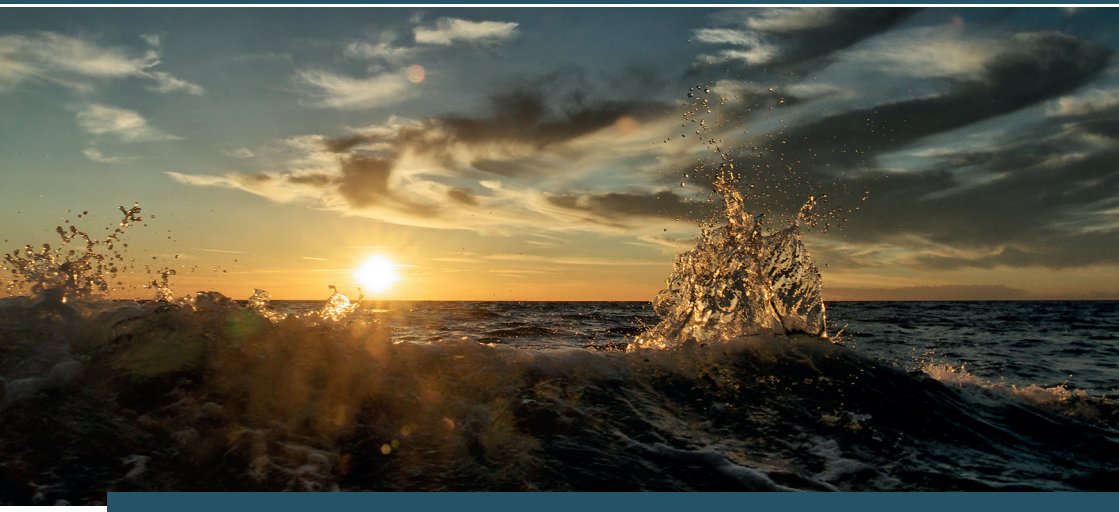
# The 11th Baltic Sea Science Congress

## ‘Living along gradients: past, present, future’



# ABSTRACTS

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# The 11th Baltic Sea Science Congress

## ‘Living along gradients: past, present, future’










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# Keynote Lectures

## Introduction to the invited speakers

### Martin Visbeck: “The future of the ocean – challenges and opportunities for humanity”

Opening lecture on Tuesday, June 13, 2017

Prof. Dr. Martin Visbeck is the head of the research unit “Physical Oceanography” at GEOMAR Helmholtz Centre for Ocean Research Kiel and professor at Kiel University, Germany. After receiving a Ph.D. in physical oceanography from Kiel University in 1993, he moved to USA for a postdoctoral fellowship at Massachusetts Institute of Technology. Subsequently, he worked as an associate research scientist at the Lamont-Doherty Earth Observatory and as an associate professor at the Department of Earth and Environmental Sciences, Columbia University. He was awarded the Storke-Doherty Lectureship in 1997 and tenure by Columbia University in 2003. He returned to Kiel, Germany, in 2004 to take up his current position. Martin’s research interests revolve around the ocean’s role in the climate system with an emphasis on understanding climate change and climate variability. His interest in the development of integrated ocean observatories led to the launch of a large-scale EU project “AtlantOS” in 2015, set out to better coordinate the ongoing in-situ observations of the Atlantic Ocean with the participation of European and international partners. As the speaker of the German excellence initiative 'The Future Ocean' in Kiel, he is involved in integrated marine sciences bringing together different disciplines to work on marine issues. More recently, he has been heavily engaged in promoting integrated marine science in support of sustainable development of the ocean. Through his active participation in several national and international advisory committees, Martin is involved in strategic planning and decision-making processes about the ocean at a national, European and global level. His work revolves around improving global and interdisciplinary science on the ocean for providing solutions. More information: http://www.geomar.de/ • https://www.uni-kiel.de/index-e.shtml • http://www.futureocean.org/en/index.php • https://www.atlantos-h2020.eu • http://www.dkn-future-earth.org/en/

### Maren Voß: “Continuum and gradients: what are the linkages of nutrient cycles in the Baltic Sea?”

Keynote lecture on Tuesday, June 13, 2017

Prof. Dr. Maren Voß is the head of the working group “Marine Nitrogen Cycle” at the Leibniz Institute for Baltic Sea Research Warnemünde. She studied Biology with the focus on Biological and Chemical Oceanography at Kiel University, where she received her PhD in 1991.
In 1992, she changed to the Leibniz Institute for Baltic Sea Research in Warnemünde, where a stable isotope laboratory was established under her direction. In 2002, she habilitated at the University of Rostock. A mayor focus of her work is the biogeochemical cycling of nitrogen compounds and related elements. Several projects in the past focused on nitrogen fixation activity in the Baltic Sea, the South China Sea off Vietnam and the Atlantic Ocean under the present situation and under ocean acidification scenarios. Research in the Baltic Sea concentrates on budgets of nitrogen for the entire Sea, and on nitrogen cycling in coastal and estuarine waters. Maren Voß is member of the management committee of the European network “Nitrogen in Europe (NinE)”. More information: https://www.io-warnemuende.de/maren-voss-en.html

### Byron C. Crump: "Estuaries as bioreactors: transdisciplinary research on the Columbia River estuary"

**Keynote lecture on Tuesday, June 13, 2017 – afternoon session**

Prof. Byron C. Crump studied Biology at the Oberlin College and Biological Oceanography at the University of Washington, Seattle, where he received his PhD in 1999. As a Postdoctoral Scientist, he worked at the Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts. In 2003, he changed to the University of Maryland, Center for Environmental Science, Horn Point Laboratory, Cambridge, Maryland, where he worked for ten years as an Assistant Professor, and Associate Professor, respectively. Since 2013, his home institute is the Oregon State University, College of Earth, Ocean, and Atmospheric Sciences where since 2016, he is Professor in the disciplines Ocean Ecology and Biogeochemistry. The areas of his professional expertise are

- Aquatic microbial ecology in marine and freshwater ecosystems.
- Bacterial and Archaeal biogeography and metagenomics.
- Organic matter and nutrient cycling.
- Microbial food web structure.
- Composition and development of microbial communities.
- Influence of hydrodynamics and particle cycling on microbial activity

More information: http://people.oregonstate.edu/~crumpb/index.html

### Hans-Otto Pörtner: "Climate change impacts on ocean biology: physiological underpinnings, projections and uncertainties"

**Keynote lecture on Wednesday, June 14, 2017**

Prof. Dr. Hans-O. Pörtner studied at Münster and Düsseldorf Universities where he received his PhD and habilitated in Animal Physiology. As a Research and then Heisenberg Fellow of the German Research Council he worked at Dalhousie and Acadia Universities, Nova Scotia, Canada and at the Lovelace Medical Foundation, Albuquerque, NM. Currently he is Professor and Head of the Department of Integrative Ecophysiology at the Alfred Wegener Institute for Marine and Polar Research, Bremerhaven, Germany. He acts as an associate editor "Physiology" for Marine Biology and as a co-editor of the Journal of Thermal Biology. He was Honorary International Associate Member of the Society for Integrative Biology, USA, between 2006 and 2013. Until the end of 2014 he served as a Coordinating Lead Author of IPCC WGII AR5, chapter 6, Ocean Systems and as a member of the author teams for the WGII Summary for Policymakers and Technical Summary, as well as a member of the Core Writing Team for the IPCC AR5 Synthesis Report. In October 2015 he was elected Co-Chair of Working Group II of the IPCC. His research interests include the effects of climate warming, ocean acidification, and hypoxia on marine animals and ecosystems with a focus on the links between ecological, physiological, biochemical and molecular mechanisms limiting tolerance and shaping biogeography and ecosystem functioning. More information: https://www.awi.de/en/about-us/organisation/staff/hans-otto-poertner.html

### Caroline P. Slomp: "Hypoxia in the Baltic Sea: causes and consequences"

Keynote lecture on Thursday, June 15, 2017

Prof. Dr. Caroline P. Slomp started her academic career at the Royal Netherlands Institute for Sea Research (NIOZ) where she worked as a PhD student from 1991 – 1995. As a post-doctoral researcher, she changed to Wageningen University (1996-1998). Since 1998, she is working with the Utrecht University, first as a post-doctoral researcher, from 2001 to 2004 as a Fellow of the Royal Netherlands Academy of Arts and Sciences. From 2004 on as Assistant Professor in Geochemistry, later as Associate Professor in Biogeochemistry. In 2013, she was appointed Professor in Marine Biogeochemistry at the Utrecht University. Her research interests focus on marine biogeochemistry, paleoceanography, biogeochemical ocean modeling, reactive transport modeling, and hydrogeochemistry.
More information: http://www.uu.nl/staff/CPSlomp

### Ragnar Elmgren: "Remembering Fredrik Wulff – Baltic Sea ecosystem modeler, institution leader and creator of the Baltic Sea eutrophication management decision support system"

Keynote lecture on Friday, June 16, 2017

Prof. Dr. Ragnar Elmgren is professor emeritus of Brackish Water Ecology at the Department of Ecology, Environment and Plant Sciences at Stockholm University and a long-term colleague of Fredrik Wulff. Elmgren received his Ph.D. from Stockholm University in 1976 for the thesis "Baltic Benthos Communities and the Role of the Meiofauna". In 1977-78 he studied the ecological effects of marine oil pollution at the Graduate School of Oceanography, University of Rhode Island. After returning to Stockholm University he studied Baltic Sea ecosystems, with an emphasis on bottom fauna, ecosystem effects of eutrophication, cyanobacterial blooms, and, increasingly, management issues. He has supervised 20 Marine Ecology PhDs. His current research projects deal with adaptive management of nutrient discharges to the coastal zone, and Baltic Sea cyanobacterial blooms. More information: http://www.su.se/profiles/ragnare-1.192387

### Anna-Katharina Hornidge: "Epistemic mobilities, sealevel rise and the contestation of the ocean – land borderline"

Keynote lecture on Friday, June 16, 2017

Prof. Dr. Anna-Katharina Hornidge is sociologist and development researcher and is appointed as Full Professor for 'Social Sciences in the marine Tropics' at the University of Bremen, Institute of Sociology. She is head of the department 'Social Sciences' and of the working group 'Development and Knowledge Sociology' at the Leibniz Center for Tropical Marine Ecology in Bremen. Her research interest comprises the topics 'social construction of knowledges, social, political and ecological environments, risks and 'realities', 'cultures of knowledge production and sharing, innovation development processes and science policy' as well as 'social differentiation and the governance of change'. Her working group is aiming to further develop marine social sciences in the thematic area of marine science and future research. More information: http://www.zmt-bremen.de/en/Anna-Katharina_Hornidge.html

# Oral Presentations

June 13, 2017

OPENING LECTURE

## THE FUTURE OF THE OCEAN – CHALLENGES AND OPPORTUNITIES FOR HUMANITY

Visbeck, M.
*GEOMAR Helmholtz Centre for Ocean Research Kiel and Kiel University, Germany*

The ocean covers two thirds of the earth's surface and forms the largest coherent ecosystem of our planet. It shapes our lives today and our future will also depend on how we deal with the ocean: It not only produces more than half of the oxygen we breathe and drives the global water cycle. It also regulates the global climate, provides humans with natural resources such as food, materials, important substances, and energy, and is essential for international trade and recreational and cultural activities. For a long time people thought these services of the ocean were inexhaustible and free of charge. However, the past decades have shown that ocean resources are finally vulnerable and marine ecosystems are vulnerable. Together with human development and economic growth, free access to, and availability of, ocean resources and services have exerted strong pressure on marine systems, ranging from overfishing, increasing resource extraction, and alteration of coastal zones to various types of thoughtless pollution – the ocean is warming, acidifying, deoxygenating and its water level is rising. International cooperation in science and effective local, regional and global governance are required to protect the marine environment and promote the sustainable use of marine resources to preserve an 'healthy' and productive ocean to keep delivering fundamental ocean services to meet the needs of future generations. Some of the global challenges such as food security, marine community health, and material and energy supply require more science from discovery and sustained ocean observations to understanding and the development of scenarios and predictions. This information needs to be assessed and recommendations for development pathways given. We need both a better understanding of ocean change and its challenges as well as more knowledge about new opportunities in order to develop towards a more sustainable relationship between humans and the ocean.

KEYNOTE LECTURE

## CONTINUUM AND GRADIENTS: WHAT ARE THE LINKAGES OF NUTRIENT CYCLES IN THE BALTIC SEA

Voss, M.
*Leibniz-Institute for Baltic Sea Research Warnemünde, Germany*

The Baltic Sea is one of the most studied areas worldwide but a unifying framework explaining budgets, rates, and concentration changes of nutrients is difficult to establish. One reason is the complexity of input sources and fates of substances as detailed in many site- and process based studies from all regions of the Baltic Sea. Moreover, numerous model studies have substantiated a general framework of nutrient fluxes but could not consider the wealth of processes and interaction of fluxes across boundaries.

A major feature of the Baltic Sea is of course the gradient from the Kattegat to the Baltic Proper and further on into the Gulf of Finland and Bothnian Bay. Likewise important is the differentiation between the coastal zone and the offshore deep basins. The latter feature an entirely different suite of biogeochemical processes largely driven by the oxic-anoxic interface. In which way coastal zones and the off-shore basins are linked and how nutrient cycling differ, has remained rather unclear. A major question is whether the coastal zones are sources or sinks for the nutrients delivered to the Baltic Sea from the catchments. Composition and turnover of organic and inorganic compounds depend on the land use and other human activities. Organic material is most abundant in rivers from northern Swedish catchments but inorganic nutrients dominate the input via the major southern rivers. Observations suggest that all dissolved substances are transported alongshore while they undergo substantial turnover especially through closely linked water-sediment coupled processes. Since the heterogeneity of coastal zones around the Baltic Sea is high and input and removal likewise variable, depending on the residence time of waters, oxygen concentration, sediment characteristics and other factors, it is be difficult to define typical scenarios of nutrient turnover and removal.

In this lecture we will present key results from the past years including data from past and ongoing BONUS projects like AMBER, COCOA and others. A major focus will be on the cycling and microbial processes impacting the nitrogen and phosphorus cycles. Removal versus transport processes of characteristic coastal sites will be presented along with conceptual thoughts on the importance of individual processes. How the coastal nutrient cycles are then connected to the central basins will be evaluated. Finally we will speculate on how climate change can impact the processes and which consequences human pressure will unfold on the Baltic Sea ecosystem.

KEYNOTE LECTURE

## ESTUARIES AS BIOREACTORS: TRANSDISCIPLINARY RESEARCH ON THE COLUMBIA RIVER ESTUARY

Crump, B. C.
*Oregon State University, College of Earth, Ocean, and Atmospheric Sciences, USA*

Estuaries act as coastal filters for fluvial materials in which microbial, biogeochemical, and ecological processes combine to transform riverborne organic matter prior to export to the coastal ocean. This critical function of estuarine 'bioreactors' is linked to material residence times and is based on heterotrophic activity of estuarine microbial communities. Many river dominated estuaries, like the Columbia River estuary in North America, support highly active estuarine microbial communities on suspended particles that are retained in estuarine turbidity maxima (ETM). ETM particle trapping in this rapidly flushed estuary extends particle residence time from 1-2 days (the average water residence time) to several weeks, which facilitates organic matter transformations by microbes, and permits establishment of discrete and metabolically dominant particle-associated microbial communities. However, we know little about the diversity of this estuarine microbial community, the genomic capabilities that allow them to thrive under estuarine environmental conditions, or the degree to which they respire riverine organic matter. This talk will summarize research on the Columbia River ETM conducted by the Center for Coastal Margin Observation and Prediction (CMOP) which brings together physical models of water and particle transport with predictive models of microbial productivity and detailed studies of microbial metagenomics to describe the ecology of ETM microbial communities and to evaluate the contribution of ETM particle trapping to the estuarine bioreactor.

SESSION 1: DYNAMICS OF GRADIENT SYSTEMS

## STABLE CARBON ISOTOPIC SIGNATURES OF THE BALTIC ORGANIC MATTER - REVISITED. CONSTRAINS RELATED TO THE ORIGIN, SEASON, AREA AND DEPTH

Winogradow A.[1], Szymczycha B.[1], Koziorowska K.[1], Stokowski M.[1], Kuliński K.[1], and Pempkowiak J.[1]

[1]*Institute of Oceanology Polish Academy of Sciences, Sopot, Poland*

Organic matter (OM) is an important component of seawater as it influences the properties of the marine environment and processes occurring there. Organic matter is also a part of the carbon cycle in the Earth's crust, and has a direct link to the carbon dioxide abundance in seawater and an indirect influence on the $CO_2$ concentration in the atmosphere. The biogeochemistry of organic matter depends on the proportion of terrestrial vs. marine derived fraction. It is believed that the proportion can be unraveled using bulk isotopic composition and the so called 'end members' approach. To this end $\delta^{13}C$ equal to -22‰ and -28‰ for marine derived and terrestrial derived organic matter, respectively, are used commonly in the Baltic Sea studies.

The hypothesis put forward was that the carbon isotopic signatures assigned commonly in studies on organic matter in the Baltic do not reflect the actual situation. Thus the main aim of the study was to measure the $\delta^{13}C$ in samples of terrestrial, marine and mixed organic matter origin in the Baltic Sea. Southern Baltic was selected as a study area.

POC samples were isolated from vertical profiles of water of the southern Baltic deeps-Bornholm, Gdańsk and Gotland, several times per year in the period 2011-2016. Moreover POC was collected on the monthly basis from the Vistula water, and the surface-most southern Baltic sediments (60 locations). Altogether stable carbon isotopes ($\delta^{13}C$) were measured in the collected samples (0.03‰ accuracy) in about 500 samples.

The values of $\delta^{13}C$ in the sediment samples range between -23.9‰ to -26.9‰, while in the POC samples they range between -23.2‰ to -26.8‰ - in spring and summer months and between -26.1‰ to -28.9‰ - in autumn and winter months. The conclusion is that the obtained results of $\delta^{13}C$ in the Baltic Sea are not in good agreement with the literature values for marine derived POC in the Baltic. As the $\delta^{13}C$ signatures commonly assigned to marine derived organic matter are equal to 22‰, estimates as to the origin of sedimentary organic matter derived from the 'end members' might be grossly biased, and require re-evaluation.

SESSION 1: DYNAMICS OF GRADIENT SYSTEMS

## MULTI-ISOTOPE (C - O - S - H - B - MG - CA - BA) AND TRACE ELEMENT VARIATIONS IN A PORE WATER PROFILE ACROSS A BRACKISH-FRESH WATER TRANSITION OF A BALTIC SEA SEDIMENT

Böttcher, M.E.[1], Lapham, L.[2], Gussone, N.[3], Struck, U.[4], Buhl, D.[5], Immenhauser, A.[5], van Zuilen, K.[6], Nägler, T.F.[6], Pretet, C.[6], Dellwig, O.[1], Huckriede, H.[7], and Halas, S.[8]

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The Holocene Brackish Sea has been switched several times between fresh water and brackish water stages. The change in paleo-environmental conditions caused downcore gradients in the concentrations of dissolved species from modern brackish waters downward to fresh paleo-pore waters. These extreme physico-chemical changes caused by e.g., microbial activity and further physical and chemical water-solid interactions may lead to multiple stable isotope fractionation processes, that in turn have strong implications for isotope and trace element partitioning upon early diagenetic mineral (trans-) formations. In the present study, we communicate the results from the first integrated multi-isotope and trace element investigations ever conducted in this type of gradient system. It is found that concentrations of conservative elements (e.g., Na, Cl) decrease with depth due to diffusion of ions from brackish waters into underlying fresh waters. This is associated with pronounced depletions in H-2 and O-18 of pore water with depth. Co-variations of both stable isotope systems are close to the meteoric water line as defined by modern Baltic Sea surface waters. A downward increase and decrease of Ca and Mg, respectively, is associated with a decrease in the Ca-44 and Mg-26 isotope signals. B-11 isotope signals decrease in the limnic part of the sediments, too. On the other hand, an increase in Ba concentrations with depth is associated with an increase in Ba-137/134 isotope signals. Microbial sulphate reduction and organic matter oxidation lead to an increase in DIC, but a decrease in sulphate concentrations and in C-13 contents of DIC with depth. Suess (1981) was probably the first to suggest, that desorption of Ca and Ba from glacial sediments due to downward diffusing ions may be responsible for a downcore increases in pore water concentrations of earth alkaline ions and the formation of authigenic barites. Coupled S-34 and O-18 isotope signals in authigenic barites suggest O-18 signals close to -20 per mil (vs. VSMOW) in pre-Yoldia pore waters. In the present communication, we will discuss possible impacts of diagenetic processes on multi-isotope signals in pore waters and potential solid phases. A combination of mixing between brackish and fresh water, ion exchange, precipitation/dissolution, and transport reactions is considered to explain most of the observed isotope variations along the vertical pore water profile.

SESSION 1: DYNAMICS OF GRADIENT SYSTEMS

## INCLUDING BACTERIAL DOC UPTAKE INTO A BIOGEOCHEMICAL MODEL OF THE BALTIC SEA

Müller-Karulis, B.[1], Sundh, J.[2], Berg, C.[2], Hagström, Å.[2], and Humborg, C.[1]
*[1]Baltic Sea Centre, Stockholm University, [2]Department of Biology and Environmental Science, Linnaeus University Kalmar*

We have expanded a biogeochemical model of the Baltic Sea to include a more comprehensive description of bacterial growth, grazer dynamics and nutrient mineralization in the surface layer of the Baltic Sea. Microbial growth stoichiometry, growth yields and maximum growth rates were derived on a simplified energetic representation of electron flow in bacterial metabolism. Heterotroph nanoflagellates and ciliates were added to represent grazing on bacteria, detritus and phytoplankton, together with a mesozooplankton group that predates on all organisms except bacteria.

In the surface layer, heterotroph bacteria channel dissolved organic carbon, nitrogen and phosphorus into the microbial foodweb. With their ability to cover their nutrient demand from inorganic and organic sources, bacteria both compete with phytoplankton for ammonium and phosphate, or – depending on their growth yield and the nutrient content of their substrate – act as a source of inorganic nutrients. In order to represent the role of bacteria in carbon and nutrient turnover, we split dissolved organic carbon into a mainly phytoplankton derived carbohydrate pool, a nutrient rich, but energy poorer, protein-nucleotide DOM, and a low-energy, terrestrial DOM. The simulated heterotroph bacterial community shows seasonality in the uptake of different DOM types, that has feedbacks on ammonium and phosphate availability. In particular, in the northern basins of the Baltic Sea, terrestrial DOM is an important carbon source for bacteria before the spring bloom supplies the community with autochthonous DOM. Representing bacterial growth and the microbial loop explicitly has resulted in higher simulated phytoplankton primary production in the northern basins of the Baltic Sea, since the model now is able to represent the role of terrestrial organic carbon for carbon and nutrient turnover.

SESSION 1: DYNAMICS OF GRADIENT SYSTEMS

## A CASCADE OF MULTI-SCALE PROCESSES SHAPING THE SIGNAL DYNAMICS AND MAINTAINING THE ENERGY TRANSFER IN STRATIFIED BALTIC SEA BASINS

Lips, U.[1], Liblik, T.[1], Lips, I.[1], Rünk, N.[1], Kikas, V.[1], Laanemets, J.[1], and Väli, G.[1]
[1] *Tallinn University of Technology*

The main physical forcing components for the non-tidal Baltic Sea system are the atmospheric forcing, exchange of heat energy and freshwater through the sea surface, and input of freshwater from rivers and saltier water through the Danish Straits. The geographically localized freshwater and saltier water inputs together with the seasonally variable heat flux and atmospheric forcing create the observed layered structure and lateral gradients in the Baltic Sea. This thermohaline structure combined with relatively shallow depths is a challenge to be accurately described by contemporary numerical models. While the role of mesoscale processes in shaping the spatial and temporal patterns as well as maintaining the energy transfer between the processes with different scales is well recognized and studied, the contribution of sub-mesoscale processes is unclear yet. Partly, this gap in knowledge exists due to the low resolution of observations in space and time to map the sub-mesoscale dynamics.

