confirm that, by optimizing deployment strategies (such as minimizing surface time and excluding noisy events), PAM-equipped gliders can efficiently detect specific acoustic signals, such as relatively high frequency pingers (in this study from 34 to 76kHz), even in highly stratified environments like the Baltic Sea. However, depth, orientation of the glider, and variations of the thermocline introduce significant signal variability, highlighting the need for further refinement of acoustic propagation models and analytical approaches to account for such complexities.

This study underscores the potential of coastal gliders as a transformative tool for advancing passive acoustic monitoring of underwater soundscapes in shallow stratified waters and contributes to assessing the impacts of underwater noise pollution, for example by monitoring ship traffic. It also demonstrates the utility of gliders integrated with acoustic sensors as a promising platform collecting data with the potential to assist fisheries stock managers, providing regional feedback about fish population, and likely their habitat.

Abstract ID: 83

Shedding light on phytoplankton monitoring in the Baltic Sea

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The Baltic Sea, with its strong salinity gradient, large areas of anoxic bottom water and intensive anthropogenic use, is characterised in large parts of its biosphere by low biodiversity, both naturally and due to anthropogenic pressures. Changing climate and increased frequency of extreme events exert further pressure on this delicate ecosystem, leading to changes in phenology of phytoplankton communities and mismatches in food web interactions, with unclear consequences for trophic transfer and uncertainty about its future stability. In response to this challenge, the Leibniz Institute for Baltic Sea Research Warnemünde and the Federal Maritime and Hydrographic Agency are developing an interdisciplinary research concept to enhance ecosystem monitoring in the western Baltic Sea. The concept builds on traditional biological monitoring techniques and established programmes and integrates hyperspectral in situ and remotely sensed observations with bio-optical water quality modelling, data on phytoplankton functional types, organismal data from eDNA and lipid biomarkers for phytoplankton biomass for different ecological applications within the Baltic Sea. Our focus is on workflows which leverage reflectance-based approaches to develop indicators of change in phytoplankton biodiversity in response to climate change as well as anthropogenic influences (e.g., eutrophication, marine heatwaves) by empirically associating diagnostic reflectance features to the taxonomic and functional composition of phytoplankton assemblages. By including biogeochemical proxy records from past climate periods in our analysis, we aim to connect across different temporal and spatial scales, and look to unravel drivers of past changes and how these may inform present and future changes. In a first step towards achieving these goals, we present a case study in the western Pomeranian region of the Baltic Sea, which prototypes a workflow integrating Copernicus Sentinel-2 and Sentinel-3 water quality products, hyperspectral in situ optical measurements, and bio-optical water quality modelling. We evaluate the fitness for purpose of the Copernicus products in German coastal waters and their suitability for monitoring purposes, and propose a sampling programme for satellite product validation. The aim is to establish a holistic ecosystem observing system, which optimizes the use of existing data with new satellite data sources and provides a framework towards operationalising indicators for management directly relevant for implementing, e.g. the Marine Strategy Framework Directive (MSFD) and the HELCOM Baltic Sea Action Plan. This is a big step towards rapid detection of biodiversity changes in phytoplankton communities, including emerging invasive species and harmful algae blooms.

Abstract ID: 90

Application of SMOS SSS L4 data to improve the understanding of the salinity dynamics and circulation of the Baltic Sea

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The Baltic Sea is a semi-enclosed shelf sea and characterized by its distinct geographical and oceanographic features. One of the Baltic's most remarkable features is its surface salinity gradient that is horizontally decreasing from the saline North Sea to the near fresh Bothnian Sea in the north, and Gulf of Finland in the east. Additionally, a vertical gradient and strong stratification separate between less saline surface water and deep saline water. These salinity features are mainly driven by a combination of river runoff, net precipitation, wind conditions, and geographic features that lead to restricted and irregular inflow of saltwater into the Baltic and limited mixing. The overall positive freshwater balance causes the Baltic to be much fresher compared to fully marine ocean waters with a mean salinity of only about 7 g/kg. The Baltic Sea is particularly sensitive to climate change and global warming due to its shallowness, small volume and limited exchange with the world oceans. Consequently, it is changing more rapidly than other regions. Recent changes in salinity are less clear due to a high variability but overall surface salinity seems to decrease with a simultaneous increase in the deeper water layers. Furthermore. the overall salinity distribution is indirectly linked to the general circulation of the Baltic Sea which consists mainly of cyclonic circulation cells comprising the main sub-basins of the Baltic Sea. Thus, improving the understanding of the salinity dynamics ultimately leads to a better understanding of the circulation in the Baltic Sea.

Within the project 4DBALTDYN highly spatially resolved SMOS SSS (Sea Surface Salinity) satellite data will be combined with in situ observational data and numerical modeling to improve our understanding of the salinity dynamics of the Baltic Sea. SMOS SSS data (2011-2019) provide a continuous monitoring of the evolution of the surface salinity of the entire area of the Baltic Sea.

Abstract ID: 92

Cod (*Gadus morhua*) otoliths reveal unexpected patterns of boron in the Baltic Sea

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Seawater boron is positively correlated with salinity, but its dynamics in living animals is poorly described in the Baltic Sea. Here we focus on populations of Atlantic cod in the Baltic. We quantified boron concentrations (as B:Ca) in cod and other fish otoliths. Otoliths are calcium carbonate structures that form part of fishes' hearing and balance systems. They grow incrementally and provide lifetime chemical signatures that can be related to fish exposure to hypoxia, changes in salinity, temperature, and migration. Previously we detected a significant decline in otolith boron amongst cod populations in the Baltic Proper (Limburg et al. 2023, Biogeosciences 20: 4751–4760). This was inversely correlated with salinity and alkalinity, contrasting with expectations. More recently, we have discovered an unusual group of cod that not only grows better than other populations, but also has 30-300 times more boron in their otoliths. This group appears to be associated with the region around Åland. Elevated B in the Åland Sea is unexpected due to its low salinity. Indeed, otoliths of large cod caught closer to Sweden in the Åland Sea lack this marker. We are currently delineating the extent of the marker by identifying where fish have been caught. We do not know the ultimate source of the boron marker.

Abstract ID: 110

Introduction of an Agile Underwater Communication Network for the Use in the Baltic Sea

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The Baltic Sea, as a semi-enclosed marginal sea, is of significant scientific interest in the fields of marine research, offshore wind energy, and critical infrastructure. Its unique hydrographic and geomorphological characteristics—including shallow depths, low salinity, strong stratification, and limited water exchange with the North Sea—create a dynamic and sensitive environment that influences both natural processes and human activities. These conditions require the adaptation of marine research methodologies and the development of specialized underwater technologies to ensure sustainable resource utilization, environmental protection, and resilient infrastructure.

The research project OTC-Base2Swarm, funded by the German Federal Ministry of Education and Research (BMBF) as part of the Ocean Technology Campus Rostock, aims to establish a highly agile underwater communication network adaptable to diverse operational scenarios and environmental conditions. This network consists of both stationary communication nodes—serving as sensor platforms—and mobile agents such as gliders, autonomous underwater vehicles (AUVs), and autonomous surface vehicles (ASVs). Together, these components enable large-scale spatial and temporal monitoring of marine environments.

The stationary infrastructure comprises a central node equipped with various sensors and docking mechanisms for AUVs, gliders, and remotely operated vehicles (ROVs), as well as smaller communication nodes outfitted with environmental sensors and acoustic modems. These nodes create an interconnected underwater network, facilitating seamless data exchange. Within this network, autonomous and semi-autonomous agents, such as AUVs and Gliders dynamically integrate to perform adaptable measurement and monitoring tasks based on user-defined requirements.

This presentation will outline the design approach for such an underwater communication network, emphasizing preliminary research and future strategies to enhance system adaptability. Additionally, various use cases will be explored, demonstrating the potential applications of both the full-scale system and modular configurations with a reduced number of agents in the unique environment of the Baltic Sea.

Abstract ID: 115

Roboelf: A GPU-Accelerated Model for Efficient Uncertainty Quantification and Benthic Process Representation in Marine Biogeochemical Simulations

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We present “roboslave”, a new model implemented from scratch to help address challenges in biogeochemical (BGC) simulations through native GPU acceleration. This approach significantly reduces computational time and cost, enabling the generation of large model ensembles for the evaluation of structural and parametric uncertainties. A key feature of roboslave is the incorporation of a vertically-resolved early diagenetic module, which improves the representation of benthic processes critical for water quality in estuaries and marginal seas.

The methodology employs a combined Eulerian-Lagrangian advection scheme, in which tracer transport is resolved using precomputed Lagrangian particle trajectories. This approach eliminates the “CFL criterion”, which commonly slows down Eulerian models. Each grid cell on the seafloor is coupled to a sedimentary column, enabling explicit representation of benthic-pelagic matter exchange. The coupling through biodiffusion, bio-irrigation, sedimentation, and resuspension can be locally parameterized to represent differentiated sedimentary environments.

We demonstrate the performance and challenges of the approach using the example of a MOM6-ERGOM model for the Baltic Sea. We show why the computation of model ensembles benefits from our approach. Finally, we outline the next steps toward improved uncertainty propagation in marine BGC modeling.

Abstract ID: 124

Application of deep neural networks for identifying stock components of Baltic herring based on otoliths

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Accurate identification of fish stock components is essential for effective fisheries management, particularly in cases like Baltic herring, where genetic differences and environmental factors complicate fish classification. This study investigates the use of deep neural networks to differentiate stock components of Baltic herring based on otolith morphology.

Otolith samples were collected from herring in the southern Baltic during scientific surveys conducted between 2021 and 2024. The study focused on distinguishing the southern (CBSC) and northern (CBNC) components of the central Baltic herring stock—traditionally classified through expert examination of key biological otolith features. To enhance efficiency and reduce reliance on manual labor, an automated system was developed for sample collection, i.e., otolith imaging and object detection.

A ResNet-34 model was employed to classify herring otoliths using digital images. The model achieved relatively high classification accuracy, demonstrating strong performance in distinguishing the two stock components. Stable training and validation loss trends indicated good generalization, ensuring reliable predictions on unseen data. While classification was slightly more precise for one stock component, the overall results confirm the model's robustness in automated otolith classification.

To improve interpretability, the Grad-CAM technique was applied, revealing that the model primarily focused on biologically relevant otolith features, such as edge regions and specific structural characteristics. This suggests that the neural network successfully identifies key morphological traits distinguishing the two stock components.

Additionally, growth analysis using the von Bertalanffy model revealed significant differences in growth parameters between CBNC and CBSC, with CBNC exhibiting a slower growth rate. Age structure analysis further indicated that older individuals dominated CBNC compared to CBSC, another factor that may influence stock productivity. These findings emphasize the importance of distinguishing both components for accurate stock assessment and effective fisheries management.

Abstract ID: 126

Estimation of non-directional wave spectrum from Sentinel-1 SAR in the Baltic Sea

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Estimation of wave spectra in wind-wave-dominated coastal seas from Synthetic Aperture Radar (SAR) is challenging due to several factors, including the absence of a dedicated method, the lack of long swell waves, and lower-resolution SAR acquisitions. This work provides an overview of three machine learning approaches for estimating non-directional wave spectra from Sentinel-1 SAR in the Baltic Sea. Over 70,000 Sentinel-1 Interferometric Wide (IW) swath sub-images, paired with corresponding NORA3 WAM hindcast spectra, are processed and used to train various models.

The first approach explores a Long Short-Term Memory (LSTM) neural network. Despite the difficulties posed by short wind waves on SAR data, the LSTM model achieves frequency-to-frequency correlations exceeding 0.8 between 0.2 Hz and 0.4 Hz, with modest differences in peak frequency (0.13 Hz) and peak spectral value (0.38 m^2/Hz). The significant wave height (H_S) derived from the predicted spectra reaches a correlation of 0.78 and RMSD of 0.39 m—comparable to previous empirical methods—while the wave period (Tm_{02}) achieves a correlation of 0.72 and an RMSD of 0.52 s.

The second approach adapts the Transformer architecture, traditionally used in natural language processing, for purely numeric data. By modifying the tokenizer and encoder-decoder components, this technique is applied to estimate wave spectra in the Baltic Sea, yielding a mean correlation coefficient of 0.71 between true and predicted spectra. This result highlights the potential of Transformers for complex numeric prediction tasks beyond language modeling.

Finally, the third approach explores an array of statistical machine learning models—including linear and polynomial regression, regression trees, random forests, and shallow neural networks—to estimate the wave spectrum from Sentinel-1 SAR. Unlike LSTM and Transformer models, which predict the full 1D spectrum at once, these simpler models predict individual frequency components and then combine them into a full spectrum. The results indicate that boosted models and simple multilayer perceptrons deliver the highest accuracy, with correlation coefficients reaching 0.8 at certain frequencies. Bulk wave parameters derived from these predicted spectra, such as H_S and Tm_{02}, also show good accuracy and low errors ($r = 0.78$, RMSD < 0.5 m; $r = 0.63$, RMSD < 1 s, respectively).

Abstract ID: 140

Data-Driven Insights into Multi-sectoral Waterway Utilization in the Baltic Sea

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The Baltic Sea serves as a crucial maritime corridor for Finland, supporting national welfare, supply security, and sustainability objectives. However, increasing maritime traffic, emerging offshore infrastructure, and evolving environmental challenges necessitate a deeper understanding of how these waterways are utilized and how risks can be effectively managed. The WATERWAYS project aims to address these concerns by integrating data-driven methods, artificial intelligence (AI), and advanced risk analysis to enhance the safety, security, and sustainability of maritime activities in the Baltic Sea.

As part of the WATERWAYS team, we focus on multi-sectoral utilization of marine waterways, analyzing the interactions between different maritime sectors and their contributions to environmental sustainability. We apply deep learning models to extract meaningful insights from Automatic Identification System (AIS) and Geographic Information System (GIS) data. These methods allow us to identify patterns of maritime events and activities, detect high-risk areas, and predict peak usage times, facilitating better understanding of maritime operations and utilizations.

Additionally, we employ expert knowledge elicitation techniques to integrate insights from stakeholders across different maritime sectors, ensuring a comprehensive understanding of bottlenecks and inefficiencies in navigation systems. The results will contribute to enhance the coexistence of different maritime sectors.

The expected outcomes of this study include: 1. A detailed and visualized mapping of sectoral and stakeholder activities and events in the Baltic Sea region; and 2. Identification of maritime operations and activities that lead to critical risks such as high-accident zones and environmental pollution hotspots. By leveraging cutting-edge AI and data analytics, this research will provide scalable solutions for managing maritime usage not only in the Baltic Sea but also in other sensitive marine environments worldwide.

Abstract ID: 142

Exploring ocean events using continuous high resolution observations and interactive dashboard visualisations

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Our understanding of the oceans, and the Baltic Sea, is built through the combination of observations and models. Recent regional model intercomparison work showed differences in internal model dynamics for the Baltic Sea, leading to disparity in future projections of marine heatwaves intensity, upwelling events and thermal stratification. A deeper understanding of small scale dynamic processes (1 m – 1 km; hours to days) is critical to further improve internal model dynamics and parameterisations, requiring high resolution observations. Voice of the Ocean foundation maintains Ocean Observatories around the Baltic Sea, occupied by underwater gliders continuously (24 hours a day, 365 days a year) sampling at ~10 cm vertical resolution. All data are openly accessible through our Observations Portal and explored using the Glider Dashboard. This interactive tool is used to visualize the full time-series of data, capably loading over 200000 profiles from the observatories, stitching together individual glider missions. The interface enables the user to find relevant missions and observation parameters, visualize them as interlinked time-series, TS or profile diagrams and zoom in on events of interest. Here, we demonstrate the Glider Dashboard, locating ocean events including Storm Hans (August 2023), eddy and filament transport through the Bornholm Basin and chlorophyll blooms (surface, deep chlorophyll maximums and export to depth). We highlight the importance of continuous observations to capture these transient events and promote the Glider Dashboard to explore this openly accessible dataset.

Abstract ID: 158

Importance of improving tools and developing new techniques for better environmental assessment: a case study of infrared (IR) spectroscopy in marine science

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The constantly growing world population have an increased impact on the environment. Antropopression is a consequence of various activities, such as the marine transport, tourism or food economy. All human actions result in environmental changes and increase the need for ecological monitoring.

For marine environmental assessment, multiple methods are being used depending on the aim and object of the research. When considering fish surveys, biological studies (general condition, gender/age distribution, malformation, parasite infection), chemical analysis (fat content and composition, concentration of toxic substances in tissues) and genetic tests (species verification, gene distribution in environment) are sources of valuable data. The disadvantage of this approach is the fact that they require separate equipment, techniques and knowledge as well as different sample treatments. Also, some of these methods are time- and cost-consuming. Creating a new or improvement of an already existing tool providing results faster or enabling simultaneous analysis during one procedure is an object of interest. One of the possible solutions can be infrared spectroscopy.

Although the main concept of spectroscopy was defined over 100 years ago, modern technical solutions lead to modification including work with a specific wavelength (e.g. near, mid- or far infrared, visible radiation) and type of analyzed signal (absorption, emission, reflectance), offering a wide range of applications.

Current projects carried out in the National Marine Fisheries Research Institute in Gdynia are focused on different aspects of supporting sustainable living marine resource management through:

a) collecting information on the diet composition of Baltic fish as a part of monitoring changes in the trophic web in Polish fishing areas. The new approach could help with the precise identification of prey to the lowest possible taxonomic level b) identification of species being adulterated using edible and inedible body tissues. The research is based on previous pilot studies conducted with muscle lyophilisates and otoliths of Baltic herring to verify the population classification.

The applied technique is Fourier-transform infrared in near-infrared spectral range (FT-IR NIR spectroscopy) whereas biological and chemical data are obtained with standard reference method. The collected spectrometric spectra will be a part of spectra library for future tests and further adaptation of the method for environmental studies.

Funding: The project is funded from special-purpose subsidy of the Ministry of Agriculture and Rural Development Republic of Poland.

Abstract ID: 160

Cumulative impacts of off-shore wind farms on sea ice fields

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The expansion of offshore wind energy production into ice-prone regions necessitates advanced sea ice modeling to assess its impact on basin-wide ice conditions. This study examines the influence of wind farm developments on the sea ice field in the Gulf of Riga using a high-resolution finite element model (FEM) for local-scale analysis and a coupled ice-hydrodynamic model for basin-scale simulations.

Local-scale FEM simulations capture the interaction between a drifting level ice field and a monopile turbine. The initial collision creates an open ice channel, approximately equal in width to the monopile diameter, dividing the ice into two large floes. Subsequent perpendicular movement of the ice floes leads to channel closure, forming ridging and rafting structures. The resulting interaction forces serve as input for basin-scale modeling to assess broader ice-structure effects.

Basin-wide ice conditions are simulated using the NEMO-SI3 coupled model at sub-km resolution for the severe winter of 2010/2011 in the Gulf of Riga. Additional stress terms are incorporated into the SI3 ice model to account for wind farm resistance to drifting ice, calibrated using FEM-derived ice loads. Lagrangian analysis tracks deformed ice pathways, enabling quantification of cumulative channel length with deformed ice and characterizing wind farm impacts on the ice field per unit area.

While overall changes in ice extent and volume remain minor, wind farm structures significantly alter ice breakup patterns and lead formation. Changes in spatial deformation geometry lead to localized increases and decreases in total ice days. Compared to a reference simulation without wind farms, the presence of wind farms modifies local ice presence by up to 20 days over 4 months in extreme winters near development areas.

Lagrangian tracking further reveals that wind farm-induced ice deformation can impact remote shipping routes, winter navigation, and wind farm maintenance, potentially posing risks to coastal communities. Pylon-induced ice tracks and subsequent compression of the ice field result in local track densities of 5-10 km per km², reaching up to cumulative lengths of 30 km per km² in compressed channels along major shipping lanes.

Abstract ID: 163

An Integrated Marine Environmental Insight for the Southern Baltic Sea: The CSI-POM Project

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The CSI-POM (The Digital Information System for Polish Maritime Areas) is an advanced digital system designed to monitor and model environmental conditions across the entire Polish marine area of the Southern Baltic Sea, encompassing both coastal zones and open waters. Developed in two phases, the initial stage (CSI-POM 1) focused on establishing robust models for physical and hydrodynamic processes, while the ongoing second phase (CSI-POM 2) expands the scope to include biochemical analyses. This comprehensive approach aims to enhance understanding of the dynamic interactions between natural marine processes and human influences.

At the core of the system is a high-resolution ecohydrodynamic model (3D CEMBS-PolSea), which integrates satellite data assimilation for sea surface temperature (SST) and chlorophyll-a concentrations. This integration enables precise spatial and temporal assessments of key processes, including nutrient transport, primary productivity, and cyanobacterial bloom dynamics. An automated detection module, utilizing both satellite imagery and model outputs, assists in predicting the spatial distribution and development of these blooms, providing valuable insights into ecological trends.

Furthermore, the CSI-POM 2 system tracks essential biochemical parameters such as nitrate, phosphate, silicate, dissolved oxygen, and chlorophyll-a, to improve understanding of marine ecosystem variability. These observations contribute to a more detailed characterization of environmental conditions, supporting scientific research and informing various maritime activities.

By integrating advanced modeling techniques with real-time observational data, the CSI-POM 2 project provides a comprehensive framework for assessing marine environmental dynamics. Through interdisciplinary collaboration, the project serves as an important tool for enhancing knowledge of the Southern Baltic Sea, supporting a range of maritime and ecological applications.

Funding: This study is financed from the state budget under the programme of the Minister of Education and Science (Poland) entitled "Science for Society II" No. NdS-II/SP/0003/2023/01, amount of funding PLN 1 996 763.77, total value of the project PLN 1 996 763.77 and "Science for Society" No. NdS/546027/2022/2022, amount of funding PLN 1 702 130.65, total value of the project PLN 1 702 130.65.

Abstract ID: 170

Advancing Wave Measurement and Forecasting in the Baltic Sea: Machine Learning for Enhanced Prediction and Data Interpolation

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Interest in investments in the Baltic Sea and its coastal zone is growing, particularly in areas related to renewable energy, transportation, and tourism. Accurately predicting wave heights is becoming increasingly important — not only for planning and maintaining offshore infrastructure but also for monitoring coastal areas in the Baltic Sea, where wave activity directly influences shoreline changes.

This research explores innovative machine learning (ML) approaches for wave forecasting, focusing on artificial neural networks (ANNs), Multi-Layer Perceptrons (MLPs), and Long Short-Term Memory (LSTM) models. Two specific case studies of ML methods application are presented.

The first examines site-specific wave forecasting using optimized ANN models trained on real-world buoy data from deep-water zones. The results demonstrate that fine-tuning model parameters significantly enhances prediction accuracy. This underscores how ANNs can support the predictive maintenance of offshore infrastructure, for example floating offshore energy farms by providing more reliable wave height estimates.

The second part of the study focuses on filling gaps in measured wave height data to improve coastal monitoring. Leveraging data from nearby buoys, MLP and LSTM models are applied to estimate missing wave heights, ensuring continuous and accurate observations in coastal zones. The findings illustrate how AI-driven interpolation can expand both the spatial and temporal coverage of wave data, leading to better decision-making for maritime safety, coastal management, and offshore operations.

Ultimately, this research highlights the usability of AI in marine science, opening the door to smarter, more data-driven management of the Baltic Sea's environment and its growing offshore energy sector.

Abstract ID: 179

Data-driven models for decision support in winter navigation in the Baltic Sea

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The Baltic Sea experiences seasonal ice cover, which affects ship manoeuvrability and operability. Icebreaker is often needed to assist merchant ships struggling to navigate in challenging ice conditions. Climate change increases ice variability, while stricter environmental regulations may further raise the demand for assistance, highlighting the need for optimized icebreaker resource allocation. Accurate estimation of assistance needs is critical for future optimization efforts. However, current estimations rely on expert judgment, which is complex and subjective due to varying expertise and challenging operational conditions. Objective and quantitative methods for estimating navigation modes remain limited. To bridge this gap, this study develops data-driven models to estimate the navigation modes, incorporating traffic data, environmental conditions, and ship characteristics. To obtain a comprehensive dataset, the study gathers data from multiple sources, providing insights into traffic information, environmental conditions, and ship characteristics. Next, to infer navigation modes without labeled data, a multi-step clustering model is employed to assign labels by measuring the similarities between the trajectories of icebreakers and merchant ships. Additionally, logistic regression is used to assess how complex operational conditions influence navigation mode estimation. The findings reveal the varying effects of different factors and demonstrate the potential of machine learning for estimation based on ice conditions, environmental factors, and ship characteristics. Finally, a deep learning-based model is proposed to refine the prediction, with results confirming its accuracy in predicting the need for icebreaker assistance in the study area. The study demonstrates that data-driven models can effectively estimate the need for icebreaker assistance based on the integrated dataset, achieving 97% accuracy. Its application further suggests the capability to generate maps identifying areas where assistance is needed. Additionally, it holds the potential to optimize icebreaker deployment and improve resource allocation. Leveraging advanced data analytics, this work lays the groundwork for the future development of an intelligent decision-support system for winter navigation.

Abstract ID: 184

Hydrodynamic Monitoring of the Hel Peninsula: Data Acquisition and Numerical Modeling of Coastal and Marine Processes

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Understanding hydrodynamic processes in coastal zones is essential for assessing environmental changes, shoreline stability, and the impact of marine dynamics on infrastructure. The Hydrodynamic Monitoring of the Hel Peninsula represents the first comprehensive measurement campaign in this area, aiming to enhance the observation and modeling of physical processes in the southern Baltic Sea through systematic data collection and advanced numerical simulations.

The project integrates in-situ measurements, including deep- and shallow-water wave data, currents, and meteorological parameters from four locations along the peninsula, with hydrodynamic modeling. Special attention is given to the validation and calibration of models to ensure their accuracy in representing complex coastal interactions.

This presentation will discuss the methodologies employed in data acquisition and processing, the numerical techniques applied in hydrodynamic simulations, and the role of open-access datasets in improving coastal monitoring efforts. The findings contribute to a deeper understanding of the Baltic Sea's physical environment and support the development of more reliable forecasting tools for scientific and operational applications.

By advancing measurement and modeling capabilities, this research provides valuable insights into the dynamics of the Hel Peninsula and strengthens efforts to monitor and manage the changing conditions of Poland's coastal zone.

Abstract ID: 192

Big Data and Cybersecurity-Enhanced Monitoring of Icebreaker Operations and Pollution in the Baltic Sea

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The Baltic Sea experiences significant seasonal ice cover, necessitating the use of icebreakers to maintain year-round maritime transport. While icebreaking is crucial for regional trade and logistics, it also induces environmental challenges, including increased fuel emissions, oil spills, and disruptions to marine ecosystems due to ice fragmentation and sediment resuspension. Traditional monitoring approaches remain fragmented, delayed, and reactive, limiting effective environmental management and cross-border regulatory compliance. This study proposes a big data-driven and cybersecurity-enhanced monitoring framework that integrates Satellite Remote Sensing Data (Copernicus Sentinel-1 & Sentinel-3), Automatic Identification System (AIS) data, IoT-enabled smart buoys, and AI-based predictive analytics to assess icebreaker efficiency and environmental impact in real-time. The key components of the proposed system include:

By integrating high-resolution satellite imagery, real-time environmental data, and predictive analytics, this study enhances the accuracy of pollution detection, ice navigation efficiency, and ecosystem impact assessment. The fusion of big data and AI-driven decision support systems ensures early detection of pollution hotspots and icebreaker-induced environmental risks, facilitating proactive intervention strategies. The results of this research will contribute to sustainable icebreaker operations, improving compliance with HELCOM environmental regulations and fostering international collaboration in the Baltic region. This work highlights the potential of advanced data analytics, remote sensing, and cybersecurity to transform icebreaker monitoring, ensuring maritime safety while mitigating environmental consequences in the rapidly evolving Baltic Sea ecosystem.

Abstract ID: 193

Role of small-scale processes in the coastal offshore exchange in the Baltic Sea: results from multi-year high-resolution modelling study

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GETM model simulations with different resolutions are used to study the role of small-scale processes in the coastal offshore exchange in the central Baltic Sea. Additional numerical ink and corresponding age tracers are added as passive tracers to the model to track riverine freshwater and its spatial distribution over a 9-year period in the Baltic Sea. Systematic differences between simulations occurred in the northern part of the central Baltic Sea and regions with large freshwater input. The advection in the low-resolution model is generally stronger, and the tracer is transported away from its sources faster than in the high-resolution simulation. In addition, the low-resolution model results show smaller amounts of the ink tracer in the Gulf of Finland and the Gulf of Riga. The differences between model simulations are smaller in the basin centers, and the tracer distributions are similar, indicating an overall balance in coastal offshore exchange. However, there are specific differences in the freshwater distributions in some sea areas. For instance, the westward transport of the riverine waters is more intense along the northern coast of the Gulf of Finland in the coarse simulation than in the high-resolution simulation. Instead, freshwater reaches more westward along the southern coast of the Gulf of Finland in the latter case. Moreover, riverine water penetrates more below the upper mixed layer in the high-resolution simulation, probably indicating the impact of small-scale processes.