We estimated the role of sub-mesoscale processes based on an analysis of two datasets and comparing the results with the high-resolution model simulations. The first dataset contains the flow-through data from the surface layer collected during regular monitoring cruises (6 times a year covering the Gulf of Finland, Gulf of Riga and northern Baltic Proper) since September 2013. The analyzed twenty 1000-km long data series with 250-m resolution showed the high levels of sub-mesoscale variations in connection to the coastal upwelling events and enhanced river discharge. However, the sub-mesoscale variability was not higher in the vicinity of thermohaline fronts formed in the straits connecting the Baltic sub-basins than in the open sea areas. The second set contains the data from a dedicated 12-days measurement campaign in spring 2016 when a cross-shore section was repeatedly mapped by an underwater glider in the vicinity of fixed profilers. Variability at the meso- and sub-mesoscale is analyzed in relation to the varying wind forcing and development of the seasonal thermocline in the coastal slope area. We show the link between the high levels of sub-mesoscale variations at the thermocline depths and the dynamics of a coastal-offshore thermohaline front.

We conclude that the sub-mesoscale features play a considerable role in transferring the energy from larger to smaller scales especially in the conditions of high mesoscale variability in non-constrained sea areas (outside of narrow straits).

SESSION 1: DYNAMICS OF GRADIENT SYSTEMS

## ON THE TURBIDITY DYNAMICS IN THE NEAR-BOTTOM LAYER OF THE GULF OF FINLAND

Buschmann, F.[1], Suhhova, I.[1], Liblik, T.[1], and Lips, U.[1]
[1]*Department of Marine Systems at Tallinn University of Technology, Estonia*

The near-bottom currents and their influence on the water characteristics (temperature, salinity, dissolved oxygen, and turbidity) in the Gulf of Finland were analyzed using data from different locations in the Gulf in the period from September 2010 until May 2014. The measurements consist of seven bottom-mounted ADCP and turbidity sensor deployments, CTD casts and laboratory water sampling of dissolved oxygen concentration and total suspended solids. Four stations (at one station, two series were acquired) were located in the western part and two in the eastern part of the central Gulf.

The study is focused on processes below the quasi-permanent halocline which prevent the mixing of upper oxygen rich water with deeper less oxygenated saltier waters. In the western part of the Gulf, the halocline is located approximately in depths 60-80 m and exist throughout the year, while in the eastern part, the halocline is dependent on the season and wind conditions.

Water masses below the halocline are not directly influenced by the wind or convective mixing and have almost linear vertical profiles. However several high-turbidity events or occasions have been registered. During the periods with higher current speed (variability), which could cause sediment resuspension, the variations in turbidity had better correlation with the currents compared to the calm periods. We found that in most cases the flow was influenced by the bottom topography and the strongest currents were observed in relation to the channel-like topographic features.

The measurements have revealed the other type of relatively high turbidity in the deep layers of the Gulf of Finland, which was not related to the strong near-bottom currents. During these occasions, hypoxia was always detected in the near-bottom layer. Possible causes and responsible processes/mechanisms of these events, associated with the redoxcline, are discussed.

SESSION 1: DYNAMICS OF GRADIENT SYSTEMS

## HIGH-RESOLUTION ICE DYNAMICS IN THE GULF OF FINLAND

Lilover, M-J.[1], Kõuts, T.[1], and Leppäranta, M.[2]
[1]*Department of Marine Systems at Tallinn University of Technology, Estonia,*
[2]*Department of Physics, University of Helsinki, Finland*

High-resolution Eulerian and Lagrangian sea ice dynamics is examined based on bottom-track facility of ADCP (Acoustic Doppler Current Profiler) and icebound drifter buoys in the Gulf of Finland (GoF), Baltic Sea. The measurements performed in the central GoF in winter 2010 from January to March were analysed. The ice cover and ice-free periods were detected by ADCP bottom-track error velocity and compared with available MODIS satellite images. Altogether five ice periods with duration of 6-12 days were obtained. Ice drift was mostly in near-free drift state driven by winds and at time also by ice-independent currents in the basin. Internal friction was significant apart from off-ice forcing toward open boundary. Asymptotic wind factor and deviation angle at large wind speed were 0.034 corresponding to the ratio of 0.92 of the air-ice and water-ice drag coefficients, and 9° in the oceanic boundary layer respectively. The ice velocity clockwise spectra (CW) showed a wide peak at inertial frequency and a power law by exponent -1.9 in the higher frequencies. Eulerian CW spectra showed higher level than Lagrangian in the frequencies of 0.04-0.2 cph. Eulerian and Lagrangian counterclockwise spectra had roughly the same energy density values. Spatial velocity correlations were higher than 0.5 up to 42 km distance, and the best-fit falling power was -0.18 with distance. The integral correlation length scale was 48 km.

SESSION 2: PROCESSES THAT AFFECT COASTAL SEAS

## TO BLOOM OR NOT TO BLOOM: THE GENESIS AND CONSEQUENCES OF CYANOBACTERIA BLOOMS IN THE BALTIC LAGOONS

Razinkovas-Baziukas, A.[1], Bartoli, M.[2], Bresciani, M.[3], Giardino, C.[3], Z. Gasiūnaitė, Z.[1], E. Grinienė, E.[1], I. Lubienė, I.[1], J. Petkuvienė, J.[1], Pilkaitytė, R.[1], Umgiesser, G.[4], Vaičiūtė, D.[1], and Žilius, M.[1]

*[1]Klaipėda University, Lithuania, [2]Department of Environmental Science, Parma University, Italy, [3]Optical Remote Sensing Group, CNR-IREA, Milano, Italy, [4]ISMAR-CNR, Venice, Italy*

Three Baltic lagoons (Oder, Vistula and Curonian) are the largest coastal lagoons in Europe and characterized by the oligohaline salinity gradients and strong riverine influence. Despite differences in the external nutrient loads and water residence time (Vistula lagoon receives much less freshwater inputs than Curonian or Oder) the cyanobacteria blooms are common but not cyclic phenomena. Based on the analysis of the long-term data, recent experimental biogeochemical research mostly in the Curonian lagoon and the application of remote sensing methods, we have developed a conceptual model of the cyanobacteria bloom development. This conceptual scheme involves the multiple interactions between climatic, hydrologic, chemical and biological factors that trigger cyanobacterial blooms, focusing also on the importance of seasonal shifts and interannual variability. Our results reveal that the timing, duration and stoichiometry of external nutrient inputs combined with such climatic conditions as wind and temperature are the main factors deciding the development and collapse of the bloom. The impact of zooplankton grazing is an important top down mechanism only during the so called "Clearwater period" and not sufficient to control the cyanobacteria bloom development. The spatial patterns of the bloom development correspond well to the hydrodynamics expressed as spatially distributed water residence time. We also assess the impact of the cyanobacteria blooms on the role of coastal lagoons as a coastal filter as the prolonged cyanobacteria blooms change dramatically the retention of different nutrient forms, especially phosphorus which in turn is related to the internal loads. We also have hypothesised further the impact of cyanobacteria blooms on the present and future ecosystem services provided by the lagoon ecosystem in a view of climatic trends using BBN as a tool.

The work was supported by BONUS "COCOA", FP7 "INFORM" and H2020 "ECOPOTENTIAL" projects.

SESSION 2: PROCESSES THAT AFFECT COASTAL SEAS

## AMINO ACID SYNTHESIS AND TURNOVER DURING $N_2$ FIXATION IN A DECAYING CYANOBACTERIA BLOOM AND BIOCHEMICAL MATCH WITH ZOOPLANKTON

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$N_2$ fixation rates are routinely used in studies of nitrogen flow through ecosystems, yet the synthesis of nitrogenous compounds underlying $N_2$ fixation rates and their quality for heterotrophs are not well understood. Here we examined the rate of synthesis of 13 amino acids (AA) in field samples of the marine diazotroph ($N_2$-fixing) *Nodularia spumigena* and compared their AA profile to that of zooplankton during a decaying bloom in the central Baltic Sea in July 2015 using gas chromatography-mass spectrometry and gas chromatography-combustion-isotope ratio mass spectrometry. High rates of $N_2$ fixation into total nitrogen (TN) integrated the variation in volumetric AA nitrogen (AAN) synthesis rates. Relatively fast turnover times of 11-40 days calculated for all AAs during $N_2$ fixation at invariant high AAN concentrations suggest a saturation level for cell proteins and point to catabolism or exudation of AAs in the autotrophs. Total hydrolysable amino acid nitrogen (THAAN) concentrations (wt% TN as µg THAAN per 100 µg TN) of the diazotrophs were very low in a healthy bloom in July 2014 in comparison to values measured during the decaying bloom in July 2015. The low AA concentrations in diazotrophs were also reflected in much lower THAAN wt% TN concentrations in zooplankton from the same food web in 2014 compared to 2015, which was mainly due to very high concentrations of ketogenic lysine in zooplankton in 2015. Amino acid nitrogen synthesis and turnover appear to control amino acid nitrogen content in cyanobacteria and in the rest of the planktonic food web.

SESSION 2: PROCESSES THAT AFFECT COASTAL SEAS

## WINTER-SPRING CLIMATE EFFECTS ON SMALL-SIZED COPEPODS IN THE COASTAL BALTIC SEA

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Small copepods (*Eurytemora affinis* and *Acartia* spp.) play an important role in the coastal Baltic Sea, among other things as a primary prey for larval and adult herring. The positive effect of warming winters on the abundance of small-sized zooplankton in the following spring and early summer has been reported from different parts of the Baltic Sea, but the mechanism of this link is not clear. Although causal links cannot be deduced with confidence from observational data, detailed analyses can nevertheless provide insights to the potential mechanisms. We present the results of such an analysis, scrutinizing the effects of winter and spring hydroclimate on the abundance of small-sized dominant calanoid copepods, using data from 2080 zooplankton samples collected over 55 years (1957-2012) from a shallow coastal habitat (Pärnu Bay, Gulf of Riga) in the Baltic Sea. Our results indicated that the milder winters brought about not only higher abundances, but also the reduced seasonality of small-sized copepods in the following spring, whereas ambient sea surface temperature (SST) mostly affected the relative abundance of adult stages. Furthermore, using the sliding window tests, we also found the effects of abiotic variables to be non-linear and non-stationary: with the continuous increase of the SST in spring over the last 50 years, the effect of winter conditions on the abundance of *Acartia* spp. weakened gradually. The effect of winter conditions on *E. affinis*, in contrast, was not affected by the long-term warming of spring SST, but the effect of winter was stronger during the colder periods. Our results exemplified the intricacy of processes controlling the secondary producers in marine ecosystems, including the importance of species specific responses; as well as the usefulness of sliding window type of analyses in identification of non-stationary links between the environmental and biological variables from long term observations.

SESSION 2: PROCESSES THAT AFFECT COASTAL SEAS

## LINKING ABIOTIC AND BIOTIC INFORMATION FOR EVALUATION OF SEDIMENTARY SERVICES IN THE GERMAN BALTIC SEA

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The project SECOS – The service of sediments in German coastal seas – aims at assessment and evaluation of sedimentary services in order to provide a scientific knowledge basis for planning procedures for a sustainable and integrated coastal zone management.

Climate changes, anthropogenic impacts and changes in activity of macrofauna lead to changes of sedimentary redox conditions, reactivity and release of nutrients. Core incubations and pore water analysis supported by REC/PROFILE software allow determining the magnitude and effects of such changes as a function of selected disturbances (resuspension, anoxia, salinity change). Carbon isotope composition of dissolved $CO_2$ used to decode biogeochemical processes regarding mineralization of organic carbon and release of carbon dioxide in the sediment is likewise used as a signal for the assessment of disturbances.

The mixing of sediment particles (Bioturbation) and solutes (bioirrigation) through the activities of benthic macrofauna affects multiple ecosystem functions like biogeochemical processes, nutrient cycling and organic matter regeneration. Based on information about species distribution and biomass, the following tasks are addressed: (i) to assess the seasonal and interannual variability of ecosystem functioning expressed by the community bioturbation potential (BPc), (ii) to identify key species contributing to bioturbation and (iii) to estimate, model and map its spatial differences in the study area. Using particle-bound chlorophyll a as a tracer, patterns of regional differences in the mode of particle reworking emerge that are generated by benthic fauna. Bioirrigation, likely coinciding with these patterns, may be visible in the biogeochemical signals found.

Subsequently, the scientific results will be incorporated into the Baltic Sea Atlas (http://bio-50.io-warnemuende.de). This web GIS application visualizes spatial research results from SECOS. Developed for experts and public access, it has a simple user interface and contains geodata linked with metadata. Geodata comprise six SECOS themes (geochemistry, geology, benthology, models, monitoring, water quality in terms of the European WFD/MSFD). Four additional themes (administration, protection, bathymetry, base maps) complete the content. A permanent update ensures the sustainability of the atlas representing main outcome of the project.

SESSION 2: PROCESSES THAT AFFECT COASTAL SEAS

## WHO OR WHAT SHAPES THE GRADIENTS IN PORE-WATER PROFILES? ON THE HUNT FOR AN EXPLANATION OF THE IMPACT OF BENTIC MACROFAUNA ON BIOGEOCHEMISTRY AND BENTHIC-PELAGIC ELEMENT COUPLING

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At water depths where physical factors such as wave action are no longer dominant in structuring the substratum macrofaunal activities such as bioturbation have large effects on sediment biogeochemistry. Previous studies have established that macrofaunal reworking can cause much higher nutrient flux from sediments into the water column than molecular diffusion. Bioirrigation generates transport of pore water especially in presence of tube-dwelling animals or gallery-building biodiffusers. Where macrofauna is abundant, oxygen is introduced into the sediment surface while shifting the sulfidic zone downwards. Although this is recognized, the actual quantitative field estimates are scarce. During several cruises in the south-western Baltic Sea conducted in different seasons from 2014 to 2016 over 30 sediment short cores were collected for pore water chemistry and nutrient fluxes analysis. Stations were located along salinity gradient and covered various sedimentary habitats ranging from mud to sand. Total fluxes of nutrients and oxygen in the supernatant water were derived from sediment core incubation experiments. Subsequently, sediment from the pore water and incubation cores was sieved for taxonomic identification and estimation of benthic macrofauna density. We aim to use this combined dataset to find main players responsible for altered geochemical profiles in the studied habitats and extract similarities and patterns explaining significant alterations of calculated fluxes in sediment and on sediment-water interface. Variability in thickness of sulphide-free surface sediments, sulphide flux, ammonium, phosphate and silicon profiles as well as oxygen consumption is determined and related to macrobenthic community taxonomic and functional characteristics using statistical modelling. Possible mechanisms behind these alterations based on species behavioural and functional traits are discussed.

SESSION 2: PROCESSES THAT AFFECT COASTAL SEAS

## DISENTANGLING ENVIRONMENTAL AND TROPHIC VOLATILITY FOR A FISHERY IN FLUX: NON-STATIONARY MODELING OF THE BALTIC SEA SYSTEM.

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Fishery management has historically focused on population elasticity of target fish based primarily on demographic modelling with the key assumptions of stability in environmental conditions and static trophic relationships. The predictive capacity of this fishery framework is poor especially in closed systems where the benthic and boundary effects are important. Here we present a probabilistic model that couples key fish populations to a complex suite of trophic, environmental and geomorphological factors. Using 41 years of observations we model the changes in Baltic cod, herring and sprat (*Gadus morhua*, *Clupea harengus* & *Sprattus sprattus balticus* respectively) for the Baltic Sea within a Bayesian Belief Network. The model predictions are spatially explicit and show the transfer of the central Baltic Sea from cod to sprat dominated ecology during the 41 years. This also highlights that the 2004 to 2014 years deviate in the typical cod-environment relationship with environmental factors being less influential on cod population abundances than in previous periods. Indications are that a decoupling of the Baltic cod growth from environmental conditions which, combined with a trophic alteration in the prime fish growth regions, resulted in a regime shift to sprat dominated environments in the central Baltic Sea. Fisheries management that is able to accommodate shifting ecological and environmental conditions relevant to habitats will be more effective and realistic. In particular each homogeneous habitat region has a specific ecology that is relevant to understanding the fish population behaviour.

CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## MAJOR BALTIC INFLOW STATISTICS - REVISITED

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Major Baltic Inflow events (MBI) transport large amounts of saline water into the Baltic. They are the solely source for deep water ventilation in the central Baltic basins and control to a large extent the environmental conditions below the halocline. The available time series of MBI frequency and intensity depict strong decrease of MBI frequency after the 1980s, followed by long lasting stagnation periods in the central Baltic basins. However, the expected decrease in mean salinity of the Baltic was not observed. It was explained by a compensation effect of increased frequency of baroclinic saline inflows. Also the frequency of large volume changes of the Baltic has not changed and recent model studies predict a slight increase of MBI frequency with warming climate.

Triggered by the exceptional MBI in December 2014 the MBI time series was revisited. Using long term data series of sea level, river discharge and salinity from the Belt and Sound a continuous time series of barotropic inflows was constructed for the period from 1890 till present. A comparison with the MBI time series of Fischer and Matthäus (1996) revealed significant differences in the period since the 1980s. The reasons for the deviations are mainly the lack of appropriate data between 1976 and 1991 and the change in observation methods afterwards, which caused a bias in the inflow statistics.

In contrast to earlier investigations the revised MBI time series depicts no significant long term trend in MBI frequency and intensity, although a decadal variability of MBI exists. Three periods with reduced MBI frequency were identified. The revisited MBI time series was verified with observations of dissolved oxygen and salinity in the bottom layer of the Bornholm basin.

CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## DETAILED OBSERVATION OF ROTATING BOTTOM GRAVITY CURRENTS INDUCED BY A MAJOR BALTIC INFLOW

Umlauf, L.[1] and Holtermann, P. L.[1]

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Strong density contrasts, significant rotational effects and the relatively easy accessibility with oceanic instrumentation, compared to the ocean, make the Baltic Sea an ideal natural laboratory for the investigation of rotationally influenced bottom gravity currents. Here, recent data from an extensive field campaign in spring 2015 are discussed, when one of the largest inflows of salty and oxic North Sea water ever recorded arrived in form of a dense bottom current in the central Baltic Sea. Measurements obtained during this exceptional event include densely-spaced simultaneous turbulence microstructure and velocity (ADCP) transects across the bottom gravity current as well as high-resolution moorings positioned along its pathway. These data reveal a vigorously turbulent dense bottom layer of 10-20 m thickness traveling, strongly affected by rotation, along the south-eastern slope of the Gotland Basin, finally merging with its lower flank into a pre-existing pool of dense bottom waters. These data, constituting the first of their kind obtained during a Major Baltic Inflow, are used to analyze the dynamics of frictionally-dominated rotating gravity currents, identify the key mixing processes, and compare the results to large-scale oceanic overflows. Briefly addressed will also be the implications of this analysis for the description of thin but energetic near-bottom currents with the help of numerical models of the Baltic Sea.

CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## TOWARDS AN IMPROVED MECHANISTIC UNDERSTANDING OF MAJOR SALTWATER INFLOWS INTO THE BALTIC SEA

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The Baltic Sea is a semi-enclosed water body connected to the North Sea via the shallow and narrow Danish Straits. Of special importance to the salinity and oxygen dynamics of the Baltic Sea are Major Baltic Inflows that are the only process to effectively ventilate water masses below the permanent halocline. Their occurrence is typically explained by a sequence of easterly winds over a period of several weeks followed by westerly gales during which the highly saline Kattegat water is pushed over the entrance sills. While this explanation is accurate in a descriptive sense, it does not necessarily serve as sufficient explanation for the occurrence of Major Baltic Inflows. Recently, attempts were made to understand Major Baltic Inflows in the context of large barotropic inflows and it was found that a sequence of easterly and westerly circulation types forced not only Major Baltic Inflows (highly saline barotropic inflows) but large barotropic inflows in general. Thus, clarification of the factors that are exclusive to the formation of Major Baltic Inflows is needed. Based on a realistic numerical ocean model setup of the Baltic Sea system and the simulation period 1979-2015, we investigate on the important ingredients to the occurrence of Major Baltic Inflows. The correlation analysis is based on the complete set of large barotropic inflows, and both atmospheric and oceanic factors are covered. We find that both, the salinity in the transition area between the North Sea and Baltic Sea, as well as details in the atmospheric circulation during the event are important. Furthermore, based on sensitivity experiments with the strong Major Baltic Inflow of December 2014, the importance of runoff and atmospheric circulation in shaping the salinity in the transition area is investigated. Finally, an attempt is made to synthesize insights into the ingredients to effective Major Baltic Inflows into a flow diagram in which an improved mechanistic understanding of Major Baltic Inflows is outlined.

CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## CLIMATE VARIABILITY, EXTREMES AND TRENDS OF TOTAL SEA LEVEL VARIATIONS OF THE BALTIC SEA

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The total sea level change of the Baltic Sea is a combination of wind-driven large volume changes (LVCs), local sea level variations (water level raised by wind and seiche) and wind waves including the sea level change by climatic-driven water density changes and the global sea level rise. The ocean surface velocity is a combination of Ekman surface flow, baroclinic and barotropic flow components and Stokes drift. The first two components can be calculated by standard hydrodynamic 3-dimensional ocean circulation models. But the calculation of the Stokes drift needs an additional approach. The Stokes velocity is a function of the significant wave height and period. It is important for the generation of Langmuir circulation which in turn contributes to the vertical mixing near the ocean surface and to the wind-driven surface transport. We used the Kiel Baltic Sea ice-ocean model (BSIOM) coupled with a simple fully integrated wave model to determine total sea level changes of the entire Baltic Sea for the period 1979-2016. BSIOM has been forced by ERA-Interim reanalysis data (1979-2016). The coupled model system allows the calculation of the total sea level change on a 2.5 km model grid of the entire Baltic Sea as a combination of large volume changes (LVCs), local sea level variations and wind waves including the sea level rise due to climatic-driven water density changes. Thus, combining sea level changes of different time and space scales. Different areas of the Baltic Sea show different trends in significant wave heights over different seasons. During winter, an increase of significant wave height is mainly associated with the retreat of the sea ice cover. There is also an increase of significant wave height of about 5 cm/decade in the eastern Gotland basin during winter. In summer and autumn we found negative trends strongest in the south-western Baltic Sea. Extreme total sea level variations occur if LVCs coincide with local sea level variations and wind waves.

CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## GLOBAL MEAN SEA LEVEL RISE CHANGES SALT INFLOW INTO THE BALTIC SEA

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The semi-enclosed Baltic Sea experiences salt inflow events from the North Sea. Beside regular small events, Major Baltic Inflows (MBI) occur about every one to ten years and are important for increasing the oxygen concentration in the Baltic Sea. Strength and duration of these events may change with changing global mean sea level (GMSL) in a warming climate. Hence the regional General Estuarine Transport Model (GETM) is used to simulate the change in the characteristics of the water exchange through the Danish Straits with global mean sea level change as is has been shown by previous studies that the model is capable of simulating past inflow events. GETM solves the primitive equations by applying the Boussinesq and boundary layer approximations. The model comprises the Western Baltic Sea with a curvilinear grid having a horizontal resolution of 200 meter and 42 vertical adaptive coordinates, whose adaption focuses on stratification. A process study, where the water exchange during small inflow events, MBIs and the outflow of brackish water, is presented. In addition, the change in water exchange between the Baltic and North Sea due to projected GMSL of the RCP scenarios is analysed.

CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## TWO-LAYER EXCHANGE BETWEEN THE NORTH SEA AND THE BALTIC SEA. FINE-RESOLUTION 3D NUMERICAL MODELLING.

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The water and salt balance are in the heart of dynamics of estuarine basins because they are intimately related to the major drivers, such as the evaporation, precipitation and river run off. However these balances are largely dependent on the dynamical control in the straits connecting the semi-enclosed basins and the open ocean. There are a number of process studies dealing with hydraulic processes in the straits and the two-layer exchange, which capture the basic physics. There are also many 3D numerical model studies, even such as climate model scenarios, analysing the response of estuarine basins to sea-level rise. In the process studies straits' dynamics is usually addressed using simplified/idealistic concepts, in the past 3D modelling the estuaries are resolved in the best case with a resolution of 1 km, in many scenario studies even coarser. This resolution is not optimal for the narrow straits as the Sound or the Little Belt. We present here a new approach enabling to resolve accurately the exchange between the North Sea and Baltic Sea. The Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM) employed here uses unstructured grids with a resolution in the narrow straits of ~100 m. The analysis in this paper is focused on the two-layer exchange, its dependence on the atmospheric forcing and dominant physical balances. The relationship between the barotropic and two-layer exchange is also studied for the individual straits. In a comparative analysis it is shown that the three straits' system develops specific dynamics, with some time lags and differences between current systems in the individual straits during inflow and outflow conditions. The relationship between the transports in the straits and the bottom currents in the western Baltic Sea is also analyzed and possible control mechanisms of deep water mass formation are presented.

PLENARY LECTURE

## EFFICIENCY OF THE COASTAL FILTER: NITROGEN AND PHOSPHORUS REMOVAL IN THE BALTIC SEA

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An important function of coastal ecosystems is the reduction of the nutrient flux from land to the open sea, the coastal filter. In this study, we focused on the two most import coastal biogeochemical processes that remove nitrogen and phosphorus permanently: denitrification and phosphorus burial. We compiled removal rates from coastal systems around the Baltic Sea and analyzed their spatial variation and regulating environmental factors. These analyses were used to scale up denitrification and phosphorus burial rates for the entire Baltic Sea coastal zone. Denitrification rates ranged from non-detectable to 12 mmol N $m^{-2}$ $d^{-1}$, and correlated positively with both bottom water nitrate concentration and sediment organic carbon. The rates exhibited a strong decreasing gradient from land to the open coast, which was likely driven by the availability of nitrate and labile organic carbon, but a high proportion of non-cohesive sediments in the coastal zone decreased the denitrification efficiency relative to the open sea. Phosphorus burial rates varied from 0.21 g P $m^{-2}$ $yr^{-1}$ in open coastal systems to 1.83 g P $m^{-2}$ $yr^{-1}$ in archipelagos. Our analysis suggests that archipelagos are important phosphorus traps and account for 45% of the coastal P removal. High burial rates could partly be sustained by phosphorus import from the open Baltic Sea. We estimate that the coastal filter in the Baltic Sea removes 16% of nitrogen and 53% of phosphorus inputs from land. We suggest that the coastal filter efficiency can be improved by management actions specifically targeting hypoxia and coastal erosion.

PLENARY LECTURE

## RIVER PLUME AND BOTTOM BOUNDARY LAYER – HOTSPOTS FOR NITRIFICATION IN A COASTAL BAY?

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Coastal zones, impacted by major rivers, comprise specific environments, including the river plumes, the bottom boundary layer (BBL), and deep offshore water. These environments are characterized by high nutrient concentrations and high microbial activities and thus offer favourable conditions for nitrification, a key process in the coastal nitrogen cycle. Because nitrification provides substrates used in both primary production and denitrification, elucidation of its magnitude and regulation is crucial for understanding the nitrogen cycle in coastal zones. During three research cruises to the Bay of Gdansk, in the southern Baltic Sea, nitrification rates and their relationship to environmental variables, including salinity, temperature, oxygen, and inorganic and organic nitrogen were investigated in river plumes, the BBL, and deep offshore water both in summer and in winter. Our results showed that increasing temperature and decreasing oxygen concentrations enhance nitrification in deep offshore waters during a Major Baltic Inflow. Along the salinity gradient that characterized the surface waters, changes in the magnitude of the nitrification rate and of the regulating variables suggested a substantial shift in the nitrifier community. In summer, but not in winter, nitrification rates were significantly higher in the BBL than in the overlying water. The relationship of nitrification to environmental variables in the BBL differed between the two seasons as well, providing evidence of the BBL's importance in nitrification only under the specific environmental conditions of stable stratification and the accumulation of organic material. Since the nitrate produced by nitrification remains in the water column rather than being denitrified in the sediment, further knowledge regarding its transport especially by bottom currents, is needed to fully understand the fate of nitrification products and hence the coastal filter function.

PLENARY LECTURE

## KEY PROCESSES IN THE COUPLED CARBON, NITROGEN, AND PHOSPHORUS CYCLING OF THE BALTIC SEA

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Biogeochemical and physical key processes in a marine system can be quantified by means of large-scale budget calculations through the use of numerical models. This approach allows estimates of e.g. internal sinks, net transports, and fates of different elements. Such overarching understanding is essential while determining the usefulness of different system-scale management solutions. Numerical models may further serve as prognostic tools under certain assumptions of future nutrient loads, atmospheric $CO_2$ levels, etc. In this study we use the physical-biogeochemical BALTSEM model to examine pools and distributions of organic and inorganic carbon (C), nitrogen (N), and phosphorus (P) in the Baltic Sea. We further quantify key processes and fluxes, i.e., the external loads, internal source and sink processes, and export out of the system. Our calculations include pelagic pools and transformations as well as the storage and transformations in the active sediment layer, which allows a complete coverage of the overall C, N, and P cycling on a system-scale. Basin-wide pools and average concentrations of N and P based on observations are used to validate model results. A striking property of N and P cycling compared to C cycling is that while the permanent sink terms for total N and P (TN and TP) are largely coupled to internal removal processes (87 and 73% respectively), the sink terms for total carbon (TC) are in contrast dominated by a net export out of the system (94%). Another finding is the contrasting properties of pelagic reservoirs versus storage in the active sediment layer – pelagic TC pools exceed the sediment pools by a factor ten; pelagic TN pools are similar to the sediment pools; pelagic TP pools store less than half of the sediment pools. Further, although there is a net export of TN and TP out of the system, there is nonetheless a net import of dissolved inorganic N and P (DIN and DIP). There is on the contrary a net export of both the organic and inorganic fractions of TC. Pelagic pools of TC and TP are dominated by inorganic compounds (82 and 69% respectively), whereas TN largely consists of organic N (82%). There are however large basin-wise differences in C, N, and P elemental ratios as well as inorganic versus organic fractions. These differences reflect different external loads, oxygen conditions, and redox-sensitive fluxes of DIN and DIP.

PLENARY LECTURE

## BALTIC SEA COASTAL EUTROPHICATION IN A THOUSAND YEARS PERSPECTIVE

Norbäck Ivarsson, L.[1], Andrén, T.[1], Moros, M.[2], Lönn, M.[1], and Andrén, E.[1]
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Sediment cores from three sites along the east-coast of Sweden, north-western Baltic Proper, have been studied with respect to lithologies, geochemistry and diatom assemblages. The three sites, Bråviken, Himmerfjärden and Ådfjärden, have different histories for example concerning industries in the drainage area. Even so, the results show some similar patterns for all three sites. Early changes in the ecosystem, already in the first half of the 18$^{th}$ century is identified from $\delta^{15}N$ in all sites and is reflected in the diatom composition in two of the sites. During the 20$^{th}$ century the environmental degradation has escalated, with changes in the species composition and decline in benthic taxa. These environmental changes of the last centuries are unique in a thousand years perspective.

# Oral Presentations

June 14, 2017

KEYNOTE LECTURE

## CLIMATE CHANGE IMPACTS ON OCEAN BIOLOGY: PHYSIOLOGICAL UNDERPINNINGS, PROJECTIONS AND UNCERTAINTIES

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Observations of climate impacts on marine ecosystems reveal crucial roles for water temperature, $CO_2$ and oxygen levels as climate drivers in the ocean. They also highlight the need for an understanding of organismal thermal ranges, their dynamics and their implications at the ecosystem level. Where changes in aquatic animal populations have been observed, the integrative concept of oxygen- and capacity-limited thermal tolerance (OCLTT) has successfully characterized the onset of thermal limits to performance and field abundance. The OCLTT concept addresses the molecular to whole-animal mechanisms that define thermal constraints, by focusing on the capacity for oxygen supply in relation to demand. Routine performance relies on the 'total excess aerobic power budget' supporting motor activity, reproduction and growth. OCLTT explains why thermal vulnerability is highest at whole-animal and lowest at molecular levels. OCLTT also integrates protective mechanisms that expand temperature tolerance at thermal extremes – mechanisms such as chaperones, anaerobic metabolism and antioxidative defense. The talk will summarize the OCLTT concept and update it by addressing the role of routine metabolism at ecosystem level. OCLTT may thus play a crucial role in explaining the observed impacts of climate change on marine ecosystems and support reliable projections of future changes, from impacts on individual species to those on species interactions and shifts in species composition at ecosystem level. The talk will conclude with illustrating how such approaches have contributed to the identification of climate risks to ecosystems in the last IPCC assessment report (AR5) and how these have helped to identify risk thresholds for a sustainable future.

PLENARY LECTURE

## MARINE MAMMALS IN MECKLENBURG-WESTERN POMERANIA – COMBINING DIFFERENT METHODS IS NECESSARY FOR ACQUIRING THE FULL PICTURE

Dähne, M.[1], Herrmann, A.[1], Westphal, L.[1], von Vietinghoff, V.[2], Benke, H.[1], and Gallus, A.[1]

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Monitoring top predators in the marine environment is a challenging task. To get a clear picture on how marine mammal populations are developing, a number of different methods are needed depending on species. For instance, for grey seals after absence for approximately 80 years returning to German haul out counts as well as photo-id for identification of single animals are suitable methods. Haul out counts are simple and can be carried out for all sites, but abundance is underestimated due to animals residing in the water. Photo-id gives a better estimate of abundance but needs time to establish a complete catalogue of animals present. For harbor porpoise aerial surveys are suitable for high density areas and large scale surveys, but have disadvantages for the critically endangered porpoise population east and north of the island Rügen.

Over the years a number of projects have been conducted at the German Oceanographic Museum for detecting trends in occurrence, estimating abundance and finding feeding areas of harbor porpoises in the Mecklenburg-Western Pomeranian waters using stationary acoustic monitoring by means of echolocation click loggers. Furthermore, a stranding scheme to collect carcasses from the coast line has now been run since the 1970's with high effort. In 2011 the collection of incidental sightings of all marine mammals was intensified. Nowadays sailors and other citizen scientists cruising the Baltic Sea report ~1.500 sightings of harbor porpoises per year – another source of data usable to detect changes in habitat use of marine mammals over time. We will present samples of all the mentioned methods to provide an overview. For example, acoustic monitoring throughout the Baltic sea within the SAMBAH Life+ project has led to an estimate of 497 porpoises (80 – 1.091 95% CI), resulting thus in a huge proposed Natura 2000 site. However, by means of click loggers it is still not possible to detect exactly how many animals are present during detection. Hence, only incidental sighting data can be used to estimate group size and whether calves are present or not. Photo-id of grey seals indicates that animals found at the Großer Stubber in the Greifswalder Bodden are resident and may only leave German waters for the pupping season. Continuation of the photo-id work will lead to better abundance estimates in the future. Overall, all suitable methods have to be combined continuously to monitor the status of marine mammals throughout the Baltic Sea.

PLENARY LECTURE

## QUANTIFYING SEABED GEODIVERSITY OF THE BALTIC SEA

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Geodiversity informs about the heterogeneity of the geological characteristics of a certain area. It provides several abiotic ecosystem services (geosystem services) e.g. economic resources, nutrient availability, habitats, recreation possibilities and it might serve as a surrogate for biodiversity. Geodiversity also provides potential for long-term conservation plans and spatial planning.

We have analyzed the geodiversity distribution of the Baltic seabed on the grounds of bedrock, seabed substrate and seabed structures. The broad-scale analysis was performed in GIS environment using spatial analyst methods. We have used three geodiversity measures to analyze seabed geodiversity: patchiness, richness and geodiversity index. The three measures were also analyzed against variables that describe seabed processes to find causes for geodiversity level. Here we will discuss the spatial pattern of the geodiversity distribution of the Baltic Sea and its sub-basins as well as the linkages between seabed heterogeneity and processes. The aim of the analysis is to visualize broad scale geological characteristics of the seafloor environment and to provide science-based knowledge for the ecosystem based management of the Baltic Sea.

PLENARY LECTURE

## HIGH RESOLUTION REGIONAL REANALYSIS OVER EUROPE FOR 1961-2015

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SMHI is coordinating the FP7 Project UERRA (Uncertainties in Ensembles of Regional ReAnalyses) which has developed three full upper air Regional European Reanalysis systems and two 2-dimensional ones. The project is now in its final phase and all data are archived in an openly available UERRA archive with common parameters within MARS at ECMWF.

At SMHI, historical data assimilation and forecast cycles has been produced for the period 1961 until 2015 using the HARMONIE-ALADIN system. It has been run at 11 km horizontal resolution with conventional observations and a large scale constraint that adapts large scales to the global driving ERA reanalyses. ERA40 and ERA-Interim reanalyses exist during this period and provide boundary forcing. UERRA has much higher horizontal grid resolution, about 11 km, than the global ERA analyses at 125 or 78 km respectively. This gives much more detail in precipitation, temperature and wind near the surface.

The reanalysis will be presented and compared to the ERA reanalyses.

PLENARY LECTURE

## HIGH-RESOLUTION pCO2 MEASUREMENTS ON A CARGO SHIP IN THE BALTIC SEA: PROGRESS IN BIOGEOCHEMICAL RESEARCH BY THE ANALYSIS OF CO2 DATA

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Biogeochemical processes are ultimately linked to the mutual transformations between living organic matter and carbon dioxide. Hence, these fundamental processes are reflected in the loss or gain of carbon dioxide and can thus directly be tracked by observations of the marine $CO_2$ system. Despite the obvious advantages, this approach has only slowly and with hesitation been adopted by the Baltic Sea biogeochemical community.

Here we demonstrate how high-resolution $CO_2$ partial pressure measurements on a VOS (voluntary observation ship) can be used to characterize the net community production (NCP). Following a walk through the seasons, we show how the timing and intensity of the spring bloom varies in the different regions of the Baltic Sea proper. The high-resolution $CO_2$ data facilitate furthermore to resolve short term production fluctuations and to attribute these to the control by nutrient availability, radiation and wind-driven mixing. Clear evidence was found for a continuation of the NCP after the exhaustion of nitrate and has raised the question for the nitrogen source for the post-nitrate production. Latest by mid-May no further significant surface water $CO_2$ depletion occurs and indicates the start of a period with low NCP ("blue water" period). However, already by mid-June sudden $CO_2$ depletion events are observed and indicate the start of the second major production period that is based on the mid-summer $N_2$ fixation. It could be shown that the NCP fuelled by $N_2$ fixation occurs in the form of pulses which are triggered by intensified exposition of the upper surface layer to solar radiation during calm weather conditions. The key role of phosphorus availability for the nitrogen fixation activity could not be confirmed.

By this presentation we are aiming at shedding light from a different perspective on the Baltic Sea biogeochemistry and, in doing so, also to challenge traditional views and ideas. At the same time, we consider our contribution as a plea for implementing the marine $CO_2$ system into any studies related to production/mineralization processes and eutrophication.

CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## USING SCENARIO MODELLING TO UNDERSTAND LONG TERM CHANGES IN BALTIC SEA ECOSYSTEM DYNAMICS AND EUTROPHICATION

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From 1950 onwards, the Baltic Sea ecosystem suffered increasingly from eutrophication. Simultaneously the system is highly variable and has been shown to change substantially during the last decades. The most obvious reason for the eutrophication is the huge amount of nutrients (nitrogen and phosphorus) reaching the Baltic Sea from human activities. Additionally permanent stratification limits ventilation of the Baltic Sea deep water to occasional Major Baltic Inflows (MBIs) from the North Sea and thus promotes lasting hypoxic conditions. Hence, the processes involved in Baltic Sea water quality and ecosystem status are complex and include both biotic and abiotic factors. Although nutrient loads have been decreasing since 1980, the hypoxic areas have not decreased accordingly. Thus, geo-engineering projects were discussed and evaluated to artificially ventilate the Baltic Sea deep water and suppress nutrient release from the sediments.

Here, we aim at understanding Baltic Sea ecosystem dynamics and eutrophication as well as consequences of proposed geo-engineering projects using long-term scenario modelling. For that purpose, we utilize the 3D coupled ecosystem model ECOSMO E2E, which is a novel NPZD-Fish model approach that allows estimating lower trophic level dynamics, biogeochemical cycling and higher trophic level production potential and integrate the model over a 68 year long time period (1948-2015). Additionally, we will perform and analyse model scenarios that consider changes in nutrient load dynamics, changes in the atmospheric forcing (e.g. wind, short wave radiation) and proposed geo-engineering projects such as artificial ventilation of Baltic Sea deep waters and phosphorus binding in sediments with polyaluminium chlorides.

CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## EULERIAN OBSERVATION OF THE 2014/2015 MAJOR BALTIC INFLOW IN THE EASTERN GOTLAND BASIN

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The profiling mooring GODESS (Gotland Deep Environmental Sampling Station) is designed to autonomously collect profiles through the redoxcline between the oxygenated surface layers and the anoxic deep layer (i.e. between about 200 m and 40 m depth) in the central Eastern Gotland Basin. GODESS was deployed in the water and taking profiles for 352 of the 441 days between the 28. February 2015, when the first signs of the inflow water showed in the data and the 14. May 2016, when a further inflow event had brought new oxygen in the deep layers.

The result is a unique dataset of 624 profiles showing the temporal evolution of the redoxcline after arrival and dispersal of the inflow water. It shows short term temporal dynamics in a number of variables that cannot be resolved by sporadic CTD profiles from a few cruises over the course of a year.

Of special interest is the oxygenation of the previously anoxic deep layers and the return to hypoxic and anoxic conditions by the beginning of February 2016. Neither the increase of dissolved oxygen concentration in the beginning nor the decrease after the main inflow waters had entered the Gotland basin is showing a constant gradual change, both are characterised by series of short term fluctuations.

The presentation will show the differences between pre-inflow stagnant periods with occasional intrusions of low dissolved oxygen concentration waters in the anoxic waters and the dramatic changes that the Major Baltic Inflow brought about.

CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## THE 2014 MAJOR BALTIC INFLOW AFFECTED BENTHIC GREENHOUSE GAS EMISSIONS IN THE BALTIC PROPER: AN IN SITU STUDY

Bonaglia, S.[1], Hylén, A.[2], Kononets, M. Y.[2], Marzocchi, U.[3], Nilsson, M.[2], Almroth-Rosell, E.[2], and Hall, P. O. J.[2]

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The 2014 Major Baltic Inflow (MBI) was the largest inflow of marine water to the Baltic Sea since 1951 and the third largest since oceanographic measurements in the Baltic Sea began in 1880 and it brought 198 $km^3$ of oxygenated salty water into the Baltic proper starting in December 2014 (Mohrholz et al. 2015). A large portion of the previously anoxic Baltic proper sediments have thus been re-oxygenated after this last MBI. The geochemical conditions of the Baltic proper sediments were shown to be strongly affected by increasing oxygen ($O_2$) concentrations, as a clear effect of $O_2$ on sediment-water exchange rates of nutrients (Hall et al. 2017; Sommer et al. 2017), and on sedimentary nitrogen cycling processes (Hall et al. 2017; Hylén et al. poster presentation at BSSC2017) was reported. Here we studied the effects of this re-oxygenation event on fluxes of methane ($CH_4$) and nitrous oxide ($N_2O$) by means of in situ measurements using autonomous chamber landers, which were deployed at four stations along a depth transect in the Baltic proper's Eastern Gotland Basin in 2016.

Our results show that 12 out of the 15 incubated chambers resulted in significant $CH_4$ benthic effluxes, which ranged between 0.2 and 2.1 µmol $m^{-2}$ $h^{-1}$. A significant $N_2O$ efflux, which was associated to sedimentary denitrification activity, was detected in 11 out of 12 incubations, with the only non-significant flux being from the normoxic (345 µM $O_2$) station. At the hypoxic-anoxic stations (0–30 µM $O_2$) the $N_2O$ fluxes ranged between 1.2 and 2.5 µmol $m^{-2}$ $h^{-1}$. There was a statistically significant negative correlation between $O_2$ concentration and $CH_4$ fluxes, suggesting that the re-oxygenation event may stimulate $CH_4$ oxidation in the previously anoxic sediments. Surprisingly, the flux of $N_2O$ was of the same order of magnitude as the $CH_4$ flux and represented 38–97 % of the total denitrification rate, defined as the total production of $N_2O$ and dinitrogen ($N_2$). Hence, oxygen plays a fundamental role in controlling not only nutrient sediment-water exchange but also the exchange of greenhouse gases in previously anoxic brackish sediments.

CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## THERE AND BACK AGAIN: THE IMPACT OF THE 2014 MBI AND LATER RETURN TO ANOXIC CONDITIONS ON THE DYNAMICS OF METHANE AND NITROUS OXIDE

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Methane ($CH_4$) and Nitrous Oxide ($N_2O$) are amongst the most important greenhouse gases in the atmosphere, and their rising atmospheric concentrations over the last 1.5 centuries significantly contribute to anthropogenically induced climate change. Amongst their marine sources, coastal and estuarine regions play an important role, with water column inventories and areal fluxes to the atmosphere substantially above the oceanic average. The biogeochemistry of both gases is strongly governed by redox-sensitive processes and thus, marine environments with variable and varying redox conditions represent highly dynamic regions for methane and nitrous oxide cycling. Here, we focus on the dynamics of the distribution and the governing processes of both gases in the water column as a result of the 2014-2015 Major Baltic Inflow (MBI) and the later return to anoxic conditions in the bottom waters.

In the Central Gotland Sea, methane concentrations were strongly elevated below the redoxcline (the transition zone between oxygen depletion and the occurrence of $H_2S$) before the MBI. The arrival of oxygenated water with the inflow led to displacement and, more importantly, enhanced oxidation of the deep methane pool, as indicated by microbiological, isotopic, and mass balance observations. Upon return to anoxic conditions, the deep-water methane pool successively built up again.

Before the arrival of oxygen-rich inflow waters, nitrous oxide, which is used as an electron acceptor under anoxic conditions, was basically absent below the redoxcline. Concentrations increased during the inflow, likely due to nitrification of the anaerobic ammonium pool. Interestingly, upon return to anoxia, extremely high concentrations (up to 30x equilibrium with respect to atmospheric $N_2O$) were observed near the seafloor. These high concentrations, however, disappeared after some weeks and nitrous oxide became depleted again.

We discuss the observed dynamics of both trace gases in the framework of the physical drivers, generating and consuming processes and the role of the potential microbial key players.

CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## IMPACT OF THE MAJOR BALTIC INFLOW (2014) ON MANGANESE AND TRACE METAL CYCLING IN THE GOTLAND BASIN (BALTIC SEA)

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Redox-sensitive Mn occurs in nature in the three oxidation states 2+, 3+ and 4+. While solid Mn oxides ($MnO_x$) dominate under oxic conditions, dissolved $Mn^{2+}$ usually prevails in the bottom and pore waters of euxinic basins and fjords. In suboxic zones dissolved $Mn^{3+}$ also has to be considered as an important intermediate[1,2]. If reducing pore waters reach supersaturation, solid $Mn^{2+}$ carbonate phases may precipitate in the sediments of aquatic systems[3]. Albeit known from ancient manganiferous black shales, sediments of modern euxinic systems like the Black Sea are not enriched in Mn carbonate[3,4]. A unique exception represent the deep basins of the Baltic Sea, which are well known for massive Mn carbonate enrichments. Although the detailed mechanisms of Mn carbonate formation in the Baltic Sea are still under debate, a tight link to episodic Major Baltic Inflows (MBI) is generally assumed for the Gotland Basin[4]. Unfortunately, studies on Mn cycling during MBIs are extremely rare and suffer from limited temporal resolution[5]. Here, we discuss the Mn dynamics in the water column and sediments of the central Gotland Basin currently subjected to the MBI from 2014[6]. Because $MnO_x$ is known to adsorb trace metals via scavenging, redox proxies like Co, Mo, V, and W are also affected. Water column profiles of dissolved Mn taken at monthly to bi-monthly resolution between February 2015 and November 2016 reveal a first impact of the MBI on the bottom waters in March 2015. From then on, massive $MnO_x$ precipitation and coupled trace metal (e.g. Mo, W) sequestration from the water column is documented in sediment trap, suspended particulate matter, and surface sediment samples. Since September 2015, first signals of the re-establishment of reducing bottom waters appear, which are interrupted by a second inflow pulse around February 2016. However, dissolved Mn concentrations of up to 40 µM as well as partly extremely high trace metal levels (e.g. W) in the bottom waters in June 2016 indicate pronounced $MnO_x$ reduction and element release into the open water column. The absence of a substantial Mn carbonate abundance in the surface sediments suggests that the duration of bottom water oxygenation plays an important role for their formation.