Abstract ID: 213

Over ten years of Argo data from the Baltic Sea

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Over the past decade, Argo floats have established themselves as part of the observational network of the Baltic Sea. The largest challenges in operating Argo floats in this region, such as shallowness, strong density gradients and seasonal ice cover, have been overcome. Some initial concerns have even been turned into advantages — for example, parking floats on the seafloor has proven effective in keeping them in place within dynamic regions. The success of Baltic Argo operations is a result of collaboration among several countries contributing to the fleet of floats deployed, testing of new sensors, development of internationally agreed approach to data quality assurance, and transnational coordination of deployment and the recovery of the floats.

As a result of these efforts Argo floats have significantly enhanced Baltic Sea monitoring, collecting a vast number of observations compared to the traditional ship-based monitoring. This improved spatial and temporal resolution of measurements strengthens our ability to track and document environmental change in the Baltic Sea, enhances capabilities of the operational forecasting and reanalysis systems, and offers a novel autonomous system for ground truthing of satellite measurements.

We describe the latest advancements in the Baltic Sea Argo. We explore the potential of Argo observations for analyzing seasonal and interannual variability in hydrography and demonstrate their value in assessing the environmental state of the Baltic Sea. Additionally, we showcase examples of how Argo data are utilised for process studies across different Baltic Sea basins.

Abstract ID: 240

Overview of Regional Ocean Colour products for the Baltic Sea Within the Copernicus Marine Service

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The Baltic Sea is characterized by large gradients in salinity, high concentrations of coloured dissolved organic matter, and a phytoplankton phenology with two seasonal blooms: a strong spring bloom dominated by diatoms and dinoflagellates and a summer cyanobacterial bloom. Satellite retrievals of Ocean Colour (OC) essential ocean variables (EOVs), including the chlorophyll-a concentration, are hindered by the reduced performance of the atmospheric correction process because of the high absorbing and optically complex waters of the basin.

Since 2015, the Ocean Colour Thematic Assembly Centre (OCTAC) of the Copernicus Marine Service delivers state-of-the-art OC core products for both global oceans and European seas. Global and regional high-level merged products are derived from multiple satellite missions, offering value-added information not directly available from space agencies.

The OCTAC catalogue for the Baltic Sea includes daily Level 3 consistent datasets at three spatial resolutions: multisensor datasets at 1 km resolution (available since 1997), Sentinel-3 OLCI datasets at 300 m (since 2016) and the Sentinel 2 MSI datasets produced in a 20 km strip from the coastline at 100 m resolution (since 2020). Datasets are grouped in five categories including different EOVs: plankton, with the phytoplankton chlorophyll concentration phytoplankton size classes and functional types; primary production integrated within the euphotic zone; the spectral remote sensing reflectance; transparency, with the diffuse attenuation coefficient of light; and optics, including inherent optical properties such as absorption and backscattering by particulate and dissolved matter.

This talk will provide a summary of the regional OCTAC products for the Baltic Sea across the different spatial resolutions and their evolution from 2015 to date, an overview of the uncertainty associated with selected variables and examples of the use of products for operational monitoring and reporting, as well as a description of the planned and foreseen product evolutions.

References:

Brando, V.E. et al. (2021) Phytoplankton Bloom Dynamics in the Baltic Sea Using a Consistently Reprocessed Time Series of Multi-Sensor Reflectance and Novel Chlorophyll-a Retrievals. Remote Sens. 2021, 13, 3071

Brando, V.E.. et al. (2024) Overview of Operational Global and Regional Ocean Colour Essential Ocean Variables Within the Copernicus Marine Service. Remote Sens.16(23), 4588

González Vilas, L. et al. (2024). Assessment of ocean color atmospheric correction methods and development of a regional ocean color operational dataset for the Baltic Sea based on Sentinel-3 OLCI. Front. Mar. Sci. 10, 1256990.

Abstract ID: 250

From experiment to monitoring – spatial pattern of coastal changes of the southern Baltic using airborne laser bathymetry (ALB)

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The coastal zone is subject to constant, very intensive changes, the effects of which can pose a real threat to infrastructure and local communities. In terms of presently occurring climate changes, observed sea level rise an increased number and intensity of storm events, which pose a real threat to broadly defined coastal safety, it is crucial to precisely monitor changes in the coast and to determine scenarios for the development of the coastline. However, the shallow coastal area is very difficult to study due to the need to use separate measurement methods for terrestrial and sea parts, as well as their limitations.

The traditional method of coastal zone monitoring includes topographic-bathymetric measurements carried out in profiles perpendicular to the shore, spaced every 0.5 km. In the terrestrial part of the profile and in the shallow water up to 1.5 m depth, geodetic methods, while the deeper part hydrographic methods a single-beam echosounder were used, because due to the small depth, the use of a multi-beam echosounder was not effective. Comparison of the measurements obtained in subsequent years allowed to determine the size of changes, but without any reliable information between the profiles, which is necessary to understand coastal morphodynamics. Precise results of spatial analyses based on historical aerial photographs have contributed to better understanding coastal processes and the permanent introduction of photogrammetric methods, included high resolution orthophotomaps and topographic laser scanning, to coastal monitoring conducted by Maritime Offices in Poland, since 2008. Despite enormous progress, the qualitative change in access to information mainly concerned the land part, because the infrared laser pulse is not able to penetrate water, which resulted in a further lack of information on the nearshore morphology. This gap was filled by using airborne laser bathymetry technology, with green light that can penetrate the water column, which allowed for the first time in 2023 to obtain a full picture of the morphology of the coastal zone, acquired simultaneously for parts of the onshore and nearshore.

The presented research show the results of using airborne laser scanning technology in monitoring the southern coast of the Baltic Sea. From the first attempts undertaken in 2007 to regular monitoring carried out in 2023 and 2024. From technical description, trough validation of the method accuracy, to the first results presenting spatial pattern of the coastal zone morphology changes, which is a big step forward to better understand coastal morphodynamics.

Abstract ID: 256

FAIR Data for the Baltic: Polish Oceanographic Data and Information System

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Establishment of the ODIS Infrastructure for Enhanced Collaboration and FAIR Data Compliance
Polish organizations engaged in oceanographic research actively contribute to international initiatives focused on developing oceanographic data resources. As custodians of extensive oceanographic datasets, these organizations aim to enhance data accessibility for researchers, industry stakeholders, and the general public. To strengthen Poland's role in pan-European and global oceanographic data networks, the Oceanographic Data and Information System (ODIS) was established. This infrastructure fosters international collaboration while ensuring compliance with FAIR (Findable, Accessible, Interoperable, and Reusable) data principles.

Polish ODIS Consortium and National Laboratory
The ODIS consortium comprises leading Polish research institutions, including the Institute of Oceanology Polish Academy of Sciences, Polish Geological Institute – National Research Institute, National Marine Fisheries Research Institute, University of Gdańsk, Maritime Institute of Maritime University in Gdynia, Pomeranian Academy in Słupsk, and University of Szczecin. These institutions have a long-standing history in marine research and have consolidated efforts to establish a national repository—ODIS for Polish Scientific Data—accessible online at https://odis.ecudo.pl. Currently, the repository indexes over 7 million datasets from Polish research activities in the Baltic Sea and Polar Regions, with a long-term goal of establishing the Polish Oceanographic Data Committee.

eCUDO Platform Services
The eCUDO platform adheres to the 5-star Open Data standards, ensuring openness and accessibility. The system integrates metadata compliant with ISO 19115-1:2014 geospatial data standards and assigns unique URIs to datasets, enhancing interoperability. Key services offered through the platform include: The Jupyter Hub computing environment supports interactive data exploration using Python, Julia, and R, enabling advanced analytics, statistical modeling, and computational research.

Harmonization with INSPIRE and SeaDataNet Standards
Current efforts focus on harmonizing environmental data collection with INSPIRE requirements and SeaDataNet standards, ensuring long-term data preservation and management. Additionally, digitization of historical datasets enhances data discovery and usability. The ODIS infrastructure remains open to additional stakeholders, promoting broad integration and collaboration across the scientific community

Poster Presentations

Thematic Session: Physical and Biogeochemical Changes in the Baltic Sea

Abstract ID: 8

Heat wave trends and their impact on coastal tourism in the southeastern Baltic region

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Changes in climate and in the climatic normative averages of the physical parameters that characterise it are leading to an increase in the frequency of extreme events, which have a direct impact on the state of ecosystems and on human activity and health. Analysis of historical data on extreme events such as storms, heavy rainfall, floods, and air and water heat waves can help identify their impact on coastal tourism infrastructure, visitor flow volumes, and geographical distribution.

This work examines air heat waves along the southeastern Baltic Sea coast within Lithuania's territory, which are becoming increasingly frequent and intense due to global climate change. examines air heat waves along the southeastern Baltic Sea coast within Lithuania's territory, which are becoming increasingly frequent and intense due to global climate change. Periods of extreme heat affect not only urban and rural areas but also influence tourism flows in Lithuania's coastal resorts. Heat waves often coincide with extended sunny and warm periods, which drive an influx of tourists to Lithuania's coastal resorts, such as Klaipėda, Nida, and Palanga. While warmer weather extends the tourism season, extreme heat waves can also have negative impacts.

In this work analyzes air temperature and precipitation data from 1993 to 2022 for settlements in the Lithuanian coastal climatic region, including the port city of Klaipėda and the resort towns of Nida and Palanga.

This work of heat waves and their impact on land cover changes in Baltic Sea coastal settlements employs a detailed analysis of the effects of heat waves from May to August 2018, using satellite images from the "Copernicus Open Access Hub" platform. The methods applied include the NDVI index commonly used in climatology, as well as historical meteorological and hydrological data. The study analyzes the distribution of tourist flows in relation to meteorological conditions and summarizes preliminary data on health disorders during heat wave periods.

The intended research results provide insights into the impact of heat waves on cities in the Baltic Sea coastal region. The findings indicate an increasing trend of more frequent and intense extreme weather conditions, such as heat waves and tropical nights, in the southeastern Baltic Sea coastal zones. These conditions contribute to fluctuations in human comfort levels and tourism flows.

Abstract ID: 11

The fate of oxygen in the Baltic Sea as inferred from $\delta^{18}O$ measurements of dissolved O_2

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The Baltic Sea has experienced severe hypoxia for decades, a situation that is worsening with rising temperatures and high productivity. While exchange with the atmosphere and mixing equilibrates surface waters with dissolved oxygen (DO) down to the halocline, the only significant source of DO to the deep central basins is the inflow of water from the North Sea. Respiration, driven by the microbial degradation of biomass, is the most important process responsible for the decline in oxygen concentrations at depth, both in the water column and in sediments. However, it remains unclear whether respiration in the water column or in the sediment is the more significant contributor to the community oxygen consumption.

To address this question, we conducted a research cruise aboard R/V Meteor (M200) in March 2024 starting from Rostock. The cruise coincided with a moderate North Sea water inflow event, which provided an opportunity for DO sampling along the “Talweg” of the inflow, in addition to the high-resolution profiling of the water column through the redox zone using a pump CTD. A dynamic reaction-diffusion model was employed to estimate the extent to which fractionating DO consumption (e.g., via water column respiration) dominated over diffusion-limited processes (e.g., respiration within sediments).

Community O-isotope enrichment factors (ε) ranging between -10.3 and -2.2 ‰ suggest that bacterial respiration in the water column is less important than DO consumption in sediments, with benthic respiration accounting for 50 to 90 % of total oxygen consumption along the Talweg. Overall, this study highlights the value of high-resolution oxygen isotope measurements in hypoxic zones for evaluating DO consumption in general, and for improving our understanding of the processes underlying oxygen depletion in the Baltic Sea in particular.

Abstract ID: 15

Changes in the water salinity of the Curonian Lagoon due to natural and anthropogenic factors

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The Baltic Sea and its lagoons, including the Curonian Lagoon, are among the most affected water bodies due to climate change. The salinity regime of the Baltic Sea and its lagoons has been studied for more than 100 years. However, despite this, gaps still exist in our knowledge regarding salinity changes over space and time. Sea salinity conditions are associated with changes in meteorological and climatic conditions. Nonetheless, the current scenarios for future salinity trends remain unclear, and further research on various factors related to salinity dynamics is necessary (Lehmann et al., 2023). The ensemble mean of available scenarios indicates that by 2100, the salinity in the Baltic Sea may decrease by approximately 0.6 g/kg; however, these projections do not consider global sea-level rise (Saraiva et al., 2019). The main objective of this study would be to conduct research based on available historical data, in-situ measurements, and hydrodynamic model output data to assess the salinity dynamics and spatial changes in the Curonian Lagoon due to natural and anthropogenic factors. In nature, all components are unconditionally more or less interconnected, so climate changes and the increase of anthropogenic impact can have a decisive impact on the hydrological and hydrochemical regimes of the Curonian Lagoon, and at the same time on the ecosystem.

References

Lehmann, A., Myrberg, K., Post, P., Chubarenko, I., Dailidiene, I., Hinrichsen, H.-H., Hüssy, K., Liblik, T., Lips, U., Meier, H. E. M., and Bukanova, T. 2022. Salinity dynamics of the Baltic Sea. Earth Syst. Dynam. 13, 373–392. https://doi.org/10.5194/esd-13-373-2022

Saraiva, S., Meier, H. E. M., Andersson, H. C., Höglund, A., Dieterich, C., Gröger, M., Hordoir, R., and Eilola, K. 2019. Uncertainties in projections of the Baltic Sea ecosystem driven by an ensemble of global climate models, Front. Earth Sci., 6, 244, https://doi.org/10.3389/feart.2018.00244

Abstract ID: 16

Indicators of Changing Lightscapes in Underwater Marine Ecosystems (ISOLUME)

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The ISOLUME project will investigate the impacts of changing marine lightscapes caused by coastal darkening and artificial light at night (ALAN). These transformations, driven by climate change, land-use shifts, and evolving lighting technologies, are expected to alter underwater ecosystems, affecting biodiversity, primary production, and species behavior. By combining historical datasets, remote sensing, and advanced modeling, ISOLUME will quantify long-term trends, identify key drivers, and assess ecological consequences. The project will also develop new monitoring strategies and policy frameworks to mitigate negative effects and support sustainable marine management. Through interdisciplinary collaboration, ISOLUME will generate valuable insights into the dynamics of underwater lightscapes, informing both scientific research and policy decisions. Its findings will contribute to international marine governance initiatives, helping to ensure the resilience of marine ecosystems in the face of ongoing environmental change.

Abstract ID: 24

Propagation and mixing of the winter 2023/24 Moderate Baltic Inflow in the Southern Baltic

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The winter of 2023/24 witnessed a significant Moderate Baltic Inflow (MBI), introducing approximately 198 km³ of saline, oxygen-rich water into the Southern Baltic. This study investigates the propagation, mixing, and impacts of this inflow across three key basins: the Bornholm Basin, the Slupsk Furrow, and the Gdansk Basin.

Utilizing a combination of observational platforms, including R/V Oceania cruises, glider-based surveys, and microstructure profiling, we examined the inflow's hydrodynamic and thermohaline characteristics. The results indicate notable alterations in temperature, salinity, and oxygen concentration throughout the study area. The inflow elevated the halocline in BB, facilitated the transport of saltier waters into SF, and led to an unprecedented deepening of the halocline in GB. Notably, the oxygenation of deep waters reached levels not observed in decades, with concentrations as high as 14 mg L^{-1} in GB at 75 m depth.

Analysis of turbulent kinetic energy dissipation and vertical eddy diffusivities revealed significant mixing processes accompanying the inflow. The combined use of microstructure profilers and Thorpe-scale analysis provided insights into the mixing efficiency and the dominant mechanisms governing inflow propagation.

The study highlights the critical role of MBIs in shaping the deepwater conditions of the Baltic Sea, influencing regional stratification, ventilation, and ecosystem health. The findings contribute to a broader understanding of the variability and long-term trends of inflows in the region.

Abstract ID: 40

Enrichment of the sea surface microlayer in organic matter in different regions of the Baltic Sea

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Studies on enriching the sea-surface microlayer (SML) into organic matter (OM) of different origins, carried out during Baltic cruises in 2018-2021, concern coastal and open waters in early spring and spring seasons. The concentration of absorbing organic matter decreases with the increase of salinity, and the values in SML are almost always higher than those in subsurface water (SSW). The values of E_2:E_3 and S_R, inversely proportional to molecular size and weight of OM, respectively, increase together with a distance from land and salinity. Therefore, the molecular size and weight of absorbing organic matter are smaller in open waters compared to coastal zones. The fluorescing components facilitate the calculation of the ratio (M+T)/(A+C) for SML and SSW, and the results indicate the predominance of marine-produced organic molecules in SML in both coastal and open waters. We observed a relationship between the concentration of the most abundant phytoplankton group, Bacillariophyceae, and the fluorescing organic matter components. We identified a relationship between meteorological observations (wind speed) and the enrichment of SML in absorbing and fluorescing organic matter, EF(E_2:E_3), EF(S_R), EF(AC), EF(MT), and Chl *a* concentrations for coastal and open water bodies.

Abstract ID: 45

Long term monthly evolution of a coupled temperature and salinity stratification of the Baltic Sea

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Ocean temperature and salinity are essential variables that define the physical state of the ocean (GOOS, 2020). Their changes record changes in the Earth's energy and water cycles, making them key variables in detecting climate change signals in the ocean [Tjiputra et al., 2023]. Vertical distributions of temperature and salinity offer a detailed description and dynamic understanding of oceanographic processes behind the climate change impact. This study examines the interactive evolution of temperature and salinity changes in the Baltic Sea, emphasizing vertical stratification of the salinity and temperature. We employ Self-Organizing Maps (SOMs) to categorize the coupled fluctuations of temperature and salinity by employing regionally averaged hydrographic profiles with a monthly temporal resolution from 1993 to 2021. The Baltic Sea physics reanalysis multi-year reanalysis data of the ocean model NEMO v4.0 is used for the study. To exclude dominant seasonal signal in the temperature and salinity stratification otherwise contaminating the analysis we have deseasonalized initial vertical profiles. Our findings represent five separate hydrographic states of coupled temperature and salinity stratification, illustrating the progression from a cooler and low saline phase (SOM1) (1993-1997) to a warmer and high saline condition (SOM5) (2015-2021). The transition phase, from 1998 to 2014 (SOM2–SOM4), signifies a gradual move towards a warmer and saltier Baltic Sea. A common understanding is that physical state of the Baltic Sea is determined by salinity stratification and the effect of the Major Baltic Inflows of the saline water from the North Sea. Our study shows that variations of the temperature stratification have higher sensitivity compared to salinity for the physical state of the whole Baltic Sea. We analysed the relationships between global scale climate oscillations and the variability of coupled temperature and salinity stratification in the Baltic Sea. Our analysis underscores the persistent warming trend throughout all SOM states, highlighting the East Atlantic Oscillation's significant influence on surface temperature variations in the Baltic Sea. These findings offer novel perspectives on the enduring hydrographic alterations of the Baltic Sea in response to shifting climatic conditions.

Abstract ID: 53

Modeling spectral reflectance of shallow coastal waters using bio-optical measurements and Monte Carlo simulation

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Accurately estimating the spectral reflectance of shallow coastal waters is essential for improving the understanding of optical properties, water quality, and the influence of various environmental factors on marine ecosystems. This study presents a novel approach to model the spectral reflectance of shallow coastal waters, utilizing a combination of bio-optical measurements and Monte Carlo simulations. Bio-optical measurements were collected from a range of shallow coastal environments, with a focus on key parameters including chlorophyll-a concentration, suspended particulate matter, and water depth, which significantly influence light absorption and scattering. These measurements were used to develop an empirical relationship between the spectral reflectance and the bio-optical properties of the water column. Monte Carlo simulations were employed to model light transport and interaction within the water column, accounting for scattering, absorption, and reflection from the water surface and the seabed. The model developed in this study provides an improved method for predicting spectral reflectance in shallow coastal waters, offering increased accuracy in the detection of water quality parameters from satellite and airborne remote sensing platforms. Additionally, this approach facilitates better understanding of light dynamics in coastal environments, with potential applications in water monitoring, ecosystem management, and the development of coastal zone management strategies.

Abstract ID: 58

Microbial Dissolved Organic Matter utilisation at the near-sediment waters in the Baltic Sea Deeps

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Recent studies suggest that sediment pore waters may serve as a source of bioavailable DOM to the overlying water column, which may stimulate microbial metabolism in the near-bottom waters. In this study, we aim to assess the bioavailability of DOM, released by sediments, and whether it may stimulate an increase in heterotrophic cell number. For this, we conducted measurements of dissolved organic carbon (DOC) and DOM optical properties, such as chromophoric (CDOM) and fluorescent (FDOM) DOM, and molecular composition of DOM using Fourier transform ion cyclotron resonance mass spectrometry during ex-situ incubations of the sediment cores with overlying water. Six incubations were performed using sediment cores extracted from three Baltic Sea Deeps in the Spring and Fall seasons in 2022 to infer quantitative and qualitative transformations of DOM during the incubation period (60-72 hrs). We observed an increase in bacterial cell number (by 3.6±1 fold in Spring and 5.6±0.4 fold in Fall on average) and qualitative conversion of DOM (towards higher molecular weight oxygen-enriched molecules in Spring and towards lower molecular weight aliphatic-like molecules in Fall) during incubations, suggesting stimulation of heterotrophic communities by sedimentary DOM. The variability in the magnitude of the increase in microbial abundance and in the conversion of molecular DOM composition during incubations in different seasons, which was not evident from bulk DOM parameters, suggests that the quality of the initial substrate (e.g., due to particulate organic matter quality) supply may influence the pathways of microbial DOM reworking. Our findings highlight the importance of sediment-derived DOM in stimulating microbial metabolism in the near bottom waters of the Baltic Sea.

Abstract ID: 63

Towards a coupled model of the Gulf of Finland ecosystem: the importance of spatial resolution, atmospheric forcing frequency, and biogeochemical model complexity

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The natural environment of the Gulf of Finland is characterized by factors such as the strong freshwater inflow from the River Neva, the highly variable wintertime sea ice cover, and the episodic wind-driven upwelling of deeper waters along the Finnish and Estonian coastlines. Meanwhile the geopolitical environment around the Gulf of Finland is increasingly fraught, characterized by a multitude of potential risks associated with both accidental and intentional acts of pollution. In this study we review results from different physical and biogeochemical models of the region, ultimately motivating the need for a fully-coupled high-resolution model of the Gulf of Finland ecosystem.

In a new set of hydrodynamic simulations, we force the Nucleus for European Modelling of the Ocean (NEMO) with atmospheric outputs from the Copernicus Regional Reanalysis for Europe (CERRA) on a 1 nautical mile grid covering the entire Baltic Sea, and compare against results from a dedicated 0.25 nautical mile simulation of the Gulf of Finland. We focus on the representation of currents and of upwelling episodes, elucidating the similarities and differences between model dynamics in the low-resolution and high-resolution setups.

Next, we perform a three-day running average on the wind and pressure fields from CERRA, and use these to force further simulations with atmospheric variability dampened at high frequencies. Our analysis of these results reveals the influence of mesoscale weather patterns on sea level, mixed layer depth, and water transport in the Gulf of Finland.

Finally, we present a new coupling of the Biology Light Iron Nutrients and Gases (BLING) model with NEMO, including an implicit representation of phytoplankton biomass and externally imposed rates of benthic denitrification and oxygen consumption. We use this intermediate complexity biogeochemistry model as a benchmark against which to assess results from the coupling of NEMO with the (higher complexity) Ecological Regional Ocean Model (ERGOM), developed as part of the Copernicus Baltic Sea Monitoring and Forecasting Centre (BAL-MFC). We show key differences in nutrient and dissolved oxygen concentrations resulting from different approximations of biogeochemical processes in the two models.

Abstract ID: 79

Marine Heatwave Event Maps in the Baltic Sea (1982–2023): A High-Resolution Dataset from Satellite-Derived L4 SST Observations

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Marine heatwaves (MHWs) are prolonged periods of anomalously high sea surface temperatures (SST) that can significantly impact marine ecosystems, coastal economies, and global climate patterns. Following the widely accepted definition by Hobday et al. (2016), MHWs are characterized by key parameters including baseline period, baseline type (constant or moving), percentile threshold for extreme events, and duration threshold. The Hobday et al. (2016) framework defines marine heatwaves (MHWs) as periods when sea surface temperature (SST) exceeds the 90th percentile of a climatological baseline for at least five consecutive days. The baseline is typically a 30-year period and can be either constant (fixed) or moving (updated over time).This definition ensures consistency in MHW detection across different regions and datasets, making it widely used in studies assessing the frequency, intensity, and impact of extreme ocean warming events.

We identify and analyze 192 MHW events in the Baltic Sea between 1982 and 2023 using a high-resolution satellite-derived SST dataset (0.02° × 0.02°). Our results reveal substantial variability in MHW characteristics, with the shortest events lasting just a few days and the longest extending beyond 284 days. The largest events cover extensive areas, emphasizing their spatial significance. The analysis also highlights seasonal and interannual variability in MHW intensity, duration, and extent. Given the semi-enclosed nature of the Baltic Sea and its heightened sensitivity to climate change, understanding the impact of MHWs requires careful evaluation of different baseline and threshold definitions.

This work was supported by AdapEST project (“Implementation of national climate change adaptation activities in Estonia, VEU23019”) which is funded by the European Climate, Infrastructure and Environment Executive Agency’s (CINEA) LIFE programme.

Abstract ID: 91

Nutrient dynamics in the Oder/Szczecin Lagoon as seen in a biogeochemical model

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The Oder/Szczecin Lagoon is one of the largest lagoons in the Baltic Sea and is subject to very high nutrient loads from the Oder/Odra River. For our study, we employ a modified, high-resolution 3D ecosystem model specifically adapted for this shallow lagoon. The model demonstrates stable and reliable performance over 25 years of simulation, enabling a detailed assessment of lagoon processes. Our model simulations indicate that changes in riverine nutrient inputs have an immediate impact on the lagoon's water quality, affecting parameters such as phytoplankton biomass and water transparency.

We present results demonstrating the lagoon's capacity to retain nitrogen and phosphorus under different forcing conditions. On average, the lagoon retains 12% of phosphorus and 40% of nitrogen from riverine inputs. The primary sink for phosphorus is sediment burial, while for nitrogen, it is denitrification. Nitrogen retention decreases with increasing riverine loads, dropping to approximately 30% during years with exceptionally high inputs. The nutrient retention capacity of the lagoon has significant implications for eutrophication in the Baltic Sea. However, this capacity is not currently accounted for in most Baltic Sea models, which lack the appropriate spatial resolution to consider the effects of lagoons.

Abstract ID: 102

Saltwater inflow 1951 and its influence on the Baltic Sea state. A model study

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The Baltic Sea is a semi-enclosed body of water situated in northern Europe. Because of its location and circulation features, it is naturally prone to hypoxia (oxygen levels below a certain threshold, suppressing most aerobic organisms' well-being) and anoxia (the lack of oxygen). Since the vertical exchange of oxygen is hampered in the deep Baltic Sea due to the strong permanent halocline, the significant share of oxygen supply to the deep central Baltic Sea basins (the Bornholm Basin, the eastern Gotland Basin, and the western Gotland Basin) is carried out by the sporadic strong inflow events from the North Sea, which are known as Major Baltic Inflows or MBIs. According to the sedimentary data, one particularly strong MBI in 1951 (MBI 1951) triggered the long-lasting hypoxic and anoxic conditions in the deep central Baltic Sea basins. Despite the noticeable systematic changes in the Baltic Sea in the 1950s, the role of the MBI 1951 is not entirely clear. Namely, the observational data analysis cannot quantify the inflow's contribution to the subsequent long-lasting hypoxic conditions in the deep central Baltic Sea. Whether the MBI 1951 just slightly accelerated the inevitable transition to the hypoxic state due to the elevated nutrient input from land or played a leading role in hypoxia formation by strengthening the halocline and suppressing the natural ventilation of the water column remains an open question.

In this study, we utilized a coupled hydrodynamical-biogeochemical model setup (Modular Ocean Model 6 and Ecological ReGional Ocean Model, MOM6-ERGOM) to address the abovementioned question. The model was forced with reconstructed atmospheric and hydrological forcing. We performed some model experiments, including the reference (1880-2022) and some sensitivity runs with modified forcing. By comparing the reference experiment in which the MBI 1951 takes place with the results of sensitivity studies where the MBI 1951 was suppressed due to different forcing, we conclude that the current hypoxic state of the Baltic Sea was, despite being slightly influenced by the MBI 1951, governed by the elevated nutrient input from land.

Abstract ID: 109

Improving Baltic Sea forecasts by enhancing wave-ocean coupling

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Baltic Sea operational models mostly use simplified parametrisations for sea surface wave and ocean circulation interactions. These parameterisations are often based on global ocean data. Enhancing coupling of the models aims at more refined estimates of wave-ocean interactions and of the impacts on surface layer mixing. When replacing previous implicit parametrisations with explicit formulations, reevaluation of the parametrisations governing momentum and energy transfer as well as vertical mixing and turbulence is needed. This is especially important in coastal seas, where the scales are different from those of the oceans.

We study how surface waves impact hydrodynamics and surface layer mixing in the Baltic Sea, where wave field is often fetch-limited, with an offline coupled WAVEWATCH III–NEMO Nordic setup. We compare results from simulations using an optimised sea surface roughness parameterisation, derived based on WAVEWATCH III data, to the default parameterisation in the ocean model's turbulence closure scheme. The results show that during high wind conditions, the use of optimised parametrisation reduces sea surface roughness, leading to better estimates of mixed layer deepening. For a more advanced approach, we combine the optimised parameterisation with wave-modified ocean-side stress. This leads to improved predictions of mixed layer depth and sea surface height compared to a stand-alone ocean model.

Abstract ID: 139

Submarine groundwater discharge as a driver of coastal biogeochemistry and contaminant transport in the Bay of Puck, Southern Baltic Sea

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Submarine groundwater discharge (SGD) plays a crucial role in the exchange of water and dissolved substances across the land-ocean interface, significantly influencing coastal biogeochemistry. However, its impact remains understudied in the Baltic Sea. This study examines the hydrogeochemistry of SGD in the Bay of Puck, southern Baltic Sea, with a focus on its spatial and seasonal variability, underlying geochemical processes, and environmental implications.

SGD, groundwater, and seawater samples were collected at multiple sites during field campaigns conducted between 2009 and 2021. Using a one-dimensional advection-diffusion model, SGD rates were estimated to range from 1.8×10^{-7} to 2.8×10^{-7} L cm^{-2} s^{-1} in coastal areas, while in offshore pockmarks, values varied between 0.4×10^{-9} and 0.05×10^{-7} L cm^{-2} s^{-1}. These findings highlight SGD as one of the most significant freshwater sources in the study area.

In addition to freshwater input, SGD in Puck Bay serves as a major source of dissolved inorganic carbon (DIC), alkalinity (AT), and nutrients, exerting a strong influence on coastal biogeochemistry. Under hypoxic conditions, denitrification and sulfate reduction enhance AT and DIC production; however, subsequent mixing, reoxidation, and CO_2 release lead to decreases of 32% and 37%, respectively. Furthermore, SGD is characterized by low pH and undersaturation with respect to aragonite and calcite, suggesting its potential contribution to ocean acidification and possible impacts on calcifying invertebrates.

SGD also acts as a pathway for contaminants, with pharmaceuticals such as carbamazepine, sulfamethoxazole, and diclofenac detected in groundwater, SGD, and coastal seawater.

These findings emphasize the need to incorporate SGD into regional water and nutrient budgets and call for further research to evaluate its ecological and chemical impacts on coastal ecosystems and the ecosystem services of the Baltic Sea.

Abstract ID: 141

Nitrogen removal processes in coastal and deep sediments of the Baltic Sea

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Denitrification and anammox (anaerobic ammonium oxidation) are the main nitrogen removal pathways. Denitrification is a microbial process in which NO_3^- is sequentially reduced to dinitrogen gas (N_2) while anammox is the anaerobic microbiological process in which NO_2^- and NH_4^+ are converted to N_2 under anoxic conditions. Both processes are critical in regulating nitrogen (N) availability in marine ecosystems such as the Baltic Sea. The Baltic Sea is highly complex and semi-enclosed marine ecosystem that contains brackish water due to high freshwater discharge and limited water exchange with the North Sea. The sedimentary nitrogen cycling was studied extensively in the Baltic Sea but still, understanding the nitrogen loss process, especially in the coastal area is challenging. The main aim of the study was to quantify denitrification and anammox rates in surface sediments from various locations in the Baltic Sea. Three coastal sites: MP2 and PB3 (Puck Bay), MS2 (Szczecin lagoon) and two open-sea sites IDEAL, P1 (Baltic Proper) were selected for this study. Slurry incubation experiments were conducted at each site with the addition of labeled substrates $^{15}NO_2^-$ and $^{15}NH_4^+$ to measure denitrification and anammox rates. The addition of $^{15}NO_2^-$ produced $^{14}N^{14}N$, $^{14}N^{15}N$, and $^{15}N^{15}N$ for denitrification, while $^{15}NH_4^+$ produced $^{14}N^{14}N$ and $^{14}N^{15}N$ for anammox. The denitrification rate in the coastal sites ranged from 1440.82 to 7.21 nM N L^{-1} d^{-1}, in the open sea sites at IDEAL production of N_2 was observed reaching 533.42 nM N L^{-1} d^{-1} while at P1 consumption of N_2 was noted. Apart from MP2, anammox activity was detected at PB3 (32.67 nM N L^{-1} d^{-1}), MS2 (0.41 nM N L^{-1} d^{-1}), IDEAL (0.46 nM N L^{-1} d^{-1}), and P1 (0.67 nM N L^{-1} d^{-1}). The anammox rates were lower than denitrification at all sites, indicating its minor role in nitrogen removal in the surface sediments of the Baltic Sea. However, the presence of anammox highlights the contribution of a diverse microbial community that can increase with the future expansion of anoxic areas in the Baltic Sea. The observed spatial variability in N removal rates is likely influenced by site-specific factors such as organic matter availability, nutrient discharge, and oxygen conditions. Further studies employing similar methodological approaches are essential to better understand nitrogen cycling in marine ecosystems, particularly in coastal areas.

The results were obtained within the framework of the research project IDEAL (2019/34/E/ST10/00217) funded by the Polish National Science Centre.

Abstract ID: 144

Temporal and spatial variations in the radiation budget of the Baltic Sea surface based on SatBałtyk system in 2010 – 2024

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As a result of the effects of climate change in the Baltic Sea region there is an increase in average sea surface temperature, air temperature, changes ice extent and atmosphere. This has a direct impact on the radiant energy reaching and leaving the water surface. Analyses of the radiation budget - R_{net} of the Baltic Sea from 2010 to 2024 based on data from the SatBałtyk system show an increase of R_{net} in these years. This increase correlates with the changes in the above parameters. The spatial variability of the rate of change of DR_{net} varies from about 0.4 Wm^{-2}/year to about 1 Wm^{-2}/year. The subject of the analyses presented here is the temporal and spatial changes of Rnet and its components. The increase of the short and long-wave top-down fluxes (SW_d and LW_d) is faster than that of the bottom-up fluxes (SW_u and LW_u). Annual average Rnet values for the Baltic Sea range from 60 Wm^{-2} to 75 $Wm^{-2,}$ with an annual trend of several Wm^{-2}/decade, depending on the region. The observed increase leads to an acceleration of the changes taking place in the Baltic Sea, which amplifies this effect. The research is based on data from the SatBałtyk system, determined by algorithms using satellite information and data from prognostic numerical models. The results presented are based on a unified methodology for the entire period under study. The algorithms used were verified with a monthly MD (mean bias difference) and RMSD of 0.5 Wm^{-2} and 3.7 Wm^{-2}, respectively.

Abstract ID: 153

Spatiotemporal variation of ocean heat content: insight from 31 years of Baltic Sea Reanalysis Data (1993-2023)

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Ocean Heat Content (OHC) refers to the entire amount of thermal energy that is stored within the water column of the ocean. This energy is responsible for the ocean's ability to retain heat. The OHC exerts a significant amount of control over the weather around the planet because it provides thermal inertia, which in turn influences the interactions between the ocean and the atmosphere. OHC drives thermal expansion, affecting sea-level rise and ocean circulation while influencing wave generation, energy distribution, and vertical mixing. Therefore, studying its spatiotemporal variability provides deeper insights into regional oceanography and climatology, making basin-level analysis essential.

Particularly, it maximizes the understanding of the spatiotemporal variability of OHC much more important in basin such as the Baltic Sea where all of its specification such as its shallowness, brackish water body, high-latitude position, semi-enclosed character and limited interaction of with the open ocean as well as ice extent variational behavior and rivers-induced freshwater impacts are deterministic all together.

This study first computes gridded OHC data over a 31-year period using estimated monthly mean values of density, specific heat capacity, and conservative temperature, derived from gridded potential temperature and salinity profiles in the Copernicus Baltic Sea Physics Reanalysis.

The spatial variability reveals new insights into the distinct patterns of OHC variability, highlighting differences between coastal and offshore areas. The spatial results have been justified further using trend analysis where the diverse patterns recognized in the spatial distribution of OHC increasing manner across the Baltic Sea.

Temporally, a K-means clustering with six groups shows a strong seasonal pattern, where earlier years had colder winters and moderate summers, while recent years exhibit milder winters and warmer summers. However, the spatial variability of more intense clusters reveals greater spatial anomalies compared to the smoother OHC fields observed in the more moderated clusters. Further analysis applied on the extra-preprocessed deseasonalized data highlights colder interannual periods in earlier years and warmer periods in more recent years. However, yearly variations are not entirely consistent, as sudden cooling or warming events appear in certain clusters. These anomalies are surveyed and interpreted using sub-clustering techniques, linking them to major inflow events, climatic variability, and shifting phases of influential oscillation patterns in the region.

This work received funding through the AdapEST project ("Implementation of national climate change adaptation activities in Estonia, VEU23019"), supported by the European Climate, Infrastructure and Environment Executive Agency (CINEA) via the LIFE programme.

Abstract ID: 154

Identification of cyanobacteria biomass in Baltic waters - comparative analysis of laboratory and remote methods

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In recent decades, an increase in the productivity and occurrence of cyanobacterial blooms has been observed in the coastal and open waters of the Baltic Sea and in Pomeranian lakes. Blooms of these organisms appear almost every summer, covering an area of up to 100,000 km^2. Their biomass can contribute up to 80% of the total algal biomass, and can account for over 50% of the basin's primary production.

Quantifying the biomass of cyanobacteria present in a given aquatic area is an extremely important issue, not only for determining the productivity of a given area or the amount of solar energy absorbed by these organisms, but also for their ability to produce biologically active compounds with toxic properties.

The classical method of estimating cyanobacterial biomass is based on microscopic analysis of the species composition of phytoplankton present in a given season and region. Other methods of assessing the biomass of phytoplankton groups are based on approximations using the composition and absorption and fluorescence properties of pigments, optically relevant components of phytoplankton cells. Such methods are widely used in oceanographic research and provide the possibility for remote, including satellite, qualitative and quantitative assessment of the presence of cyanobacteria in the marine environment.

The aim of the analyses presented here is to compare selected methods of approximation of cyanobacterial biomass in the Baltic Sea waters and assess their accuracy. The analyses were carried out on the basis of an accumulated data bank containing the biomass of cyanobacteria estimated on the basis of microscopic evaluation of phytoplankton species composition and values of physicochemical parameters of cyanobacteria including concentrations of color compounds contained in their cells determined by chromatographic, spectrofluorimetric and fluorescence methods. The best approximation accuracies were obtained when estimating cyanobacterial biomass on the basis of indicator carotenoids characteristic of these organisms, i.e. zeaxanthin, echinenone, canthaxanthin, myxoxanthophyll and aphanizophyll (r^2=0.4, N=826). On the other hand, for the selected subset of data in which cyanobacteria accounted for >75% of the occurring phytoplankton biomass, a relationship was established that allowed approximation of the biomass of this group of algae on the basis of phycocyanin concentration with a coefficient of determination of r^2=0.96.

Abstract ID: 156

Composition and temporal variability of dissolved organic matter in the nearshore Baltic Sea: Insights from optical spectroscopy and PARAFAC analysis

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Coastal oceans are recognized as hotspots of organic matter cycling and are considered to be highly dynamic environments. In addition to autochthonous production, inputs from rivers, groundwater, runoff from land, or release from sediments can be substantial. In the Baltic Sea, however, compared to the high background concentrations, the seasonal variability of dissolved organic carbon (DOC) is minimal, but changes in composition are not well explored. To illuminate the compositional dynamics on a timescale of days, we here assess the readily accessible optically active pool of DOM.

Weekly samples were collected over one year from an established nearshore biogeochemical time series station in the eastern part of the southwestern Baltic Sea (Heiligendamm, Germany) situated at 2-4 m water depth and analyzed via absorption and fluorescence spectroscopy. These measurements were complemented by data from two cruises in the southwestern Baltic Sea and subsequently mathematically decomposed using parallel factor analysis (PARAFAC). The validated best-fit model comprised seven distinct components: four humic-like, two protein-like, and one unknown yet not unprecedented component, each with distinct fluorescence properties.

Initial results reveal a seasonal shift in DOM composition, with a significantly higher proportion of protein-like components during spring and summer. This shift is largely mirrored by salinity, with lower salinities occurring in spring and summer, suggesting that mixing processes and primary production play a crucial role. While the coastal Baltic fluorescence landscape is dominated by humic-like components, these show only modest seasonal variations, with statistically significant differences detected only between summer and winter as well as between spring and winter. Moreover, principal component analysis segregates the humic-like components into two groups: one group consisting of C1 (C-type, Ex/Em 250 (325)/440 nm), C3 (D/E-type, Ex/Em 250/535 nm), C4 (M-type, Ex/Em 250 (310)/385 nm), and C6 (unknown-type, Ex/Em 270 (390)/475 nm), and a second group represented solely by C2 (A-type, Ex/Em 255/425 nm). Component C2 is hypothesized to be a product of photo-degraded DOM in various environments, with the potential to be removed by yet unconstrained abiotic and microbial processes.

Overall, this comprehensive dataset from the southwestern Baltic Sea enhances our understanding of DOC variability and composition in coastal environments, with important implications for nutrient cycling, light availability, alkalinity, trace element solubility, and contaminant transport.

Abstract ID: 157

Dissolved organic matter composition in the deep Fennoscandian Shield

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In addition to comprising at least a third of the earth's freshwater, deep continental groundwaters present at various hydrogeochemical conditions offer environments for the most different microbial metabolisms, while recording past conditions. In the secluded environment only slowly recharged from the surface, dissolved organic matter (DOM) serves as a major nutrient and energy source to heterotrophic organisms. In the granitic bedrock of Swedish Fennoscandia, previous studies have revealed mixing of pre-Holocene waters with recent, surface-sourced waters of Baltic Sea or terrestrial groundwater origin as a main driver of DOM compositional variability, and likely slow microbial processing by a starved community below the first meters. Located ~500 km north, in Olkiluoto, Finland, similar conditions as at the Swedish site prevail. Monitoring and research activities regarding chemistry and microbiology of the groundwaters started in the 1989, and around 60 boreholes down to 1000 m depth were drilled in the granitic bedrock to explore conditions for long-term spent fuel storage. Here, fracture waters from recent meteoric origin, but also old fractures from Littorina Sea stages of the Baltic Sea (7500-2500 years BP) partially diluted with pre-Littorina water, presumably meltwater from the Weichselian ice sheet, as well as pre-glacial waters can be accessed. In order to better understand sources and bioavailability of the deep biosphere DOM, we assess its composition on molecular formula-level in the fracture waters at Olkiluoto via ultrahigh resolution mass spectrometry. We were able to cover a wide range of fracture water chemical compositions in Olkiluoto, across which roughly 70% of the DOM composition was shared. Still, a marked increase in presumably biolabile compounds with higher H/C ratios and decreasing contribution of terrigenous organics was evident from the brackish-HCO3 to the deeper brackish/saline Cl-water type. We discuss the pronounced overlaps in the DOM fingerprints of the Swedish and Finish deep groundwaters with a focus on the role of microbial reworking in the energy-limited system.

Abstract ID: 164

Membrane-Inlet Mass Spectrometry (GE-MIMS) for continuous N_2, O_2 and Ar measurements on a VOS for the determination of N_2 fixation in the Baltic Sea

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Nitrogen fixation by cyanobacteria in the Baltic Sea plays a crucial role in the context of eutrophication, as it promotes biomass production in the absence of dissolved inorganic nitrogen (DIN). Its contribution to the N budget is comparable to the combined sum of riverine and airborne DIN input, ranging from 300 kt-N/yr to 800 kt-N/yr. The vast range is due to internal fluctuations and significant uncertainties in various techniques used to determine N_2 fixation and in extrapolate local studies to entire basins. To overcome some of the limitations we introduce a new approach based on large-scale records of the surface water N_2 depletion caused by N_2 fixation.

For our studies we use a membrane contactor (Liquicel) to establish gas phase equilibrium for atmospheric gases dissolved in seawater. The mole fractions of N_2, O_2 and Ar in the gas phase are continuously determined by mass spectrometry, yielding the concentration of these gases by multiplication with the total pressure and the respective solubility constants.

Thorough laboratory tests demonstrated that our Gas Equilibrium–Membrane-Inlet Mass Spectrometer (GE-MIMS) has sufficient accuracy and precision to detect and quantify nitrogen fixation. In June/July 2023, the GE-MIMS was deployed (i) on a voluntary observing ship (VOS, “Finnmaid”) for surface water gas analyses and (ii) for vertical water column studies on RV Elisabeth Mann Borgese along the VOS route between Helsinki and Travemünde. The VOS campaign enabled repeated identical transects thus providing high spatial and temporal resolution time series of N_2 concentration changes due to nitrogen fixation. First results clearly indicate regions and episodes where N_2 fixation was active. Concurrent records of pCO_2 and O_2 obtained from a different measurement systems on the VOS will be used for an independent characterization of cyanobacterial biomass production and thus of the associated N_2 fixation. In addition, data from an Imaging FlowCytobot (IFCB), also deployed on the VOS, will be used to gain deeper insights into the temporal dynamics of the cyanobacterial bloom by providing information on the abundance and composition of cyanobacteria and other phytoplankton species.

Abstract ID: 171

Hydrographic effects in Swedish waters of future offshore wind power scenarios

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Potential cumulative hydrographic impacts of offshore wind power expansion in the Baltic Sea, focusing on temperature, salinity, currents, and stratification are investigated in two future scenarios developed in collaboration with the Swedish Agency for Marine and Water Management. The scenarios represent an expected maximum scenario (345 TWh/year) for future Swedish wind power locations, and a more realistic scenario (131 TWh/year). For both scenarios, which represent large offshore wind power developments, that can be seen as conservative effect estimations (larger than likely), existing and planned wind farms in the surrounding countries were considered. The effect was examined by running an ocean model for the Baltic Sea and the North Sea for the period 1985–2016, comparing conditions as if offshore wind power had been installed in 1985 according to the scenarios, alongside conditions with no wind power development.

The effects from wind power and its wind wake were induced by wind stress reductions on the sea surface and by the increased friction and turbulence in the water from wind turbine foundations. Since there still is a lack of knowledge about how wind farms affect the wind at the sea surface the work is based on studies of existing wind farms in the North Sea that show a reduction of the wind by around 8% and an area that extends about 30 km behind a wind farm under stable atmospheric conditions. During unstable atmosphere conditions, which it often is in winter, the reduction is less. In order to get an estimate of the largest and smallest possible impact of wind power on the sea, for both scenarios, a minimum possible impact assuming that the reduction of wind only exists in summer and no reduction during winter, and an upper limit of impact assuming that the reduction exists all year round were assessed. The magnitudes of expected temperature and salinity changes are very dependent on the wind wake assumptions and the real response for these scenarios is probably somewhere in between these two estimates.

The results show that the expansion of offshore wind power in the Baltic Sea would generally lead to a shallowing of the halocline, as well as an increase in deep-water temperatures, however smaller than the change due to climate change. These changes are attributed to the reduction in wind speed behind the wind farms, which results in decreased vertical mixing.

Abstract ID: 173

Mesoscale Dynamics in the Baltic Sea: Oxygen and Chlorophyll Transport Insights from the 4DBaltDyn Project

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Mesoscale (10–100 km) and sub-mesoscale (1–10 km) processes in the Baltic Sea play a fundamental role in shaping its physical and biogeochemical dynamics, particularly in the transport and distribution of oxygen and chlorophyll. These eddies drive mass, energy, and nutrient exchanges across the thermocline and halocline, influencing temperature and salinity anomalies. Despite their significance, the three-dimensional structure and full impact of these eddies remain poorly understood. By promoting vertical mixing and lateral transport, mesoscale eddies help ventilate hypoxic deep-water regions, enhance nutrient availability, stimulate phytoplankton growth, and sustain marine biodiversity. The Baltic Sea Dynamics Through 4D Modelling and Integrated Earth Observation (4DBaltDyn) project (grant no. 400143924/24/I-DT) integrates satellite-derived data—including sea surface temperature (SST), sea surface height (SSH), ocean color, and sea surface salinity (SSS)—with high-resolution numerical models to generate novel, high-resolution daily 4D Baltic products (2016–2024). These products provide detailed insights into ocean currents, temperature, salinity, oxygen concentration, and chlorophyll-a distribution. This study leverages 4DBaltDyn outputs alongside in situ observations to offer a comprehensive understanding of eddy-induced transport processes and their influence on primary production and deep-water ventilation. Special emphasis is placed on low-oxygen regions, given their critical ecological importance and role in shaping the Baltic Sea's marine environment.

Abstract ID: 186

Perspectives of a holistic view into the ecosystem of the Baltic Sea – extension and collaboration of long-term data programmes

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Compared to the world ocean the signal of global warming related changes is amplified in the boreal seas. Thus, to estimate these anthropogenic changes the Baltic Sea is an ideal test case. First initiatives to gather hydrographic, chemical and biological parameters at fixed stations in the Baltic Sea were developed during the late 19th century, especially based on the hydrographic key topic of saltwater inflows. Since then, a number of regional long-term observation programs were developed by different institutions around the Baltic Sea. An intensive interregional one was developed by IOW's predecessor in Warnemünde in 1969. Stations in Danish, Swedish, Polish, and Latvian territorial waters and their respective Exclusive Economic Zones are repeatedly sampled within this long-term observation programme five times a year to cover the ecosystem dynamics from the Western Baltic Sea to the central basins in respective season. The station network is constrained by the requirements of the physical investigations of the dynamics of the water exchange and the Baltic Sea circulation. Chemical and biological investigations are limited to selected key-stations representing the individual basins. It is complemented by autonomous stations, long-term moorings and BGC-Argo floats to improve the temporal resolution.

The needs for observational data to support scientific investigations and information of the society are still increasing. To cover the Baltic ecosystem as a whole, the IOW extended their investigation sites in 2024 towards the northern basin. Once a year, the northernmost parts of the Baltic Sea, the Gulf of Bothnia are visited to investigate the spring stage, with focus on hydrographic and chemical conditions after ice melt. For measurements in this region colleagues from Umeå University joined our team temporarily. Within Swedish national monitoring Umeå University run a programme of long-term observations at five key stations ten times a year since the beginning of the 1990s. This opens new perspectives for fruitful collaboration. Key questions are dealing with the decoupled northern Baltic ecosystem compared to the central basins: how decoupled are the basins and which mechanisms lead to loss of oxygen budget, changes in nutrient concentrations and species biodiversity and composition.

The poster will represent the start of this collaboration, showing first results of our cruises in May 2022 (EMB293, as pre-expedition to our new research programme 2024-2033), May 2024 (EMB340) and May 2025 (EMB365). An intercalibration between both groups of physical measurements, chemical and biological analyzing methods was done in May 2024 for reliable data.

Abstract ID: 211

Integration of model and observational data to study excess dinitrogen gas below halocline in the Baltic Sea

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Excessive nutrient inputs drive eutrophication in the Baltic Sea, while limited water exchange with the North Sea enhances stratification, both leading to hypoxia and anoxia in bottom waters. In oxygen-depleted zones, denitrification converts nitrates into dinitrogen gas, with efficiency influenced by seasonal microbial dynamics. Although seasonal and spatial variations in removal processes of bioavailable nitrogen, particularly denitrification, have been reported, limited observational data hinder a comprehensive understanding. Numerical modeling offers a broader perspective, enabling a more representative analysis of these processes across the Baltic Sea. To trace these processes we used excess dissolved dinitrogen gas (ΔN_2) as a potential key indicator of nitrogen loss.

Thus, this study examines ΔN_2 dynamics by evaluating the ERGOM-MOM model against observational data from 2020–2021 at three Baltic Proper sites: the Gotland Deep, the Bornholm Deep, and the Gdańsk Deep, focusing on layers below the halocline. Key objectives include the investigation of spatial variability in bottom waters and seasonal changes, along with correlations between ΔN_2, temperature, salinity, oxygen, and nutrient concentrations. To gain a better understanding of ΔN_2 dynamics, model data were used to analyze correlations between denitrification rates and ΔN_2 values. Additionally, the study investigates the role of physical processes such as water transport in shaping ΔN_2 dynamics.

Notably, the Gdańsk Deep showed the strongest agreement with the model data, even though observational data at the Gdańsk Deep recorded the highest ΔN_2 in January while the model peaked in April. Additionally, a detailed analysis across all stations and seasons showed that both datasets exhibited significant seasonal variability ($p < 0.05$), driven by seasonal shifts in oxygen levels and associated biogeochemical processes. Modeled data revealed stronger ΔN_2–NO_3^- correlations ($R^2 = 0.55$, $p < 0.05$) than observations ($R^2 = 0.05$, $p = 0.395$). Regions near the Gotland Basin, known for long-term hypoxia, consistently showed the highest ΔN_2 values, which is in agreement with observational data.

Furthermore, analyses of oxygen-depleted layers revealed that correlations between ΔN_2 and denitrification rates ($R^2 = 0.11$, $p < 0.05$) were weaker than those with north-south currents ($R^2 = 0.27$, $p < 0.05$), suggesting that hydrodynamic conditions significantly influence N_2 transport alongside biological processes. These findings highlight the integrated effects of biological and physical processes on nitrogen cycling and provide a basis for understanding ΔN_2 variability in oxygen-depleted layers of the Baltic Sea.

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Abstract ID: 216

Distribution of inorganic carbon in the Baltic Sea sediments

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Carbon dioxide (CO_2) plays a crucial role in climate change and ocean chemistry, making it a key factor influencing global warming and ocean acidification. Marine sediments serve as a long-term natural carbon sink therefore quantification of the carbon distribution in sediments has been suggested to be an important topic for further studies.

Shelf seas, such as the Baltic Sea, play a significant role in carbon burial. Quantitative estimation of carbon deposition in bottom sediments requires determining the relative contributions of both organic (C_{org}) and inorganic carbon (C_{inorg}) forms. In the Baltic Sea, inorganic carbon is primarily found in the form of carbonate minerals such as calcite and aragonite, which can be deposited in sediments.

To determine the distribution of C_{inorg} in the Baltic Sea sediments we selected various basins, including coastal, semi-enclosed waters (the Szczecin Lagoon, the Gulf of Gdańsk, the Gulf of Bothnia) and open-water areas (the Gdańsk Deep, the Gotland Deep, the Bornholm Deep). This approach allows for a comprehensive analysis of the drivers shaping C_{inorg} distribution across different environmental conditions.

In the surface sediment (upper 0–5 cm layer), C_{inorg} content ranged from 0.2% to 1.9% across study areas. In coastal regions, the highest content (1.9%) was observed in the Szczecin Lagoon, which is likely the effect of the influence of the carbonate-rich Odra River and spontaneous mineral precipitation of calcite that has been previously documented in this region. On the other hand, in open-water areas, the highest values, up to 1.6%, were found in the Gotland Deep. Given the lack of pelagic calcifiers in the Baltic Sea, this is probably an effect of diagenetic processes in sediments. Our results indicate that the inorganic carbon content is highly diverse and likely influenced by local conditions such as water chemistry, terrestrial input, biological activity, and diagenetic processes. This data, although being a preliminary screening of C_{inorg} content in the sediments, is an important contribution to the understanding of carbonate chemistry in the Baltic Sea. By investigating in the future also the dissolution potential of sedimentary C_{inorg} from different regions, these results can be further used to close up the alkalinity budget which is presently one of the greatest challenges in the CO_2-system studies in the Baltic Sea.

Abstract ID: 223

The influence of active pockmarks on the zooplankton community in the Gulf of Gdańsk

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Pockmarks can be found on the seabed within the continental shelf around the world. They take the form of various-sized circular or elongated depressions in the bottom, ranging from a few centimeters to 1 km in diameter and with an average relative depth of several meters. The formation of these structures is usually associated with the release of gas (methane) and/or groundwater from the seabed. Apart from methane, additional emissions of pollutants, e.g. nutrients, also occurs. Ebullition and gas emission from the bottom disturb sediment-water interface and increase the dynamics of particles and flow of nutrients into the water column. In the case of continental shelf seas with limited exchange with open ocean, such as the Baltic Sea, the impact of such internal point sources may be particularly important for maintaining productivity and delaying ecological improvement despite reduced nutrient inputs from external sources. Thus, the presence of pockmarks, as the hotspots of nutrient emission, can be linked to changes in phytoplankton communities, and possibly also zooplankton.