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CROSSCUTTING SESSION: MAJOR BALTIC INFLOWS

## A MAJOR BALTIC INFLOW CREATES A TEMPORAL NICHE FOR CABLE BACTERIA IN EASTERN GOTLAND BASIN SEDIMENTS

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Cable bacteria are filamentous multi-cellular bacteria that generate and conduct electric currents in the seafloor by coupling cathodic $O_2$ or $NO_3^-$ reduction to anodic $H_2S$ oxidation over centimeter-scale distances. Their activity has been reported in sediments from a range of coastal and shelf locations, but their physiological limits in terms of electron acceptor availability as well as other environmental factors that regulate their growth in natural settings are not well constrained. In this study we tested if a natural bottom water oxygenation event, namely a Major Baltic Inflow (MBI), can stimulate the growth of cable bacteria in the long-term anoxic sediment of the Eastern Gotland Basin, Baltic Sea.

In April 2016 intact sediment cores were collected across a depth transect, including a permanently oxic site (60 m depth), a permanently anoxic site (130 m), and two sites that experienced a transient oxygenation (170 and 210 m). The activity of cable bacteria was investigated by geochemical and electrochemical approaches, and their abundance by Fluorescence In Situ Hybridization (FISH).

Cable bacteria were identified at the oxic and transiently oxic sites, but not at the anoxic site, suggesting that transient $O_2$ availability allowed cable bacteria growth. The highest filament density (1.3 m $cm^{-2}$) was found at the 170 m site, where a 2.5 mm zone depleted in both $O_2$ and free $H_2S$, in absence of bioturbation, indicated a substantial impact of cable bacteria metabolism on sediment biogeochemistry. At the 170 and 210 m stations, pronounced $Mn^{2+}$ peaks at the depth of 1.5-2 cm align with previous observations of enhanced Mn-mineral dissolution induced by acid production through anodic $H_2S$ oxidation. This suggests a higher cable bacteria activity in the recent past (months).

Our study shows that cable bacteria in sediments of the deep Eastern Gotland Basin can take advantage of the transient hypoxic conditions as induced by a MBI. The observed bottom water $O_2$ levels (‹15 µM) are the lowest so far reported for cable bacteria growth, and this expands our understanding on their potential environmental distribution. Their impact on the sediment geochemistry at the basin and regional level, as well as the population dynamics in response to the MBI, remains to be addressed.

SESSION 2

## ANALYSING LAGRANGIAN TIMESCALES IN THE GULF OF FINLAND

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Accurate prediction of surface currents is crucial for many applications, such as environmental monitoring, offshore commercial operations, military operations, marine renewable energy and shipping and safety at sea. Although numerical models can be used for such predictions, observational data of currents is still scarce for many sea areas.

The study of Lagrangian motion can be divided into the study of individual trajectories and the study of relative motion within a group, usually analysed by particle pairs. Single particle analysis provides information about mean transport properties and diffusivity. A key parameter for such study is the Lagrangian "integral time" $T_L$, which depends on the velocity autocorrelation for single trajectories, and provides a basic indicator of Lagrangian predictability.

In this study we use observational data from field experiments carried out in the Gulf of Finland, in the Baltic Sea in order to determine Lagrangian timescales for our study area. We carried out several field experiments during 2014, involving passive surface drifters. We used a total of 20 passive drifters with 5 different deployments in spring, summer and autumn months.

The idea is to look at the ratio between the acceleration and velocity time scales $y = T_a / T_v$ to separate Lagrangian trajectories in homogeneous classes in order to determine if motion can represented as a typical advection-diffusion problem (the classical approach) or if there is an evolution of the flow on intermediate scale that should be accounted for. It has been observed in the surface drifters data in the world's ocean basins, that that trajectories having different values of y are characterized by different shapes, correlation, and dispersal properties. If the trajectories have similar values of $T_a$ and $T_v$ , this is an indication of the influence of eddies.

The results demonstrate the complexity of surface current field in the Gulf of Finland and provide us necessary input to numerical models for parameterisation of eddy diffusivity in order to obtain reliable current predictions.

SESSION 2

## COMPRESSIBILITY OF SURFACE FLOWS UNDER THE COMBINED EFFECT OF CURRENTS AND WINDS

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Compressibility of surface flows is known to be the main driving force of the patchiness of floating litter on free surface of turbulent fluids [1][2]. In the case of Kolmogorov turbulence, the compressibility of the surface flow is ca 1/2 [3], which is the borderline between strong and weak clustering. However, in the case of quasi-two-dimensional flows (such as marine flows in many cases), the surface flow compressibility is strongly suppressed; then, the bathygraphy will play an important role giving rise to up- and downwelling regions [4]. However, there are other effects which may increase effective compressibility and thereby the clustering rate of floating litter. One of the possible effects is the flow induced by surface gravity waves; however, it has been shown that unless these waves are strongly nonlinear, their effect on surface flow compressibility is very small [5] [6], [7].

There is still one more important factor which may increase the effective compressibility and which, to our best knowledge, has not been discussed in literature: the effect of wind drift, and more specifically, the effect of the differences in the wind drift speed depending on the size of the floating objects. This mechanism is expected to be coupled with the turbulent mixing and the intrinsic compressibility of the flow field.

We present in this paper the result on surface clustering of accounting for such differences in drift speed within an Eulerian tracking model.

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Session 2

## Deep currents in the Bothnian Sea observed with Argo floats

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In this work we studied measurement series of Argo floats from years 2012-2016 to gain insight of water transport in the Bothnian Sea. This unique data set made it possible to study deep water currents in this area, where measurements are typically sparse in both time and space.

Previous studies have mainly focused on current velocities in the surface or near-surface layers. There have been two shorter measurement studies on current velocities on the sub-pycnoclinic layers. In this study we found that the magnitude of measurements from the floats are similar with earlier studies from stationary observations, in both mean velocities as well as maximum velocities. Even though the currents are overall much slower in the deeper levels, it appears that in favourable conditions faster jet currents can also be found in the deeps.

The deep water in the Gulf of Bothnia is mainly cooled winter water from the Gotland Sea, which has sunk over the southern Åland sill. During the summer, the deep water system resembles the deep water system in the Baltic Proper with strong thermocline and dicothermal layer. Direct wind mixing can only affect the layer above the thermocline. Deep mixing can only happen when the thermocline disappears during overturning. This has significant effect on for example the microbial ecosystem on the surface layer and oxygen conditions in the bottom layer.

Our results show that the transports in the sub-pycnoclinic water layers in the eastern side of the Bothnian Sea are moving rather along south-north axis following the isobaths of the basin instead of crossing them. In this study we also found evidence of fast currents in the deep areas, which can have top velocities up to 30 cm/s.

Session 2

## Hindcast statistics of surface Stokes drift in the Baltic Sea

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The Stokes drift affects the drift of substances and objects on the sea surface together with the mean wind shear currents and surface wind. The Stokes drift may have a high impact on drift trajectories of the surface following substances, such as oil. Furthermore, in areas where basin geometry causes the wave direction to differ significantly from wind direction and the direction of the surface current, accounting for the Stokes drift in the drift predictions might be even more important than in the other basins.

We used wave model WAM to evaluate the mean and maximum values of the surface Stokes drift in the Baltic Sea based on 10 years wave hindcast (2006-2015). As there is no direct way to verify the accuracy of the modelled Stokes drift we compared the modelled bulk parameters against buoy measurements to ensure the quality of the wave hindcast. The verification showed that the hindcast parameters had accuracy typical to the Baltic Sea wave models. The significant wave height was simulated with good accuracy. The peak period and peak wave direction had good quality in the open sea areas, but in the narrow gulfs, such as the Gulf of Finland, the model had some difficulties in representing the steering of the wave direction to full extent.

The importance of Stokes drift as a component of total surface drift was evaluated by calculating the hindcast mean values and percentiles of surface Stokes drift. The mean values were between 0.08 and 0.1 m/s in the open sea areas being of same order of magnitude as the mean wind shear currents. The highest values of the surface Stokes drift were slightly larger than 0.6 m/s. Furthermore, a comparison to drifter experiment showed that use of Stokes drift improves the estimate of both drift speed and direction in the Gulf of Finland.

We also evaluated the Stokes drift calculated from the modelled wave spectra to those calculated with parameterised methods, that are used e.g. in currently available Baltic Sea drift models. The parameterised methods overestimate the smaller values (under 0.3 m/s) and underestimate the larger values of the Stokes drift. The Stokes drift direction mostly followed the wind direction, even in the Gulf of Finland, where the wave direction can considerably differ from the wind direction. Due to this, the parameterised ways to evaluate the Stokes drift fairly well represented the direction, since they typically use the wind direction as an estimate for the Stokes drift direction.

SESSION 2

## EDDY CENSUS OF THE CENTRAL BALTIC SEA FOR THE PERIOD 2012-2014

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Eddies play an important role in transport and mixing processes in the ocean and in this way have a direct impact on biological processes. To gain more insight into their dynamics, we carried out an eddy census in the central Baltic Sea for the years 2012-2014. The underlying velocity fields are taken from eddy resolving numerical simulations of the central Baltic Sea with a spatial resolution of 600 m.

Two different approaches have been applied to detect and track eddies: On the one hand we utilized a flow geometry based eddy tracking approach. On the other hand, we developed an eddy tracking tool based on the idea of Lagrangian descriptors and vorticity, relying on the theory of dynamical systems. These two methods will give different insights into the dynamics of eddies. However, in combination the results offer a broad overview on types of eddies, their life cycle and their impact on mass transport.

To provide a proper quantification of the eddy field, we computed and compared eddy properties like lifetime, shape, track length, and diameter. Moreover, we computed measures to distinguish between geostrophic and ageostrophic contributions.

First results indicate that a typical eddy lifetime is 2-4 days. However, eddies with an age of 15-20 days are also observed. In general, the travel length of the eddies does not exceed 50 km, limiting the far-reached transport of mass and matter. Furthermore, we do see a significant amount of eddies which are highly nonlinear (defined by higher rotational than translation speed). On top of that, eddies with local Rossby numbers (vorticity normalized by Coriolis frequency) large than unity are common in the Baltic Sea, indicating large ageostrophic contributions. The generation mechanism of eddies are widespread: vortex shedding, baroclinic instabilities along upwelling fronts or mixed layer instabilities.

The gained knowledge of the statistical properties of the eddy field provides a first step towards a better understanding of eddy mediated mixing and transport processes of e.g. nutrients in the Baltic Sea.

SESSION 2

## LONG-TERM AND SEASONAL TRENDS IN COASTAL CARBONATE SYSTEMS

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Atmospheric $CO_2$ levels have risen almost 50% since the pre-industrial period, affecting marine carbonate chemistry. Whereas the oceanic response to increased $pCO_2$ is predictable, processes regulating coastal pH and alkalinity are far more complex leading to large temporal variations on diurnal, seasonal and decadal scales. Inputs of nutrients and organic material from land and atmosphere, variable exchanges with the open sea including import of hypoxic corrosive water, precipitation and evaporation, production and respiration, calcification and decalcification processes all contribute to varying levels of pH and alkalinity. We examined long-term (1972-2016) and seasonal trends in these variables for three Danish estuaries (Ringkøbing Fjord, Skive Fjord and Roskilde Fjord), including their freshwater input and outer boundaries. Alkalinity was mainly governed by conservative mixing although with significant seasonal variation remaining, whereas pH peaked at intermediate salinities with a pronounced seasonal pattern. Alkalinity in Ringkøbing Fjord shifted drastically between two regimes, with and without filter feeders, whereas changes in the two other estuaries were small. Conversely, pH decreased by 0.03-0.06 units per decade in Skive Fjord and Roskilde Fjord, whereas pH increased in Ringkøbing Fjord prior to the regime shift in 1995 followed by a decrease. The decreasing trends were generally associated with increasing levels of DIC and $pCO_2$. Aragonite and calcite were mostly oversaturated in Roskilde Fjord and Skive Fjord, whereas low saturation states in Ringkøbing Fjord potentially could pose a problem for calcifiers. All estuaries were sources of $CO_2$ in winter months, but changed to $CO_2$ sinks during summer months in Skive Fjord and Ringkøbing Fjord before the regime shift. Adjusting for mixing between concentrations in fresh water and the marine outer boundary as well as salinity- and temperature-dependent effects on dissociations and solubility constants, we found that pH trends were slightly smaller, although still decreasing about 0.03-0.06 units per decade in Skive Fjord and Roskilde Fjord. These declines are attributed to reductions in nutrient inputs and consequently less $CO_2$ uptake by phytoplankton. In Ringkøbing Fjord the adjusted pH increased prior to the regime shift but remained constant afterwards. Trends in coastal carbonate systems, adjusted for changes in salinity and temperature, provide information on the balance between production and respiration.

SESSION 2

## PHYTOPLANKTON VIABILITY AS A CROSSROADS IN ORGANIC CARBON FLOW

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The ratio of living cells to dead or dying cells in phytoplankton communities varies in marine environment. Characteristic of dying cells is reduced photosynthetic activity but also increased membrane permeability resulting in the release of cell metabolites. Different taxa express different mortality in similar growth conditions. Moreover, the composition of released dissolved organic matter (DOM) differs between phytoplankton taxa, and the availability of released organic matter to different heterotrophic microbes depends on its composition. The bioavailable dissolved organic carbon released by phytoplankton contributes rapidly to the pelagic heterotrophic microbial production. The viability (percentage of living cells) of the phytoplankton community therefore plays a role in determining the fate of organic carbon fixed by phytoplankton; is the newly fixed organic carbon quickly released from dying phytoplankton cells to be remineralised by pelagic heterotrophs, or does it remain in particulate form fixed in living phytoplankton cells that eventually sink out or are grazed by zooplankton. Dynamics of phytoplankton viability, and its effect on the carbon cycle, have mainly been studied in oceans, but the situation in the DOM rich coastal waters of the Baltic Sea is largely unknown. To address this, phytoplankton viability was monitored in 2015 from the start of the spring bloom to the end of the year in a shallow estuarine archipelago in northern Gulf of Finland, together with phytoplankton community composition, bacterial abundance and nutrient, dissolved and particulate organic matter and chlorophyll a concentrations. Compromised membrane integrity, identified by a membrane impermeable nucleic acid stain, was used as an indicator of dead or dying cells. Seasonal variation in phytoplankton viability was high ranging from 20% to 90%. Viability was relatively high also among sinking cells, indicating that also living cells contribute to the downward flux of organic carbon. Viability did not correlate with temperature, nutrient concentration or DOM concentration, but roughly followed changes in chlorophyll a concentration and phytoplankton biomass, being lowest shortly after spring and late summer blooms. These drops in viability also coincided with the peaks in bacterial abundance. These findings show the complexity in the seasonal dynamics of phytoplankton viability and will help to unravel its importance in the coastal carbon cycle in the northern Baltic Sea.

SESSION 2

## DISSOLVED ORGANIC PHOSPHORUS IN THE BALTIC SEA - CONCENTRATION, COMPOSITION AND UPTAKE

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Dissolved organic phosphorus (DOP) delivers phosphorus for phyto- and bacterioplankton growth and has to be regarded when phosphorus sources are discussed in marine systems, especially when phosphate is depleted. However, the mechanisms of P supply from DOP are mostly still unknown because DOP is a very heterogeneous pool consisting of low and high molecular compounds and includes compounds of a simple structure like sugar-phosphates up to molecules of a complicated structure like DNA. To improve the understanding of the functioning of the DOP pool, the DOP constituents of a high P content as dissolved adenosine triphosphate (dATP-P), dissolved phospholipids (dPL-P) and dissolved DNA (dDNA-P) were investigated in different regions of the Baltic Sea by measuring their concentrations in the upper 10 m surface layer in the summers of 2011 and 2012. At DOP concentrations of 0.18 µM to 0.32 µM, concentrations of the compounds were in the nanomolar range: 2.2 - 13.8 nM for dATP-P, 0.4-15.5 nM for dPL-P and 0.04 -0.2nM for dDNA-P with variations between the stations. The sum of all three compounds contributed only 4.2 % to the DOP pool und thus the largest portion of DOP remains unknown. In addition, turnover times and uptake rates of dATP-P and DNA-P in comparison to the uptake of phosphate was investigated at selected stations. The use of these compounds occurred in parallel with the phosphate uptake, but their contribution was lower. DOP compounds of a complex structure like dDNA have longer turnovers time compared to those which are s of a simpler in structure like dATP.

In laboratory experiments with *Nodularia spumigena*, P was acquired from the unknown DOP-portion whereas dATP, dPL-P and dDNA was released in parallel. Thus, we could show that the DOP constituents react independent from each other and in a different mode. They were used in parallel to phosphate. However, due to concentrations in the nanomolar range, their contribution to the total biological P supply is limited and changes are mostly not reflected in the DOP concentrations.

SESSION 2

## MUDDY VS. SANDY- A NEW VIEW ON SEDIMENTARY NUTRIENT FLUXES BY MEANS OF A CHAMBER LANDER

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The eutrophicated Vistula River constitutes the largest single nutrient source to the Baltic Sea, app. 70kt N reach the Bay of Gdansk every year. Dilution of the load versus biological reworking is studied in the BONUS-COCOA project. Due to the strong benthic-pelagic coupling in shallow coastal zones, we follow the hypothesis that the bioturbated sediments play a crucial role for reworking and turnover of the introduced nutrients from the river. Furthermore, the closely coupled processes within the sediments and the bottom water change nutrient ratios and impact the biochemistry of the open Baltic Sea. Our special interests are the benthic nutrient fluxes across the sediment- water interface with main focus on ammonium production and release. During three cruises to the Bay of Gdansk sediments and water were analysed from stations along the shore and offshore. Investigations of sediment characteristics show a small- scale mosaic of variables such as grain size, organic carbon content and $\delta^{15}N$-values. To quantify how much bioavailable nitrogen exits the sediment and potentially reaches following turnover processes in the bottom water, a benthic chamber lander was used for in situ- incubations. Thus, we were able to calculate total net nutrient fluxes and identified different coastal sediment types as a source for overall 6 kt $NH_4^+$-N $yr^{-1}$ to the bay. Loads have been calculated also for $NO_3^-$-N, $SiO_2$-Si and $PO_4^{3-}$. Compared to sediment basic data and porewater analysis we can thereby show that the muddy organic- and nutrient-rich sediments are not the main source for nutrient release. Rather the sandy coastal areas close to the river mouth, which lack high organic matter content and porewater nutrient concentrations, show high total nutrient fluxes. In this area large abundances of deep burrowing and effective filter feeding macrofauna were found, so we consider the bioturbating macrozoobenthos community as a key player for the filter function of the coastal zone. Furthermore, coastal sediments show higher $\delta^{15}N$- values than offshore sediments which seems to be an eutrophication signal caused by the Vistula and allows us to estimate the 50 m depth line as a transition zone between river impacted coastal regions and offshore areas.

Additionally, continuative experiments with natural coastal sediments quantified the change in bioavailability of nitrogen due to macrofauna in temporal scales.

SESSION 2

## MODEL BASED INVENTORY OF NUTRIENT RETENTION EFFICIENCY AND COASTAL FILTER FUNCTION ALONG THE SWEDISH COASTLINE

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The retention capacity of the coastal zones might be of large importance for the water quality in open waters since the coastal zone acts as a filter and not all of the nutrients supplied from land reach the open sea. We use a coupled physical and biogeochemical multi-basin model to calculate the average nutrient retention efficiency in all water bodies along the Swedish coast, stretching from the Norwegian border in Skagerrak to the Finnish border in the Northern Baltic Sea. The Swedish Coastal zone Model setup describes, with high vertical resolution, all the water bodies defined by the water framework directive and describe the transports across natural topographic constraints between sub-basins. We analyse the model results clustered into 7 major areas and several smaller coastal type areas (archipelagos, river dominated, open coast or embayment's, mainly fjords). We also discuss the possibility to estimate the nutrient retention corresponding to different rivers along the coast. The aim is to calculate and understand nutrient retention, the coastal filter, and retention efficiency along the Swedish coastline, and also relate the coastal filter and retention efficiency to different aspects of the coastal zone. The work has been financed by the Swedish Agency for Marine and Water Management and the BONUS COCOA (Nutrient COcktails in COAstal zones of the Baltic Sea) project.

SESSION 4: COASTAL SEAS AND SOCIETY

## THE ROLE OF ECOSYSTEM SERVICES AND PRESSURES IN PROTECTED AREAS: DIFFERENT VIEWS OF SCIENTISTS AND PA MANAGERS

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There is an increasing awareness on the role that marine coastal ecosystems, as also the Baltic, play in the provision of essential ecosystem services (ES) to human societies. In the last decades, however, intense anthropogenic pressure caused serious threats to ecosystems, leading to habitat degradation, worsening environmental quality, and thereby increasing the risk of loss of ES. The designation of Protected Areas (PA) may help to counterbalance the degradation and associated loss of services.

In the EcoPotential project the state-of-art view was surveyed among environmental scientists and among managers of PA regarding the importance of various ecological, environmental, and socio-economic indicators for ES, and drivers of change in their PA. The PAs considered in this study were the coastal areas of the Curonian lagoon together with other European coastal PAs as Wadden Sea and Camargue. Moreover, for further comparison, the views of researchers and managers in some mountainous areas (as e.g. Kalkalpen and Sierra Nevada) were surveyed.

Among scientists in coastal areas ES of abiotic origin (e.g. flood protection, water regulation) were indicated to be the most important. ES of biotic (e.g. fisheries) and socio-economic and cultural nature (e.g. recreation) were found to be less important. For the threats those of anthropogenic origin (e.g. overexploitation, eutrophication, disturbance) were by far the most important, and to a lesser extent biotic (e.g. invading species) and abiotic pressures (e.g. habitat loss).

The view of the scientists regarding ES was at odds with the view of managers who indicated that in their PA the ES of cultural and anthropogenic nature (e.g. recreation, education) were much more important. Managers hardly notified any abiotic pressures.

In mountainous PA the ES of biotic origin (e.g. forestry) were much more important than in coastal areas. In mountainous PA also the role of Climate Change as a threat is considered more important than in coastal PA.

Main conclusion is that, in joint cooperation between scientists and managers, social and economic factors need to be more emphasised and integrated with the abiotic and biotic factors. This study will help to achieve this integration and to assess factors, including ES and pressures, which can set or alter management strategies and policy options for current and novel Protected Areas.

SESSION 4: COASTAL SEAS AND SOCIETY

## MARINE ECOSYSTEM SERVICES ASSESSMENT: FROM SZCZECIN LAGOON TO POMERANIAN BAY

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The importance of coastal areas for human wellbeing is connected to the environment's ability to provide ecosystem goods and services. Unfortunately, with the increasing anthropogenic pressures and impacts on the environment, the provision of many services may be compromised. Therefore, the concept of ecosystem services is being introduced as a tool to support decision makers in the processes of management and spatial planning. The objective of this study is to support these processes by assessing the provision of ecosystem services of coastal waters. The area chosen was the Southeast part of the Baltic Sea in the border between Germany and Poland, where the Szczecin Lagoon and the Pomeranian Bay are located. Services provision were assessed using a newly developed methodology, Ecosystem Services Assessment Tool (ESAT), which aims to assess the ecosystem services for coastal waters and how it's provision changed over time, taking into consideration different ecological statuses of the studied ecosystem. In total 31 services and 54 indicators were assessed. The application of the tool resulted in the assessment of two periods of time: (representing different ecological statuses) the initial status (1960's) and the present status (2010's). The results show that for the Szczecin Lagoon there was overall decrease in the provision of Provisioning and Regulating & Maintenance following a decrease in the ecological status, and an accentuated increase in Cultural services following an increase in the tourism, from 1960 to today. Regarding the Pomeranian Bay the application resulted in the increase in the provision of Provisioning services, the category Regulating & Maintenance the provision did not change over time, and for Cultural services there was a notable increase of services provision. The results can support decision makers to understand how the provision of services changed over time, and in this way future management scenarios can be drawn considering potential changes in the provision of services.

SESSION 4: COASTAL SEAS AND SOCIETY

## ASSESSMENT OF HUMAN AND CLIMATE CHANGE IMPACTS ON THE COASTAL BALTIC SEA FLOOR

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Human pressures on the coastal seafloor are manifold, including offshore construction, ship traffic, sand extraction, dredging and dumping. When poorly planned, such activities can have detrimental effects on the seafloor environment and ecosystem services it provides. On the other hand, climate change is predicted to result in stronger and more unpredictable storms that have the potential to change the erosion and accretion of coasts and shallow sea areas, leading to adverse effects such as the loss of habitats and property. Storm influence on the shallow seafloor is particularly strong in areas such as the Baltic Sea, where the tidal energy is negligible, and the sea level is predominantly controlled by wind and atmospheric pressure.

Marine Strategy Framework Directive (MSFD) and Marine Spatial Planning Directive aim to promote sustainable use of the seas and conserve marine ecosystems, and to ensure that pressures from human activities are compatible with Good Environmental Status (GES). The Descriptor 6 (seafloor integrity) of GES within MSFD is targeted to assess the degree to which the seafloor is altered by natural and anthropogenic processes. As defined in MSFD, the seafloor is at the core of the benthic ecosystem, encompassing both its abiotic and biotic components. Indicators for determining the seafloor integrity and its change are being developed; however, these efforts are focused on the biological (e.g. macrofauna) and hydrochemical (e.g. $O_2$, $NO_3$) aspects of the seafloor ecosystem. As yet, there is no consensus on how to determine the geological stability (physical integrity) of a seafloor, or to quantify its change, although that is required by MSFD by 2018.

This study aims to develop easy to understand indicators for assessing the status and potential change of seafloor physical integrity (geological stability), discriminating anthropogenic effects from natural variability. The seafloor is investigated by multibeam surveys (hardness, roughness and morphology), sediment coring (grain-size distribution, organic content etc.) and the seafloor deployment of the Sensoriitta sensor platform (including Sequoia LISST-100X suspension grain size sensor). Useful indicators will be based on seabed parameters that can be routinely collected to promote the establishment of robust, cost effective monitoring programmes which will be required for future assessments of the Baltic Sea environmental status.

This work is part of SmartSea project funded by the Academy of Finland.

SESSION 4: COASTAL SEAS AND SOCIETY

## THE RESULTS OF THE GULF OF FINLAND YEAR 2014 THEMATIC ASSESSMENT

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This paper describes the results of a comprehensive assessment on the environmental state of the Gulf of Finland in 1996 – 2014. It was produced by together over 100 scientists from Estonia, Finland, and Russia in the context of the Gulf of Finland Year 2014. The thematic year aimed at – and succeeded in – giving additional value for the protection and restoration of the Gulf of Finland environment by enhancing political presence and interaction between the private sector, decision-makers, and citizens. This assessment paper concentrates on the past development and the current state of the Gulf of Finland environment and pressures affecting it. The themes include climate in the Gulf of Finland area, Gulf of Finland physics, geology and geodiversity, eutrophication, hazardous substances, biodiversity, fishes and fisheries, nonindigenous species, marine litter, underwater soundscape, maritime traffic and its safety, and environmental valuation. Each chapter also delivers expert opinions and recommendations for the future.

SESSION 4: COASTAL SEAS AND SOCIETY

## INTEGRATION IN MARITIME SPATIAL PLANNING AS AN ENABLER FOR SUSTAINABLE GOVERNANCE IN COASTAL AND MARINE WATERS

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As a means to govern the increasingly complex interactions between society, economy and coastal and marine ecosystems, Maritime Spatial Planning (MSP) has become prominent in the recent two decades. Since it attempts to integrate and balance a range of socio-economic, socio-cultural and environmental goals in decision-making, it can be seen as a framework for balancing the three pillars of sustainable development – economic, social and ecological. Moreover, MSP can be seen as a response to a lack of integration, which means in a broad sense coordinated, cohesive, coherent and multi-sectoral decision-making over activities at sea. Starting from this broad definition, the focus of attention can be narrowed down to the conceptualisation of four prominent integration challenges, which are frequently occurring in different MSP contexts. We draw attention to the implications of transboundary and cross-scale integration, stakeholder integration, knowledge integration as well as policy and sector integration in different MSP case study settings in the Baltic Sea region.

The presentation gives an overview on the concept and interim results of the BALTSPACE project, focussing on the MSP challenge of transboundary integration in a pan-Baltic setting. Whether MSP is conducted disjointed or coherently across borders affects the possibilities for a harmonised approach to socio-economic development and environmental protection and thus for effective sustainable development. In the Baltic Sea MSP community, which has been evolving through international projects and working group meetings, there is the goal to draw up and implement transnationally coherent Maritime Spatial Plans applying the ecosystem approach throughout the region by 2020. In the light of nationally different stages in the MSP cycle and a multitude of different spatial planning legislations and frameworks, this is a challenging endeavour from an integration perspective.

SESSION 4: COASTAL SEAS AND SOCIETY

## TOWARDS AN ECOSYSTEM APPROACH IN MARINE SPATIAL PLANNING

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European Directives (MSFD, MSP-FD) as well as regional seas' conventions (HELCOM, OSPAR) call the ecosystem approach an overarching principle on which to base the management of human activities and the use of resources of the seas. To implement the ecosystem approach in Marine Spatial Planning (MSP) comprehensive scientific data and knowledge transformation into planning options are needed.

In this study we identify and illustrate spatial claims of protected and representative species and biotopes. The focus is on marine mammals, avifauna, macrozoobenthos and benthic biotopes in the German part of the North Sea and the Baltic Sea. We analyse the distribution of species and biotopes, the type of ecological use they make of areas (e.g. feeding, nursery ground, passage) and their respective sensitivities to anthropogenic activities.

Besides designated marine protected areas, additional important spatial claims are identified. Avifauna in particular shows seasonal differences in sensitivities to human activities. Recommendations for human activities vary from general exclusion of activities to temporary restrictions. As a next step, building on our findings, planning options for human activities and use of space can be developed in compliance with nature conservation needs.

Comprehensive information on spatial claims for a variety of species and including benthic biotopes foster the integration of nature conservation into planning. Our results provide the scientific basis to apply the ecosystem approach in MSP and thus strengthen marine conservation in MSP processes.

SESSION 4: COASTAL SEAS AND SOCIETY

## AN INDICATOR SYSTEM TO SUPPORT COASTAL AND MARINE MANAGEMENT

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Integrated Coastal Zone Management (ICZM) aims for coordinated application of policy processes affecting the coastal zone, addressing land-sea interactions in a coordinated way with a view to ensuring their sustainable development. On 23 July 2014 the European Parliament and the European Council adopted the new European directive on Maritime Spatial Planning (MSP) – (Directive 2014/89/EU), establishing a framework for MSP and ICZM. Management and planning of coastal and marine areas are complex processes that are more and more required to effectively support a coordinated development of socio-economic activities while preserving the environment. Increasing problems in coastal zones and high-ranking political initiatives promoting ICZM/MSP have resulted in indicator-based efforts to measure the state of and the progress towards sustainability in coastal zones. Sustainability and process indicators can be used to evaluate the effects of specific management actions over time.

We present a set of indicators and how the appropriate use of indicators can be a powerful tool in addressing the sustainability of coastal and marine management. We compare the environmental, economic, social well-being impacts of different plan alternatives for achieving more sustainable solutions. We demonstrate application results and indicate what progress has made towards sustainability and to which extent targets have been met.

SESSION 4: COASTAL SEAS AND SOCIETY

## NUTRIENT RETENTION MEASURE IN GERMAN BALTIC SEA WATERS – POTENTIALS AND LIMITS OF SOME ECO -TECHNOLOGIES

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Most coastal waters of the Western Baltic Sea are (strongly) eutrophied, mainly induced by high nutrient loads from the river catchments over the last century. As a result, nutrient concentrations and phytoplankton biomass have increased, while secchi depth, macrophytes coverage and bottom oxygen have decreased. Although, several actions have been implemented to reduce nutrient loads, the water quality has improved not or only little, raising the question, if additional measures within the coastal water bodies are necessary to achieve the Good Ecological State as demanded by EU`s Water Framework Directive.

Two possible measures seem thereby promising: (i) stabilize the sediment and reduce the resuspension of nutrient-rich material from the bottom by re-establishing submerged macrophytes or the installation of groin systems; (ii) increase the stock of mussels by installing appropriate settling material. The filter feeders reduce phytoplankton biomass and thereby potentially increase secchi depth. Furthermore, by harvesting the mussels incorporated nutrients are actively removed from the water body.

Over the last decades commercial blue mussel farms (*Mytilus edulis*) have been established along the shorelines of Sweden, Denmark and Germany, while their use as a low-cost nutrient retention measure became recently more prominent. In the German Baltic Sea the potential of mussel mitigation cultures is limited, as the low salinity of most coastal waters causes reduced (Bay of Greifswald) or no (Oder Lagoon) growth of *M. edulis*. In some of these waters alternative mussel species, like *Dreissena polymorpha*, may be cultivated to mitigate excess nutrient loads.

Following the System Approach Framework, all relevant stakeholders could be involved in the process of finding potential measures from the beginning. Highlighting the benefits resulting from an improved water quality and transparency, the commercial value of a mussel farm and the potential conflicts with other usages of the lagoon was studied.

The talk will focus on (i) the adaptation of mussel farming techniques to develop a low-cost nutrient retention measure; (ii) the potentials and limits of retention measures in the western part of Oder Lagoon; (iii) the potential for farming *Mytilus edulis* in low saline waters, like Bay of Greifswald; (iv) how stakeholders and spatial planning can be included in the process of finding adequate locations for a mussel farm.

SESSION 4: COASTAL SEAS AND SOCIETY

## THINNER FEMALES - FEWER EGGS? TEMPORAL TRENDS IN EASTERN BALTIC COD FECUNDITY (2005-2016)

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Baltic cod (Gadus morhua) due to its high trophic level in the food web and economic value for humans, has been a very important species for scientific research in Baltic Sea. To improve stock assessment and recruitment estimates, it is important to have a detailed understanding of the species fecundity. This is particularly crucial for Eastern Baltic cod as condition indices have shown a major decline over time, however fecundity information about recent years remain uninvestigated.

We hypothesize that the strong decline in Eastern Baltic cod condition during the last decade led to lower fecundity. As part of GEOMAR's annual multidisciplinary cruises, fisheries data is available from 1987 until now to assess stock structure and egg production of cod alongside other species. To subsequently calculate annual fecundity, pre-spawning female stage 4 ovaries have been collected and stored in -20°C. These long-standing samples have great potential to assess the temporal development of fecundity.

The study includes the period with average condition decline from 2005 until 2014 as well as the increased abundances of small sized (<30 cm) cod from 2007 until the present. Females from a range of nutritional conditions and several size classes that exist among all the years will be included for analysis. Area of focus will primarily be the principle spawning ground, Bornholm Basin. The effect of environmental factors, such as surface water temperature or inflow events, on annual fecundity will be investigated for the stock of interest.

Fecundity data that will be obtained by this study will provide valuable long-term information for better management strategies of this important species.

SESSION 4: COASTAL SEAS AND SOCIETY

## TRANSPORT AND FATE OF TOXIC CONSTITUENTS OF DUMPED MUNITIONS IN THE WESTERN BALTIC SEA

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As much as 1.6 million tonnes of conventional munitions was dumped after World War II in German territorial waters of the North and Baltic Seas. Munitions resting on the seabed are not only a risk for maritime traffic and impede the construction of offshore installations, they are also an environmental hazard due to the release of toxic constituents (e.g., TNT, RDX, HMX). Here we report on results of the German project UDEMM (Environmental monitoring for the delaboration of munitions on the seabed). We investigated the dispersion pathways of toxic constituents released from dumped munitions in the western Baltic Sea. Based on available information on the quantities of explosives disposed in the study area (see: www.underwatermunitions.de), we assessed the transport and fate of these contaminants in dissolved and suspended particulate phases. We applied an eddy-resolving western Baltic Sea configuration of the hydrodynamic model GETM (General Estuarine Transport Model), coupled with an Eulerian sediment transport module within the Framework for Aquatic Biogeochemical Models (FABM). The model took into account dissolution and microbial degradation rates of the contaminants as well as sediment-water interaction. The parameterizations of these processes was based on laboratory experiments and analysis by high performance liquid chromatography-electrospray ionization mass spectrometry (HPLC-ESI-MS). Dissolution of solid explosive material from the study site indicated rates for TNT, RDX, and HMX of 235, 80 and 1.6 µg $cm^{-2}$ $d^{-1}$, respectively. Observed microbial degradation of TNT in Baltic Sea water had half-life times of 100 days, while degradation of RDX and HMX were negligible over the 30 day incubation period. Measured dissolution rates and limited degradation suggest that transport ranges of the dissolved contaminants can be high. Our results will support analysis of the potential risk associated with munitions disposal sites and the development of mitigation strategies.

SESSION 4: COASTAL SEAS AND SOCIETY

## RELEASE, TRANSPORT, AND FATE OF EXPLOSIVE COMPOUNDS (TNT, RDX, HMX) FROM DISCARDED MUNITIONS IN THE BALTIC SEA

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More than 100,000 tons of conventional munitions were residual or intentionally discarded at various sites throughout the Baltic Sea following WWII. The primary explosive compounds (EC) in these munitions include TNT, RDX, and HMX, which exhibit marked toxicity to biological receptors, in addition to the direct threat of spontaneous or provoked detonation. Within the framework of the Project "Environmental monitoring for the delaboration of munitions on the seabed (UDEMM)", the current work developed a method for ultrasensitive detection of dissolved EC in seawater using solid-phase extraction and HPLC-ESI-MS analysis. The distribution of dissolved and sedimentary EC were evaluated at a munitions dump test site in the Kieler Bucht. Pico- to nanomolar concentrations were detected at the site, suggesting limited transport of EC. This contrasts with controlled laboratory experiments showing relatively rapid dissolution of EC from munitions material and slow rates of microbial degradation. Further experiments provide evidence for the importance of abiotic degradation mechanisms including photochemical pathways and reactive oxygen species, as well as sorption to solids. The results of this ongoing study will be discussed in context of environmental conditions that affect EC release and transport in the Baltic Sea. Future efforts to remediate these munition dump sites will need to evaluate how potential EC release during remediation activities may affect the prior steady state balance with natural degradation processes.

SESSION 1: DYNAMICS OF GRADIENT SYSTEMS

## PHOSPONATES, AN ADDITIONAL PHOSPHORUS SOURCE FOR NODULARIA SPUMIGENA CYANOBACTERIA IN THE BALTIC SEA

Teikari, J. E.[1], Fewer, D. F.[1], Shrestha, R.[1], Hou, S.[2], Leikoski, N.[1], Mäkelä, M.[1], Simojoki, A.[1], Hess, W. R.[2] and Sivonen, K.[1]

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Absence of dissolved inorganic phosphorus ($P_i$) is the major growth limiting factor for every summer occurring toxic and diazotrophic cyanobacterial blooms in the Baltic Sea. However, availability of phosphonates, the organophosphorus compounds containing carbon-phosphorus bond, is ubiquitous in the water ecosystems and their occurrence have supposed to be up to 10 % of the total dissolved organic phosphorus reservoir. Bacteria are capable to utilize phosphonates when their genomes harbor phn gene cluster which is also found from the genomes of *Nodularia spumigena*. In this study, growth of *Nodularia spumigena* strains UHCC 0039 and UHCC 0060 were followed in the medium where $P_i$ was replaced by either methylphosphonate (MPhn), ethylphosphonate (EPhn), 2-aminoethylphosphonate (APhn) or glyphosate. We found that naturally produced MPhn enabled prompt growth of *Nodularia spumigena* and based on RNA sequencing results MPhn replacement caused only minor transcriptional reconstruction. With no surprise, expression of phn gene cluster was drastically increased in MPhn condition but further analysis showed that genes responsible for phosphonate transport (phnC-E) were upregulated in $P_i$ limited condition as well. Thus, in environmental monitoring perspective, genes responsible of C-P bond cleavage, such as phnJ, would be more suitable to indicate the phosphonate availability in the environment. In addition, we found that methane, carbon remnant from MPhn, were released to surrounding environment and cyanobacteria may thus participate in aerobic methane release. Here we showed that capability to utilize phosphonates can serve competitive advantageous for *Nodularia spumigena* under $P_i$ limited blooms of cyanobacteria in the Baltic Sea and this may also partially explain supersaturation of methane in the water column in this area.

SESSION 1: DYNAMICS OF GRADIENT SYSTEMS

## STRUCTURING OF BALTIC SEA BACTERIAL COMMUNITIES BY SALINITY AND SEASON

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Our ability to predict bacterial distributions and functions in ecosystems depends on understanding key processes that control bacterial community composition. Bacterial communities in the Baltic Sea are structured in accordance to the salinity gradient but exhibit also significant seasonal changes. We used the Baltic Sea as a model system to examine the importance of salinity and season as driving factors for bacterial community composition. Abundances of 16S rRNA gene amplicon sequencing reads were assessed from samples taken on similar geographic locations in summer (June/July) and winter (February/March) at brackish (salinity 3-9) and marine (salinity 10-32) conditions. Significant changes in species richness were only found between summer and winter conditions but not at different salinities. In contrast to species richness, we found major differences in the bacterial community composition at the different salinity regimes and seasons. Principle coordinate analysis revealed that salinity explains most of this variability, whereas seasonality was the second most important factor. Similarly, quantitative phylogenetic clustering implicated a phylogenetic signal for both salinity and seasonality. Our results suggest that global patterns of bacterial community composition with respect to salinity and season are the result of phylogenetically clustered ecological preferences with stronger imprints from salinity.

SESSION 1: DYNAMICS OF GRADIENT SYSTEMS

## ANALYSIS OF DIASPORE BANK OF BALTIC COASTAL WATERS

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Coastal waters are important transition zones, receiving and transforming terrestrial runoff of nutrients and pollutants before they enter the open Sea. During the last decades, especially anthropogenic eutrophication has negatively influenced macrophyte communities of coastal water bodies, raising restoration activities.

This study analysed the recent macrophyte vegetation, reproduction potential and sediment diaspore content of ten sampling sites along the German Baltic Sea coast.

Macrophyte community composition was mainly dependent from salinity with large perennial species (e.g. *Stuckenia pectinata*, *Myriophyllum spicatum*) being the most common species found. In contrast to this, oospores of small charophytespecies (e.g. *Tolypella nidifica*) clearly dominated the sediment diaspore bank. Germination rates differed from both, recent vegetation composition as well as diaspore bank composition with *Zannichellia palustris* as the dominating species.

However, a number of species not observed during vegetation mapping at the respective sites were represented in the diaspore bank (e.g. *Chara contraria* and *Lamprothamnium papulosum*) and did germinate at low rate. The germination success of diaspores was independent from sediment depth within the interval sampled, maximum number of germling corresponded with the sediment horizon in which diaspore density was highest (5-15 cm).

In conclusion, the diaspore bank of all sites tested has been proven as vital and, with respect to the differences between diaspore composition, recent vegetation and germination success, illustrate the potential of diaspore banks for regeneration of macrophyte composition after at least mid-term periods of disturbance.

SESSION 1: DYNAMICS OF GRADIENT SYSTEMS

## CLIMATE VARIABILITY OF HYDROGRAPHIC CONDITIONS OF THE BALTIC SEA AND THEIR IMPACT ON COD NURSERY AREAS

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The Baltic Sea deep waters suffer from extended areas of hypoxia and anoxia. Their intra- and inter-annual variability is mainly determined by saline inflows which transport oxygenated water to deeper layers. During the last decades, oxygen conditions in the Baltic Sea have generally worsened and thus, the extent of hypoxic as well as anoxic bottom water has increased considerably. Climate change may further increase hypoxia due to changes in the atmospheric forcing conditions resulting in less deep water renewal Baltic inflows, decreased oxygen solubility and increased respiration rates. Feedback from climate change can amplify effects from eutrophication. A decline in oxygen conditions has generally a negative impact on marine life in the Baltic Sea. Thus, a detailed description of the evolution of oxygenated, hypoxic and anoxic areas is particularly required when studying oxygen-related processes such as habitat utilization of spawning fish, survival rates of their eggs as well as settlement probability of juveniles. One of today's major challenges is still the modeling of deep water dissolved oxygen, especially for the Baltic Sea with its seasonal and quasi-permanent extended areas of oxygen deficiency. The detailed spatial and temporal evolution of the oxygen concentrations in the entire Baltic Sea have been simulated for the period 1979–2016 by utilizing a hydrodynamic Baltic Sea model coupled to a simple pelagic and benthic oxygen consumption model. Model results are in very good agreement with ICES sub-division data taken in different areas of the Baltic Sea. The model proved to be a useful tool to describe the detailed evolution including trends of oxygenated, hypoxic and anoxic areas in the entire Baltic Sea and the impact on cod nursery areas.

SESSION 1: DYNAMICS OF GRADIENT SYSTEMS

## HYBRIDIZATION BETWEEN BALTIC BLUE MUSSELS (MYTILUS EDULIS, M. TROSSULUS): DOES PERVASIVE GENE FLOW CAUSE ADAPTATION TO LOW SALINITY CONDITIONS?

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Genetic analyses revealed pervasive gene flow between blue mussels of the western Baltic (Skagerrak/Kattegat, considered as *M. edulis*) and the eastern Baltic Proper (considered as *M. trossulus*) resulting in a hybrid swarm. This is an exceptional situation because secondary contact between Mytilus species usually results in stable mosaic hybrid zones. However, genetic transition is not gradual and Baltic mussels maintain distinct phenotypic characteristics. This motivated us to analyse mechanisms underlying the maintenance of species integrity in Baltic mussels and to investigate factors that drive pervasive gene flow. We follow an integrative approach combining genetic investigations, phenotype analyses and hydrodynamic modelling to disentangle the relative importance of reproductive barriers, environmental adaptation and passive larval drift in shaping Baltic Mytilus population structure and species barriers. Our research supports the view that genetic transition of Baltic Mytilus species occurs along longitude 12°-13°E, i.e., a virtual line between Malmö (Sweden) and Stralsund (Germany). Although hydrodynamic modelling suggests short distance larval dispersal (10 - 30km), passive drift patterns do not sufficiently explain the position of the genetic transition zone. Instead, genetic transition correlates with an area of maximum salinity change (15 - 10 psu). We argue that weak reproductive barriers and adaptation to environmental conditions explain the maintenance of species identity in Baltic Mytilus. Ongoing research addresses the question whether introgressive hybridization is adaptive and, therefore, is one precondition for colonizing low salinity marine environments in these species.