In this study we decided to test the influence of active pockmarks, located in the Gulf of Gdańsk, on hydrochemical and physicochemical water conditions, and the composition and density of zooplankton community. Therefore, we collected vertically-stratified seawater and zooplankton samples at two stations over pockmarks with active gas outflow, and two nearby sites without gas leaks, in summer 2023 and winter 2024. Higher nutrient and chlorophyll *a* concentrations were observed above gaseous sediments, and the difference between seep and reference sites was most pronounced in summer, especially in the deepest parts of the water column. The zooplankton community exhibited large seasonal fluctuations, and differed significantly between the sampled layers. These factors strongly influenced the zooplankton community, but its composition over the pockmarks with active gas outflow, and sites without gas leaks was the most variable, possibly due to their impact, while the surface assemblage was very similar at every station. In addition, the zooplankton community was significantly affected by nutrients emitted from active pockmarks, such as phosphates and silicates, as well as total organic carbon, temperature, salinity and pH.

This research was supported by the grant number 2022/45/B/ST10/00395, from the National Science Centre, Poland.

Abstract ID: 249

Salinity distribution in Puck Lagoon - a modeling approach

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Puck Lagoon, a hydrologically distinct subregion of Puck Bay (part of the Gulf of Gdańsk, southern Baltic Sea) is characterized by limited water exchange with the open sea and substantial freshwater inflows. As an ecologically important area supporting diverse benthic fauna and flora, it is sensitive to variations in marine environmental parameters such as salinity. In situ measurements from June and August 2020 revealed unexpectedly high salinity in the lagoon during summer compared to the outer part of Puck Bay. However, point-based measurements provide only limited insights into the spatial and temporal variability of salinity. To achieve a more comprehensive understanding, model simulations are necessary.

Existing numerical models either lack the spatial resolution necessary to capture these dynamics or reproduce salinity with insufficient accuracy. To address this gap, we developed a high-resolution numerical model specifically designed to simulate salinity variability in Puck Lagoon with improved accuracy. The model's key assumptions will be discussed and a comparison of initial simulation results with in situ measurements will be presented.

Thematic Session: Ecosystem Health and Biodiversity

Abstract ID: 59

Environmental Adaptation with Biotechnological Potential: Antibacterial Activity of Baltic Cyanobacterial Strain *Limnothrix* sp.

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The spread of antimicrobial resistance (AMR) among pathogens is recognized as one of the biggest threats to public health by the World Health Organization. A crucial aspect of the fight against AMR is the identification of novel antimicrobial compounds. One of the strategies is to search for such compounds among the metabolites of living organisms. In the environment, these metabolites and the microbes whose interactions they mediate coevolve, continuously developing and optimizing their antimicrobial properties, making them promising drug candidates. Marine microorganisms, such as cyanobacteria, are an interesting source of those compounds. Cyanobacterial metabolites often exhibit antibacterial activity, mainly against Gram-positive bacteria, such as streptococci. A bioactivity screening of the Baltic cyanobacterial extracts against *Streptococcus pyogenes* ATCC12344 was conducted at the Marine Biotechnology Laboratory at the University of Gdańsk. Among 45 strains that were tested, *Limnothrix* sp. KUCC C4 showed promising antibacterial activity. The aim of presented research was to closely characterize this strain, its metabolites and antimicrobial properties.

For the characterization of the strain previously identified solely based on morphology, a phylogenetic analysis was performed using 16S rRNA, *cpcBA*, and *rbcLX* genomic sequences. KUCC C4 crude extract was fractionated using Solid Phase Extraction and tested against two strains of *S. pyogenes* – ATCC12344 and BAA-946, latter of which exhibited drug resistance to erythromycin, a macrolide antibiotic. Fractions were then analyzed with the use of mass spectrometry.

Some of the *Limnothrix* sp. strain polar fractions inhibited the growth of both *S. pyogenes* strains that were used in the assays. The presented studies are an important step in the process of natural product discovery and could contribute to finding a novel compound, active against drug-resistant group A Streptococci which are recognized as priority pathogens by the World Health Organization.

Funding: This research was funded by the Lithuanian Research Council and the Ministry of Education, Science and Sports of the Republic of Lithuania (Project No. S-A-UEI-23-9) and statutory activity of University of Gdańsk under DS531-O303-D879-25.

Abstract ID: 81

Multiple peripheral primordia in the otolith of herring (*Clupea harengus*) larva

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Otoliths play a crucial role in reconstructing the life history of fish, as their microscopic structure preserves valuable information about both the individual and its environment. These calcified structures, located in the inner ear, grow incrementally, enabling researchers to analyze past environmental conditions, growth rates, and migration patterns. However, various factors—both internal, such as genetic mutations and physiological stress, and external, including temperature fluctuations, pollution, and habitat degradation—can lead to structural anomalies in otoliths. Such irregularities may manifest as deformations in shape, asymmetry between paired otoliths, or alterations in chemical composition and microstructure. In this study, we report a unique structural anomaly observed in the sagitta otolith of a Atlantic herring (*Clupea harengus*) larva collected from the Polish part of the Vistula Lagoon - a crucial spawning and nursery area of the species. The anomaly, characterized by multiple peripheral primordia, has not been previously documented in Baltic herring larvae. Given the ecological importance of this region, identifying and analyzing otolith deformations may provide insights into potential environmental stressors affecting larval development. To our knowledge, this is the first reported instance of this particular anomaly in Baltic herring, highlighting its significance for future research on developmental abnormalities in fish populations.

Abstract ID: 94

Diversity in coastal areas of the northern Baltic Sea – epiphytic and seawater bacteria

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Coastal macrophytes function as a filter in aquatic ecosystems by removing excess nutrients and degrading organic matter entering the coastal system via land runoff and wastewater emissions. These aquatic plants act as biodiversity hotspots by providing food and shelter for a variety of micro- and macroorganisms. Studying the biodiversity of macrophytes and associated bacteria provides important benefits to understand and preserve the Baltic Sea ecosystem health and resilience. In this study, we collected seawater and macrophyte samples, from *Najas* and *Potamogeton* meadows, from three different bays in the Bothnian Sea: Skeppsviken, Kronoren, and Otronsviken in summer 2023. We measured physicochemical parameters such as temperature, salinity, and dissolved organic carbon concentration in seawater of the three different bays. The DNA from filtered seawater and macrophyte samples was sequenced using 16S rRNA long-read sequencing. The sequencing reads were processed using the NGSpeciesID pipeline (v0.1.2.2) to determine the bacterial community composition. Our study provides valuable insight on how bacterial community composition varies on different macrophytes as well as in seawater. The findings will contribute to a better understanding of macrophyte-bacteria interactions and their role in ecosystem functioning in subarctic coastal areas.

Abstract ID: 116

Application of ballast water exemptions decision support tool for identification of confirmed non-indigenous species introductions, with special emphasis on Baltic Sea and Port of Gdańsk

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Maritime transport represents a significant vector for the unintentional introduction of species into marine ecosystems. Due to the similarity of habitat conditions among ports worldwide, the risk of successful establishment and spread of non-indigenous species remains notably high.

Following the UN Conference on Environment and Development (Rio de Janeiro 1992), the IMO initiated negotiations to develop an internationally binding instrument to address the transfer of harmful aquatic organisms and pathogens in ships ballast water. This led to the adoption in 2004 of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (IMO BMWC), which entered into force globally on 8 September 2017. The IMO BWMC requires ships engaged in international traffic to implement ballast water management measures, such as ballast water exchange (D-1) or compliance with a specific discharge standard (D-2). Furthermore, an additional measure implemented under the Convention was the assessment of the risk associated with the introduction of selected non-indigenous species, designated as target species, between ports within the HELCOM and OSPAR regions. To facilitate this, in 2013, specialized research methodologies tailored for port environments were developed to detect the presence of 'target species', following the guidelines outlined in the Joint Harmonized Procedure for the Contracting Parties of HELCOM and OSPAR on the granting of exemptions under the IMO BWMC, Regulation A-4.

Based on research conducted in accordance with Regulation A-4, we analyzed a dataset from 48 ports, collected over 13 years to identify patterns in the spread of non-indigenous species. Since zooplankton and zoobenthos are particularly prone to introduction through ballast water and are among the most frequently identified alien species in the Baltic Sea, the analysis was focused on these groups, with special attention to 'target species'—non-indigenous species that are likely to impair or damage the environment, human health, property, and resources.

Emphasis was placed on the Port of Gdańsk, as it was surveyed in 2024, providing the most recent data, including the identification of two 'target species' a Polychaetae *Laonome xeprovala*, and a new invasive jellyfish species, *Moerisia inkermanica*.

Abstract ID: 134

Molecular tool development for assessing genetic diversity in the garfish (*Belone belone*)

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The garfish (*Belone belone*) is an increasingly important species in Baltic Sea recreational fisheries, yet its genetic diversity and population differentiation remain poorly understood. To meet the recommendations for the recognition and conservation of genetic resources of exploited species, this study aims to address this gap by developing a microsatellite-based genetic analysis approach, which has not been previously applied to the species. By amplifying microsatellite loci developed for related Beloniformes, we aim to establish a molecular tool for assessing genetic diversity in *B. belone*. This approach simultaneously considers the optimization of cost and time for molecular analyses using the mutli-PCR technique. It will provide a foundation for investigating population connectivity, genetic variability, and potential substructuring in the Baltic Sea as well as within the range of the species. These insights will contribute to a more comprehensive understanding of the species' biology, supporting future research on its distribution, population dynamics, and ecological role. Additionally, the results will inform conservation and management strategies as the species gains prominence in the Baltic ecosystem and fisheries. Preliminary results are to be presented at the conference.

Abstract ID: 136

Blue mussels in decline in the Baltic Sea: The effects on mussel-eating seabirds and possible solutions

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Recent studies indicate that the blue mussel (*Mytilus edulis trossulus*) is declining in certain regions of the Baltic Sea. This is a significant concern due to its ecological role as a major foundation species, filter feeder and prey item. Similarly, some mussel-eating seabirds, such as the common eider (*Somateria mollissima*), are also experiencing declines.

This poster will present the ongoing work by the Björn Carlsons Baltic Fellows to address these issues. The network is currently collecting monitoring data across the Baltic Sea to evaluate if declines in blue mussels are widespread. Initial analyses show declines in some areas. Additionally, we will gather data on spatial and temporal variation in blue mussel condition and quality as prey, including fatty acids, stable isotopes, and thiamine concentrations. All of these data will be used to determine the potential impacts of changes in mussel abundance and quality on seabird populations.

The poster is presented by the Björn Carlson Baltic Fellows, a network of 21 researchers dedicated to promoting healthier Baltic ecosystems.

Abstract ID: 146

Marine Research and Innovation in Hanö Bay

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Marint centrum, hosts a research and innovation environment in collaboration with Lund University and Region Skåne, focusing on the marine ecosystem of Hanö Bay, coastal development, marine industries, advanced water treatment, and circular water management. Hanö Bay is a vital habitat in the Baltic Sea, featuring unique geological and marine archaeological sites. Through interdisciplinary collaboration between academia and society, the center addresses pressing environmental challenges to develop practical solutions that promote sustainable development in the region.

We actively collaborate with other universities and research institutions and welcome new partnerships. Current research projects include artificial cod reefs in Hanö Bay, the invasive round goby, offshore algae and mussel farming, fisheries policy, genetic analyses of Baltic herring, the effects of PFAS chemicals, microplastics' impact on marine mammals, wetland efficiency, and advanced wastewater treatment. Additionally, solutions for water scarcity in Österlen are being explored.

Marint centrum provides researchers with office and meeting spaces, as well as access to a well-equipped field laboratory for sampling and data collection in Hanö Bay. The field lab facilitates underwater studies using waders, water scopes, and underwater cameras. It also houses equipment for collecting and analyzing water, sediment, plant, and animal samples, with facilities including microscopes, reference literature, refrigeration units, -80°C freezer, and drying ovens. The lab also supports small-scale experimental studies.

The center offers exciting thesis projects and internships for students passionate about marine science and sustainability, and we actively seek collaborations to further research and innovation.

Abstract ID: 176

Artificial islands in the Szczecin Lagoon (southern part of the Baltic Sea) as a habitat increasing biodiversity: first biological studies

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The construction of two new islands in the eastern part of the Szczecin Lagoon can be seen as the latest example of human interference in the environment of this reservoir, which undoubtedly translates into the functioning of the entire area, taking into account the state of the basic environmental elements, i.e. abiotic variables of the water column and bottom sediments, as well as biotic variables. According to literature, these islands function as a kind of artificial reef, particularly attractive to fouling organisms.

The fouling communities themselves are interesting as biocenoses developing on a hard substrate almost never encountered in the Lagoon area. Creating artificial substrates for the development of such biocenoses as a result of locating various hydrotechnical structures in the underwater zone diversifies the range of habitats available to organisms, contributing to a local increase in the overall biodiversity of fauna and flora. On the other hand, artificial underwater structures can also cause certain ecological problems, resulting, e.g., from arising conditions for the intensive settlement of invasive species.

Therefore, there is a need to monitor changes in this artificially created environment. With this in mind, in June 2024, the first biological studies concerning macrophyte communities and fouling fauna were conducted within the northern island of W-22. The macrophytes of the island consisted exclusively of green algae (Chlorophyta); macrobenthos communities (including fouling organisms) were abundantly represented by sessile filter feeders – bivalves of the genus *Dreissena*, creating a habitat for species of mobile crustaceans, primarily gammarids; many alien species were found in the macrobenthos communities, and all of them, apart from the newcomer *Sinelobus vanhaareni*, were present in the macrofauna of the Lagoon before the construction of the islands.

It can be concluded that the construction of the island played the role of an artificial reef creating new habitats for both macrophytes and macrofauna, increasing their biodiversity in a place previously covered with fine-grained sediments that were a habitat only for a narrow group of organisms (e.g. oligochaetes and larvae of Chironomidae).

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Abstract ID: 196

Assessing biological effects of chemical contamination on the clam *Macoma balthica* and the amphipod *Monoporeia affinis* in the Gulf of Riga

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Chemical pollution represents one of the main threats to the Gulf of Riga (GoR) environment, negatively affecting the health of its biota, vital ecological functions, and endangering its biodiversity. Increasing evidence shows that effect-based methods, such as biomarkers and bioassays, can provide a powerful tool to distinguish chemical toxicity from other potential causes of biodiversity decline and serve as an early warning of possible threats. Employing a designed battery of biomarkers in addition to measuring various contaminants and key physicochemical variables in monitoring improves our understanding of biological responses to environmental stress. Identifying potential toxicity through effect-based approaches reveals active toxicants and their associated effects at the cellular and organismal levels, thereby enhancing the assessment of impacts from pollutant mixtures.

The main goal of this study was to evaluate chemical contaminants (trace metals and organic pollutants) in GoR sediments and tissues of benthic target organisms and attempt to link the observed contaminant levels with a battery of biomarkers (AChE, CAT, GST, GR, TBARS and reproductive disorders) in Baltic clams (*Macoma balthica*) and amphipods (*Monoporeia affinis*). In 2023, samples of benthos community, sediments, and organisms for chemical contaminants and biomarker analysis were collected at two coastal stations located 20 meters deep in the GoR near the main harbour areas.

The findings indicate that biological effect methods are effective for assessing environmental quality. The Integrated Biomarker Response Index (IBR) calculated from the single biomarker results showed elevated values at the same selected station for both clams and amphipods. However, the response was more pronounced in clams, indicating species-specific differences in reactions among benthic organisms. The oxidative stress biomarkers in *M. balthica* and *M. affinis* responded significantly to various groups of organic contaminants, such as PAHs, that accumulate in the sediments. Meanwhile, a marked AChE inhibition was observed at the stations with elevated levels of PCBs. Considering the complexity of pollutant mixtures and environmental conditions, biological effect indicators provide a more reliable approach to evaluating the impact of contaminants across ecosystems compared to the measurement of chemical concentrations alone.

Our findings highlight the importance of integrating chemical and biological assessment methods in the evaluation of ecosystem health. This study contributes to a better understanding of pollution effects in the Baltic Sea and supports the development of monitoring strategies for benthic communities under environmental stress.

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Abstract ID: 226

Alien talitrid among indigenous ones – comparison of population characteristics

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Platorchestia platensis is a non-indigenous species that has been present on the Puck Bay coast since 2005. It is an expansive species with characteristics that presumably enable it to outcompete indigenous talitrids. These traits include, among others, high density and fertility. The density is probably associated with its fertility and the absence of a hibernation phase. In contrast, the protected *Talitrus saltator* and rare *Deshayesorchestia deshayesii* undergo a hibernation phase in the cold season. Furthermore, *P. platensis* is more active than Baltic talitrids, giving it an advantage in avoiding potential predator attacks. Little is known about the population structure of the alien *P. platensis* along the Polish coast. Therefore, the aim of this study was to compare the population characteristics of three species co-existing in the same area. The research was carried out in August, September and December of 2018, and May of 2019. The individuals were obtained from the coastal areas of Hel Peninsula. The density, total length, and sex of three species were examined.

The presented research is a preliminary investigation into year-long studies on the population dynamics of the alien *P. platensis,* indigenous *T. saltator*, and *D. deshayesii*.

Abstract ID: 232

Macrozoobenthos functioning vs. sediment type – the case of the Bornholm Basin

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In the marine soft-bottom environment, one of the main activities of the benthic macrofauna in the bottom zone is bioturbation and bioirrigation. Animals, by burrowing into the sediment, play a key role in the circulation of chemical elements and nutrients on the seafloor. Sediment type is a strong factor influencing the occurrence and abundance of soft-bottom zoobenthic species. Benthic faunal species usually show an ecological optimum associated with a particular sediment type. The functioning of animals varies depending on the sediment parameters. Therefore, it is important that environmental studies take into account the functional aspect of the zoobenthos as well. The impact of benthic macrofauna on the ecosystem can be estimated based on bioturbation (BPc) and bioirrigation (IPc) potential indexes and biological trait analysis (BTA). The BTA approach uses a number of selected organisms traits that are related to their role in the functioning of marine ecosystems. The aim of the study is to compare the taxonomic and functional diversity of the benthic fauna along sediment type gradient. The study was carried out in the eastern part of the Bornholm Basin in the area designated for the construction of offshore wind farms (OWF). Quantitative samples of macrozoobenthos were collected with a Van Veen grab. Information on sediment type was obtained from concurrent geological studies (Szymczak, 2023). The study determined the taxonomic structure, density and biomass of the zoobenthos. Based on the created catalogue of biological traits of benthic macrofauna, analyses of functional differences of benthic communities and their potential activity in sediments (BPc and IPc) were performed. The highest functional diversity was observed on the sediment with the coarsest gain size. The highest values of BPc and IPc potentials were observed in very fine-grained sand. The study enables us to bridge the gaps in our knowledge of the changes in the functioning of the benthic communities that will occur after the construction of the OWF in the area. It is known that the grain size of the sediment near farm constructions can change, usually shifting to fine-grained sediment with an increased contribution of organic matter. Such changes will significantly affect the composition and functioning of the benthic communities.

Abstract ID: 234

Fitness and mercury accumulation in soft tissues of *Mytilus trossulus* from rocky habitat in the Bornholm Basin

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Mytilus trossulus plays an important role in the ecosystems functioning in the Baltic Sea. The Baltic mussel beds provide an excellent habitat for other species, giving shelter, breeding ground and food. They prefer hard substrates such as rocks or stones, which are rare in the open waters of the Baltic Sea. Large areas of rocky substrate can be observed in relatively few places in the southern Baltic Sea. The rocky reefs of Slupsk Bank are one of the most important feeding grounds for birds during wintering and provide a stable and year-round food base for non-migratory species. Diving birds such as dabbling ducks prefer smaller specimens of mussels not exceeding 2.5 cm in length. The mussels in this size range also provide food for fish belonging to the goby and flounder families.

Mercury (Hg) is a pervasive environmental contaminant detected across various abiotic and biotic components of ecosystems, including sediments, fauna, and human populations. Despite the absence of any known physiological function in biological systems, mercury exhibits high toxicity and poses a significant risk of poisoning. It bioaccumulates within organisms and is inherently challenging to eliminate. Furthermore, mercury undergoes biomagnification within trophic networks, leading to progressively higher concentrations in organisms at successive levels of the food chain. As filter-feeders bivalves accumulate mercury from water and sediments, which can lead to its bioaccumulation in their tissues. Long-term exposure to mercury can cause them to suffer from metabolic disorders and a decrease in their ability to reproduce, as well as posing a threat to the organisms that feed on them. Our study aimed to determine the concentration of mercury and fitness of *M. trossulus* at different depths in the Bornholm Basin.

Sampling was carried out near Slupsk Bank at depths of 28 to 42 m. Macrozoobenthos-covered boulders up to 25 cm in size were collected. Bivalves were sorted according to established size classes. The dry tissues of the bivalve were analyzed for total mercury on a DMA 80 analyzer. The results indicate a positive correlation between average condition index values and station depth, suggesting that mussels in deeper waters exhibit better overall condition. Conversely, an inverse relationship is observed for mercury content in dry tissues, where higher mercury levels correspond to lower condition index values. This finding suggests that increased mercury accumulation negatively impacts the mussels physiological condition.

Abstract ID: 245

Epifauna of wrecks

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Shipwrecks serve as artificial reefs, significantly influencing habitat heterogeneity and local biodiversity, particularly in areas where hard-bottom habitats are rare. The biofouling epifauna developing on the surfaces of wrecks creates ecosystems primarily composed of filter-feeding organisms, which form the foundation of the newly created community. Their presence is an important addition to the local food web and improves water clarity and quality. Additionally, epifauna provides shelter from predators, a place for reproduction and a food-bank for associated mobile invertebrates and fish. Shipwrecks can also facilitate the survival and expansion of invasive species by enabling them to overcome natural environmental barriers (e.g. sandy areas). Invasive species, often introduced unintentionally through human activities, may negatively affect local biodiversity by competing with native species for space and resources. This study was conducted on the wreck of the ORP Groźny, located on the Gulf of Gdańsk seabed of Puck Bay at 18 meters depth of, southern Baltic. The aim of the research was to determine the biodiversity of assemblages of epifauna and associated organisms on a shipwreck, considering a long-term perspective (over 10 years) based on samples collected in the winter season in February 2012 and February 2024, and a seasonal perspective based on samples from the winter, spring, summer, and autumn seasons of 2024. Additionally, samples collected from vertical and horizontal surfaces were compared. A total sum of 38 taxa were identified. Studies have shown that the vast majority of identified organisms belonged to biofouling species as *Mytilus trossulus* and *Amphibalanus improvisus*, which are characteristic of the early stage of succession. These species play a crucial role in the formation of an "habitat builders," which provides shelter many associated organisms. Vertical surfaces were characterized mostly by biofouling organisms, while horizontal surfaces were characterized by a significantly greater abundance of Oligochaeta and Polychaeta due to the high amount of sediment. This study allowed for an assessment of biodiversity changes on the investigated wreck and provided insights into its' impact on the local ecosystem.

Abstract ID: 253

First record of invasive hydroid *Calyptospadix cerulea* Clarke, 1882 in the proper Baltic Sea

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A widely distributed invasive hydroid, *Calyptospadix cerulea* (Cnidaria, Hydrozoa), is reported for the first time in the proper Baltic Sea. This species was previously recorded in the western Baltic, including Kiel Bay, the Bay of Mecklenburg, and the Warnow Estuary, albeit under the name *Garveia franciscana*. We also suggest that *Bimeria baltica*, described from Greifswald Lagoon by Stechow (1927), may be conspecific with *C. cerulea*. Our study site was an offshore WWII torpedo testing facility in Gdynia, where extensive colonies of *C. cerulea* were collected by divers from concrete structures and biotic surfaces at depths of 6 to 8.8 m in November and December 2024. The colonies were sexually immature (without gonophores) but formed dense, bushy meadows, coexisting with *native hydroid Gonothyraea loveni* without apparent competition. They were densely overgrown by epibionts, including diatoms and protozoans. Hydranths persisted despite water temperatures below 10°C but regressed by late December. *Calyptospadix cerulea* was successfully brought into culture at the University of Gdańsk, which has allowed further morphological and molecular analyses. By sequencing two mitochondrial genes (16S and COI), we determined the phylogenetic placement of *C. cerulea* within Anthoathecata and enabled future screening for this species using eDNA. Our finding brings the total number of Hydrozoa in the Polish zone of the Baltic Sea to 10 species and suggests potential of *C. cerulea* for further range expansion, warranting future monitoring and molecular studies to clarify its distribution and taxonomy.

Abstract ID: 255

Baltic *Synechococcus* response to different colors of light and low oxygen concentrations

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Picocyanobacteria from coastal habitats are exposed to changes in irradiance, spectral waveband, and sometimes [O_2], by vertical movements through the mixed layer. Picocyanobacteria from the genus *Synechococcus* are major contributors to primary marine production, across a wide range of environments including the Baltic Sea region, but interactive influences of [O_2] and spectral wavebands on their growth rates and ecophysiology have not yet been investigated. In this work, we determined the abundance of PC-rich and PE-rich *Synechococcus* cultures in the southern Baltic Sea during spring, summer, and fall season. We then tested the growth and functional responses of Baltic PC-rich and PE-rich *Synechococcus* cultures to the interaction of different oxygen concentrations (250 or 2.5 µmol/L [O_2]), and spectral wavebands (405–730 nm).

We found that PE-rich *Synechococcus* achieved faster growth rates (µ), across the spectral waveband from 405 to 730 nm, under 2.5 µmol/L [O_2], characteristic of oxygen minimum zones (OMZs), than under 250 µmol/L [O_2]. In contrast, PC-rich cultures showed generally similar µ under 2.5 and 250 µmol/L [O_2]. For PC-rich and PE-rich *Synechococcus*, µ showed also positive linear responses to both phycobiliproteins:chlorophyll ***a***, although the relations vary across strain and [O_2]. We showed that PE-rich *Synechococcus* are currently typically found at greater depths, and lower light, than are PC-rich strains, but we suggest that the PE-rich strains are actually limited to lower light habitats by an interaction between light and full air-saturated [O_2]. In expanding OMZs PE-rich strains will likely exploit higher light niches, across a wider spectral range.

Abstract ID: 257

The effects of simultaneous changes in temperature and salinity on the osmoregulation and metabolic rate of *Rhithropanopeus harrisii*

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This study investigated the combined effects of temperature and salinity changes on the osmoregulation and metabolic rate of *Rhithropanopeus harrisii*, a non-indigenous species in the Baltic Sea. Native to North America, *R. harrisii* can survive in a wide range of salinities (0.5–40) and temperatures (below 0–37°C), making it a successful coloniser. Experimental conditions were based on projections of temperature and salinity changes in the Baltic Sea by the end of this century, with rising temperatures and decreasing salinity expected. The experiment included four environmental conditions with different combinations of temperature (15°C and 20°C) and salinity (2 and 7). The research was conducted on 10 adult males of *R. harrisii* for each salinity-temperature combination collected from the Gulf of Gdańsk. Metabolic rate was measured using an isoperibol twin calorimeter (Calveta type), and osmoregulation was assessed by analysing hemolymph osmolality with a vapor pressure osmometer.

The results indicated a significant ($p<0.05$) increase in metabolic rate with rising temperature. Salinity of 7 was more profitable for *R. harrisii* than salinity of 2, with the species incurring higher energy costs at 20°C compared to 15°C by 13,45% in salinity 7 and 17,27% in salinity 2. The greatest differences between metabolic rate of *R. harrisi* from different experimental temperatures were observed at lower salinity, suggesting that this species exhibits greater metabolic sensitivity to temperature changes in low-salinity waters. A statistically significant ($p<0.05$) increase in metabolic rate was observed between specimens from different salinities, but only at the higher temperature (11,99% higher at salinity 2). Furthermore, hemolymph osmolality was significantly ($p<0.05$) higher reaching 623,28 $mOsm/kg^{-1}$ (at 15°C) and 628,40 $mOsm/kg^{-1}$ (at 20°C) at higher salinity (S=7) compared to lower salinity conditions reaching 559,58 $mOsm/kg^{-1}$ and 581,08 $mOsm/kg^{-1}$ respectively. Osmotic capacity was higher in lower salinity by 15,41% at 15°C and by 17,94% at 20°C. A positive correlation between osmotic capacity and metabolic rate was identified, indicating a relationship between these two physiological processes and their joint influence on the physiology of *R. harrisii.*

Importantly, this is the first study to simultaneously examine the effects of changes in both temperature and salinity on the metabolic rate and osmoregulation of *R. harrisii*. This knowledge enhances our understanding of the ecology of this species and its potential future impact on the Baltic Sea.