SESSION 3: PAST AND FUTURE CHANGES

## PLANKTON PHENOLOGY AND PATHWAYS OF PRIMARY PRODUCTION IN THE WARMING NORTHERN BALTIC SEA

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Increasing water temperature and sea ice loss are apparent in the northern Baltic Sea, and surface temperature is projected to increase further by 2-3 degree over the coming decades. These changes can be anticipated to have long-term impacts on biogeochemical cycling through altered phenology, magnitude, and composition of primary production, and by affecting heterotrophic food web components and processes. Projected changes include an earlier initiation and longer duration of the spring bloom. Mild winters with higher temperature are also favourable for the development of zooplankton biomass in spring, conceivably leading to increased grazing impact on spring-term primary production. Because the match or mismatch between zooplankton and phytoplankton is a crucial factor determining the direction of primary production towards pelagic (through grazing) or benthic (through sinking of organic matter) food webs, a long-term increase in temperature potentially reduces organic matter input to the seafloor in the northern Baltic Sea. Historical observations of primary production, plankton phenology, and vertical export from a well-studied part of the western Gulf of Finland are synthesised to elucidate variations in organic matter pathways between years and to identify potential long-term trends. An earlier start of the spring bloom was observed in recent years, with maximum biomass of ca 20 mg Chl $m^{-3}$ occurring 28 days earlier in 2015 and 2016 compared to the 1980ies. While no consistent trend in the magnitude of spring-term primary production is discerned, there is a greater temporal overlap of phytoplankton and zooplankton biomass in warmer years, leading to smaller export of organic matter as measured by sediment traps. Data collected in 2016 will further shed light on the role of microzooplankton vs. mesozooplankton and the role of phytoplankton cell mortality for organic matter cycling in this dynamic environment.

SESSION 3: PAST AND FUTURE CHANGES

## CARBON STOCKS AND CARBON SEQUESTRATION IN COASTAL REED BEDS OF THE SOUTHERN BALTIC SEA

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Coastal reed beds in lagoon systems such as the Darss-Zingst Bodden Chain at the German Baltic coast are important for storing and sequestering carbon. However, quantitative data of carbon stocks and sequestration rates are rare.

Data about carbon storage in reed beds are necessary to assess the potential of carbon sequestration and mitigation of greenhouse gas emissions. Carbon stocks and sequestration rates were assessed at several sites in the Darss-Zingst Bodden Chain. Stocks were measured by means of spatially distributed sediment sampling up to 1 m depth in three different zones of the reed beds (terrestrial, transitional, littoral). Sequestration rates were estimated by measurements of Cs-137 and Pb-210 profiles in selected sediment cores.

The results revealed large stocks of organic carbon up to 60 kg C / m², and maximum storage in 40 – 60 cm soil depth. Estimated sedimentation rates range between 2 and 4 mm / year. This implies that reed belts at the Southern Baltic Sea can accommodate the recent sea level rise at some, but not all, locations and could possibly contribute substantially to carbon sequestration and greenhouse gas mitigation.

SESSION 3: PAST AND FUTURE CHANGES

## HIGHLY VISIBLE INDICATORS OF CHANGE: POPULATION TRENDS OF WATERBIRDS BREEDING AND WINTERING ALONG THE BALTIC SEA COAST

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The Baltic Sea coast hosts a large variety of breeding birds in summer and considerable numbers of resting waterbirds in winter. The multitude of species can be distinguished into differing groups representing distinct foraging guilds feeding on different prey and using different habitats. They thus represent viable indicators for ecosystem changes in the different marine habitats.

Long-term datasets of breeding numbers and coastal wintering birds offer the possibility to analyse trends for specific species and foraging guilds. We used data from coastal sites of the entire Baltic Sea to calculate population indices and abundance trends for the period 1991-2015 using TRIM software and GAM modelling framework. Though there may be locally diverging results, the aim was to calculate trends for the entire Baltic.

Major proportions of both breeding (50%) and wintering birds (59%) showed decreasing population trends. One third of all species studied exhibited significant increases in population numbers. Significant negative trends were above all recorded for benthic feeders both in breeding and wintering birds. Other foraging guilds showed varying results. According to differing population trends, herbivorous birds perform well during the breeding season but seem to face unfavourable conditions during winter. In breeding birds, it appears that pelagic fish feeders and herbivorous birds are doing much better than surface feeders, benthic feeders and wading feeders. The trends of wintering birds mostly reflect population changes in nearshore parts of the Baltic and do not correspond to the magnitude of population losses estimated from large-scale surveys in offshore parts of the Baltic. Namely the strong decreases of seaducks and divers reported for the entire Baltic could not be found in the coastal data.

While part of the observed trends may be related to conditions outside the Baltic Sea, other causes for increases and decreases in population sizes can be assigned to effects occurring in the Baltic Sea itself. Major threats for a number of waterbirds are hunting, drowning in gill nets, oiling, predation, and disturbance from recreation and shipping. Habitat is degraded in the breeding area due to overgrowth of suitable sites and in the wintering sites caused by wind-farming, aggregate extraction and bottom trawling. On the other hand, overfishing of large fish may promote waterbirds feeding on smaller fish.

SESSION 3: PAST AND FUTURE CHANGES

## GENETIC DIVERSITY OF EUROPEAN INVASIVE POPULATIONS OF RANGIA CUNEATA (BIVALVIA: MACTRIDAE)

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Currently the ballast water of ships is one of the main invasion vectors in case of aquatic introduced species. The transcontinental invasion of the Gulf Wedge Clam *Rangia cuneata* (G.B. Sowerby I, 1831) from the North American east coast to Europe, occurred recently. Twelve years ago, in 2005, the species was first observed in the harbour of Antwerpen (Verween et al. 2006). Shortly thereafter, in 2007, the species was reported from the Noordzeekanaal in the Netherlands (Gittenberger et al. 2014). In 2010 it appeared in the Baltic Sea (Ezhova, 2012; Rudinskaya, Gusev 2012) and finally, in 2009-2010, in the estuaries of Eastern England (Willing, 2015).We examined the genetic diversity of *R. cuneata* populations in Europe (invasive) and North America (both native and invasive) and we analysed its invasion history. Most of the invasive populations of *R. cuneata* were characterized by a high diversity of the mitochondrial cytochrome oxidase I (COI) gene fragment. We suggest that the invasion history of *R. cuneata* could be explained partially by the ‘‘invasive bridgehead effect’’ (Lombaert et al. 2010) whereby successful invasive populations serve as a source of colonists for new areas. In the case of *R. cuneata* we consider that the first European successful invasive populations from Belgium and the Netherlands served as base for secondary invasions. Our results support multiple introductions in Europe consisting of at least two different sources. One area of origin of wedge clams in Europe is localised in the Gulf of Mexico and the estuaries of the North American east coast are another possible source.

SESSION 3: PAST AND FUTURE CHANGES

## ASSESSING INVASION POTENTIAL OF THE NON-INDIGENOUS SPECIES BASED ON THEIR EXPANSION RATE

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Expansion rate (ER) is important characteristics of the non-indigenous species (NIS) invasion potential. Using the expansion rate estimation method (Sandvik et al., 2013) we assessed the invasion potential of NIS, which either newly arrived to the Baltic Sea or have changed their distribution within the region in recent decades. The georeferenced data was obtained from different sources, ranging from environmental reports and peer-reviewed papers to field research and monitoring data from ICES Data portals and other databases. The level of certainty of georeferenced data varies from "exact coordinates"(i.e. latitude/longitude data of a sampling point, where the species was found extracted directly from data providers) to "map digitalization", where coordinates were collected from the published maps or based on verbal description of a finding location in a literature source. All these data are stored in the information system on aquatic non-indigenous and cryptogenic species AquaNIS (http://aquanis.ku.lt). The study presents the result of ER estimations, which allow to classify species according to their invasion potential from ca. 10 to ca. 220 km/yr. The ER based invasion potential can be used for measuring effectiveness of prevention measures (e.g., ships' ballast water management) and predicting future spread of invasive species. The study was supported by the Taiwan–Latvia–Lithuania Cooperation Project BALMAN "Development of the ships' ballast water management system to reduce biological invasions" (TAP LLT-03/2015).

# Oral Presentations

June 15, 2017

KEYNOTE LECTURE

## HYPOXIA IN THE BALTIC SEA: PAST, PRESENT AND FUTURE

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Hypoxia in bottom waters (i.e. oxygen concentrations below 2 mg/l) is becoming increasingly common in coastal areas worldwide. The decrease in oxygen is at least partly related to increased anthropogenic inputs of nutrients from waste water and fertilizer that fuel algal blooms. When the algal blooms sink to the seafloor and decompose this can lead to an oxygen demand that outpaces oxygen supply. Global warming may further amplify the expansion of hypoxia because of the lower solubility of oxygen in warmer waters and a decreased ventilation of the bottom water through vertical mixing. The expansion of coastal "dead zones" poses a major threat to marine life. The Baltic Sea is currently the largest coastal dead zone caused by human activity.

This talk will discuss what is known about the expansion of low oxygen conditions in the Baltic Sea over the past century. The results will be placed in a historical context using sediment records showing two previous intervals of hypoxia in the Baltic Sea during the past 8000 years. I will show, for example, that the onset of the modern interval of hypoxia was much faster than that of previous hypoxic intervals. In addition, I will present geochemical evidence for more intense and more widespread hypoxia in the modern Baltic Sea than in the past. This highlights the role of anthropogenic nutrients during the modern event. I will also discuss recent insights in differences between the development of hypoxia in coastal and open sea areas and possible future scenarios for changes in hypoxia in the Baltic Sea.

PLENARY LECTURE

## HYPOXIC TO EUXINIC CONDITIONS IN THE BALTIC SEA 1969-2016 – A SEASONAL TO DECADAL SPATIAL ANALYSIS.

Naumann, M.[1], Feistel, S.[1], Nausch, G.[1], Ruth, T.[2], Zabel, J.[2], Plangg, M.[2], Hannsson, M.[3], Andersson, L.[3], Lysiak-Pastuszak, E.[4], Feistel, R.[1], Nehring, D.[1], Matthäus, W.[1], and Meier, H.E.M.[1]

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The Baltic Sea is a complex ecosystem characterized by a strongly fluctuating, fragile balance between high freshwater runoff and saline water inflows, a stable stratification and a topography composed of interconnected sub-basins. The sensitivity of the system "Baltic Sea" amplifies climatological fluctuations on the decadal scale. Such changes may be irrelevant in the open ocean but constitute significant indicators in the Baltic Sea. Salt and nutrients in the Baltic Sea remain present there for about 30 years before being flushed to the Atlantic along with the freshwater export. This long residence time attenuates short-time fluctuations in environmental conditions, but highlights systematic, even small long-term anomalies. Thus a main scientific focus is on the evaluation of inflow events, on the progress of oxygen-consuming processes and on the development of hydrogen sulphide distribution over longer periods of time.

Mapping of hypoxic to euxinic layers in the deep-water from the western to central Baltic Sea visualizes these effects of inflow processes adequately. Based on regular seasonal sampling done by intensive environmental monitoring and long-term data programmes of neighbouring countries since 1969, a most complete dataset was compiled for this study. It shows a spatial analysis of the distribution of oxygen deficiency for the last five decades, which includes more or less the time span of two cycles of water exchange in the Baltic basin. Seasonal to decadal changes are shown for the entire area and separate sub-basins. This provides a closer look into deep-water oxygen dynamics, their regional differences and changes during the past 47 years. These results can support multiple interdisciplinary studies, such as studies on ecosystem modelling, analysis of reproduction rates of vulnerable fish stocks in the highly dynamic western and southern parts or studies concerning trends in regional climate change, as well as studies on human footprints in the sensitive Baltic Sea ecosystem.

PLENARY LECTURE

## IMPACT OF THE RECENT MAJOR INFLOW ON THE WATER COLUMN STRUCTURE IN THE NE BALTIC

Liblik, T.[1], Naumann, M.[2], Hansson, M.[3], Alenius, P.[4], Lips, U.[1], Nausch, G.[2], Wesslander, K.[3], Lips, I.[1], and Viktorsson, L.[3]

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After decade of absence of Major Inflows several deep water ventilation events have been occurred and their impact detected in the Eastern Gotland Basin in 2014-2016. The effects of barotropic inflows, including the consequences of the recent inflows, have been rigorously studied from the Danish Straits to the Gotland Deep. In the Northern Baltic Proper and Gulf of Finland, the impact and its spatial and temporal scales are not clear. Bottom water properties in this area are very variable (e.g. in comparison to the central Baltic Proper) due to the sensitivity of deep layer circulation to the wind forcing. The hypoxic salt wedge becomes thicker if easterly winds dominate, but it could be vanished in the case of westerly winds prevalence. Thus, considerable in-situ measurement efforts are needed to capture the effects of the recent inflows in this variable area. Several general tendencies have been detected after the previous major inflows in 1993 and 2003. The Gulf of Finland has had stronger pycnocline (quasi-permanent halocline) between the cold intermediate layer and deep layer after the inflows. Secondly, the oxygen conditions in the deep layers of the gulf have degraded.

In the present study we aim to capture the signs of the impact along the pathway from Eastern Gotland Basin to the Central Gulf of Finland. Data collected in Estonia, Germany, Finland and Sweden during the research vessel cruises and by autonomous devices (profiling moorings) from 2014 to 2016 are compiled.

Preliminary results show that similarly to the previous inflows, no positive impact on the deep layer oxygen conditions is detected in the Northern Baltic Proper and in the Gulf of Finland. Rather very thick hypoxic layer was observed in the Gulf of Finland in 2016. The temperature-salinity diagrams show that saltier and warmer water appeared in the deep layer in winter 2015/2016. This change can be detected all the way from the area between Hiiumaa Island and Hanko peninsula to the central Gulf of Finland. The causes of this change will be discussed. Collected oxygen and nutrient data will be utilized in order to estimate the effect of the inflow on the biochemical fields in the gulf.

PLENARY LECTURE

## CLIMATE CHANGE DRIVES THE FORMATION OF HARMFUL CYANOBACTERIAL BLOOMS IN THE BALTIC SEA

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The modern Baltic Sea suffers from massive blooms of $N_2$-fixing heterocystous cyanobacteria. Such blooms pose a severe threat for the aquatic ecosystem health as their increased frequency has led to a significant spread of bottom water hypoxia, turning the Baltic Sea into one of the world's largest dead zones. The anthropogenic loading of nutrients is considered a main driver for the formation of cyanobacterial blooms but the impact of other environmental parameters is less well constrained. Here, we report a high-resolution study of paleoenvironmental change and cyanobacterial activity in the Baltic Sea since the last deglaciation using sediment records collected upon IODP Expedition 347: "Baltic Sea Paleoenvironment". Sediments from the Little Belt, Bornholm Basin and Landsort Deep deposited under post-glacial conditions consist of organic-lean varved to homogeneous clays that evidence a low primary productivity and only minor cyanobacterial activity in the early Baltic Sea. At the transition to the Littorina Sea, however, total organic carbon contents increase significantly with maxima of up to 9 wt% observed during the Holocene Thermal Maximum (HTM), Medieval Climate Anomaly (MCA) and Modern Hypoxic Period (MHP). Sediments deposited during these time intervals are well laminated and characterized by high total sulfur values (›2%) indicating the development of anoxic to euxinic conditions and likely persistent water column stratification. A coeval occurrence of negative $\delta^{15}N$ excursions and exceptionally high abundances of biological markers specific for heterocystous cyanobacteria (e.g. heterocyst glycolipids and branched alkanes) at all three sites provide evidence for a simultaneous, basin-wide spread and intensification of cyanobacterial blooms. Importantly, periods of increased cyanobacterial activity coincide with high $TEX^{L}_{86}$-reconstructed sea surface temperatures, indicating that not only nutrient overenrichment but also water temperatures exceeding a threshold of about 16 °C are a key for fostering the formation of extensive cyanobacterial blooms. Moreover, our data indicate that cyanobacterial bloom formation was more intense and frequent during the HTM and MCA as compared to the MHP. In turn, this suggests that future climate warming will significantly intensify cyanobacterial activity and that the impact of cyanobacterial blooms on the health of the Baltic Sea ecosystem and the spread of bottom water hypoxia will be more severe than previously anticipated.

PLENARY LECTURE

## A NORTH SEA-BALTIC SEA REGIONAL COUPLED MODELS: ATMOSPHERE, WIND WAVES AND OCEAN

Schrum, C.[1], Ho-Hagemann, H.[1], Staneva, J[1], and Rockel. B.[1]
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The coupling of models is a commonly used approach when addressing the complex interactions between different components of earth system. In climate and forecasting research and activities, advanced models are needed and there is an urge towards the use of coupled modelling. This study presents the development of a new, high-resolution, coupled atmosphere, ocean and wave model system for the North Sea and the Baltic Sea, which is part of the Geesthacht COAstal model SysTem GCOAST. We focus on the nonlinear feedback between strong tidal currents and wind-waves, which can no longer be ignored, in particular in the coastal zone where its role seems to be dominant. The proposed coupling parameterizations account for the feedback between of the upper ocean on the atmospheric circulation by accounting for the effects of sea surface temperature and the sea surface roughness. Several sensitivity experiments are performed to estimate the individual and collective effects of different coupling components. The performance of the coupled modelling system is illustrated for the cases of several extreme events. For example, the inclusion of wave coupling leads to decreases strong winds through wave dependent surface roughness or changes sea surface temperature, the mixing and ocean circulation; leading to better agreement with in-situ and satellite measurements. Comparisons with available atmospheric and oceanic observations showed that the use of the fully coupled system reduces the errors, especially under severe storm conditions. This justifies the further developments and implementation of the coupled model systems, (i.e. including the land, biogeochemical, fishery, etc components) for both, operational and climate, research and development activities.

CROSSCUTTING SESSION: MONITORING / OBSERVATION /ASSESSMENT SYSTEMS

## ASSESSING SPATIAL DISTRIBUTION AND STATE OF MARINE BENTHIC HABITATS IN THE SW BALTIC – OPERATIONAL SEAFLOOR MAPPING IN CONTEXT OF THE EU DIRECTIVES

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Verifying the conditions of the marine environment is a big issue worldwide since the society recognized that a sustainable use of natural resources is essential to maintain diversity, healthiness and value-adding processes of ecosystems. A set of EU Directives (e.g. HD, WFD, MSFD) were launched to provide legislative tools aiming to support marine conservation and ecosystem based management. Within this framework, the State Agency for Agriculture, Environment and Rural Areas – Schleswig-Holstein (LLUR) together with its partners spend a lot of effort to investigate, map and monitor the seafloor in order to examine its conditions. This task is crucial, as the distribution and state of the substrate is a major compartment for habitat assessment. Since off-shore investigations are logistically complex, time consuming and data processing is still not straight forward, the road from the single data point to the assessment that is demanded in context of the marine directives is still bumpy. In this context, the development of regional adapted and well-suited monitoring strategies is crucial. A set of scientific studies on benthic habitats in the coastal and territorial waters of Schleswig-Holstein, SW Baltic Sea, are presented. The methods used to investigate the seabed cover a variety of hydroacoustic techniques, namely side scan sonar (SSS), multi-beam echo sounder (MBES), acoustic ground discrimination systems (AGDS) and sub-bottom profilers (SBP). The acoustic data are verified and supported via analysis from sediment samples, video observations and scientific diving operations. Based on the collection of case studies, the seabed complexity and dynamics in the coastal waters of Schleswig-Holstein (SW Baltic Sea) at various spatial and temporal scales is demonstrated. It is shown, how the variety of information is transported, harmonized and abstracted for the production of broad scale maps or EU-reports. The discussion focuses on the relevant scales, anthropogenic vs. natural habitat alterations and the assessment of measured seabed parameters in strict categories, like “good”, “moderate” and “bad”. The illustrated considerations may help to develop long-term monitoring concepts that are required to establish well suited and cost-efficient environmental surveillance in the SW Baltic Sea.

CROSSCUTTING SESSION: MONITORING / OBSERVATION /ASSESSMENT SYSTEMS

## HIGH RESOLUTION TSM MAPPING OF DREDGING OPERATIONS USING AUTOMATED UAV ACTIVATED BY ONLINE IN SITU MEASUREMENTS: PROOF ON CONCEPT

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In recent years, UAV industry has developed significantly, both for industrial and recreational purposes. In this study, possible application of Unmanned Aerial Vehicles (UAV) for high resolution Total Suspended Matter (TSM) mappings using automated UAV that is activated by online *in situ* buoy station is explored.

DJI's Inspire 1 aircraft was used to carry out monitoring flights. The aircraft is equipped with a standard 4K video camera with 3-axes gimbal stabilisation system and is capable to fly up to 25 minutes in favourable conditions. During dredging period, three monitoring flights were done on 17 September, 6 October and 28 October 2015. Monitoring program of dredging operations in the Pärnu harbour also included an independent *in situ* water turbidity measurements, both continuous and as lab analysis of water samples.

*In situ* buoy measurements were done using autonomous buoy equipped with Seapoint turbidity meter detecting scattered infrared light from particles in water. The buoy was equipped with GPS receiver for position and GMS antenna which allowed to transfer measurements to online service. Turbidity measurements of the buoy were calibrated by laboratory analysis of TSM in water samples collected near the buoy location. Environmental agency limits the maximum allowed TSM concentration for the area when dredging intensity should be decreased. If TSM exceeds the value, the map of suspended matter cloud is needed to evaluate the environmental impacts.

Before the dredging TSM concentrations varied between 5-35 mg/l. During dredging the concentration in the sediment cloud were usually 30-40 mg/l, reaching up to 75-90 mg/l for a short time when the dredge worked near to the buoy. The dredging company was notified when the maximum allowed TSM concentration (33mg/l) was exceeded.

The developed system is a procedure of TSM mapping, where *in situ* sensor triggers necessity to obtain spatial variability map of the suspended matter, and where the dredging company and environmental authority are notified in real time.

DJI's Inspire 1 aircraft has proven the usability of monitoring of dredging operations. It was found that these tools are best for giving good regional overview of situation in high resolution, especially areas where access with research vessels is too expensive or impossible. Moreover, aerial image data can be extended for various other applications, for example monitoring shipwrecks, oil spill detection, sea ice monitoring, characterisation of wind waves, etc.

CROSSCUTTING SESSION: MONITORING / OBSERVATION /ASSESSMENT SYSTEMS

## RAPID ASSESSMENT SURVEYS: A PRACTICAL WAY TO ASSESS THE ABUNDANCE AND DISTRIBUTION RANGE OF NON-INDIGENOUS SPECIES

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The International Convention for the Control and Management of Ship's Ballast Water and Sediments (BWMC) will entry into force in September 2017. This Convention is aimed to prevent introduction of non-indigenous species (NIS), i.e. potentially harmful aquatic organisms and pathogens. In order to measure the effectiveness of the BWMC a NIS monitoring programme should be established in the Baltic Sea and one of the promising methods for such programme is a Rapid Assessment Survey (RAS). RAS is aimed to detect species that can be recognized in the wild from conspicuous morphological characteristics and whose abundance and distribution can be determined for a particular area. The approach requires a preliminary familiarisation of target species that are already present and those that are expected to arrive, based on recent assessments from horizon scanning workshops. One approach to select NIS for a RAS is to follow IMO (2007) definition of target species: "…Species identified by a Party that meet specific criteria indicating that they may impair or damage the environment, human health, property or resources and are defined for a specific port, State or biogeographic region…". It is obvious that RAS cannot be conducted equally in the countries with an extensive coastal marine environment, therefore, careful selection of the representative sampling sites and adequate research methods should be performed prior to the start of any large scale field campaign. The selection of the sampling sites should be based on the analysis of most likely "entry" points/hubs where introductions are likely to arrive and "hot spots" containing elevated numbers of NIS, such as ballast water discharge areas, docks, marinas and aquaculture sites with stock movements by undertaking rapid surveys for targeted species. Also, areas of special interest or concern, such as nature conservation sites, may be included The paper presents the results of practical application of the RAS method in the Baltic Sea area, Celtic Sea and other marine regions of the world. The value of RAS for providing information for BWMC, the EU Marine Strategy Framework Directive and other legislative instruments as well as for the research community is discussed. This work was supported by the Taiwan–Latvia–Lithuania Cooperation Project BALMAN "Development of the ships' ballast water management system to reduce biological invasions" (TAP LLT-03/2015).

CROSSCUTTING SESSION: MONITORING / OBSERVATION /ASSESSMENT SYSTEMS

## AUTOMATIC CLASSIFICATION OF CTD PROFILES IN THE BALTIC SEA

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Today there are two very different kinds of problems with the amount of data from the sea. In regular monitoring, the amount of data is limited and temporally sparse in relation to annual thermal cycle of the Baltic Sea. The challenge is to interpret the data correctly when estimating long-term trends from it. The new observations techniques, especially gliders, on the other hand, produce huge amounts of data. There the quality control of thousands of profiles of different parameters is a challenge. In both cases automatic classification of profiles could help in quality control and in interpretation of the data.