Thematic Session: Geological Processes and Coastal Erosion

Abstract ID: 38

Connection between seafloor pockmarks and submarine groundwater discharge in the Gulf of Finland: constraints from seafloor images and porewater geochemistry

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Offshore discharge of groundwater is globally recognised as an important process contributing freshwater and trace elements to the costal oceans. Its potential impacts on seafloor features have also been suspected in recent studies. Here we report a site from the southern Gulf of Finland where both seafloor pockmarks and offshore groundwater discharge (SGD) are confirmed. Seafloor depressions of ca. 75-100 meters in diameter with glacial varves outcropped from the wall were observed from our remote operating vehicle surveys onboard R/V Electra from Stockholm University. From the sediment porewater taken in the region, brackish groundwater (dissolved chloride concentration down to 76 mM) characterised by depleted water isotopic signatures (down to -60.6‰ for $\delta^{2}H$ and -8.0‰ for $\delta^{18}O$) and low radiocarbon activity of dissolved inorganic carbon (DIC, down to 1.86±0.08 pMC) is detected. The conventional radiocarbon age of the DIC (up to 32±0.35 kyr BP) is much older than the ages of particulate organic matter (2.7 to 14.8 kyr BP, n=14) pointing to an ex-situ DIC source that is associated with the submarine groundwater. We discuss the potential aquifer for the observed SGD and its connection to the formation of seafloor pockmarks.

Abstract ID: 52

Mapping Seabed Sedimentation Rates: Winds of Change Beneath the Waves

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Introduction: Sediment deposition and resuspension are key processes shaping the seabed environment. Information on sedimentation rates is essential for e.g., carbon cycle and carbon budget studies, monitoring pollutants and microplastics, and understanding changes in sediment dynamics.

Data and Methods: The EMODnet Geology project collects and delivers harmonized data on seabed sedimentation rates. The data is compiled from all available information on the rate of sedimentation in European maritime areas, provided by EMODnet Geology project partners from their national waters (including EEZ). This data focuses on present-day sedimentation rates, covering the past decades, since ca. AD 1900. Estimations of modern sedimentation rates can be based e.g., on established historical records of anthropogenic radionuclides (e.g., ^{137}Cs), lead (Pb), mercury (Hg) and stable lead isotope ($^{206/207}$Pb ratios). Sedimentation rate estimates can be based also on varve/laminae counting, radionuclide ^{210}Pb and ^{14}C decay dating methods, as well as monitoring the seabed change (e.g., by multibeam echosounder surveys). In addition, local stratigraphic marker horizons, like in the Baltic Sea, horizons formed by documented Major Baltic Inflow events, can be used in the estimations. The data is presented as point-source information, currently consisting of over 1600 data points.

Results and discussion: Sedimentation rates vary greatly from place to place. Accumulation does not occur everywhere, e.g., in the Baltic Sea Basin it has been estimated that sediment accumulation areas cover approximately one-third of the seafloor. Generally, sedimentation rates in the accumulation areas of the European Seas varies from some mm/year up to some cm/year. The highest rates occur in the estuaries as well as in certain deep(er) basins/depocenters. In some estuaries the sedimentation rates can be up to several cm/year. Furthermore, the data supports recent observations of significant changes in some sea areas, marked by an increased deposition of organic carbon-rich sediments on the seabed (e.g., Moros et al., 2024).

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Discover Europe's seabed geology at: https://emodnet.ec.europa.eu/en/geology

Reference:

Moros et al. (2024) Giant saltwater inflow in AD 1951 triggered Baltic Sea hypoxia. Boreas, 53, 125–138. https://doi.org/10.1111/bor.12643

Abstract ID: 55

Simulating rock coast profile evolution and cosmogenic 10Be accumulation in Kakumäe, Estonia

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Rock coasts are fully erosional environments that usually lack datable sediments. Exposure dating using cosmogenic nuclides is currently the only method to reconstruct millennial-scale retreat rates of coastal cliffs. The method has been used to, e.g., calculate average cliff retreat rates in the late Holocene, demonstrate shore platform inheritance from previous sea-level high stands, constrain shore platform evolution processes (waves versus weathering) and quantify long-term retreat of intertidal rock layer edges (step back-wearing). Relative acceleration, deceleration and steady character of coastal cliff retreat rates has been found for different locations around the world. The method has also been used to forecast future cliff erosion for different emissions scenarios.

Kakumäe peninsula is located at the western edge of Tallinn, NW Estonia. The area is densely populated with a road running meters from the cliff edge. The cliff is cut in 10-m high Cambrian sandstone overlaid by glacial till and fronted by a 500-m wide submerged shore platform. Cliff retreat rates averaged 0.6 ± 0.05 m/yr for 1959-2010 and 0.8 ± 0.01 m/yr for 1995-2010 (based on repeat levelling surveys and cartographic analyses). In order to understand how contemporary erosion rates compare to long-term coastal evolution we have designed an experiment that combines numerical modelling with measurements of 10Be concentrations across the shore platform. Here we present the simulations of coastal topographic profile evolution and 10Be accumulation for different scenarios of long-term rates and trends of the cliff and shore platform erosion.

Abstract ID: 70

Exploring South Baltic Sea Morphodynamics with Bathymetric Surveys, Sonar Images and Subaqueous footage & photos

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This study presents the results of bathymetric and sonar surveys conducted in the remote nearshore zone of the South Baltic Sea, approximately 1–2 nautical miles off the Polish coastline near Lubiatowo, at depths ranging from 16 to 20 meters. High-resolution multibeam echosounder measurements were collected during five field campaigns in November 2017, December 2018, and three in 2023 (April, September, and December), and processed to generate detailed bathymetric maps. These maps accurately reflect seabed conditions and highlight morphological changes over time.

In addition to the bathymetric surveys, divers performed seabed observations, documented potential bedform appearances, and collected seabed soil samples for grain size analysis. Underwater videos and photographs were captured using an underwater drone equipped with a ruler, ensuring precise measurement references.

The analysis includes a differential bathymetric map, showing seabed elevation changes ranging from a few centimeters to more than 1 meter over the course of a few months, a year, and several years. The sonar images and subaqueous photos and videos reveal bottom ripples with various dimensions, contributing valuable insights into the dynamic seabed morphology of the South Baltic foreshore zone.

This region holds significant environmental and geological interest, making it a frequent subject of research related to coastal dynamics, sediment transport, and marine habitat analysis. The region serves as a hub for scientific research; studies often focus on coastal engineering, sediment management, and the development of renewable energy projects, such as offshore wind farms. Lubiatowo's dynamic environment and strategic location make it an essential area for advancing understanding of coastal and marine processes.

Abstract ID: 73

Morphology and settings of coastal cliffs in Estonia

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Rocky coasts of the Baltic Sea have so far received limited scientific attention despite their popularity as tourist destinations and the presence of extensive infrastructure nearby. Compared to soft-sediment coasts, rocky shores exhibit lower morphological dynamics. However, in the context of ongoing climate change, a precise understanding of their morphology and environmental conditions is essential for conducting further detailed studies on their dynamics, raising public awareness, and preventing damage to nearby infrastructure.

The coast of Estonia displays significant geological diversity. In the northern and northwestern parts of Estonia, the Baltic Klint is exposed, composed of Cambrian and Ordovician rocks, whereas in the southern part, on the island of Saaremaa, the Silurian Klint is exposed, revealing its sedimentary layers. This study focuses on ten different locations along the Estonian coast, each characterized by distinct geology and environmental settings.

The morphology of the cliffs was described using LiDAR data, digital terrain models, and orthophotos, allowing for the determination of key differences in their shapes and settings. Geological maps allowed lithology mapping that was complimented with rock hardness and discontinuity measurements in the field at four sites—Kakumäe, Pakri, Osmussaar, and Panga.

The distribution of study sites along the Estonian coastline exposes them to diverse environmental conditions. The differences in wave energy, precipitation, air temperature and sea ice conditions were analyzed to assess their influence on erosion rates.

Changes in relative sea level, duration of sea ice cover, storm frequency and intensity, and temperature fluctuations are key environmental drivers that may affect the erosion of rocky coasts of the Baltic Sea. Characterizing coastal morphology and environmental conditions is a crucial first step for further studies. Moreover, increasing public awareness will contribute to better coastal management and the protection of coastal infrastructure in the future.

Abstract ID: 166

EMODnet Geology – Providing marine geological information about the European maritime areas

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The European Marine Observation and Data Network (EMODnet) is a long-term initiative funded by the European Commission to assemble and make accessible high-quality marine data from various sources across Europe. Since its inception in 2009, EMODnet has aimed to support sustainable marine and coastal management by providing open-access FAIR data and data products essential for scientific research, policymaking, and industry. Today, this network of over 120 organizations covers several broad disciplinary themes: bathymetry, biology, chemistry, geology, human activities, physics, and seabed habitats. Each theme contributes to a comprehensive understanding of Europe's marine environment, with datasets available through the EMODnet Central Portal (https://emodnet.ec.europa.eu/en).

EMODnet Geology, one of the thematic areas, focuses on the collection and harmonization of marine geological data. This thematic provides extensive datasets on seabed substrates, sedimentation rates, seabed erosion, sea floor geology (including lithology and stratigraphy), Quaternary geology, geomorphology, coastal behavior, geological events, marine mineral resources, and submerged landscapes of the European continental shelf. It covers the full areal extent of European seas and is expanding to new areas, including the Caspian and Caribbean Seas. EMODnet Geology delivers harmonized interpreted data layers (maps) rather than raw data, with metadata providing information on data holders for users needing access to the underlying data. By integrating data layers from national geological surveys, research institutes, and marine organizations, EMODnet Geology ensures the availability of accurate and standardized geological information to support maritime spatial planning, environmental impact assessments, and sustainable resource management.

The current EMODnet Geology project phase (2023-2025) aims to further enhance data coverage and quality. Coordinated by the Geological Survey of Finland (GTK), it is executed by a consortium of 40 partners and subcontractors, primarily members of the EuroGeoSurveys (EGS) network, supported by other partner organizations with valuable expertise and data.

EMODnet Geology also supports third-party data submission, either directly or through EMODnet Ingestion, which reaches out to potential data providers from private and public sectors. By facilitating data sharing and collaboration, EMODnet Geology continues to support informed decision-making and sustainable management of marine environments. It is a dynamic initiative where existing datasets are continuously updated with new data.

The EMODnet Geology project is funded by The European Climate, Environment and Infrastructure Executive Agency (CINEA) through contract EASME/EMFF/2020/3.1.11 - Lot 2/SI2.853812_EMODnet – Geology.

Abstract ID: 174

Analysis of Beach Replenishment Effectiveness as a Method of Polish Coastal Protection: A Case Study of Artificial Beach Fill in Kuznica – Environmental Aspect

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Beach replenishment is a widely used method aimed at protecting the coastline from marine abrasion. It involves the artificial deposition of sand on the beach, thereby increasing its length and height, which ultimately attenuates the impact of sea waves. Beach replenishment also has a socioeconomic aspect, enhancing the tourism potential of coastal towns.

Artificial beach replenishment was carried out on April 24, 2024, along the section of the Hel Peninsula from 10.5 km to 12.5 km near the town of Kuźnica. On May 9, 2024, the Operational Oceanography Scientific Circle of the University of Gdańsk, in collaboration with the Institute of Hydro-Engineering of the Polish Academy of Sciences, conducted a measurement expedition to determine the spatial appearance of the beach and the coastline in this region. Within the area subjected to beach replenishment, 9 tachymetric beach profiles and 14 bathymetric coastal profiles were measured, along which sand samples were collected and subsequently subjected to granulometric analysis. Additionally, the meteorological and hydrodynamic conditions prevailing 30 days prior to the expedition were examined, based on data from the measurement station in Hel and the hydrodynamic model of the Baltic Sea.

The aim of this study is to establish the beach morphology after replenishment, which will allow for the subsequent evaluation of the loss of the replenished material after the summer season and following the first storms. The acquired data can serve as a valuable source of information, facilitating future administrative decisions.

Abstract ID: 217

Application of satellite data and surveying to detect changes in the coastline and seabed evolution in the spit coast as an element of hydromorphological characteristics

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Spit coast is not a common type of Baltic Sea coast. The most numerous of this coastal type is found in Poland, and the largest form is the Hel Peninsula. This spit, which is a scythe-shaped sand barrier, is exposed to shore erosion due to the exposure of waves and dominant longshore currents. The sensitivity of this area, resulting mainly from the geological structure constituting a narrow spit and increased hydrodynamic conditions, determines the need for observations and the development of new complementary methods to support decisions on the protection of the shore and habitat. The Hel Peninsula was formed at the turn of the Pleistocene and Holocene and is constantly subject to geomorphological changes. Thanks to the marine transgression, a sandy underwater dike was formed, which rose to the surface during the withdrawal of the sea (regression), giving rise to the formation of the Hel scythe. The spit is an extension of the beach (land), which accrues due to the movement of sandy material along the shore. Coastal currents and wave action are responsible for the transport of material. An important element of marine environmental monitoring is the analysis of bathymetric-orographic conditions of the coast in the form of geodetic field measurements of the coastal zone and sonar measurements of the seabed. Detection and identification of geomorphological changes in both the shore and the seabed are important for shore protection, land reclamation, ongoing and planned investment activities, and marine flora and fauna habitat. Due to the field surveys conducted in 2019 and 2022, it was possible to compare the variability of transects in terms of the increase or decrease in the ordinate of the seabed and its association with erosion or shore accumulation compare the results obtained in this way with high-resolution (30-50 cm) Neo Pléiades satellite images. Using Matlab's Image Processing Toolbox and a library of high-resolution Neo Pléiades satellite images, shorelines were delineated, which further enabled the Haversine method to calculate the distance of the shoreline from the reference line. This made it possible to identify regression or shoreline growth and, consequently, the growth or lowering of the seabed, according to Bruun's theory. The main objective of the research is to demonstrate the applicability of high-resolution satellite data for detecting and identifying changes in seafloor geomorphology and to determine the horizontal length of the sedimentologically active seabed as an alternative method for hydromorphological monitoring studies.

Thematic Session: Land-Ocean-Atmosphere Interactions and Catchment Processes

Abstract ID: 31

Enrichment of the sea surface microlayer in selected contaminants in six ports of Europe and on transects between them

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The sea surface microlayer (SML) is the most superficial layer (top 1–1000 µm) of the surface ocean. It is lying at the interface between the atmosphere and hydrosphere. SML is a unique biological, physical and chemical habitat, characterized by different properties from subsurface water (UWL). Dissolved and particulate organic matter can be enriched up to 1000 times in the SML compared to UWL. SML plays an important role in the exchange of gases, aerosols and energy on a global scale. It takes a collecting role for natural and anthropogenic pollutants deposited from the atmosphere. It is a microhabitat for a diverse range of living organisms (phytoplankton, zooplankton, bacteria, ichtyoneuston). The expansion of world trade and the resulting increase in demand for maritime transport services make harbours a main emitter of anthropogenic contaminants. In addition to the role of sea ships, everyday activities in ports are also important determinants to take into consideration for seawater quality in port areas and their surroundings. Despite this, there is still insufficient information in these areas about SML and UWL contamination with compounds that can be included in the trophic chain or deposited in sediments. Therefore, the aim of this study, conducted during a cruise on the R/V Oceanograf from Gdynia (Poland) to Cadiz (Spain) and back, was to compare the contamination of the sea surface microlayer and subsurface water with Polycyclic Aromatic Hydrocarbons (PAHs), trace metals and elemental carbon. Samples were collected in six European ports and on transects between them from May 25 to July 14, 2022. The research was supplemented with suspended particulate matter concentration, chlorophyll-a, meteorological parameters and air masses trajectories. The obtained results showed that SML was enriched in all measured compounds both in ports and on transects between them. The enrichment factor values (EF) were always higher than 1. In ports the highest median enrichment factors of SML were noticed for: Pb (4.8) > EC (4.4) > B(a)P (3.6) > FLU (3.2). On transects the median EF decreased in the series: Cr (8.4) > Cu (7.4) > Pb (5.9) > EC (5.8) >FLU (5.6). The median B(a)P enrichment factor on transect was just slightly lower than in ports (3.0). Among all compounds Mo was characterized by the highest EF in the SML of ports compared to transects (2.5 times higher). In turn on transects SML was as much as 3 times more enriched in Cr compared to ports water.

Abstract ID: 41

Spatio-Temporal Variability of Greenhouse Gas Dynamics in Shallow Bays Along the Swedish Baltic Sea Coast

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Coastal ecosystems play a crucial role in greenhouse gas (GHG) cycling, yet they remain less studied compared to open oceans and terrestrial systems. In this study, we present measurements of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) concentrations from shallow coastal environments in the wider Stockholm archipelago.

Sampling was conducted in April and September 2024 using cavity ring-down spectroscopy combined with a water equilibration system. Our study focused on shallow bays, including eutrophic and habitat-altered environments, where surface water CH_4 concentrations reached up to 580 nmol L^{-1}, suggesting substantial CH_4 emissions. Interestingly, CH_4 concentrations below 200 nmol L^{-1} showed a negative correlation with N_2O, whereas levels above this threshold exhibited a shift to a positive correlation. We propose that this transition reflects changes in oxygen availability, where hypoxic conditions ($0.2 < O_2 < 2$ mL L^{-1}) promote CH_4 production, while the reoxygenation of euxinic sediments contributes to an additional late-summer N_2O peak.

Moreover, GHG concentrations in surface seawater were linked to environmental parameters such as water retention time, vegetation coverage, total organic carbon content, turbidity, chlorophyll-a concentration, pH, and total phosphorus levels.

This comparative study highlights the importance of integrated approaches to better understand GHG emissions in coastal zones, which are increasingly affected by anthropogenic pressures such as nutrient enrichment and habitat modification. Our findings contribute to a broader understanding of coastal ecosystems as dynamic interfaces in the global carbon and nitrogen cycles, informing the development of evidence-based environmental policies.

Abstract ID: 43

Multi-year gradient measurements of sea spray fluxes over the Baltic Sea and the North Atlantic Ocean

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Ship-based measurements of sea spray aerosol (SSA) gradient fluxes in the size range of 0.5–47 µm in diameter were conducted between 2009–2017 in both the Baltic Sea and the North Atlantic Ocean. We observed notable differences in the amount of SSA between the two regions. The Baltic Sea exhibited lower aerosol emissions compared to the Atlantic Ocean. The study revealed a marked reduction in SSA fluxes in the Baltic Sea when biological activity, indicated by higher chlorophyll-a levels, increased. In particular, when chlorophyll-a concentrations were elevated, SSA emissions decreased under stronger wind conditions. This suggests that biological activity plays a significant role in moderating aerosol emissions in this semi-enclosed sea. Environmental factors such as wind speed, wave dynamics, and the physical state of the sea surface were closely linked to the observed SSA emissions in both regions. The results showed that younger waves in the Baltic Sea generated more SSA than those in the Atlantic, highlighting the role of wave age in aerosol production. The analysis also found weak correlations between SSA emissions and air and water temperatures, as well as atmospheric stability, suggesting that these factors may play a lesser role in influencing SSA emissions in comparison to wind and wave dynamics. This study provided the first detailed comparison of SSA emissions in these two distinct marine environments, using the same measurement techniques across both regions. The findings underscore the complexity of SSA generation, influenced by the interaction between biological activity and physical oceanographic processes, particularly in regions like the Baltic Sea, where local environmental conditions are unique. The contrasting behaviors of SSA emissions between the Baltic and the Atlantic emphasize the need for region-specific models to better predict aerosol fluxes and their broader implications for atmospheric and oceanic processes.

Detailed results are presented in the publication: Markuszewski P. et al. Multi-year gradient measurements of sea spray fluxes over the Baltic Sea and the North Atlantic Ocean. *Atmospheric Chemistry and Physics*, 2024, 24.19: 11227-11253.

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Abstract ID: 44

Modelling the impact of land-use changes to the local climate in Estonia

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Regional climate model covering the Baltic Sea area is employed to assess its sensitivity to land-use changes in Estonia and to demonstrate the potential impacts of changes in forested land area on the local climate. An experiment is constructed for a historical 30-year time period (1981 to 2010) using a global land-use database, which is demonstrated to fairly accurately describe the forested land area in Estonia. To evaluate the effect of deforestation in the region, model simulations are performed with differing forested area and open land proportions, and the magnitude of the impact is quantified. The impact of local land-use change is assessed in terms of common climate parameters, such as temperature, precipitation, etc. In addition, the impacts on the hydrological cycle, including runoff and evapotranspiration, are studied.

Abstract ID: 75

EnviAgri—Digital decision support system for environmentally-friendly agriculture

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The intensification of agriculture has significantly contributed to environmental degradation, particularly in terms of nutrient runoff, greenhouse gas emissions, and soil depletion. Addressing these challenges requires innovative tools that integrate environmental protection with agricultural productivity. The EnviAgri project aims to develop a digital decision support system that assists farmers in meeting regulatory requirements while optimizing resource use and minimizing environmental impact.

The core of the system is the Digital Farm Model, which integrates expert knowledge with user-provided data and external environmental parameters. The system operates through an interactive interface, linking farm-specific data with meteorological inputs, soil properties, and regional regulatory constraints. The computational module of EnviAgri consists of eight functional submodules designed to evaluate critical environmental indicators:

Each submodule processes data using tailored algorithms and provides farmers with actionable insights to reduce emissions, enhance soil health, and improve overall resource efficiency. By identifying sensitive areas prone to nutrient loss and energy inefficiencies, the system supports strategic decision-making for both environmental sustainability and economic viability.

The pilot implementation in the Pomeranian Voivodeship will serve as a testbed for refining the system before broader deployment. Future iterations will include additional user-centric features, ensuring accessibility for farmers, advisors, researchers, and policymakers. With growing market interest in low-emission agricultural products, EnviAgri aligns with the European Green Deal, Farm to Fork Strategy, and Carbon Farming initiatives, contributing to sustainable agricultural practices and ecosystem resilience.

By integrating advanced computational tools with real-world agricultural challenges, EnviAgri represents a forward-looking approach to balancing food production with environmental stewardship, supporting both regulatory compliance and long-term farm profitability.

This research was funded by National Centre for Research and Development of Poland within the GOSPOSTRATEG IX program No. GOSPOSTRATEG.IX-000T/22.

Abstract ID: 85

Meteorological conditions during extreme wave events in the Gulf of Gdańsk based on EOF analysis

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Extreme events, such as storms, have been highlighted as one of the key research topics for the Baltic Sea region. Large-scale atmospheric circulation influences local wind wave conditions. Due to the shape of the Baltic Sea, high variability in the directions of winds generating the most extreme storm events with respect to wave heights has been observed. As storm events are usually a result of the low-pressure system moving in the vicinity of the Baltic Sea, its trajectory and position relative to the areas of high pressure are crucial for the development of extreme wave heights in different areas. Winds from certain directions, even though they meet the definition of storm winds over Baltic, that is 15–17 m/s, will rarely result in an extreme wave event.

In this study, characteristic patterns of large-scale atmospheric pressure anomaly distribution during extreme wave events over southern Baltic have been detected with empirical orthogonal function (EOF) analysis. With respect to the wind wave fields, Gulf of Gdańsk has been selected as the main area of interest since it is the most populated area on the Polish coast with high human activity (tourism, high marine traffic, numerous investments in the coastal zone area).

From datasets generated within the HIPOCAS project, which contain meteorological and wind wave parameters over the Baltic Sea in 1958–2001, 34 distinct extreme wind wave events, critical for the Gulf of Gdańsk, have been selected. Empirical Orthogonal Function analysis was applied to the sea level atmospheric pressure anomaly fields over central and northern Europe for these extreme wave events. Our aim was to find common characteristics in the spatial distribution of the atmospheric pressure fields and their evolution during analysed storm events. Our results show that two groups of storm events can be identified in the Gulf of Gdańsk, characterised by distinctly different features. These two types of extreme wave events are result of low-pressure systems moving over two distinct groups of trajectories, leading to different angular ranges of the evolution of wind direction during analysed storms. First four EOF modes highlight five regions with highest variability of atmospheric pressure anomaly. Additionally, evolution of the related principal components is distinctly different for the identified groups of extreme wave events in the Gulf of Gdańsk.

Abstract ID: 105

Atmospheric mineral dust effect on surface termoelasticity of Baltic Sea coastal waters

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The purpose of this study is to analyze the thermoelastic and rheological properties of seawater surfaces containing mineral dust inclusions. Their presence affects surface tension, adsorption of surface-active species, and the ability of the surface to respond to temperature changes and shear stresses. These properties modify several physicochemical and transfer processes occurring at the atmosphere/seasurface region, including aerosol transport, gas exchange, heat flow, generation and damping of surface waves etc. Elastic surface film parameters i.e., Gibbs adsorption, elasticity modules were derived from the surface pressure-film area $(\pi\text{-}A)_T$ isotherm and the surface pressure-temperature $(\pi\text{-}T)_A$ isochore dependences. The examined surface thermodynamic functions were: surface free energy, entropy, enthalpy, and surface specific heat of air-seawater (AW) interface. Any relaxation process in films leads to complex quantity- dilational viscoelasticity modulus E, composed of real E_d (dilational elasticity) and imaginary E_i (dilational viscosity related) parts derived from the surface pressure-time (π-t) response of a film to a rapid step relative surface area deformation in a Langmuir trough system [1]. The measurements were carried on water samples with natural mineral particles and the model hydrophobic material (of μm- diameter), and differentiated hydrophobicity corresponding to the water contact angles (CA) ranging from 60° to 140°(- talc, silica spheres, combustion dust) in Baltic Sea coastal waters (Gulf of Gdańsk, Poland). The particle surface density (number cm^{-2}) and particle diameter distribution were derived from the microscope picture analyses of the greased cover glass deposition plates. The composite surface dilational modulus predicted from the theoretical approach, in which natural dust load signatures (particle number flux, daily deposition rate, diameter spectra, and CAs) originated from *in situ* field studies performed along Baltic Sea near-shore line stations, agreed well with the direct experimentally derived data[2]. The hydrophobic particles incorporation at a sea surface film structure increased the elasticity modulus by a factor K (1.29–1.58). CA of the natural dust particles were varying in a wide range from 47.3° to 106° depending on the collection site. Particle diameter distribution histograms, 24-hour collection time, revealed mean values between 5.8 and 7.6 μm depending on the distance from the shore line. The ambient daily dry deposition rate or dust flux (mg m^{-2} day^{-1}) registered in Sopot ranged from 10.82 to 2.30.

References:
[1] K. Boniewicz-Szmyt & S. Pogorzelski, Oceanologia,2016, 58, 25-38;
[2] A.Z. Mazurek & S. Pogorzelski, International J. Oceanogr. vol. 2012, article ID 638240.

Abstract ID: 150

Surface pCO2 and air-sea CO2 fluxes during two upwelling events in the southern-east Baltic Sea

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Coastal upwelling is a common phenomenon in the Baltic coastline, bringing up deep, often colder, and more saline water from the sea interior. These waters are characterized by their higher levels of pCO_2 (compared to the surrounding surface waters), turning upwelling into key processes for regional air-sea CO_2 fluxes, marine ecosystems, carbon inventory, and water mass dynamics. To date, in-situ pCO_2 observations are insufficient to accurately estimate the importance of upwelling-induced carbon fluxes. In this study, we combined in situ and satellite-derived data to understand the temporal and spatial extension of two upwelling events near the Hel Peninsula (southern Baltic Sea). In May and October 2024, surface waters were displaced by colder and more saline water with higher pCO_2 concentrations covering an area of approximately 3400 km^2. Measured pCO_2 correlated significantly with temperature ($R^2 > 0.95$). The relationship obtained from in situ measurements was applied to satellite-derived sea surface temperature to monitor the temporal and spatial variability of pCO_2 through both events. The results show that during both, the area covered by the coastal upwelling became a net source of CO_2 to the atmosphere, with pCO_2 values as high as 620 µatm in May and 2.500 µatm in October. Potential density measurements indicated that the latter water mass was upwelled from as deep as 60m water depth. Even though both events served as a net source of CO_2, the air-sea CO_2 flux estimations indicated large differences between them, with fluxes up to 6.42 mmol m^-2 d^-1 in May and a maximum of 804.13 mmol m^-2 d^-1 in some sectors during October. These results provide new insights into CO_2 air-sea fluxes, inorganic carbon inventory, and water mass dynamics in the Baltic Sea.

Abstract ID: 175

The Development of Agro-Hydrological Model for the Puck Bay Area based on Publicly Available Datasets

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Agro-hydrological modeling frameworks, such as the Soil and Water Assessment Tool (SWAT/SWAT+), are becoming increasingly important for assessing and improving agricultural management, crop yields, and water quality in coastal regions. Such modeling tools can help bridge knowledge gaps by providing outputs that are consistent across different computational modules, effectively managing the connections between the atmospheric conditions, soil and plant at a daily step resolution. Once models are calibrated and validated, with identified sources of uncertainty, they can provide detailed insights into river water flow, water quality as well as plant development and the occurrence of growth constraints throughout the growing season, effectively accounting for temporal and spatial scales. Although SWAT+ provides a wide range of output information, it requires several key input datasets, including daily meteorological data, a digital elevation model, land use maps, and soil maps, many of which are publicly available and contain sufficient information to support the model. Input data play a crucial role in model development, directly impacting their accuracy and usability. As a general rule, the quality of input data has a direct influence on the reliability and usability of the output. Data from the Head Office of Geodesy and Cartography, the Institute of Meteorology and Water Management – National Research Institute, Institute of Soil Science and Plant Cultivation – State Research Institute, Copernicus services, national agencies, and external sources were used for model development. Here, we present the results for the first Case Study in the Puck Bay Area, other areas of interest in applying agro-hydrological frameworks such as SWAT/SWAT+, along with the sources of input datasets, the key information we aim to obtain through model development, as well as future needs and perspectives.

Abstract ID: 248

Environmental Drivers of Sea Spray Aerosol Production in the Baltic Sea: Insights from a novel Sea Spray Simulation Chamber

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Sea Spray Aerosols (SSA) are a vital link between the ocean and the atmosphere, and understanding their formation dynamics is crucial to clarify their implications for the global climate. Changes in seawater properties, such as temperature, salinity, and biological activity, can alter the number flux and composition of nascent SSA produced, however the processes controlling this production remain incompletely understood. Long-term measurements are needed to better understand these complex interactions and improve our knowledge of marine aerosol processes.

A novel floating sea spray was designed to address this knowledge gap by enabling consistent measurements over a long period of time. The chamber generates SSA in the coastal Baltic environment using a breaking wave analogue that closely mimics the bubble plume, foam, and aerosol production mechanisms that occur during oceanic wave breaking. Using a floating laboratory located beside the chamber, we have measured the physical and chemical properties of the nascent SSA. This approach aims to provide a more comprehensive understanding of SSA production dynamics in the coastal zone and their climate implications. The chamber is located at the Askö Laboratory, located approximately 80 km south of Stockholm.

This project also falls within the goals of the CoastClim research school “Perspectives on Climate Change in Coastal Seas” which aims to understand the interactions between coastal seas and the atmosphere using a transdisciplinary approach.

We plan to present an overview of the chamber’s design and our planned research activities at the Baltic Sea Congress.

Thematic Session: Marine Pollution: Sources, Trends, Effects and Solutions

Abstract ID: 14

Why the Baltic Sea is so important – An international view

Marek Krawczynski

Rotary International, Warszawa, Poland. Baltic Sea Regional Action Group BASRAN, Helsinki, Finland

Comparing to Australia, the Baltic Sea has as many attractions as the amazing beaches on that distant continent. But on the Baltic the beaches are even more people friendly and the history is even more fascinating. I am an environmental architect who worked for 30 years in Australia. My work included the rebuilding of the famous Sydney Opera House after Joern Utzon. This building as well as the extensive Australian beaches are all world famous icons. The Baltic Sea has the potential to be an equally important icon of natural beauty and I wiil demonstrate why! Over 20 inspiring slides and texts will be shown during this presentation. We now have the technologies to remove and stabilize all the dangerous post-war materials which lie on the bottom of the Baltic Sea. This will pose a very serious environmental hazard before the middle of this century. We must act now to preserve this amazing natural treasure so that future generations can enjoy all its wonders for centuries to come. Promoting these solutions and the beauty of the Baltic will generate much revenue to enable this mission to be completed in time. Rotary International is ready to assist with this promotion thru its thousands of international members including its young Rotaractors living in the 9 countries within the Baltic Basin. Education and awareness building are very important at this time. We should be an example for the world to follow. What kind of Baltic do you want for your children?

The presentation materials will be prepared together with hydrographer Dr. Benedykt Hac from Sopot in Poland.

Abstract ID: 35

Impact of sediment resuspension on near-bottom mercury dynamics: Insights from a Baltic Sea experiment

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Marine sediments serve as significant reservoirs of legacy pollution, with the potential to release toxic mercury (Hg) into the water column when disturbed. This study investigated Hg remobilization from surface sediments during resuspension events, focusing on sediment characteristics, Hg concentrations, and speciation. Research was conducted in the southern Baltic Sea, encompassing a range of environmental conditions and human influences. The results indicate that sediment resuspension is the dominant mechanism driving Hg remobilization, while diffusion flux plays a minor role. Both dissolved and particulate Hg were rapidly released upon resuspension, with elevated concentrations persisting long enough for potential transport beyond the affected area. The diffusion of dissolved Hg was enhanced by labile sedimentary Hg fractions, with reducing conditions and high organic matter content further facilitating this process. Particulate Hg remobilization was primarily governed by sediment properties, particularly bulk density, which influenced resuspension dynamics and the dispersion of suspended material. Additionally, total Hg concentrations and labile organic-bound Hg fractions played a key role in particulate Hg release. These findings underscore the critical role of sediment composition in managing Hg-contaminated sites and provide valuable insights for environmental protection strategies and marine operations.

Financial support for this research was provided by the National Centre for Research and Development, Poland, through the MarTERA ERA-NET Cofund (projects AMMOTRACe – MarTERA-2020_101, and ProBaNNt – MarTER A-2020_1 6), the National Science Centre, Poland (project 2018/31/N/ST10 /0021 4), and the Institute of Oceanology, Polish Academy of Sciences (statutory funds, task II.8.1).

Abstract ID: 84

Endocrine-Disrupting Phenols in the Vistula Lagoon: The Role of Non-Commercial Fish in Contaminant Flow Within the Trophic Network – A Pilot Study

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In recent years, scientific interest has focused on Endocrine Disrupting Compounds (EDCs), including 4-nonylphenol (4-NP), 4-tert-octylphenol (4-t-OP), and bisphenol A (BPA). These substances do not naturally occur in the environment but can be released during the manufacture and degradation of plastics, as well as from non-ionic surfactants, detergents.

Our previous research demonstrated the presence of these compounds in organisms from all trophic levels in the Gulf of Gdańsk, confirming their potential for bioaccumulation within the food chain. This study aimed to assess the role of non-commercial fish species from the Vistula Lagoon (South Baltic Sea) in incorporating phenol derivatives into the trophic network. The Vistula Lagoon is a shallow water body with limited water exchange, making it particularly prone to contaminant accumulation across various environmental components, including fish.

The concentrations of phenol derivatives were analyzed using the HPLC-FL method in the muscle tissue of perch (*Perca fluviatilis*), ruffe (*Gymnocephalus cernuus*), and bleak (*Alburnus alburnus*), while bream (*Abramis brama*) and roach (*Rutilus rutilus*) were analyzed as whole fish.

The concentrations of 4-t-OP ranged from <0.3 to 2405.5 ng/g dw, 4-NP from <0.3 to 15451.7 ng/g dw, and BPA from 2.1 to 2209.5 ng/g dw. Whole-fish samples exhibited more times higher levels of these compounds compared to muscle tissue alone. Previous studies on birds conducted demonstrated that the physicochemical properties of phenol derivatives influence more accumulation in specific organs, especially rich in fat like subcutaneous fat, brains, gonads, kidneys, livers. This This may explain the higher concentrations in whole fish and the accumulation in other fish tissues beyond muscle.

Moreover, benthivorous fish exhibited higher concentrations of 4-t-OP and 4-NP in their muscle tissue compared to pelagic fish. Since phenol derivatives tend to accumulate in sediments, where they correlate with organic matter content, organisms with benthic feeding habits are at greater risk of exposure to these land-derived toxicants.

This study represents preliminary, pilot research. Ongoing investigations are expanding the scope by incorporating additional fish species, analyzing a broader range of tissues, and extending the study area to other regions of the southern Baltic Sea. These efforts are expected to yield further valuable insights into the bioaccumulation and ecological risks of endocrine-disrupting phenol derivatives in marine ecosystems.

The samples originate from the project: Primary producers as a key carrier of historical and contemporary mercury in the estuarine food web, led by Professor Magdalena Bełdowska.

Abstract ID: 88

Mercury contamination of small, non-commercial fish in the southern Baltic Sea and their role in the transfer of toxic elements into the trophic network

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Mercury is one of the most toxic metals, posing a significant threat to human health. It undergoes bioaccumulation in aquatic organisms and biomagnification within the marine trophic network, ultimately reaching humans at the highest trophic level. Upon entering the human body, mercury exhibits neurotoxic properties, leading to damage in the central nervous system, which may result in cognitive, motor, and sensory dysfunctions. Vulnerable populations, such as children, are particularly susceptible to the detrimental effects of mercury, as even low doses of Hg can negatively impact neural development. Pregnant women are also at heightened risk, as mercury readily crosses the placental barrier, posing a threat to fetal development. Furthermore, mercury exposure has been associated with adverse effects on the cardiovascular system, immunological dysfunctions, and renal impairment. Consequently, continuous monitoring of mercury concentrations in the environment, particularly in aquatic ecosystems, is imperative for public health protection. Equally crucial is the dissemination of knowledge regarding the hazards posed by mercury contamination, particularly concerning dietary exposure. Extensive research has been conducted on mercury concentration levels in sediments and commercially significant fish species; however, data on its transformation and bioavailability across various trophic levels remain insufficient. This knowledge gap is particularly evident concerning small, non-commercial fish species, which may play a pivotal role in the transfer of mercury within marine ecosystems. The objective of this study is to elucidate the role of non-commercial small fish species in the trophic transfer of total mercury within the marine food web, with particular emphasis on lagoon ecosystems in the southern Baltic Sea region. Experimental analyses were conducted on fish specimens collected from the Vistula Lagoon and the Puck Bay during the spring of 2023. The study was carried out at the laboratories of the Faculty of Oceanography and Geography at the University of Gdańsk, employing a direct mercury analyzer (DMA-80) based on thermal desorption to quantify mercury concentrations with high precision.

Abstract ID: 93

Radioactive concentrations of ^{137}Cs, ^{238}Pu and $^{239+240}Pu$ in the bottom sediments of the southern Baltic Sea in 2022-2024

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The study is focused on the concentrations of radionuclides ^{137}Cs, ^{238}Pu, and $^{239+240}Pu$ in the bottom sediments of the southern Baltic Sea from 2022 to 2024. Measurements were conducted as part of the marine environment monitoring program to assess the distribution and dynamics of changes in radioactive concentrations. The main sources of radioactive contamination in the Baltic Sea were the major accident at the Chernobyl nuclear power plant and the nuclear weapons tests conducted in the southern hemisphere during the 1950s and 1960s.

Bottom sediments were analyzed in stratified samples – 12 samples per one 19 cm high core. Sediments from the Gulf of Gdańsk (P110, P116), the Gdańsk Deep (P1), the Gotland Basin (P140), and the Bornholm Basin (P39, P5) were examined. ^{137}Cs concentrations were studied using gamma spectrometry method. The highest concentrations of ^{137}Cs were observed in the Gulf of Gdańsk. In 2022, the average radioactive concentration for location P110 was 90,6 ± 2,2 $Bq \cdot kg^{-1}$; in 2023 it was 83,2 ± 2,4 $Bq \cdot kg^{-1}$, while in 2024 the average concentration for this location was 76,5 ± 2,8 $Bq \cdot kg^{-1}$. The lowest radioactive concentrations were obtained in the open sea area in the Bornholm Basin. In 2022 this value was 23,8 ± 1,1 $Bq \cdot kg^{-1}$ for location P39. In the years 2023-2024, the lowest average radioactive concentrations of ^{137}Cs were obtained for station P5 and it was: 15,4 ± 0,9 $Bq \cdot kg^{-1}$ and 14,2 ± 1,5 $Bq \cdot kg^{-1}$, respectively.

For plutonium concentrations radiochemical method was used, where in the final stage plutonium isotopes ions were deposited on steel plates by electrodeposition. Analysis of all six locations in terms of $^{239+240}Pu$ concentrations is carried out on a three-year system, with two locations for each year. Similarly to ^{137}Cs, plutonium isotopes concentrations were higher in the Gulf of Gdańsk compared to the open sea region. The highest average radioactive concentration of $^{239+240}Pu$ was recorded in 2023 at location P110, measuring 2,30 ± 0,10 $Bq \cdot kg^{-1}$, and the lowest for location P5 0,37 ± 0,03 $Bq \cdot kg^{-1}$.

The obtained results show a decreasing trend in radioactive contamination of anthropogenic origin. Concentrations of studied radionuclides also indicate that no new sources of radioactive contamination are observed in the southern area of the Baltic Sea. However, the monitoring program should be continued to ensure current assessment of the state of the marine environment and early detection of potential changes.

The research was funded by the National Atomic Energy Agency.

Abstract ID: 95

Radioactive concentration of ^{226}Ra in fish from the southern Baltic Sea in 2022-2024

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The study is focused on the concentrations of ^{226}Ra in fish from the South Baltic Sea in years 2022 – 2024. Fish are a recognized bioindicator of long-term changes in the concentrations of radionuclides present in water environment. ^{226}Ra is the most common of the natural radionuclides. The concern about ^{226}Ra stems from the fact that it has been identified as a significant source of environmental pollution caused by both nuclear and nonnuclear applications. Naturally it is found in various types of rock and geologic formations including U ores. ^{226}Ra has high radiotoxicity, long half-life and permanent presence in nature. ^{226}Ra is an alpha-emitter, belonging to the natural series of uranium. It can be easily incorporated into bones because of its physiological and chemical similarity to calcium and barium. Therefore, consumption of food or water contaminated with ^{226}Ra leads to accumulation of short-lived progenies of ^{226}Ra in the human body and contributes to radiological dose.

Monitoring of the ^{226}Ra radiation exposure risk requires accurate determination close to the detection limit, due to its presence in trace amounts. The emanation method for determining ^{226}Ra in consists in separating radium from other mineral components by co-precipitation with a Ba^{2+} carrier, then dissolving the precipitate and deemanating ^{222}Rn in equilibrium with ^{226}Ra. ^{222}Rn is transferred to a Lucas-type scintillation chamber. After equilibrium is established between ^{222}Rn and its derivatives, the alpha radioactivity of ^{222}Rn and its short-lived decay products is measured. The emanation method is characterized by high sensitivity and very low detection limit.

In 2022 the highest radioactive concentrations of ^{226}Ra were determined in cod (0,084 ± 0,008 Bq·kg^{-1}). The average concentrations of ^{226}Ra in the studied species were: 0,024 ± 0,002 Bq·kg^{-1} (herring), 0,052 ± 0,004 Bq·kg^{-1} (flounder) and in 0,075 ± 0,001 Bq·kg^{-1} (sprats).

The average concentration of ^{226}Ra in 2023 in all the species was 0,052 ± 0,007 Bq·kg^{-1}. The highest occur in cod, average 0,077 ± 0,010 Bq·kg^{-1}and the lowest in herring (0,022 ± 0,004 Bq·kg^{-1}). The rest of concentration was: 0,048 ± 0,009 Bq·kg^{-1} in flounder and 0,061 ± 0,009 Bq·kg^{-1} in sprats.

The average radioactive concentration of ^{226}Ra for all fish samples in 2024 was 0,046 ± 0,016 Bq·kg^{-1}. In sprats it was 0,057 ± 0,015 Bq·kg^{-1}, in herring 0,027 ± 0,009 Bq·kg^{-1}, in cod 0,052 ± 0,010 Bq·kg^{-1} and 0,050 ± 0,009 Bq·kg^{-1} in flounder.

The research was funded by the National Atomic Energy Agency.

Abstract ID: 101

Toxic oil or fish fat emulsion? Identifying oil in natural seawater based on excitation-emission matrix patterns

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Toxic oil contaminants pose a serious threat to marine organisms and lead to a reduction in biodiversity, disturbing the balance of the ecosystem. Due to intensive maritime traffic and limited water exchange with the ocean, the Baltic Sea is particularly vulnerable to the accumulation of oil-derived substances. Detecting these contaminants is essential for sustainable development and marine environment protection. However growing demand for omega-3 acids has increased the maritime transport of fish oils risk of accidental spills. The presence of fish oils in seawater complicates the detection of toxic oils, as their optical properties can lead to false-positive results. Moreover, natural fish oil in small amounts may exist in the marine environment due to the decomposition of dead organisms, further challenging the identification of pollution sources.

This study aims to distinguish fish oil emulsions from toxic oil contaminants in natural seawater.

Crude oil was used as a representative toxic oil contaminant while cod oil was selected as a model fish oil relevant to the Baltic Sea. Fluorescence spectroscopy was used as a research method to differentiate oil emulsions from fish fats.

The obtained results of excitation-emission matrix (EEM) spectra allow to distinguish fish oil emulsions from toxic oil pollutants in seawater. However, this distinction becomes challenging at low concentrations of about 5 ppm. In addition, the detecting fish oil at low concentration is hindered by partial overlap of its EEM spectra with fluorescence signals of natural seawater components, such as colored dissolved organic matter (CDOM). Therefore, we propose the Relative Peak Elevation Index (RPEI), derived from EEM spectra at selected wavelengths. The RPEI index facilitates the identification of oil emulsion types and concentration levels, enabling the effective differentiation of fish oil from toxic oil pollutants in the sea.

Abstract ID: 122

Distribution of macro- and mesolitter in the Estonian beaches, NE Baltic rea region

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Human-induced litter is a global problem. Marine litter can be found in all marine compartments (beaches, sea surface, water column, seafloor, and is also ingested by biota) close to human-populated areas and in remote areas. The aim of this paper is to provide an up-to-date overview of the beach litter distribution in the Estonian coastal region. 13 beaches across the Estonian coastline representing urban, semi-urban, and natural beaches were visited three times per year in the period 2023-2024. The amount and composition of macro- and mesolitter items were monitored on all the beaches. The mesolitter monitoring included gaining information about plastic pellets. The amount of macrolitter items varied between 0-406 items per 100 m long beach section, with a median of 31 items in 2023 and 32 items in 2024. In 2024, plastic was the most dominant litter material (66%), followed by wood (12%), glass and ceramics (8%), and paper (6%). Out of plastic, polyethylene PE and polypropylene PP were the most commonly (>15%) registered plastic types. Plastic pellets were found in low amounts on two occasions in 2023, none were recorded in 2024. Mesolitter, in general, was recorded in 50% of beach surveys, and plastic and glass items dominated. The most common plastic type of mesolitter was polystyrene PS (73%), followed by PE and PP. A slight change has been noted in the most common litter items over the years (e.g., the amount of plastic bottle caps has decreased). The poster provides a general overview of the current situation and discusses methodological aspects of the beach litter survey on the NE Baltic Sea region.

Abstract ID: 131

PFAS Contamination in the Baltic Sea: Wastewater Treatment Plants as a Source of Pollution

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Per-and polyfluoroalkyl substances (PFAS) is a collective name for approximately 10 000 synthetic chemicals used in a myriad of products. Their commonness results in large exposure to humans and the environment. PFAS have been associated with cancer, developmental toxicity, immunotoxicity, endocrine disruption and other health effects. Only a few PFAS have been studied and the currently regulated and monitored are only a small fraction of the total PFAS released into the environment. The Baltic Sea is considered a vulnerable ecosystem with low resilience, mainly due to the low number of key species dominating the ecosystem as well as the high level of contamination including PFAS. The contribution of different sources of PFAS to the marine environment remains unknown. Wastewater treatment plants (WWTP) represent one source of aquatic PFAS pollution but their specific role in contributing to this environmental issue is still not fully understood. This study aims to create a PFAS contamination profile of WWTPs at two sites in the Baltic Sea (i.e. the archipelago south of Stockholm and Himmerfjärdens WWTP and in Gdansk).

The concentrations of emerging and conventional PFAS was measured in a gradient from the WWTP outlet, in different matrices including water, sediment, plankton, bivalves and In Sweden, contamination levels of PFAS are generally higher compared to Poland.

In Poland, no clear gradient of contamination from WWTPs is observed, while in Sweden, higher concentrations of PFAS are found in water closer to WWTPs. Interestingly, a reversed gradient is seen in the sediment, with higher concentrations further from the WWTP. Overall, PFAS levels are low in most environmental matrices, except for in crustaceans, particularly *Monoporeia*, which exhibit concentrations up to 100 times higher than the bivales. These elevated levels are primarily due to Perfluoroalkylcarboxylic acids (PFCAs).

Abstract ID: 133

Optical Properties of Microplastic Pollutants in Seawater: Implications for Shortwave Energy Balance Models

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Microplastic pollution in marine environments has emerged as a critical environmental issue, impacting ecosystems and biogeochemical cycles. One of the key aspects of understanding the influence of microplastics on the marine environment is their interaction with solar radiation. This study investigates the optical properties of microplastic particles suspended in seawater, focusing on their absorption and scattering coefficients as well as phase functions. These properties are computed using Mie theory for the shortwave spectral range (400–4000 nm), which is particularly relevant for climate studies.

The presence of microplastic particles in seawater alters the way sunlight is absorbed and scattered, potentially affecting oceanic radiative transfer processes. By characterizing these optical interactions, we provide crucial input data for shortwave energy balance models. Mie theory allows for precise calculations of scattering and absorption properties, accounting for particle size distribution, refractive index, and composition. In our analysis, we consider common microplastic types such as polyethylene terephthalate (PET), polystyrene (PS), polyvinyl chloride (PVC), and polymethyl methacrylate (PMMA), which are prevalent in marine pollution.

Our results show that the absorption and backscattering ratio of microplastics vary significantly with particle size and material type. In the visible spectral range, smaller microplastic particles exhibit higher scattering efficiency, whereas larger particles contribute more to total absorption. Additionally, the phase functions indicate a strong forward scattering component, which may influence underwater light penetration and heat distribution. These findings highlight the potential role of microplastics in modulating oceanic heat budgets and primary productivity.

By integrating our computed optical properties into radiative transfer and climate models, we aim to enhance predictions of the impact of microplastic pollution on marine energy balance. This study underscores the necessity of incorporating microplastic optical effects into broader environmental and climate assessments. Further research should focus on in-situ validation of these theoretical calculations and exploring the effects of microplastic aggregation and biofouling on their optical properties.

Our findings contribute to a better understanding of the interactions between microplastic pollution and solar radiation, with implications for climate modeling and marine ecosystem dynamics. The data generated in this study will support the development of more accurate energy balance models, ultimately aiding in the assessment of microplastic-induced perturbations in the marine environment.

Abstract ID: 169

Identifying potential reference and contaminated sites in the Gulf of Finland and the Gulf of Riga (northeastern Baltic Sea) using biomarkers in the clam *Macoma balthica*

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As part of the BIODIVERSA+ funded project Detect2Protect, this study focused on the effects of chemical pollutants on Baltic Sea biota by combining various biomarkers in the deposit-feeding bivalve *Macoma balthica* with sediment contamination analysis.

The clams were collected from three offshore sites in the Gulf of Finland (GoF), including Narva Bay, during two consecutive years (autumns of 2023 and 2024), and from offshore and coastal sites in the Gulf of Riga (GoR) during the autumn of 2023. A field sampling campaign targeted well-known polluted sites and presumed reference sites in these northeastern Baltic Sea sub-basins experiencing significant anthropogenic pressure, with environmental contamination by hazardous substances being a key contributing factor.

Specimens of *M. balthica* were collected to analyze biomarkers of oxidative stress (enzymatic activities of catalase (CAT), glutathione reductase (GR) and glutathione S-transferase (GST), as well as lipid peroxidation (LPO) levels), neurotoxicity (acetylcholinesterase (AChE) activity), genotoxicity/cytotoxicity, and a morphometric condition index. Based on the calculated Integrated Biomarker Response (IBR) index it was possible to identify the most impacted areas among the studied locations, representing high, intermediate, and low pollution levels within the study areas.

Elevated levels of CAT and GR were observed in clams from the contaminated Narva Bay in GoF. However, GST activity among the presumed reference sites in both sub-basins was significantly higher in the GoR. The significant increase in GST activity in clams from the eastern part of the GoR may be related to the detoxification of PAHs, which were previously found to be abundant in the sediments. Overall, the chemical data from bottom sediment samples indicate probable pressure from priority hazardous substances (such as PAHs, trace metals, PCBs, and organotins) in the studied regions and align with the environmental health status of the sampled locations as determined here by the analysis of biomarkers.

Abstract ID: 194

Characteristics of microorganisms in microplastic biofilm in the Vistula Lagoon (Baltic Sea) - in situ experiment

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Microplastics (MPs) are persistent, non-functional organic materials that are distinct from other persistent natural polymers that have various biological functions. Over the course of evolution, nature has developed microorganisms that are capable of breaking down resistant substances. Studies have demonstrated that plastics are not completely resistant to microbiological degradation. This study aimed to select microorganisms specific to MP that are potentially effective for their degradation in a brackish, eutrophicated lagoon (Vistula Lagoon, Baltic Sea). The microbial composition of natural matrices (water, sediment, gravel) and biofilms developed on MPs (polypropylene, expanded polystyrene, polylactide) were analyzed. MPs were incubated in the lagoon for four weeks in summer, spring, and winter. Over 50% of the OTUs were represented by rare OTUs in natural matrices and MP biofilms. MP biofilms showed a higher absolute abundance of prokaryotes than natural matrices. Venn diagram analysis indicated that water and sediment served as a bacterial source for MP biofilm organisms. Expanded polystyrene had the highest absolute abundance among the synthetic plastics across all the seasons. *Cyanobacteria* and *Proteobacteria* dominated MP biofilms and natural matrices in spring and summer, while *Bacteroidetes* and *Proteobacteria* dominated in winter. Community biodiversity parameters decreased in the order summer≥spring>winter. Differential abundance analysis identified taxa-discriminating MP biofilms, with *Planococcaceae, Comamonadaceae*, and *Cytophagaceae* families achieving the highest relative abundances. Most of the selected taxa are known as capable of degrading resistant organic matter (hydrocarbons; celulose; lignin; bioplastics). These studies suggest rapid colonization of microplastics by potentially plastic-degrading bacteria. However, further laboratory studies are needed to confirm their plastic-degrading potential.

Abstract ID: 197

Investigating air-sea exchange of microplastics: airborne samples comparative study of the Baltic Sea and preliminary results from campaign at the Maldives Climate Observatory-Hanimaadhoo (Indian Ocean)

Kinga Stawiarz[1,2], Piotr Markuszewski[2,3,4,5], Luca Ferrero[4], Lorenzo Scibetta[6], Ilaria Guardamagna[4], Niccolo Losi[4], Mikołaj Mazurkiewicz[2,7], Przemysław Makuch[2], Patrycja Jutrzenka-Trzebiatowska[8], Małgorzata Śmiszek[1,2]

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Background: Microplastic pollution is an escalating global concern, with particles detected across marine and atmospheric compartments. Understanding their transport through air-sea interactions is particularly important in semi-enclosed seas like the Baltic Sea, where local emissions and regional atmospheric transport can significantly influence microplastic distribution. This study aims to characterize airborne and marine microplastics in the Baltic Sea to better understand their sources, transport mechanisms, and potential re-emission processes.

Methodology: Field measurements were conducted aboard the rv Oceania in the Baltic Sea, applying an integrated sampling approach to capture both airborne and marine microplastics. Airborne microplastics were collected using a custom-designed "Deposition Box" that combines passive and active sampling. Pre-cleaned glass microscope slides inside the box captured total suspended microparticles (TSmPs), later analyzed with micro-Raman (μ-Raman) spectroscopy for polymer identification and particle characterization.

Simultaneous meteorological and oceanographic data—such as wind speed, direction, sea surface temperature, and salinity—were recorded. Atmospheric back-trajectory analyses were used to investigate potential long-range transport pathways.

Highlights:

- Integrated Air-Sea Sampling: Simultaneous collection of airborne and marine microplastics in the Baltic Sea enabled direct assessment of air-sea exchange processes.
- Microplastic Composition: Fibers were the predominant particle type in both compartments, with polyethylene (PE), polyethylene terephthalate (PET), and polypropylene (PP) as the most common polymers.
- Atmospheric Influence: Back trajectory analyses and wind data indicate that regional atmospheric transport from industrial and urban areas significantly contributes to microplastic concentrations.
- Re-Emission Potential: Higher airborne microplastic concentrations observed during elevated wind conditions suggest ocean-to-atmosphere re-emission.
- Environmental Implications: The Baltic Sea functions both as a receptor of transported microplastics and as a potential re-emission source, emphasizing the need for integrated monitoring strategies.

This study highlights the effectiveness of combined airborne and marine sampling methodologies for investigating microplastic dynamics in marine environments, contributing valuable data for understanding pollution patterns in the Baltic Sea. Building on these findings, our research continues with plans to apply the same integrated approach during the pascampaign at the Maldives Climate Observatory-Hanimaadhoo (MCOH) in the Indian Ocean. This will enable comparative analysis of microplastic transport and air-sea interaction processes between the Baltic Sea and the Indian Ocean region.

This research was supported by the National Science Center grants SMART (grant no. 2023/49/B/ST10/00513).

Literature: Ferrero, L., (2022). Airborne and marine microplastics from an oceanographic survey at the Baltic Sea: an emerging role of air-sea interaction?. Science of The Total Environment, 824, 153709.

Abstract ID: 198

Investigating air-sea exchange of microplastics: water samples comparative study of the Baltic Sea and preliminary results from campaign at the Maldives Climate Observatory-Hanimaadhoo (Indian Ocean)

Małgorzata Śmiszek[1,2], Piotr Markuszewski[2,3,4,5], Mikołaj Mazurkiewicz[2,6], Lorenzo Scibetta[7], Ilaria Guardamagna[5], Niccolo Losi[5], Przemysław Makuch[2], Luca Ferrero[5], Patrycja Jutrzenka-Trzebiatowska[8], Kinga Stawiarz[1,2]

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Background: Microplastic pollution is an escalating global concern, with particles detected across marine and atmospheric compartments. Understanding their transport through air-sea interactions is particularly important in semi-enclosed seas like the Baltic Sea, where local emissions and regional atmospheric transport can significantly influence microplastic distribution. This study aims to characterize airborne and marine microplastics in the Baltic Sea to better understand their sources, transport mechanisms, and potential re-emission processes.