We tested clustering and machine learning algorithms in classifying vertical profiles of temperature and salinity in the Baltic Sea. Our aim was to find a classification that describes the thermal seasons of the sea where annual cycle of temperature is very strong. The idea is to put each profile in its place in context of the course and length of the thermal seasons that vary from year to year. This helps in estimating e.g. true trends from the data from calendar based monitoring programmes. In glider data the method would help in finding outliers and in quality assurance of the profiles.

In this work we analysed CTD casts from R/V Aranda monitoring data, data from FMI's glider missions in 2016 and profiles from FMI's Argo floats in the Gotland Deep and in the Bothnian Sea. For every profile we defined several describing parameters and used them as a basis for clustering. We used methods that are commonly used in time series clustering. For each cluster we defined thermocline and halocline depths too.

Our results show that time series classification algorithm can cluster vertical profiles of CTD temperature and salinity and classify them according to sea area and season. The algorithm found outliers both, in relation to specific marine processes and in relation to quality problems in instruments. This enables development of automatic tools for quality assurance and also tools for real time piloting of gliders.

CROSSCUTTING SESSION: MONITORING / OBSERVATION /ASSESSMENT SYSTEMS

## ON THE POTENTIAL IMPACT OF SO2 DEPOSITION FROM VESSEL ENGINE WASH WATER ON NORTH SEA PH

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The input of acid substances (like $SO_2$) into the sea has been recognized as an environmental issue that needs to be considered in terms of ocean acidification, acid inputs and techniques to deal with them have implications for member states' obligations under the Water Framework Directive and Marine Strategy Framework Directive. This study provides an initial assessment on the potential impact of on-board desulphurisation equipment (open loop scrubbers) on the seawater quality with focus on SOx Emission Control Areas (SECAs). The study focuses on the potential impact of ship-borne $SO_2$ on acidification (pH) of seawater in comparison to the impact from climate change employing a dedicated modelling exercise covering the North Sea region.

A coupled hydrodynamic-chemistry model (GETM-FABM-ERSEM) was implemented to assess the impact of adding $SO_2$ and $CO_2$ on the complex carbonate system in sea water.

The impact on the pH decrease in the open North Sea region from discharging the acid wash water into the seawater was found to be small but not insignificant and regionally varying. The calculated annual mean decrease of pH due to $SO_2$ injection for the North Sea total water column is 0.00011, when considering only the change in the surface layer (0-20m), the annual decrease is 0.00024. The total annual impact from increasing atmospheric $CO_2$ concentrations on the acidification of the North Sea surface area is about 8 times stronger (0.001) than the impact from wash water injection. However, because of the pronounced spatial variations the mean impact does not reflect the overall situation well. Consequently, we find critical regions with high ship traffic intensity, for example along the shipping lanes and in the larger Rotterdam port area. Here, the contribution from $SO_2$ injection can be double the impact from increasing $CO_2$ concentrations and 20 times larger than the North Sea mean value.

These critical regions indicate potential problems related to the surface water quality in ports, estuaries and coastal waters that are subject to regulation under the Water Framework Directive (WFD). In addition, the problem of decreasing pH caused by $SO_2$ input from ship exhaust gases in regional seas (North Sea) is relevant to the obligation of the Member States to assess the environmental state of their marine areas and to establish a Good Environmental Status (GES) under the Marine Strategy Framework Directive (MFSD), as pH value is one of the GES criteria.

SESSION 3: PAST AND FUTURE CHANGES

## COASTAL MORPHOGENESIS OF THE SOUTHERN BALTIC SEA -MODELLING APPROACHES AND PARAMETERIZATION

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Morphogenetic coastal processes of the southern Baltic Sea are determined by a complex interplay of the geological setting, eustatic sea-level change, glacio-isostatic adjustment, wave driven sediment dynamics, storm surges and aeolian processes. For a management of the coastal zone including protection and its economic use, models describing not only the geological past, but also generating scenarios of future projection are irreplaceable tools. Relative sea-level change can be effectively treated by the application of sea-level equations mirroring the response of the visco-elastic Earth's crust to the climatically driven changing load of ice and water on the continents and marine basins. The parameterization for reconstruction on the geological time scale is provided by decoding of proxy-data of the sedimentary record. On the decadal scale, tide gauge data are available. Climatically effects as sea-level pressure, wind field, and temperature can be deduced from coupled atmospheric-oceanographic models. To understand the postglacial sediment dynamics in the coastal zone of the southern Baltic Sea consisting mainly of glacial sediments erosion, transport, and accumulation together with aeolian processes have to be described as an effect of meteorological forcing of the mainly west-east directed air-flow from the northern Atlantic Ocean to Eurasia. The model has to couple process-based modules for subaquatic sediment transport with modules for subaerial aeolian sand transport and vegetation growth. Regional coastal morphogenesis can generally be described by alongshore sediment transport pattern derived from the integration of sub-regional to local models of transport capacities. Related approaches have been applied for selected key areas of sandy spits, open cliffs, and dune coasts displaying exemplarily core processes of the southern Baltic Sea coast. As coastal erosion under the pressure of climate change is one of the current foci of coastal human communities the effect of coastal hydro-engineering constructions is investigated as case studies in comparison to the result of modelling of morphodynamics and empirical meteorological and oceanographic data. These empirical studies complete modelling approaches as they estimate accurate sediment balances resulting from the application of state-of-the-art techniques (such as ALS) and qualify the value of model results as additional data categories to be used for decision making in coastal zone management.

SESSION 3: PAST AND FUTURE CHANGES

## FENNOSCANDIAN ICE SHEET DEGLACIAL DYNAMICS IN THE BALTIC SEA – NORTH ATLANTIC TRANSITION AREA

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Anholt Loch sedimentary basin is located in the Kattegat, a gateway between the Baltic Sea Bain and North Atlantic. During the Integrated Ocean Drilling Program Expedition 347: "Baltic Sea Palaeoenvironment" in 2013, Anholt Loch (Site M0060) was drilled. Ca. 200m thick sediment package consisting of seven different lithostratigraphic units was recovered. Here is presented an age-depth model for the topmost ca. 80 meters consisting of three main units. On top is a sandy near-shore shallow marine unit (0-6 mbsf), in the middle a sandy and silty pro-grading marine delta unit (6-24 mbsf) and on the bottom a fine-grained marine unit with glacier melt-water influence (24-80 mbsf). In total 30 samples were radiocarbon (14C) dated at laboratories in Lund, Poznan and Zurich. Age determinations from the upper and middle unit samples were made from shell samples and from the bottom unit shell and foraminifera samples. 17 out of 30 ages were selected into the final age model.

The topmost 80 meters of the Anholt Loch sediments form a Late Glacial-Holocene sequence, starting from ca. 17.9 thousands years before present (kyr BP) ago. Results indicate that the study area was affected by the Fennoscandian Ice Sheet (FIS) at least until ca. 14 kyr BP. The topmost sand unit bears signs of wave erosion, redeposition and/or sediment slumping, suggesting a possible hiatus between the Late Glacial and Holocene sediments. The studied sediment series may help to estimate the effect of the meltwater outflow from the Baltic Sea Basin on the North Atlantic Deep Water (NADW) formation during the late Pleistocene and constrain the deglacial chronology and history of the FIS.

This work is a part of the CISU project funded by Academy of Finland and Russian Foundation for Basic Research.

SESSION 3: PAST AND FUTURE CHANGES

## SATELLITE ALTIMETRY SHOWS CHANGES IN EXTREME WAVE HEIGHTS OVER THE BALTIC SEA

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Storms over the Baltic Sea and Europe have a large impact on the marine habitat. Among other, extremes in wave climate are a potential threat to the population, offshore industry, coastal infrastructure, and shipping. The knowledge of long-term changes in the extreme events in sea wave heights which can be caused by climate change and variability is critical for assessment of flooding risks and coastal protection. The Assessment of Climate Change for the Baltic Sea Basin (BACCII) showed that the analysis of extreme events in wind waves is currently not very well addressed. Here we discuss the study of all existing satellite altimetry data over the Baltic Sea Basin regarding extremes in the wave heights.

The satellite altimetry data for the Baltic Sea region collected up to date about 700 000 measurements, extend for more than 23 years (1991 - 2016) and provide an excellent spatial coverage over the Baltic Sea, allowing to study in details trends in extreme wave heights and their spatial variations.

In this talk for the first time, we present an analysis of 100-years return periods derived from fitted Weibull and generalized Pareto distributions, number, and frequency of extreme events in significant wave heights in the Baltic Sea measured by the multi-mission satellite altimetry. The results are based on an application of the Annual Maxima method, Initial Distribution, and Peak-Over-Threshold approaches to the satellite altimetry data validated in comparison with in-situ measurements from SMHI and FMI stations.

Here we show that the 100-years return periods of wave heights reveal significant gradients over the Baltic Sea, indicating a decrease in the southern part of the Baltic Sea and an increase in adjacent areas, which can significantly affect coast vulnerability. We will also discuss a comparison of the observed changes with data about storm tracks and talk about a spatial correlation and possible connection between variations in the storm tracks over the Baltic Sea and the change in the extreme wave heights.

SESSION 3: PAST AND FUTURE CHANGES

## TRENDS IN THE EXTREME WATER LEVELS OF THE BALTIC SEA

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The problems stemming from the frequent presence of high water levels are particularly challenging in semi-enclosed water bodies such as the Baltic Sea where the sea-level rise and particularly the increase in sea-level extremes may be faster than in the adjacent regions. To identify which physical driver is responsible for an increase in the average and extreme sea levels in this region, we separate the Baltic Sea water level into weekly-scale average that (is a proxy of the water volume of the entire sea) and to short-term variations that characterise storm surges.

Long-term changes of contributions of both components into sea-level extremes are studied using numerically simulated water level time series extracted from RCO model (1961–2005) and Nemo-Nordic model (1979–2012). The annual maxima of the weekly-scale average exhibit an increasing trend of 3–4 mm/yr. The increase is higher in the eastern parts of the Baltic Sea and lowest in the vicinity of Danish Straits. The slopes of formal trend lines of the maxima of short-term variations vary remarkably. Large rates of the relevant increase are concentrated in the eastern part of the Baltic Sea from the Gulf of Finland to the Lithuanian nearshore while these maxima decrease in many parts of the western Baltic Sea. This asymmetry signals that a large part of the variability in the extremes of the local water level in the Baltic Sea is controlled by the dominating wind directions and changes in the wind direction in strong storms.

SESSION 3: PAST AND FUTURE CHANGES

## TRENDS OF SEA WATER COLUMN PROPERTIES AND METEOROLOGICAL VARIABLES BASED ON MORE THAN 100 YEARS OF OBSERVATIONS AT UTÖ ISLAND, BALTIC SEA

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The Utö Atmospheric and Marine Research Station (http://en.ilmatieteenlaitos.fi/uto) is located on Utö Island (59°46'50N, 21°22'23E) at the outer edge of the Archipelago Sea, Baltic Sea. Meteorological observations at the island started in 1881 and vertical profiling of sea water salinity and temperature in 1900. Meteorological observations have been carried out at least three times a day for the whole period while hydrographic observations are done with an interval varying from 11 to 30 days.

In this study, our focus is on atmospheric temperature changes and vertical profiles of sea salinity and temperature. The number of quality assured vertical sea water temperature and salinity profiles used in the study is 1522. Together with this set of vertical profiles, we are using more than 100 000 atmospheric temperature observations converted to daily and annual averages, and monthly values of NAO.

Different statistical methods (e.g. dynamic linear model) are used to analyse long-term trends in the atmospheric and sea water variables. Part of the study focus on use of observations for estimating the direction and magnitude of changes caused by the warming climate.

Preliminary results indicate that atmospheric temperatures have increased in Utö, but due to the location 80 km from the coast, the increase is significantly smaller than on the land areas. It also seems that the atmospheric change is most evident in the monthly minimum temperatures but in the monthly maximum temperatures the change is not significant. Corresponding to the increased atmospheric temperatures, similar changes were also observed in the sea surface water temperature.

The analysis of differences between warm and cold years (25% and 75% percentiles based on annual average temperatures) shows that climate change will most probably decrease the sea water salinity especially during the winter. As expectable, also the length of summer period will increase, together with warmer sea water temperatures.

SESSION 3: PAST AND FUTURE CHANGES

## IMPACT OF ACCELERATED FUTURE GLOBAL MEAN SEA LEVEL RISE ON HYPOXIA IN THE BALTIC SEA

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Expanding hypoxia is today a major threat for many coastal seas around the world and disentangling its drivers is a large challenge for interdisciplinary research. Using a coupled physical-biogeochemical model we estimate the impact of past and accelerated future global mean sea level rise (GSLR) upon water exchange and oxygen conditions in a semi-enclosed, shallow sea. As a study site, the Baltic Sea was chosen that suffers today from eutrophication and from dead bottom zones due to (1) excessive nutrient loads from land, (2) limited water exchange with the world ocean and (3) perhaps other drivers like global warming. We show from model simulations for the period 1850-2008 that the impacts of past GSLR on the marine ecosystem were relatively small. If we assume for the end of the 21st century a GSLR of +0.5 m relative to today's mean sea level, the impact on the marine ecosystem may still be small. Such a GSLR corresponds approximately to the projected ensemble-mean value reported by the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. However, we conclude that GSLR should be considered in future high-end projections (› +1 m) for the Baltic Sea and other coastal seas with similar hydrographical conditions as in the Baltic because GSLR may lead to reinforced saltwater inflows causing higher salinity and increased vertical stratification compared to present-day conditions. Contrary to intuition, reinforced ventilation of the deep water does not lead to overall improved oxygen conditions but causes instead expanded dead bottom areas accompanied with increased internal phosphorus loads from the sediments and increased risk for cyanobacteria blooms. The research presented in this study is part of the Baltic Earth program (Earth System Science for the Baltic Sea region, see http://www.baltic.earth).

SESSION 4: COASTAL SEAS AND SOCIETY

## MYTHS OF THE BALTIC SEA EUTROPHICATION

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The applied science cycle, from description of the phenomenon to cause-effect explanations to scenario modelling to managerial recommendations, can be distorted at any of these stages, especially when natural scientists are wandering too far away from their "ivory towers" into socio-economic and political considerations. Although studies of the Baltic Sea eutrophication have matured on the path through the entire cycle from concerns of the early 1970s to the Baltic Sea Action Plan (BSAP) of nowadays, there are still some confusions and misinterpretations that can misdirect future studies and mitigation measures. The suggested gentle reminders and warnings are illustrated with and supported by results derived from both empirical data and mathematical models.

A few burning questions could be arisen from these considerations as a contribution to ongoing studies and discussions:

a) Are we going to tolerate current cyanobacteria blooms and hypoxia for decades, waiting for large scale effects of expensive nutrient load reductions?

b) Could we try weakening the "vicious circle of the Baltic Sea" by removing part of accumulated phosphorus with geoengineering measures?

c) Are the Baltic cod existence and fishery important enough to search for a balance between cod food supply and cod reproduction impairment, both generated by nitrogen-fixing cyanobacteria?

d) Is it expedient and possible to develop the Baltic Health Index as being more ecosystems protective rather than commercially exploitive?

SESSION 4: COASTAL SEAS AND SOCIETY

## ASSESSMENT OF EUTROPHICATION STATUS BASED ON SUB-HALOCLINE OXYGEN CONDITIONS IN THE GULF OF FINLAND (BALTIC SEA)

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Sub-halocline oxygen conditions in the deep Baltic Sea basins depend on natural (climate and hydrography related) forcing and anthropogenic impact. HELCOM has a long tradition to characterize the status of the seabed and deep waters by estimating the extent of anoxic and hypoxic bottoms. A eutrophication-related indicator "oxygen debt" has recently been introduced. A major issue in such assessments is the availability of data due to the low time resolution of open sea monitoring cruises.

We present the oxygen conditions in the near-bottom layer of the Gulf of Finland (GoF). An attempt is made to estimate the areal extent of bottom layer hypoxia and its dynamics based on autonomous profiling devices, which were deployed in the three different locations in the GoF in 2014-2016. The devices acquired vertical profiles of temperature, salinity and oxygen from the sea surface to the seabed with the time resolution varying from 2 to 8 times a day.

Based on the vertical profiles of dissolved oxygen the depths at which hypoxia starts (defined as oxygen content ‹ = 2.9 mg/L $O_2$ or ‹ = 2.0 mg/L $O_2$) were found. The average depth of the upper boundary of hypoxia for certain time periods (year, season, and month) and the maximum duration with hypoxia at different depths were estimated. The results suggest that the GoF area affected by hypoxia has decreased from 2014 to 2015, and increased again in 2016 with an occasionally (for short periods) very shallow boundary of hypoxia. The estimates of the contributions of lateral advection, mixing and local oxygen consumption suggest that the quick changes in oxygen conditions are related to the former two physical processes. However, the magnitude of the change in salinity related to the upper boundary of hypoxia during the productive season indicates the role of local consumption, and thus eutrophication status.

SESSION 4: COASTAL SEAS AND SOCIETY

## THE "DIATOM/DINOFLAGELLATE INDEX" AS AN INDICATOR FOR THE MARINE STRATEGY FRAMEWORK DIRECTIVE

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The Diatom/Dinoflagellate index (Dia/Dino index) is a newly created indicator of ecosystem changes for applications pertaining to the Marine Strategy Framework Directive (MSFD). The principles of the Dia/Dino index and the conditions for its calculation are explained using examples from two very different water bodies, the Eastern Gotland Basin and Kiel Bay. The index is based on seasonal mean diatom and dinoflagellate biomass values. A precondition for its applicability is that measurements are carried out during spring blooms, i.e. the maximum diatom or dinoflagellate biomass has to exceed a predefined threshold, e.g. 1000 µg/L. If this condition is not fulfilled, an alternative Dia/Dino index can be calculated based on silicate consumption data. The Dia/Dino index was able to identify the changes from diatom-dominance to dinoflagellate-dominance which occurred at the end of the 1980s in the Baltic Proper. Such changes may impact the pelagic-benthic coupling. If diatoms are dominant, their rapid sinking reduces the food stock for zooplankton but delivers plenty of food to the zoobenthos. Consequently, the Dia/Dino index can be used to follow the food pathway (Descriptor 4 of MSFD: "food web"). Moreover, a low Dia/Dino index may indicate silicate limitation caused by eutrophication, whereas a high Dia/Dino index supports mitigation of eutrophication, as the strong sedimentation of nutrients removes them from the water and deposits them in the sediment (Descriptor 5 of MSFD: "eutrophication"). Diatom dominance, and thus a high Dia/Dino index, is typical in historical data and is therefore assumed to reflect a good environmental status (GES). For the Eastern Gotland Basin and Kiel Bay, GES thresholds of 0.5 and 0.75, respectively, are suggested. The GES thresholds as calculated for the alternative Dia/Dino index are 0.84 and 0.94, respectively.

SESSION 4: COASTAL SEAS AND SOCIETY

## BIODIVERSITY IMPACT ON ECOLOGICAL NICHE PARTITIONING OF NATIVE AND INVASIVE SPECIES IN MICROPLANKTON OF THE BALTIC SEA

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This study analyses three decades of the peculiar bloom-formation history of the potentially toxic invasive planktonic dinoflagellates *Prorocentrum minimum* (Pavillard) Schiller in the SW Baltic Sea. A research hypothesis was tested, which suggests that the unexpectedly long delay (nearly two decades) in population development of *P. minimum* prior to its first bloom was possibly caused by competition with one or several closely related native dinoflagellate species due to ecological niche partitioning which hampered the spread and bloom-forming potential of the invader. Phytoplankton species diversity, environmental characteristics and invasion history of *P. minimum* in the SW Baltic Sea coastal waters were analysed. The ecological niche dimensions of *P. minimum* and its congeners were identified as the optimum environmental conditions for each species during its bloom events, based on water temperature, salinity, pH, concentration of nutrients, TN/TP-ratio and habitat type. These data contributed to the development of the protistan species-maximum concept for the challenging zone of critical salinity 5-8. High microplankton diversity in the critical salinity regions of the Baltic Sea was considered as a possible reason for the significant niche overlap and pronounced competitive interactions among congeners in the highly variable brackish water environment. Implications of these results for predictive modelling of the ecosystem vulnerability to alien species invasions are discussed. The work was funded in part by the RFBR grant 15-29-02706.

SESSION 4: COASTAL SEAS AND SOCIETY

## MARINE INVASIVE SPECIES INDICATORS: IMPLICATIONS FOR ENVIRONMENTAL ASSESSMENT AND MANAGEMENT

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The paper considers biological invasions and their role in changing marine environment. There are philosophical and emotional differences regarding the status of alien and introduced species in which perceptions by invasion biologists are not necessarily defended by fact. For example, the debate regarding "once a non-indigenous species (NIS) then always a NIS", that "invasive species cannot become part of the accepted and native fauna and flora", that the "transmission by one vector (Man) is bad whereas by another (e.g. currents, birds) is good". On another hand, there is an increasing demand to take into account adverse impacts of invasive alien species (IAS) in assessments of marine ecosystem health. For example, the EU Marine Strategy Framework Directive (MSFD), which aims to improve the environmental status of the European regional seas, specifically addresses the problem of biological invasion by defining the Good Environmental Status Descriptor 2 (D2): "NIS introduced by human activities are at levels that do not adversely alter the ecosystems". The paper presents a critical review of the proposed MSFD NIS indicators and considers uncertainties, which may be caused by IAS in various indicator systems used to establish the progress towards achieving the environmental targets set by MSFD. This work was supported by the Taiwan–Latvia–Lithuania Cooperation Project BALMAN "Development of the ships' ballast water management system to reduce biological invasions" (TAP LLT-03/2015).

SESSION 4: COASTAL SEAS AND SOCIETY

## DEVELOPING A RISK ASSESSMENT MODEL FOR BALLAST WATER MANAGEMENT UTILISING THE ANALYTICAL HIERARCHY PROCESS (AHP)

Liu, T. K. [1] and Cheng, M. H. [1]
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The ballast water mediated introductions of non-indigenous species (NIS) may have adverse effects on biological diversity, ecosystem functioning, socio-economic values, and human health. It has prompted the International Maritime Organisation (IMO) to adopt the "International Convention for the Control and Management of Ships' Ballast Water and Sediments" (BWM Convention) and it will soon enter into force in 2017.

BWM Convention made provision for the utilisation of risk assessment methodologies and thus different RA decision-making tools were developed to address objectives and needs at different national, regional and global level. In this study, we proposed a comprehensive framework for evaluating the incoming vessel's risk level of introducing Harmful Aquatic Organisms and Pathogens (HAOP) via ballast water by employing Delphi method and an AHP-based decision analysis process. Three rounds of survey were iteratively conducted by posing questions, synthesizing feedback and guiding the group towards a common ground.

First two rounds of questionnaire were distributed to 21 marine experts from Baltic region and Taiwan to collect their opinions on pre-determined risk factors. The framework was then modified according to the experts' feedbacks. Eleven risk factors were selected under two categories, which are risks associated with source of ballast water and vessel character respectively. On the one hand, for risks associated with source of ballast water, the similarity of temperature, salinity, biogeographic of donor and recipient port, presence of known invasive species of donor port and distance from ballast water intake location to discharging port are included. On the other hand, ballast water capacity, ship-type, ballast water management plan on board, flag state status and frequency of calling recipient port are factors associated with vessel character.

The framework was developed into a risk assessment model after a series of pairwise comparison was made by the same group of marine experts to determine weights of individual attributes. The derived framework could serve as a tool to assist port state control to screen the high risk vessels with appropriate input data on the border and thus enhance an effective implementation and enforcement of BWM.