Methodology: Field measurements were conducted aboard the rv Oceania in the Baltic Sea, applying an integrated sampling approach to capture both airborne and marine microplastics. Marine microplastics were sampled using a HydroBios net with a 300 µm mesh, towed at controlled speeds and durations to ensure representative surface water sampling. Samples underwent laboratory processing, including sieving, hydrogen peroxide treatment to remove organic matter, and polymer analysis via Fourier-transform infrared (FTIR) spectroscopy. Simultaneous meteorological and oceanographic data—such as wind speed, direction, sea surface temperature, and salinity—were recorded. Atmospheric back-trajectory analyses were used to investigate potential long-range transport pathways.

Highlights:

- Integrated Air-Sea Sampling: Simultaneous collection of airborne and marine microplastics in the Baltic Sea enabled direct assessment of air-sea exchange processes.
- Microplastic Composition: Fibers were the predominant particle type in both compartments, with polyethylene (PE), polyethylene terephthalate (PET), and polypropylene (PP) as the most common polymers.
- Atmospheric Influence: Back trajectory analyses and wind data indicate that regional atmospheric transport from industrial and urban areas significantly contributes to microplastic concentrations.
- Re-Emission Potential: Higher airborne microplastic concentrations observed during elevated wind conditions suggest ocean-to-atmosphere re-emission.
- Environmental Implications: The Baltic Sea functions both as a receptor of transported microplastics and as a potential re-emission source, emphasizing the need for integrated monitoring strategies.

This study highlights the effectiveness of combined airborne and marine sampling methodologies for investigating microplastic dynamics in marine environments, contributing valuable data for understanding pollution patterns in the Baltic Sea. Building on these findings, our research continues with plans to apply

the same integrated approach during the past campaign at the Maldives Climate Observatory-Hanimaadhoo (MCOH) in the Indian Ocean. This will enable comparative analysis of microplastic transport and air-sea interaction processes between the Baltic Sea and the Indian Ocean region.

This research was supported by the National Science Center grants SMART (grant no. 2023/49/B/ST10/00513).

Literature: Ferrero, L., (2022). Airborne and marine microplastics from an oceanographic survey at the Baltic Sea: an emerging role of air-sea interaction? Science of The Total Environment, 824, 153709.

Abstract ID: 204

Effect of seawater salinity on size distributions of oil droplets formed under mechanical mixing conditions

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Oil spilled on seawater surface undergoes immediately a series of changes in physical and chemical properties known as oil weathering. The most significant weathering processes are evaporation of light oil fractions, emulsification and natural dispersion. Natural dispersion of oil spilled in the sea takes place when the mixing energy provided by the waves and wind is sufficient to overcome surface tension at the oil-water interface. As the effect of mechanical mixing oil slick is broken into droplets of variable sizes. In a long-term perspective tiny oil droplets can remain floating in seawater in measurable concentrations for years after an oil spill. Oils with a lower viscosity (e.g. crude oils) are more easily naturally dispersed than those with a higher viscosity (engine oils, fuel oils). The process of formation of oil droplets under natural wave-induced mechanical mixing depends on seawater salinity. Precise knowledge of droplet size distribution (DSD) is important in oil spill modeling especially for prediction of the fates of oil. Furthermore, droplet size distribution strongly determines the absorptive and scattering properties of oil dispersed in seawater. In this study we compared oil droplet size distributions formed in saline water of salinities from 8.75 (brackish water of Baltic Sea) to 35 PSU (open ocean waters) prepared under the same mixing conditions. Dispersed oil samples of crude oil, engine oil and biodiesel were prepared in concentration of 1000 ppm on orbital shaker at the rotation speed of 200 rpm, resulting in mixing energy similar to breaking waves in natural seawater. Droplet size distribution were then collected using laser diffraction particle size analyzer LS13320 (Beckmann Coulter). The general shape of oil droplet size distributions was well approximated by two or three-modal log-normal function. Increasing water salinity caused decrease in natural dispersion effectiveness and had influence on the shape of droplet size distribution dependent on oil type. The analysis included also the impact of mixing time and sample aging on the formation of droplet size distribution. In the next step, obtained droplet size distributions were included in mathematical modeling of the spectral absorption and scattering coefficients based on Lorenz-Mie theory. We discuss the effect of the variability of oil droplet size distribution on the inherent optical properties of seawater polluted by dispersed oil.

Abstract ID: 206

Mercury and methylmercury in wet atmospheric deposition in the coastal zone of northern Poland

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Studies on the concentration of mercury in wet precipitation are an important element of environmental pollution monitoring, aimed at assessing air quality and identifying potential sources of emissions of this toxic heavy metal as well as the inflow of Hg to land and sea surfaces. Mercury, due to its toxic properties, has a negative impact on human health and ecosystems. The aim of the study was to determine the variability of the concentration of total mercury (THg) and one of the most toxic forms of Hg, methylmercury (MeHg), in rainfall depending on the heating and non-heating season and to identify factors influencing the observed changes. Particular attention was paid to the analysis of the impact of the heating season, restrictions related to the COVID-19 pandemic and changes in the share of energy sources on mercury concentrations in rainfall.

In the years 2021-2023, on a monthly basis, 36 samples of wet precipitation were collected using an automatic collector located at the Faculty of Oceanography and Geography in Gdynia. The analysis of THg and MeHg concentrations was performed using the cold vapor atomic fluorescence spectrometry method using the MERX analyzer (Brooks Rand, USA). The highest mercury concentration was recorded in 2021, decreasing in the following years. In 2022-2023, the THg concentration in the heating season was higher than in the non-heating season. This trend was not observed in 2021, which could be related to the COVID-19 pandemic restrictions. In the winter months of this period, most people worked from home, which could increase the demand for heating households near the sampling site. Additionally, the summer easing of restrictions resulted in an influx of tourists to Gdynia. Another factor influencing the annual decrease in mercury concentration could be the reduction in the share of hard coal in electricity production in favor of renewable energy sources such as wind farms or photovoltaic panels. The percentage of MeHg in the total mercury concentration ranged from 0.15% to 1.90%. In contrast to total mercury, no effect of the heating and non-heating season on the MeHg concentration was observed. In summary, the analysis of total mercury and methylmercury concentrations in wet precipitation in Gdynia in 2021-2023 revealed significant variation resulting from seasonal and anthropogenic factors. The results indicate the need for further monitoring and research to better understand the mechanisms influencing the variability of these pollutants' concentrations in the atmosphere.

Abstract ID: 207

Iron-manganese (Fe-Mn) nodules from the Polish Exclusive Economic Zone as a potential reservoir of phenols and microplastics – preliminary studies

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Polymetallic iron-manganese nodules are sedimentary mineral accumulations rich in iron and manganese oxides, found on sea and ocean floors. While well-studied in the Pacific for their rare earth (REE) and technology-critical elements (TCE), Baltic Sea nodules remain poorly explored, with limited and outdated research. Nodules from the Polish Exclusive Economic Zone may hold valuable REE and TCE deposits. However, little is known about their contamination with toxic organic compounds. This study investigates the presence of endocrine-disrupting phenols (BPA, 4-t-OP, 4-NP) and microplastics in Fe-Mn nodules and sediments from the Baltic Sea.

Samples of iron-manganese nodules and surface sediments were collected using a Van Veen scoop from three stations in the north-eastern part of the Polish Exclusive Economic Zone of the Baltic Sea from the deck of the R/V Oceanograf. The nodules were separated from the sediments after macroscopic examination and divided into two size fractions: "large" (>5 cm) and "small" (<5 cm).

BPA, 4-NP and 4-t-OP were determined using high-performance liquid chromatography (HPLC). The presence of microplastics in the nodule samples was checked using density separation and infrared spectrometry based on infrared microscopy with imaging combined with an FT-IR spectrometer equipped with an ATR diamond attachment. It was initially shown that polymetallic nodules are a significant reservoir of phenols. The concentration of BPA in the nodules was almost 200 times higher than in the sediment where the nodules were observed. On the other hand, the concentrations of 4-NP and 4-t-OP in the nodules were 4 and 8 times higher than in the surrounding sediment. Additionally, in the group of "large" nodules, almost 2 times higher BPA concentrations were found than in the group of "small" nodules. In the case of 4-NP and 4-t-OP, higher concentrations were obtained in "small" nodules. The studies also showed the presence of microplastics: modified polyethylene, neoprene and vinylidene chloride copolymer with acrylonitrile.

The pilot results obtained indicate the great importance of the research conducted on the nodules in terms of their composition, especially as a storage facility for hazardous substances. This aspect seems to be important due to the risk of re-release of these substances during extraction from polymetallic nodules needed for various branches of the metals industry.

Abstract ID: 208

Mercury Removal Efficiency in Wastewater Treatment Plants and Its Impact on the Baltic Sea: A Multi-Country Study

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Mercury, a persistent and bioaccumulative neurotoxin, poses a significant threat to human, animal and ecosystem health, particularly in vulnerable environments such as the Baltic Sea. While natural processes contribute to mercury levels, anthropogenic activities, including coal combustion, industrial discharge, and wastewater effluents, are primary drivers of the contamination. In marine ecosystems, inorganic mercury is transformed into methylmercury, a highly toxic compound that accumulates in organisms and magnifies in food webs, posing a particular risk to pregnant women and young children.

The Baltic Sea, a semi-enclosed and brackish water body, is particularly vulnerable to mercury pollution due to its limited water exchange and high anthropogenic pressure. Mercury enters the Baltic from atmospheric deposition, riverine input, and wastewater discharge. Understanding the role of wastewater treatment plants (WWTPs) in reducing mercury emissions is crucial for assessing their contribution to pollution control. This study evaluates the efficiency of mercury removal in WWTPs across Estonia, Germany, Poland, and Sweden and investigates the impact of WWTP effluents on mercury levels in coastal Baltic waters.

Over 500 samples were collected from different types of WWTPs and coastal areas during multiple seasons. The results indicate that all investigated WWTPs effectively reduce mercury concentrations in effluents, significantly limiting direct inputs into the Baltic Sea. However, despite high removal efficiency, residual mercury still reaches marine ecosystems, underscoring the need for ongoing monitoring and improved wastewater treatment technologies to further minimize mercury release. In addition, the study highlights the importance of WWTPs in regional pollution control and calls for strengthened international cooperation to protect the Baltic Sea's biodiversity, fisheries, and health. International regulations, such as the Minamata Convention on Mercury and the European Union's Water Framework Directive, provide a framework, but stricter controls on industrial discharge and enhanced treatment processes may be necessary. Further research is required to evaluate long-term trends in mercury contamination and its ecological consequences in the Baltic Sea.

This research was conducted under the project 2023/05/Y/NZ9/00169, supported by the National Science Centre within the framework of the Joint Programming Initiative on Antimicrobial Resistance (JPI-AMR). It is part of the "Standardized One Health Surveillance of Antibiotic Residues and Antibiotic and Heavy

Metal Resistance in Baltic Water Environments and Wild Birds" (BALTIC AMR) project, which investigates the combined environmental risks of heavy metals and antimicrobial resistance in the Baltic Sea region.

Abstract ID: 210

The impact of dumped munition remediation on release of explosive chemicals

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Dumped munitions from both World Wars continue to be a persistent source of underwater pollution in many seas and oceans. These munitions contain explosive chemicals, such as TNT, RDX, and their degradation products, which are known to be toxic, carcinogenic, and harmful to marine organisms. Once released from corroded casings, these compounds can enter the marine food web, posing risks to aquatic life and potentially affecting human health through seafood consumption. The issue is particularly pressing in the Baltic Sea, where a significant amount of unexploded ordnance remains on the seafloor, continuously leaching hazardous substances into the environment.

This environmental concern prompted the German government to initiate an unprecedented, proactive clearance of munitions dumped in Lübeck Bay. The remediation activity aimed not only to reduce the environmental risks but also to set a benchmark for future environmentally safe remediation practices in other contaminated areas. In the framework of the MUNIMAP project, sediment and suspended matter samples were collected during the remediation activities conducted in October 2024. The water column was monitored using a moored sample collector, followed by onboard measurements with the mass spectrometry-based Xplotector system.

The results revealed that the remediation activities did not lead to an increase in the concentrations of explosives and their degradation products in the water column or neighboring sediments relative to background levels. This finding is significant as it demonstrates the possibility of safely removing underwater munitions without exacerbating environmental contamination. Additionally, it highlights the effectiveness of the applied remediation techniques in minimizing the release of toxic compounds during the clearance process.

The study provides valuable insights into the environmental impacts of underwater munition clearance and emphasizes the need for continuous monitoring and advanced analytical methods to assess the risks associated with dumped munitions. The successful implementation of this environmentally friendly remediation in Lübeck Bay sets a precedent for similar efforts in other historical dumping sites, contributing to improved marine ecosystem health and safety in the Baltic Sea and beyond.

This research is part of the project “MUNIMAP: Baltic Sea Munitions Remediation Roadmap”, the Interreg Baltic Sea Region programme, co-funded by the European Union.

Abstract ID: 212

Emerging contaminants in marine sediments of the Baltic Sea

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Emerging contaminants (ECs), including pharmaceutical residues and other micropollutants, have become a growing environmental concern due to their potential long-term impacts on ecosystems and human health. While their occurrence in wastewater and surface waters has been widely studied, the accumulation of ECs in marine sediments remains insufficiently explored. Given the role of sediments as both a sink and potential source of pollutants, understanding the distribution and risks of ECs in this matrix is crucial for assessing marine ecosystem health. Therefore, the main aim of this study was to assess the degree of contamination of marine sediments collected in 2017 – 2022 from different areas of the Baltic Sea. 31 contaminants were selected for analysis, including pharmaceuticals from various therapeutic groups (non-steroidal anti-inflammatory drugs, sulfonamides, beta-blockers, psychotropic drugs, and hormones) and other micropollutants like caffeine and phenols. The extraction process combined microwave-assisted solvent extraction (MAE) and solid-phase extraction (SPE). Liquid chromatography-tandem mass spectrometry (LC-MS/MS) was used for the final analysis. The results confirmed the presence of 19 contaminants, with concentrations reaching up to 56 μg kg^{-1} d.w. The most frequently detected substances were *p*-nitrophenol, diclofenac, and caffeine. A preliminary environmental risk assessment showed that several detected compounds occur at concentrations potentially hazardous to marine organisms, raising concerns about their effects on biodiversity and sedimentary ecosystem stability. These findings provide valuable insights into the contamination status of the Baltic Sea's marine sediments and highlight the need for continuous monitoring and further research on ECs.

Abstract ID: 215

Caffeine – a potential risk for marine environment – Gulf of Gdańsk (southern Baltic Sea case study)

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Caffeine (1,3,7-trimethylxanthine), a well known stimulant, is a common component of many food and pharmaceutical products. Its consumption is so extensive that it can be considered as one of the most widely used psychoactive substances in the world. Despite being well metabolized in the human body, caffeine enters the environment in important amounts, reaching also marine costal ecosystems. Nevertheless, due to e.g. high degree of degradation it is not considered as important emerging pollutant and it is rather used as an indicator of anthropogenic contamination.

The aim of this study was to evaluate the level of exposure of organisms towards caffeine in the ecosystem of the Gulf of Gdańsk (southern Baltic Sea) and to assess resulting harmful effects. Caffeine concentrations were measured in surface and near-bottom waters well as in surface sediments of the Gulf in 2017-2022 during r/v Oceania cruises. In addition samples were collected from Vistula river, small streams and ground waters discharging to the Gulf of Gdańsk. The analysis was performed applying LC-MS/MS technique after extraction and clean-up steps. Caffeine was detected in almost all examined samples (detection frequency=98%). The range of measured concentrations was quite wide depending on location of sampling site and sampling period. Vistula River has been identified as a main source of caffeine pollution in the Gulf, however caffeine was also detected in streams and groundwater discharges. A predicted no-effect concentration (PNEC) approach was used in order to perform an environmental risk assessment of caffeine detected in the collected samples. In addition chronic toxicity studies with use of marine diatom *Phaeodactylum tricornutum* and freshwater/brackish cyanobacterium *Microcystis aeruginosa* were performed. Ecotoxicological risk of caffeine presence in the investigated area has been identified. The degree of risk (from low to high) of adverse effects occurrence depended on location, matrix and ecotoxicological endpoint applied.

Abstract ID: 220

Microplastics in the waters of the southern Baltic Sea – the impact of sampling methods on the assessment of the state of the environment

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Microplastics (MP) (plastic particles < 5 mm in size) have become the most ubiquitous type of anthropogenic litter polluting aquatic environments around the world. Its presence is problematic due to the documented harmfulness of marine organisms and humans. As a result, the number of microplastic studies in marine areas has increased significantly. However, the key issue for the final result is the method of sampling, including from the water column and surface layer, which was considered the most appropriate due to the density of most types of plastic being lower than that of seawater. Plankton nets are used to collect samples of microplastics, which allow samples to be taken from the water column, as well as manta trawl, which allows samples to be taken in the surface layer. The study aimed to determine the quantitative composition of microplastics in seawater samples collected in the open sea regions, Gulf of Gdańsk and lagoons using plankton nett and manta trawl. The results obtained are of particular importance in the context of the environmental status assessment carried out in accordance with the requirements of the Marine Strategy Framework Directive. The currently ongoing work on determining the threshold value, informing about the permissible number of microparticles in seawater, focuses on data expressed in the number of microparticles per surface, which would indicate the need to use manta trawl for sampling. Our research covering 2023 and 2024 aims to verify the collection methods in the context of the best reflection of the scale of the problem of marine pollution with microplastics.

The research is based on data from the Chief Inspectorate for Environmental Protection obtained within the framework of the State Environmental Monitoring and from the project (FBW-5/2024) „*Temporal and spatial distribution of plastic microparticles as a constant in the environmental assessment of the southern Baltic Sea*”

Abstract ID: 222

Exposure to perfluorotetradecanoic acid (PFTeDA) affects the respiratory, reproductive and digestive systems of the blue mussel *Mytilus trossulus*: an experimental study

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Perfluoroalkyl substances (PFAS) are extensively used in various aspects of daily life and their usage is expected to grow. PFAS enter marine environments via multiple sources including atmospheric deposition, agricultural and municipal runoffs and wastewater treatment plants outlets. They are present in various biotic and abiotic environmental congeners at different concentrations, also exerting negative effects on marine life. Perfluorotetradecanoic acid (PFTeDA) belongs to long-chained perfluoroalkylcarboxylic acids, has been commonly found in the marine environment and is able to accumulate in living organisms. Yet, the effect of exposure of marine fauna to PFTeDA are poorly understood.

Here, we present the results of an experimental study in which the blue mussel Mytilus trossulus has been exposed to two environmentally relevant doses of PFTeDA, 3ng/L and 30ng/L, over a period of seven days. General health and toxicity biomarkers from the respiratory, gonadal and digestive systems were used in order to evaluate PFTeDA toxicity. In addition, aromatization efficiency and biomarkers of oxidative stress, neurotoxicity and cellular detoxification were measured in the gill tissue.

No clear signs of oxidative stress or neurotoxicity or other biochemical biomarkers were seen. Yet, histological examination highlighted the negative effect of PFTeDA on respiratory, reproductive and digestive systems. In the blue mussels exposed to 3ng/L and 30ng/L, changes such as gill atrophy, oedema and inflammations (manifested by local haemocytic infiltration) were commonly found in the respiratory system. Elevated number of regressive changes such as digestive tubules atrophy were also detected in exposed mussels. Higher gonadal index (GI) and elevated frequency of gonadal atresia was found in mussels treated with PFTeDA highlighting that

Abstract ID: 225

Chemical pollution and biodiversity of benthic communities - Gulf of Gdansk (southern Baltic Sea) case study

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Chemical pollution alters extensively marine environments and is recognised as one of the main global drivers accelerating biodiversity loss although the direct linkages are often missing. In environmental pollution monitoring, relying solely on the assessment of single substances cannot be considered sufficient to provide protection of populations and communities because it fails to detect the impact of the entire mixture of compounds. Moreover, to enhance sensitivity of assessments, the application of effect-based methods employing biomarkers and other health status metrics is currently widely recommended. Regarding the Baltic Sea, a comprehensive integration of chemical data and biological variables using ecologically important species can improve the current environmental monitoring and risk assessment approaches and establish more appropriate indicators.

This study presents a preliminary evaluation of the impact of chemical pollutants on marine biota in the in the Gulf of Gdansk (southern Baltic Sea), by integrating chemical analyses, biochemical markers and biodiversity indicators, the latter including species richness of benthic meio- and macrofauna. Furthermore, to evaluate the general health of the macrofauna community the Benthic Quality Index was determined. Field sampling campaigns were carried out in May and September 2024 in the frame of the BIODIVERSA+ funded Detect2Protect project (”New approaches in determining the impacts of chemical pollution to protect the biodiversity of the Baltic Sea”) from reference and contaminated sites. The collected sediment and biota samples were analysed for stable isotopes (food web niche indicator) and a set of pollutants including heavy metals, persistent organic pollutants, and endocrine active phenols. At each site, local key species such as the mussel *Mytilus trossulus* were collected and their tissues used for the determination of selected biomarker responses (acetylcholinesterase, catalase and glutathione *S*-transferase activity) and a condition index to assess contamination-related effects and health status of the populations.

Abstract ID: 231

Shipwrecks as a Potential Source of Mercury to Surface Sediments of the Gulf of Gdańsk

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Armed conflicts in Europe in the first half of the 20th century have had a negative impact on the natural environment to this day. The Baltic Sea is a particularly vulnerable body of water, as it is a shallow body of water (average depth 52 m), inland, with limited water exchange. Military operations that took place in this area left many sunken wrecks on the bottom of the seafloor, often together with ammunition and supplies. This contributed to the problem of potential contamination of the sea with chemicals released from ships. It is estimated that there are about 10 to 100 thousand shipwrecks on the bottom of the Baltic Sea. Some wrecks sunk in the Baltic Sea have been lying on the seabed for over half a century. During this time, they corrode, which can lead to leaking hulls and, consequently, to the leakage of hazardous substances i.e. heavy fuels, light fuels, lubricants or weapons, including chemical weapons. The main aim of the research is to estimate mercury concentration in sediments near selected wrecks located in the southern Baltic Sea.

In order to conduct the research, surface sediment was collected near ten wrecks: Abille, ORP Delfin, Munin, ORP Groźny, UJ1102, S/S Stuttgart, T/S Franken, U-272, U-367, U-768. A total of 106 sediment samples were collected. All the examined wrecks were located in the Gulf of Gdańsk. Before chemical analysis, the research material was freeze-dried and homogenized. The samples were analyzed for the concentration of total mercury and its stable and unstable forms using the thermodesorption method on the DMA-80 analyzer (Milestone, Italy).

The concentration of total mercury in surface sediments was the highest at stations near the S/S Stuttgart wreck than any other station in this study. Very high concentrations were observed near the slope behind the S/S Stuttgart. Based on the available literature, it can be concluded that this was the highest Hg concentration measured in Baltic Sea sediments. It was almost 14 times higher than the maximum concentration of this metal previously measured in this area. Additionally near T/S Franken hotspots of high concentration of mercury was observed. Moreover, Hg is transported by sea currents along with sediment to places far from the wrecks. Statistical analyzes indicate that wrecks are a potential, significant source of Hg to surface sediments and nearby environment.

The research was financed by Interreg South Baltic within the BaltWreck Project No STHB.02.02-IP.01-0009/23.

Abstract ID: 241

Brominated flame retardants (PBDEs, HBCDD) in selected fish species from the southern Baltic Sea

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Polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecane (HBCDD) are added to various materials to prevent ignition and delay spread of fire. They are also toxic and persistent substances that bioaccumulate and biomagnify in the marine food web.

The aim of the study was to determine the current levels of selected brominated organic compounds in fish collected from the southern Baltic Sea. Interspecific species differences and trends were also discussed. Concentration levels of six PBDE congeners (BDE-28, BDE-47, BDE-99; BDE-100, BDE-153, BDE-154) and HBCDD were measured in the muscle tissue of herring (*Clupea harengus*), flounder (*Platichthys flesus*) and perch (*Perca fluviatilis*). Fish (10-12 specimens) were caught every year between 2014 and 2023 in six fisheries. Herring came from eastern Gotland Basin and Bornholm Basin, perch from Szczecin Lagoon and Vistula Lagoon, flounder from Bornholm Basin and Gdańsk Basin. In addition, flounder were taken from Bornholm Basin Polish coastal waters in 2020-2023. In total, muscles of 680 individuals representing three fish species were analyzed throughout the study period.

For both HBCDD and ∑6PBDE, the median concentration values obtained in herring muscles were an order of magnitude higher compared to flounder and perch. However, the highest value for HBCDD was observed in flounder (6.23 $ng \cdot g^{-1}$ ww), while the maximum value of ∑6PBDE was determined for perch (12.37 $ng \cdot g^{-1}$ww). In the period 2014-2023 a decrease in HBCDD concentrations was observed for all three fish species, while an increase in ∑6PBDE concentrations over time was recorded for perch from the Szczecin and Vistula Lagoons.

Considering the entire study period, herring and flounder were characterized by similar proportions of individual congeners in the sum of analysed PBDEs. The dominant congener for these fish was the tetrabrominated BDE-47, with 51% and 43% share of ∑6PBDE, respectively. The percentage of the congener BDE-100, which was the second largest contributor, was less than 20% for both species. The levels of the other congeners ranged from 7-12%, with BDE-28 higher in herring and BDE-154 higher in flounder. A different PBDE profile was observed in perch. In this species, one of the pentabrominated compounds, BDE100, had the highest share of almost 60%. The levels of the other congeners (BDE47, BDE-99, BDE-153, BDE-154) were similar and within a narrow range of 9-10%. The exception was BDE-28, which was <4%.

The research is based on data from the Chief Inspectorate for Environmental Protection obtained within the framework of the State Environmental Monitoring.

Abstract ID: 242

Influence of riverine inflows and atmospheric deposition on cadmium (Cd) concentration in the southern Baltic

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Cadmium (Cd) is a highly toxic metal with very little to no nutrient value and is widely distributed in the natural environment. Cadmium is released into the environment by both natural processes and human. The natural biogeochemical cycle of Cd has been altered by human activities that gradually intensify the transfer of Cd from the continents to the atmosphere, rivers, seas, and oceans. Once in the marine environment, Cd is adsorbed to or associated with surface sediments. This eventually leads to Cd enrichment in sediments. Evidence suggests Cd levels in sediments have increased several-fold in many parts of the world as a result of agricultural and industrial activities. However, when environmental conditions change, Cd accumulated in sediments can be released into the pore water where it threatens aquatic biota. Spatio-temporal distribution of Cd in the southern Baltic Sea were investigated using data from six sediment cores. Local point Cd sources such as riverine inflows and atmospheric depositions are the main controlling factors of Cd distribution. The contribution of Cd from river discharge surpasses that from atmospheric deposition. For atmospheric deposition of cadmium, dry deposition was more important. However, in both cases, a downward trend in the supplied Cd load to the sea was observed. Vertical profiles of Cd concentrations combined with ^{210}Pb dating reveal the history of Cd pollution in the southern Baltic Sea over the last century. Data show Cd unvaried before the 1800s, a slight increase from the 1800s to the late 1950s and an increase to the 2001. With a decrease in riverine Cd inputs and atmospheric deposition between 2000 and 2019, sediment cadmium concentrations have remained fairly stable in the 21st century.

The research is based on data from the Chief Inspectorate for Environmental Protection obtained within the framework of the State Environmental Monitoring.

Thematic Session: Exploitation of Ecosystem Services and Its Impact on the Baltic Sea Ecosystem

Abstract ID: 2

Water Quality and Valuation of Cultural Ecosystem Services of Melnrage Beach Using Travel Cost Method

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This study explores the recreational value of Melnragė Beach, located within the plume zone of the Curonian Lagoon (SE Baltic Sea), and investigates how water quality affects beach visitors. The beach, located near Klaipėda, is popular for water sports and is pet-friendly. With a warming climate and a lengthening swimming season, the increasing concentration of phytoplankton, starting from the second week of August and continuing until the end of September will become increasingly significant. Although the sea warms slowly and the swimming season begins only in early July, other active recreational activities, that begin earlier (walking, exercising, kiting, surfing) may also be affected by the spring blooms of the Curonian Lagoon — turbid water, unpleasant odors. How visitors emotionally, spiritually, and intellectually perceive these natural phenomena should be addressed by socio-cultural methods of ecosystem service evaluation. As part of more holistic approach, the cultural ecosystem services could be assessed using economic methods and expressed in monetary terms.

From May to September 2024, chlorophyll-a concentrations were measured daily as an indicator of water quality. Visitor counts were also recorded, and visitor surveys were conducted in July and August. Survey responses from 231 participants (127 tourists and 104 locals) were used to develop a travel cost model. The model showed that travel cost significantly influences visit frequency, which enables calculation of average willingness to pay for one visit. The chlorophyll-a concentration fluctuated within the medium-risk range (10–50 µg/l) for more than half of the time studied. During the rest 36% of the time water quality was excellent. Nonetheless, the algal bloom phenomenon is well-known to visitors and frequently mentioned by them. When it comes to specific experiences at Melnragė Beach, the responses of local residents and tourists differ: 39% of tourists and only 7.6% of local residents reported never having encountered algal blooms at this beach. Only 13% of tourists and 24% of surveyed local residents responded that water blooms at the beach would shorten their visit by an average of 56–57%. The report will present the overall beach value, estimated using travel cost model, along with more detailed information about the time visitors spend at the beach and their recreational activities.

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Abstract ID: 66

Ecosystem-model-based valuation of ecosystem services in a Baltic lagoon: long-term interventions and short-term variability

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We conducted 3-D ecosystem model simulations over a 10-year period, supplemented by socio-economic data, to evaluate the ecosystem services provided by the large, shallow Oder/Szczecin Lagoon. Our analysis focused on three scenarios reflecting the progressive deepening of the navigational waterway across the lagoon: from 6 meters (1880) to 10.5 meters (1984) and finally to 12.5 meters (2023). For the 10.5-meter scenario, the total value of all six ecosystem services was estimated at €272 million/year, or approximately €0.4 million/year/km². The individual contributions of each ecosystem service were as follows: nitrogen-retention: 166 million €/a, phosphorus-retention: 5 million €/a, carbon storage: 0.4 million €/a, active recreation: 61 million €/a, landscape aesthetics: 36 million €/a, wild fish catches: 3.2 million €/a, and transportation: 32 million €/a. Among these, denitrification emerged as the most economically important process, valued at €178 million/year, or €0.26 million/year/km². Regulating ecosystem services displayed substantial interannual variability and pronounced seasonality. Additionally, the two parts of the lagoon, Kleines Haff (Germany) and Wielki Zalew (Poland), exhibited distinct patterns. Our model indicates that channel deepening enhances sediment burial and significantly increases phosphorus and carbon retention. However, the associated increase in connectivity to the Baltic Sea appears to have a minor effect.

Abstract ID: 89

Ecosystem services of the Baltic Sea–state and changes during the last 150 years

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We assess the ecosystem services across the entire Baltic Sea using ecosystem model simulations and historical socio-economic data. Our approach covers 150 years, aggregated for the years around 1880, 1960 and 2010. The ecosystem services assessed include commercially usable wild fish biomass and wild plant biomass, water quality regulation (nitrogen and phosphorus retention), carbon storage, biodiversity and habitats, as well as active recreation and landscape aesthetics. In 2010, the commercially usable fish biomass in the entire Baltic Sea was 9.24 million tons. The total retention of nitrogen in the Baltic Sea was 884,135 t/a, phosphorus retention was 32,058 t/a, and carbon storage was 3,668,100 t/a. Between 1880 and 2010, the Baltic Sea-wide average biodiversity index de-creased from 73 to 60, the active recreational quality index decreased from 76 to 69 and the observational recreation index declined from 91 to 78. In 2010, the most monetary significant single ecosystem service in the Baltic Sea was nitrogen retention with 26,822 million €/a, followed by cultural ecosystem services. Other relevant services were fish catches (277 million €/a), phosphorus retention (3854 million €/a), and carbon storage (202 million €/a). The latter has recently shown a steep increase due to rising prices for CO2 certificates.

Abstract ID: 168

The Fish Module: A Predictive Tool for Sustainable Fisheries Management in the Gulf of Gdańsk

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The Fish Module is an innovative predictive tool designed to identify optimal environmental conditions for key fish species in the southern Baltic Sea, with a particular focus on the Gulf of Gdańsk. By integrating the ecohydrodynamic model EcoFish with fuzzy logic and comprehensive fish preference data, the module calculates the Habitat Suitability Index (HSI) for species such as sprat, herring, cod, and flounder. This study leverages extensive fishing expedition data, correlating physicochemical sea parameters with fishing success, to establish precise HSI threshold values. The findings provide insights for optimizing fishing routes while challenging conventional assumptions about the relationship between fishing duration and catch efficiency.

Developed under the "Knowledge Transfer Platform FindFISH – Numerical Forecasting System for the Marine Environment of the Gulf of Gdańsk for Fisheries" project, the Fish Module serves as a critical advancement in balancing economic fishing interests with environmental sustainability. This tool exemplifies a fusion of traditional fishing expertise with cutting-edge scientific research and technological advancements, fostering a data-driven approach to sustainable fisheries management.

The Fish Module stands as a transformative solution for the fishing industry, offering real-time, evidence-based guidance to improve efficiency, reduce environmental impact, and ensure the long-term viability of fish stocks in the Gulf of Gdańsk. Its implementation highlights the potential for similar advancements to revolutionize fisheries management worldwide, supporting both economic sustainability and marine conservation efforts.

Partial support for this study was provided by the project “Knowledge transfer platform Find-Fish Numerical Forecasting System for the Marine Environment of the Gulf of Gdańsk for Fisheries”, funded by the European Union through European Regional Development Fund Contract RPPM.01.01.01-22-0025/16-00.

Some elements of the EcoFish model (i.e., river runoff data) are based on the solutions developed during the WaterPUCK project funded by National Centre for Research and Development of Poland within the BIOSTRATEG III program BIOSTRATEG3/343927/3/NCBR/2017.

Abstract ID: 239

Explosions of the Nord Stream Pipelines – Numerical Analysis of Environmental Risk

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On September 26, 2022, a series of underwater explosions occurred near the Danish island of Bornholm, impacting two branches of the Nord Stream pipelines (NS1 and NS2). The detonations, estimated to be equivalent to approximately 500 kg of TNT (some sources suggest up to 750 kg), triggered four major gas leaks and caused significant seabed sediment resuspension.

These events took place merely 20 km from a World War II chemical weapons disposal site, raising concerns about potential contamination and environmental hazards. The propagation and dispersion of the resuspended material were assessed using a high-resolution three-dimensional (3D) hydrodynamic model coupled with a sediment transport model. Mathematical modeling incorporated external operational meteorological data spanning the Baltic Sea region. The explosion and the resulting gas stream introduced approximately 2.5 × 10^5 tons of suspended sediments into the water column for each of the affected areas. Numerical simulations estimated that the maximum horizontal extent of the sediment plume reached 26 km from the explosion sites, with a vertical distribution constrained between 30 m and 67 m depth. Approximately 50% of the suspended matter remained in the water column after 35 days. The period of significant environmental risk was estimated to be 15 days for NS1 and 34 days for NS2, with a total affected volume of approximately 11 km^3.

This study emphasizes the importance of computational fluid dynamics in assessing environmental risks following underwater infrastructure failures, providing insights for better risk management and response to similar incidents in the future.

Thematic Session: Emerging Technologies for Research and Monitoring

Abstract ID: 25

Anchored Argo Profiling Float as a Tool for Monitoring Shallow-Water Ecosystems of the Baltic Sea

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Argo floats have revolutionized operational oceanography by enabling large-scale, automated, long-term monitoring of oceanographic parameters. However, standard Argo floats are designed for open-ocean conditions and face challenges in shallow, highly dynamic coastal environments. This study explores the feasibility of anchoring Argo floats in coastal regions to enhance monitoring capabilities in areas where traditional Argo deployments are not viable. Three experiments were conducted in the southern Baltic Sea (Puck Bay and Hel Peninsula) in 2022–2023 using an anchored ARVOR-I float equipped with CTD and dissolved oxygen sensors. The anchored float successfully collected high-temporal-resolution data, providing insights into shallow-water hydrography. The study highlights both the advantages and limitations of this approach, demonstrating its effectiveness in semi-enclosed, sheltered environments while revealing challenges in areas with strong currents and wave activity. The results indicate that anchored Argo floats can serve as valuable tools for improving coastal and marginal sea observations, complementing the global Argo network and aligning with the OneArgo initiative.

Abstract ID: 26

Utilizing Argo Floats for Monitoring the Baltic Sea: Insights from Argo-Poland

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Argo floats have become essential for oceanographic research, providing autonomous, long-term monitoring of physical and biogeochemical properties. While their deployment has traditionally focused on open-ocean environments, recent efforts have expanded the network into marginal seas, including the Baltic Sea—one of the most complex and dynamic water bodies. The Baltic's strong stratification, variable coastal currents, and intense ship traffic pose operational challenges for standard Argo floats, yet its semi-enclosed nature facilitates float recovery and redeployment, creating opportunities for targeted research. Since 2016, Polish oceanographers have been deploying Argo floats in the southern Baltic Sea as part of the EuroArgo ERIC infrastructure. Over more than eight years of operations, the Argo-Poland program has deployed 16 floats, including seven with standard CTD (Conductivity-Temperature-Depth) sensors and eight equipped with dissolved oxygen sensors for enhanced biogeochemical monitoring. Additionally, one specialized BGC-Argo float was deployed with advanced sensors measuring chlorophyll-a, suspended particles, and irradiance—key parameters for assessing biological activity and ecosystem health. To date, these floats have collected over 8,000 CTD profiles, including 4,100 profiles with dissolved oxygen data and nearly 600 BGC profiles. These efforts have significantly contributed to a better understanding of the physical and biogeochemical conditions of the Baltic Sea.

Abstract ID: 30

Exploring the Relationship Between FTU Turbidity and Optical Properties of Water in the Vistula River Mouth Forefield

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Turbidity, a crucial indicator of water quality, results from light scattering by suspended particles that originate from both natural and anthropogenic sources. High levels of turbidity can impact marine ecosystems, affecting organisms such as phytoplankton, zooplankton, fish, and birds. Therefore, monitoring turbidity is essential to understand eutrophication dynamics, assess environmental changes, and protect biodiversity. With advances in technology, turbidity measurements are now easily accessible through user-friendly oceanographic probes, supporting the ability to collect data efficiently and precisely.

This study presents a first attempt to establish a relationship between water turbidity, measured in Formazin Turbidity Units [FTU], and suspended particulate matter (SPM), further divided into organic and inorganic fractions, in the forefield of the Vistula River mouth. Additionally, we investigated the correlation between in situ turbidity measurements and satellite-derived SPM estimates from Sentinel-2 and Sentinel-3 satellites.

Empirical data were collected during two measurement campaigns. The first took place in summer, while the second was conducted in early spring aboard the *Imoros 2* research vessel. A total of 24 measurement stations were designated along three transects: one extending 20 km offshore and two covering distances of 15 km each. At all stations, hydrophysical water parameters were measured using an SAIV SD204 multiparameter probe, recording turbidity [FTU], temperature, salinity, dissolved oxygen [mg/L] and fluorescence [µg/L]. Furthermore, at three selected stations along each transect (at the beginning, middle, and end), water samples were collected from three depth layers (surface, mid-depth, and near-bottom) to analyse the organic and inorganic fractions of SPM.

This study provides new insights into the optical properties of water concerning suspended matter composition, thus contributing to a better understanding of sediment transport and water quality dynamics in river-influenced coastal zones.

Abstract ID: 36

ICON-Baltic - A new approach to modeling the Baltic Sea

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ICON (ICOsahedral Nonhydrostatic) is a new earth system modeling framework developed by the Deutscher Wetterdienst DWD and the Max Planck Institute for Mereorology MPI-Met (Jungclaus et al. 2022). The architecture of this software enables optimum scalability on modern high-performance computers. Another innovation is the triangular computational grid used, which has no polar singularities. Furthermore, this unstructured grid can be refined locally so that the high-resolution simulation of regions embedded in a global model is possible (Logemann et al. 2021). We call ICON-Baltic the application of ICON-O, the ocean model of the ICON framework (Korn et al. 2022), running on such an irregular grid with high resolution of the Baltic Sea. With numerical experiments we examine how well this global model reproduces the complex system of the Baltic Sea. In this respect, the Baltic Sea represents a test region for the simulation of the global coast. On the other hand, the model can be understood as the prototype of a new Baltic Sea model without boundary values.

References:
Jungclaus, J. H., Lorenz, S. J., Schmidt, H., Brovkin, V., Brüggemann, N., Chegini, F., et al. (2022). The ICON Earth System Model version 1.0. Journal of Advances in Modeling Earth Systems, 14, e2021MS002813. https://doi.org/10.1029/2021MS002813
Korn, P., Brüggemann, N., Jungclaus, J. H., Lorenz, S. J., Gutjahr, O., Haak, H., et al. (2022): ICON-O: The ocean component of the ICON Earth system model—Global simulation characteristics and local telescoping capability. Journal of Advances in Modeling Earth Systems, 14, e2021MS002952. https://doi.org/10.1029/2021MS002952
Logemann, K., Linardakis, L., Korn, P. *et al.* Global tide simulations with ICON-O: testing the model performance on highly irregular meshes. *Ocean Dynamics*71, 43–57 (2021). https://doi.org/10.1007/s10236-020-01428-7

Abstract ID: 104

Adhesive-adsorptive signatures of sea-submersed hard substrata as novel physico-chemical-biological contamination indicators

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The aim of this study is to evaluate the adsorptive, adhesive, and wetting energetic properties of seawater in contact with model surfaces, such as plastics (PET, PMMA, PVC, PC, PTFE) and well-defined minerals (31 species). The research focuses on analyzing the interrelations between selected adsorption-adhesion parameters and factors such as water pollution levels, the content of photosynthesizing biological fractions, trophic status, and primary production in marine ecosystems. The characterization study included adsorptive and thermal seawater surface properties, determined from surface tension changes as a function of temperature $\gamma_{LV}(T)$ and surfactant concentration $\gamma_{LV}(c)$. These indices reflect the key parameters, such as the Gibbs excess Γ_{LV} and the critical micellar concentration (CMC) of surface-active species in the bulk. Surface wettability parameters such as surface free energy, work of adhesion, molecular partitioning at air/water and water/solid interfaces were determined from dynamic contact angles analyzed with Chibowski's approach. The aim of the project is to develop an innovative and universal formalism for analyzing the trophic state of a reservoir, the degree of anthropogenic physico-chemical pollution, including biofouling , with a wide range of applications not only in monitoring the natural environment, but also in the engineering of dental polymers and rinsing and cleaning fluids [1,2]. A quantitative description of the physical adhesion and adsorption parameters on the air/water and water/solid interfaces, the chemical parameters of the trophic state (O_2, N, P), and the parameters of the degree of transformation of biological material (primary production, *Chl a*, bioadhesion) will be formalized in the form of normalized components of multidimensional vectors of the vector space structure [3]. The idea of the project realization is based on cyclical extensive monitoring of the physical, chemical and biological properties of selected natural waters, as a model and for the needs of preliminary research in the Gulf of Gdańsk, with several techniques including classic microscopic determinations or Raman spectrum bands, as well as original methods analyzing the surface rheology of liquids, wetting energetics, photoacoustic spectroscopy etc. leading to large datesets. The collected parameter values and their time evolution will be subjected to advanced correlation analyses adopting machine learning (ML) methods using a multi-layer structure of neural networks in the structure parameter spaces enhancing predictive and operational models.

References:
[1] S. Pogorzelski et al., Materials, 2024, 17, 4755;
[2] S. Pogorzelski et al., Materials, 2023, 16, 5753;
[3] K. Boniewicz-Szmyt & S. Pogorzelski, Environ. Sci. Pollut. Res., 2018,25, 4826-4836.

Abstract ID: 123

Flying Argo – Next generation underwater glider

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The Baltic Sea and other marginal seas pose a particular challenge for autonomous vehicles whose propulsion is based on volume variation. Unlike operations in the open ocean, underwater gliders in these regions must ensure efficient and reliable functionality while facing shallow waters and areas with strong density stratifications.

As part of the OTC-Flying Argo project, funded by the German Federal Ministry of Education and Research (BMBF) as part of the Ocean Technology Campus Rostock, an underwater glider featuring a novel passive flapping-foil gliding concept was developed and implemented as a demonstrator. Compared to conventional gliders, this system is distinguished by the following innovative approaches.

Passive Flapping-Foil Gliding Concept: Unlike conventional gliders, the system uses a passive flapping-foil gliding concept. The body of the glider remains in a horizontal position throughout the entire glide, while the wings passively adjust to the preset angle of attack due to the incoming water flow. This enables an efficient gliding motion with a very shallow glide path while making the system particularly suitable for tilt-sensitive sensors.

Modular and Partially Pressure-Tolerant System Design: To allow for flexible adaptation by users, a partially pressure-tolerant system design is employed. This results in a highly modular structure, facilitating adaptation to various operational scenarios.

Intelligent Navigation and Control System: A custom navigation and control system, specifically tailored to this new development, is designed to ensure reliable operation.

Simplified Mission Preparation and Enhanced User-Friendliness: The modular system design and the absence of a fully encapsulated architecture allow easy access to the ballast and payload compartments. Additionally, algorithms for the partial automation of mission preparation and the ballasting process have been developed and will be integrated into the control system to enhance user-friendliness.

Optimized Performance in Shallow Waters and Density-Stratified Areas: The innovative gliding concept, combined with an increased volume capacity of the buoyancy control unit, enables efficient operation in shallow waters and areas with density stratifications.

The demonstrator is currently in its initial testing phase and will be further developed, optimized, and integrated into a swarm network within the OTC-Base2Swarm project, funded by the German Federal Ministry of Education and Research (BMBF) as part of the Ocean Technology Campus Rostock. Due to its novel system characteristics, the new glider concept is well-suited for deployments in the Baltic Sea and other marginal seas. The poster presents the developed demonstrator and highlights its innovative features.

Abstract ID: 137

Sea of unseen – The application of PlanktoScope in studying plankton of the Southern Baltic Sea

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Among the newest trends in worldwide plankton research, imaging techniques are rising as the future of rapid, semi-automated quantitative and qualitative solutions. In the in-flow imaging branch of plankton studies, one of the most appreciated devices by the scientific community is PlanktoScope - an inexpensive, open-source based imaging platform. The ability to acquire thousands of high-resolution images of living planktonic organisms in a relatively short time opens new possibilities in terms of monitoring the pelagic environment, as well as ecological research. The implementation of cutting-edge AI deep-learning methods provides a highly efficient, semi-automatic classification of each captured object. To seize this new opportunity and the potential of the new method in plankton research, the imaging was applied to answer the question – How do the inflows of marine waters from the North Sea affect the planktonic communities of the brackish Southern Baltic Sea?

The use of PlanktoScope was implemented during onboard operations, where a fresh sample was treated directly after the collection, to acquire the diversity of the phyto- and zooplankton. On each station, the water column was sampled separately for the upper, less saline layer above the halocline, and more marine, denser waters below to catch the variability of organisms occupying those different layers. The sampling was conducted during winter and spring months to increase the chance of noticing the impact of minor saline inflows and add the seasonal perspective to the results. Together with samples, at each station, the water was measured for essential parameters such as temperature, salinity, dissolved oxygen, and chlorophyll a concentration. This new methodology resulted in obtaining tens of thousands of high-quality images which were further investigated with the use of the sophisticated EcoTaxa environment for automated classification of each object. The acquired taxonomy was verified by experienced taxonomists to check for potential mistakes. The acquisition performed on living organisms provided images with details often lost during traditional preservation with formaldehyde – for example, it enabled capturing the diversity of rotifers, typical for the Baltic Sea, which often lose their characteristic morphological features in the preserved samples. The results showed the major differences between water masses together with responses in the abundance of planktonic species to the inflow from the North Sea. The study revealed the great potential of using PlanktoScope in the plankton research of the Baltic Sea.

Abstract ID: 149

Voice of the Ocean Foundation; providing ocean infrastructure and data processing support to the research community

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Voice of the Ocean Foundation works to make the ocean accessible to all sectors of society, focusing on the thematic areas of research, archiving and outreach. Ocean Knowledge conducts methodology development in ocean technology and ocean data collection, processing and distribution, from the sea surface to the seabed, from physical oceanography to marine archaeology. We are committed to open science, making all of our data open access and contributing to community developed tools. Here we present our ongoing Ocean Support function, describing the marine infrastructure provided and showcasing recent projects supported through this process. Through 2024, seven projects were funded for researchers from around the Baltic, ranging from habitat mapping to complex glider deployments and averaging in-kind contributions of €100000. Featured projects include seabed sediment sampling for methylmercury processes, developing methodology to use phycocyanin sensors on underwater gliders to detect algal blooms, utilizing aerial drones to sample the air-sea interface and deploying the first microstructure glider in the Baltic Sea. We also showcase a recent marine archaeology project using multibeam, side scan sonar and sub-bottom profiling to discover stone age human built structures in the Bay of Laholm. The Ocean Support programme lowers barriers, enabling access to marine infrastructure and autonomous platforms. The next application call will close in September 2025, and here we provide information and guidance towards the application process.

Abstract ID: 188

Morphologi G3SE automatic particle analyzer – development of a tool for characterization of suspended phytoplankton

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The suitability and feasibility of different approaches to monitoring phytoplankton blooms in natural waters remains a frequently debated issue among phytoplankton researchers. Accurate analysis and characterization of phytoplankton morphology is essential for ecological monitoring and understanding of phytoplankton dynamics in aquatic ecosystems, as well as for analyzing its importance in the optics of the seas. Phytoplankton play an important role in the optics of the seas and oceans, affecting the absorption and scattering of light, as well as changing the color of the water. Traditional methods of shape phytoplankton cells analysis rely mainly on manual microscopy, which is time-consuming and prone to users errors. Morphologi's G3SE automated particle analyzer presents a novel approach for high-throughput, objective and precise characterization of phytoplankton cell size, shape and quantity.

This study evaluates the Morphologi G3SE system's effectiveness in phytoplankton morphological analysis and explores how machine learning techniques enhance its measurement capabilities. This study analyses the performance with conventional microscopy-based biovolume and shape analysis techniques, along with other automated or semi-automated methods used to characterize phytoplankton. We evaluated the system's accuracy in determining key morphometric parameters, including cell biovolumes, surface areas and aspect ratios, using different geometric models. We also analyzed the device's potential for taxonomic classification and integration with ecological models. We have demonstrated that the Morphologi G3SE system provides reliable and consistent measurements, offering an alternative tool for monitoring phytoplankton blooms. The introduction of machine learning techniques as tools to improve instrument capabilities, in our opinion, increases the precision and efficiency of the research.

Abstract ID: 189

Designing a smart buoy network delivering near real-time data and products for digital representation of the Estonian marine areas (Project "Merehunt")

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High-quality environmental and navigational information covering the entire marine area is an integral part of the operation of the modern maritime economy, the sustainable management of the marine environment, and the assurance of security and safety at sea. Estonia has thematic/sectoral monitoring programmes, but the responsibilities, funding and development of the programmes are divided between the sectors, information is mostly received in a delayed mode, and information exchange is insufficient both in Estonia and regionally (Baltic Sea region). There is a lack of operational and up-to-date information for effective pollution control (except aerial surveys and remote sensing) and the protection of the marine environment. We lack infrastructure for automated/near real-time maritime surveillance, especially in offshore areas and subsurface layers of the water column. The data quality is uneven, different organizations handle data, databases are not connected, and cross-use of data is difficult.

Driven by user needs and described challenges, the Estonian government has decided to look for an efficient way to gather and interpret marine data to suit the needs of as many users as possible. A consortium consisting of experts from the Tallinn University of Technology, Flydog Solutions OÜ and Nortal AS has been tasked to tackle this demanding goal. The launched project "Merehunt" aims to offer a monitoring network design together with descriptions of platforms and sensors to be used and data management routines, including an IT platform with a database and fit-for-purpose user interfaces. An extensive user survey was conducted to gather information from governmental agencies and maritime companies, including wind park and aquaculture developers, environmental and rescue organizations, and the general public. A study of existing observational networks and available and emerging technologies has been accomplished.

We present the initial design of the monitoring network, technical descriptions of observational platforms, including smart buoys, energy management and telecommunication systems, the architecture of the data management platform, connections to the regional systems (e.g. JERICO, BOOS), as well as user interfaces to acquire, display and visualize data and data-driven products. The first phase of the project (2025-2027) aims to create working prototypes of innovative observational platforms and a prototype of the supporting data management platform. The desired result of the project would be the piloting of a network of smart buoys. The long-term aim is to build a digital representation of the marine areas for a more efficient and information-based decision system.

Abstract ID: 236

Mathematical Approach to Sea Level Forecasting Using Machine Learning

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Sea Surface Height (SSH) forecasting plays a vital role in understanding and mitigating climate change impacts. Traditional hydrodynamic models solve the Navier-Stokes equations numerically, incorporating boundary conditions such as wind stress, pressure gradients, and oceanic circulation patterns. However, these models face computational inefficiencies and struggle with regional-scale precision due to the complexity of parameterization and the nonlinearity of oceanic processes.

One of the primary challenges in SSH modeling is the presence of data gaps due to sparse or irregular measurements. Traditional statistical interpolation techniques, such as Empirical Orthogonal Functions (EOF) and kriging, fail to generalize effectively in such cases. Machine learning-based approaches incorporate probabilistic inference and transfer learning to improve SSH predictions in under-sampled regions and estimate predictive uncertainty, providing robust and reliable forecasts.

Both classification and regression models will be assessed, along with an advanced deep learning system adapted for Baltic Sea station forecasting—HIDRA2 (the second generation of deep neural networks for SSH prediction, originally developed for the northern Adriatic by Slovenian researchers from the University of Ljubljana (Rush et al., 2023)). The presentation will cover the mathematical foundations, model architectures, and performance benchmarks of machine learning-based SSH forecasting.

The dataset consists of sea level observations from Baltic tide gauges, supplemented by corresponding atmospheric data from the ERA-Interim database. The input variables include atmospheric pressure, wind speed and direction, and temperature at 2 meters above sea level.

This study evaluates the performance of machine learning-based SSH forecasting for selected Baltic stations by comparing RMSE (Root Mean Square Error), MAE (Mean Absolute Error) against conventional hydrodynamic models.

Abstract ID: 244

Assimilation of Along-Track SWOT Data in a General Circulation Model of the Baltic Sea – A Modelling Study

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The Baltic Sea is a semi-enclosed basin spanning longitudes from 9.5°E to 33°E and latitudes from 54°N to 66°N. It is one of the most extensively monitored and studied seas globally. Despite the presence of numerous modeling systems, including operational ones, ongoing development remains essential. Integrating new methodologies and data sources can enhance existing capabilities and provide more advanced insights into the Baltic Sea's dynamic environment.

Recently, the Surface Water and Ocean Topography (SWOT) mission has been developed jointly by NASA and the Centre National d'Études Spatiales (CNES), with contributions from the Canadian Space Agency (CSA) and the United Kingdom Space Agency (UKSA). SWOT provides exceptionally high-resolution sea surface height (SSH) measurements, with a spatial resolution of approximately 300 meters. Assimilating this data into numerical models has the potential to improve their accuracy and predictive capabilities.

A recently developed a Baltic Sea configuration of the Regional Ocean Modelling System (ROMS), which is numerically coupled with the CICE model. This coupled system, referred to as the Climate and Environmental Modelling System (CEMS), currently operates at a horizontal resolution of approximately 2.3 km, with planned refinements in the future. Assimilating SWOT data is expected to improve the representation of SSH within CEMS, which, in turn, will have an indirect impact on ocean currents. Given the relatively small discrepancies that already exist between modeled and observed SSH, major corrections are not expected; however, other prognostic variables will still be affected

This poster presents our preliminary results on the assimilation of SWOT data in the Baltic Sea.

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Abstract ID: 251

Record breaking marine heatwave event in the Baltic Sea in 2024: bases for improving detection criteria in operational climate service

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Since May 4, 2023, global sea surface temperatures have reached record highs and marine heatwaves (MHW) have been observed around the world, including Baltic Sea. A new operational monitoring system has been established to characterize the extent, duration and intensity of marine heatwaves and cold spells in the Baltic Sea, utilizing Copernicus satellite-based sea surface temperature data products.

In spring 2024, the Baltic Sea experienced its most severe MHW in 30 years, affecting 70% of its surface, with maximum intensity of 10.68 °C. This event was triggered by a Scandinavian atmospheric blocking event that began in mid-May and persisted for 35 days. As a result of the heatwave, an extensive blue-green algae bloom developed in the Baltic Sea since the beginning of July.

Another intense and extensive MHW event occurred in the autumn of 2024 covering 57% of the Baltic Sea with maximum intensity of 5.6 °C. The main surface area impacted by the MHW was eastern Baltic Sea where the event lasted over 70 days.

The current paper (1) demonstrates the operational marine heatwave monitoring system for the Baltic Sea which relies on satellite observations and (2) analyses the large scale impact of the two extreme MHW events in 2024. A question emerges: is the traditional MHW detection criteria (90th percentile, 5 days) by Hobday et al (2016) sufficient for MHW impact area monitoring or a should an additional “stricter” criterion be introduced?