# Oral Presentations

June 16, 2017

KEYNOTE LECTURE

## REMEMBERING FREDRIK WULFF — BALTIC SEA ECOSYSTEM MODELLER, INSTITUTION LEADER AND CREATOR OF THE BALTIC SEA EUTROPHICATION MANAGEMENT DECISION SUPPORT SYSTEM

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Fredrik Wulff (1942-2016) was a pioneer in marine systems ecology, and created the model-based decision support system underpinning the decisions on country-specific nutrient reduction quotas in the Helsinki Commission's Baltic Sea Action Plan in 2007 and 2013.

Fredrik grew up in Kalmar, on the coast of the Baltic proper, where he developed an interest in Nature and the Sea. He studied zoology and botany at Stockholm University and began doctoral studies on rock pool ecosystems at Stockholm University's Baltic Sea field station, the Askö Laboratory. When his advisor, Bengt-Owe Jansson, received a ten-year grant to study Baltic ecosystems, with the long-term goal of creating mathematical models for managing the Baltic Sea environment, Fredrik was made assistant project leader and sent to study ecosystem modelling with the famous systems ecologist Howard T. Odum at the University of North Carolina. On return, Fredrik was a major contributor to the success of the project, got his doctoral degree in 1978, and became a docent the year after.

In the 1980-ies, Fredrik gained international respect, and spent a fruitful half a year with John Field in Cape Town. His joint papers with oceanographer Anders Stigebrandt in Gothenburg made a break-through in ecosystem analysis of the Baltic Sea. In 1991-2002 Fredrik was head of Stockholm University's Department of Systems Ecology. He received major grants for studies of large-scale ecological processes in the Baltic Sea, and assembled a large data base to support the modelling. He published books on marine ecosystem analysis and Baltic Sea ecology and became Professor of Marine Systems Ecology in 1996. In 1998 he received the Great Prize of The Åland Foundation for the Future of the Baltic Sea.

From 1999 Fredrik led the project "Marine research on Eutrophication", MARE, funded by the Swedish Foundation for Strategic Environmental Research. Through international collaboration, MARE created a series of linked models that describe how different actions to mitigate eutrophication influence the Baltic Sea's ecology and fish stocks, and at what cost. When the Helsinki Commission used this decision support system for its Baltic Sea Action Plan, this was the crowning of 37 years of unrelenting, inspired work by Fredrik. After the MARE project, the research has continued and expanded at the Baltic Nest Institute, now part of Stockholm University's Baltic Sea Centre. After retiring in 2009, Fredrik continued to act as a trusted advisor. His influence on Baltic Sea environmental management is unequalled.

KEYNOTE LECTURE

## EPISTEMIC MOBILITIES, SEALEVEL RISE AND THE CONTESTATION OF THE OCEAN-LAND BORDERLINE

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Today, approximately half of the world's population lives within 60 km of the sea, and three-quarters of all large cities are located along coasts (UNEP 2015). People migrate from peripheral areas to national and regional centers – for work, education and always in the hope of a 'better future'. As people travel, so do lifestyles, particular stocks of knowledge, goods (computer chips, textiles, and foodways). Thus cross-border geographic mobilities, often encouraged by the search for social upward mobility across socio-cultural boundaries, comes with particular epistemic mobilities, travelling ideas and concepts of development, that make coastal regions not only the melting pots of ideas, inspiration and creativity, but, further exacerbated by population density, risk-prone to environmental, health and social disasters with the borderline between ocean and land being renegotiated by the effects of sealevel rise.
This keynote address the patterns of cross-border epistemic mobilities in and between the cities of Singapore, Jakarta and Manila (Southeast Asia), in the context of regional sea level change and growing flood risks. It looks at (a) the policies and institutional infrastructures of risk adaptation (dispositifs, e.g. the formulation and institutionalisation of flood management plans) and (b) the related practices in the form of solutions and attempts of standardisation put forth by donor and civil society organisations (e.g. the construction of seawalls). It is hypothesised that epistemic mobilities and thus the globally communicated and locally heard disaster mitigation and risk adaptation plans and practices, are key to assessing the local processes of renegotiating the borderline between ocean and land through the employment of policies and practices of risk mitigation and adaptation. The contribution will be based on qualitative ethnographic data collected in 2016 in the three study sites on policies and practices of mitigating and adapting to sealevel rise.

PLENARY LECTURE

## USING EXTENDED SOCIO-ECONOMIC SCENARIOS TO INVESTIGATE DRIVERS AND PRESSURES ON THE BALTIC SEA UP TO 2100

Zandersen, M.[1], Hyytiainen, K.[2], Meier, H.E.M.[3], Tomzcak, M.,[4], Bauer, B.[4], Haapasaari, P.[2], Olesen, J.E.[1], Gustafsson, B.[4], Kosenius, A.K.[2], Refsgaard, J.C.[5], Fridell, E.[6], Pihlainen, S.[2], and Letissier, M.D.A.[7]

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The Baltic Sea is an ecologically vulnerable aquatic ecosystem that is greatly influenced by human activities and the climatic system: i) diffuse and point nutrient loads from agriculture, industry and waste water treatment plants have particularly over the past 60 years caused strong eutrophication and large areas of dead sea bottoms in the Baltic Sea, threatening a range of important ecosystem services; and ii) perhaps increasing runoff integrated over the entire Baltic Sea catchment area in future climate, which in turn accelerates nutrient loads to the sea, while the resilience of the marine ecosystem is weakened due to higher surface water temperatures.

Scenarios that combine socio-economic and climate pathways, such as the Shared Socioeconomic Pathways (SSPs) and Representative concentration pathways (RCPs) can be powerful tools to help evaluate the challenges and uncertainties in ecosystem management and the scale of human contributions to regional environmental change under different plausible futures. Such scenarios can be used as input to integrated assessments to investigate how changes in nutrient emissions and subsequent responses in the ecosystem, combined with uncertainty about both future climate impacts and societal developments, may develop and what actions would be needed to obtain good environmental conditions.

We present a collaborative and interdisciplinary effort to translate global climate and socioeconomic futures into regional drivers and pressures that drive pollution in the Baltic Sea. We propose sectoral narratives of the sustainability pathway (SSP1), the Middle of the Road (SSP2), Regional Rivalry (SSP3) and Fossil Fueled Development (SSP5) along with quantifications of the drivers impacting nutrient loads and the different levels of pressures in terms of total nitrogen and phosphorous loading up to 2100. We combine the SSP/RCP matrix structure with the analytical frame of DPSIR (Drivers, Pressures, State, Impacts and Responses).

Results indicate a plausible range of different adaptation and mitigation responses needed under the different SSPs in order to ensure a good environmental status of the Baltic Sea, with and without climate change, up to 2100. The approach exemplifies the potential for applying scenario analysis stemming from climate research to regional environmental challenges, which are impacted by climate change.

PLENARY LECTURE

## HOW THE BALTIC SEA OCEANOGRAPHY SETS THE SCENE FOR THE IMPLEMENTATION OF THE EU MSFD?

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The EU has set an ambitious objective of reaching good environmental status (GES) of marine waters by 2020. This objective was laid down in the Marine Strategy Framework Directive, but the challenge of MSFD is also in ensuring comparable assessment results in the four European seas and their defined sub-regions. While the grand objective of the MSFD is to have a pan-European overview of the state of the marine environment, this cannot be reached without careful consideration of the specific conditions of each of the regions – separately and jointly. These marine regions have major differences in hydrological, oceanographic and biogeographic features. While commonly acknowledged, such differences or the natural variability of the above-mentioned features have not, until now, been summarized in the MSFD context. In this paper, we focus on oceanographic features of the Baltic Sea, one of the marine regions as defined under the MSFD. Using the indicative parameter lists of the MSFD Annex III, we describe the variability and dynamics of several oceanographic features and make comparisons to the other European seas. For instance, GES cannot be discussed in the Baltic context without understanding that the region will be under heavily eutrophicated conditions for the next decades and, although anthropogenic, it is heavily affected by physical factors. Such physical factors – e.g. stratification, water residence time, upwelling – do not have same meaning in the other marine regions. Our purpose in this study is to show how these oceanographic driving forces need to be placed in to the context of the MSFD implementation.

PLENARY LECTURE

## MICROPLASTICS: POLLUTANT WITH UNKNOWN TRANSPORT PROPERTIES

Chubarenko, I.[1], Poterukhina, I.[1], Bagaeva, M.[1], Khatmullina, L.[1], Isachenko, I.[1], and Nizhnikovskaya, O.[1]

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Microplastics particles (MPs, conventionally, 1 - 5 mm) are found nowadays in all the marine environments, from pole to pole, from water surface to deep bottom sediments. They have various densities, shapes and sizes, and all of these properties are changeable with time due to biofouling, weathering, mechanical degradation and other external forcings. As a result, MPs spreading under sea conditions is difficult to predict.

Data of a series of laboratory experiments, targeted at understanding of basic physical characteristics and transport properties of some types of MPs particles are reported. First tests examined which types of particles can be generated in the sea swash zone with coarse bottom sediment from larger objects made of polyethylene (PE), solid polystyrene (PS), foamed PS, and polypropylene (PP). Artificially made plastic samples were placed in laboratory mixer with inclined axis of rotation, filled with water and marine pebbles, and were rotated for 24 hours. Every 3 h, the type of the generated MP particles and size distribution were examined. Solid PS appears to quickly produce the largest number of MPs. Foamed PS samples break with time into individual spherules, which are difficult to disintegrate further. PE films get folded 4-8 times very quickly and remain as such afterwards for a long time, with a very small fraction of fibre-like particles generated. PP samples are the hardest: they stay practically the same after 24 h of mixing with pebbles, with practically no MPs generated.

In the second set, the settling velocity of various plastic particles was addressed. Artificially made polycaprolactone particles of various shapes, fishing line cuts, and synthetic fibres were put in the laboratory glass column, and their free fall in water was monitored. The shape of a particle is shown to play the key role in the particle' behaviour.

The third set of tests aims at understanding of magnitude of critical shear velocity of MPs of various shapes. Classical Shields experiments are modified in order to get re-suspension velocity of 3d, 2d and 1d plastic particles (of similar densities of about 1.05 g/cm$^3$ and similar size of about 3 - 4 mm) from the bottom covered with natural coarse sand (1 - 1.5 mm), granules (3 -4 mm), and cobbles (1 - 2 cm). The results indicate that, again, the particle shape is of primary importance for its re-suspension.

Investigations are supported by the Russian Science Foundation, project number 15-17-10020 (MARBLE).

PLENARY LECTURE

## SUBMARINE GROUNDWATER DISCHARGE TO THE ECKERNFÖRDE BAY, BALTIC SEA: TOWARDS A QUANTITATIVE ASSESSMENT

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Excess nutrient supply by rivers and the atmosphere are considered as one of the major causes for the poor ecological status of the Baltic Sea. One of the so far underestimated and insufficiently quantified nutrient sources is submarine groundwater discharge (SGD). SGD occurs wherever the hydraulic gradient on land is above sea level and permeable paths allow subsurface flow of groundwater to the sea. As most of the upper aquifers in the German Baltic Sea catchment are highly affected by fertilizers used in agriculture nutrient discharge via SGD is likely.

We investigated the occurrence of SGD along the coastline of the Eckernförde Bay using a variety of different methodological approaches (coastal radon and radium seawater surveys, push point piezometers, seepage meters, CTD-divers). Widespread occurrences of SGD as indicated by surface sediment pore water salinities lower than ambient seawater were detected at 15 out of the 18 locations investigated. Monitoring of sediment pore water salinities for several weeks at various locations in the Eckernförde Bay suggests a very dynamic system with rapid salinity changes largely depending on the sea-level. At low sea-level the hydraulic gradient between the coastal aquifer and the sea level is highest resulting in a higher SGD flux and thus lower pore water salinity compared to times of high sea-level when the SGD flux is lower. The mean SGD flux as determined by seepage meters is 21 cm/d (range 0.6 cm/d – 173 cm/d; n = 342) with most of the fluxes (73%) occurring in the range ‹ 20 cm/d. SGD consists on average of 16.8% of freshwater with recirculated seawater forming the remainder. Compared to other SGD systems studied world-wide this SGD fresh water fraction is relatively high. This is most probably due to the low tidal range in the Baltic Sea which reduces tidal pumping and thus the recirculation of seawater. SGD-borne dissolved inorganic nitrogen (DIN = $NO_3$ + $NH_4$ + $NO_2$) concentrations are on average 96 µmol/l (range 0.7 µmol/l – 684 µmol/l, n= 102) with higher concentrations (mean 265 +/- 99 µmol/l) in low saline waters (salinity ‹ 0.2). For estimations of DIN supply to the entire Eckernförde Bay we used two approaches: i) areal extrapolation of seepage meter measurements and ii) radium isotope mass balances. The results of these approaches, their advantages and disadvantages are discussed in the presentation.

CROSSCUTTING SESSION: MONITORING / OBSERVATION /ASSESSMENT SYSTEMS

## A NOVEL APPROACH TO ESTIMATE INFORMATION UNDER CLOUD COVER IN THE SATELLITE IMAGES USING NUMERICAL MODELS

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The remote sensing techniques play a key-role in the monitoring of environmental change. However, this observation method is often limited by the presence of cloud cover, what introduces analytical biases and usually leads to classifying data as missing values that causes discontinuities in the datasets. A variety of advanced statistical methods have been developed in order to approach that problem, but gap filling is still a task to solve in the Earth system sciences. The multivariate approaches or spatiotemporal gaps distribution analyses reveal particular problems in the areas of systematically recurring gaps due to the persistent cloud cover, where capturing any regularity or patterns is doubly difficult. Moreover, the specificity of the Baltic Sea makes it impossible to use most of the commonly applied a priori assumption or any global estimates.

Here we propose a novel approach of complementing information from the satellite imagery with the data obtained from eco-hydrodynamic models. The gap filling procedure consists of several steps. First, the systematic error between satellite data and a numerical model is found to equalize both datasets. Then, a filtration of the satellite images is performed to eliminate single-pixel gaps caused by masking singular outliers and local artifacts. In order to increase the contribution of satellite information, a mosaic from images falling into a particular time window is prepared. Finally, data from the two sources are combined together considering weights, which were introduced to smooth values in the transition between the input images. This method is efficient for the log-distributed values and produces Root Mean Square Errors (RMSE) lower than the input model or satellite datasets, which were checked against individual in situ measurements or time series collected from buoys. The algorithm was optimised for the Baltic Sea area and the optimal parameters were found and tested for the Sea Surface Temperature (SST). A particular emphasis was put on retaining the remotely sensed information to a high degree in order to preserve local mesoscale phenomena that are hard to capture through modeling. On the other hand, models as independent source of information provide a reliable solution to filling the long-term stationary gaps, especially in the recent time, when performance of various models is much increased.

CROSSCUTTING SESSION: MONITORING / OBSERVATION /ASSESSMENT SYSTEMS

## DISTRIBUTION OF SUSPENDED MATTER ACROSS THE BALTIC SEA

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There are three optical in-water components that, besides water itself, govern the under-water light field of aquatic systems: phytoplankton, suspended particulate matter (SPM) and coloured dissolved organic matter (CDOM). In essence, it is the spectral absorption and scattering properties of each optical component that govern the underwater light field, and also the colour of sea that we can perceive.

The Baltic Sea is optically dominated by CDOM, apart from during time of cyanobacteria blooms. In coastal areas, the optical properties are influenced by all optical components, as these areas are highly influenced by run-off from land. An increase in precipitation also leads to an increase in SPM and CDOM, and eventually also of phytoplankton chlorophyll-a due to the increase in nutrients.

In summer, the open Baltic Sea is often dominated by cyanobacteria blooms that often cover most of the Baltic proper. Ocean colour images reveal large-and mesoscale features and currents, which are influenced both by the Coriolis force, but also by atmospheric Rosby waves. The blooms and features in the open sea can be monitored both using the chlorophyll-a as well as the SPM products from ocean colour data.

The MERIS instrument on ESA's ENVISAT provided us with a decadal time series of high quality ocean colour data (2002-2012). ESA's OLCI instrument was launched successfully on Sentinel-3 (S3) in early 2016 (300 m resolution - same as MERIS). But ESA have also launched MSI on Sentinel-2 (S3) already in 2015, a sensor which was mostly designed for terrestrial applications. MSI can be used to derive both the SPM concentration as well as turbidity and has an improved spatial resolution (10-60 m in the visible) and is therefore of special interest for coastal applications.

In this talk I will give an overview of the distribution of SPM in the Baltic Sea basin, using both optical in-water measurements and remote sensing data (MERIS/S2/S3). I will also present recent work on algorithm development and validation, including algorithms for turbidity, Secchi depth and diffuse attenuation.

CROSSCUTTING SESSION: MONITORING / OBSERVATION /ASSESSMENT SYSTEMS

## TOWARDS AN OPERATIONAL BIOGEOCHEMICAL MODEL SYSTEM TO SUPPORT THE MARINE STRATEGY FRAMEWORK DIRECTIVE REPORTING

Lorkowski, I.[1], Schwichtenberg, F.[1], Janssen, F.[1], Brüning, T.[1], Neumann, D.[2], Neumann, T.[2], Nerger, L.[3], and Matthias, V.[4]

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The Federal Maritime and Hydrographic Agency (BSH) in Germany is a maritime service provider on national and European level. The operational model system developed and run at BSH provides an important part of the information needed to support these services. The biogeochemical model ERGOM coupled to the circulation model HBM (HIROMB-BOOS-Model) is used in operational mode for the North and Baltic Sea to simulate the biogeochemical dynamics and the oxygen development.

BSH is involved in the Copernicus Marine and Environmental Monitoring Service (CMEMS) for the Baltic Sea and is among other things contributing to the development of the operational biogeochemical model for the Baltic Sea forecast product.

The recently started project MeRamo is aiming at developing the existing model system further to support the monitoring and reporting for the Marine Strategy Framework Directive (MSFD).

The MSFD calls for the establishment of a Good Environmental Status of the marine environment until 2020. In the current reporting, mostly in-Situ data is used to determine the status of the marine environment. Although close to the real status, in-Situ data are point measurements and are sparse in time and space when looking on a regional scale. The MeRamo project aims at supporting the public authorities with results and products from an assimilative hydrodynamical-biogeochemical model system (HBM-ERGOM) for the North and Baltic Sea. Thus, a high quality data set can be generated, which is consistent in time and space. The resulting products are intended to augment in-Situ measurements with forecasts and with complementary reconstructions of the marine environment where no in-Situ data exist. The project is based on three main pillars. A data assimilation component will be included which can handle Sentinel data from the European Copernicus initiative. Additionally a nutrient tagging routine will be implemented, which will be able to track the fate of specific nutrients depending on its source. Special focus will be placed on the effect of shipping emissions on the marine ecosystem by utilizing a data set for atmospheric deposition which especially accounts for deposition from shipping emissions. As the final step, the model output will be transformed into indicators which can be directly used for reporting. This will allow direct usage of different data sets via the operational model system optimised for the reporting for the MSFD.

CROSSCUTTING SESSION: MONITORING / OBSERVATION /ASSESSMENT SYSTEMS

## ASSESSMENT OF STATE-OF-THE-ART BALTIC SEA MODELS AND THEIR SETUPS FOR USAGE IN CLIMATE APPLICATIONS

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How will the Baltic Sea climate change during the next centuries? This and related issues are of great scientific interest, but also of economic and environmental significance for all Baltic Sea countries. Understanding and modelling the state of the Baltic Sea also facilitates the assessment of other coastal seas in the world with similar physical conditions. In order to answer questions about issues like changes in the thermal balance, salinity, sea level, or ice conditions, a novel coupled regional climate system model for the Baltic Sea region will be developed which combines atmosphere, sea ice, and ocean models. By selecting suitable physical equations, constants and initial conditions for the model runs in several test cases whereby temporally and spatially high-resolution long-term observations will be taken into account, present-day simulations will be optimized. Subsequently, future predictions as well as historical reconstructions of hundreds and thousands of years can be realized. The focus of the present study is on the choice of the ocean model to be employed within the coupled climate model. For that reason, the performance of two state-of-the-art ocean circulation models, i.e. the General Estuarine Transport Model (GETM) and the Modular Ocean Model (MOM), is investigated. These models differ primarily in that GETM was developed for shallow sea applications, uses vertically adaptive coordinates, and applies for horizontal coordinates an Arakawa C-grid whereas MOM was mainly intended for large-scale ocean simulations, runs on level coordinates, and uses a B-grid so far. For the applied models, simulations with different model grid resolutions ranging from 9 nautical miles up to 1 nautical mile within the period 1949-2015 have been performed. The obtained model results of temperature, salinity, currents, and sea level for 3D fields and time series at selected stations are compared with available observations. For the assessment of the model results, various statistical methods for data analysis like correlation, standard deviation, and root mean square error are applied.

SESSION 3: PAST AND FUTURE CHANGES

## SEDIMENT QUALITY IN ESTONIAN WESTERN GULF OF FINLAND - WITH REFERENCE TO THE NORTHERN GULF OF FINLAND

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The Gulf of Finland is known to be loaded with harmful substances, sometimes with rather high contaminant levels. Maritime spatial planning requires proper knowledge of the seafloor and established sediment quality guidelines (SQG: s) provide good frame for evaluation of sediment quality for the permitting authorities. In the Gulf of Finland this approach has been used for a rather large dataset from the Northern part of the gulf where the existing heavy metal data were classified using North American and Norwegian SQG: s in lack of own Baltic Sea guidelines.

The principal target of the European Union marine strategy framework directive (MSFD) is to preserve the good environmental status of the sea areas or reach it by 2020. The Estonian SedGof project was carried out in order to reach the marine strategy goals.

The obtained results of this study reveal that only in less than half of the subsamples from Estonian waters the heavy metals and arsenic exceed the threshold levels of both used American SQG: s, none exceed the probable effect level (PEL) and only a few belong to the III and IV classes of the Norwegian guidelines, no subsamples exceeding the V: th class. The quality of the sediments in western Estonian waters can according to the used guidelines be assessed as good for most of the studied elements and the already rather low concentrations are decreasing further. The concentrations of copper and zinc, however, are on a rather high level, and as these levels are found in subsamples from close to the sediment surface the situation regarding these two metals can't be assessed as satisfactory.

SESSION 3: PAST AND FUTURE CHANGES

## C25 HIGHLY BRANCHED ISOPRENOID ALKENES AS BIOMARKERS AND TIME-MARKERS FOR THE OCCURRENCE OF THE MARINE PLANKTONIC DIATOM PSEUDOSOLENIA CALCAR-AVIS IN THE BALTIC SEA AND THE BLACK SEA

Kaiser, J.[1], Belt, S.T.[2], Tomczak, M.[3], Brown, T.A.[2], Wasmund, N.[1], Häusler, K.[1], Dellwig, O.[1], Moros, M.[1], and Arz, H.W.[1]

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$C_{25}$ highly branched isoprenoid (HBI) alkenes are lipid biomarkers produced exclusively by certain diatoms and found in sediments worldwide. Here, for the first time, it is shown that the marine planktonic diatom *Pseudosolenia calcar-avis*, isolated from near surface waters in Mecklenburg Bay (southwestern Baltic Sea), biosynthesizes one $C_{25:2}$ and two $C_{25:3}$ HBI alkenes previously reported in some benthic diatoms. The presence of the same $C_{25}$ HBI alkenes in surface sediments from Mecklenburg Bay and the Arkona Sea, as well as their co-occurrence with remnant frustules of *P. calcar-avis* in a sediment core from the northern Baltic Sea, indicates that these lipids are very likely specific biomarkers for this diatom in this region at least. Since *P. calcar-avis* has a tolerance for low salinities (8–10), we also suggest that the occurrence of some of the HBIs produced by this diatom might represent a useful proxy for measuring past changes in salinity and inflowing water from the North Sea. The application of these biomarkers to sediment cores reveals the occurrence of *P. calcar-avis*, and thus surface salinities › 8, in the northern Bothnian Sea during the Holocene Thermal Maximum, and in the Landsort Deep area during the Medieval Climate Anomaly. Interestingly, monitoring data for the last 35 years reveal that *P. calcar-avis* is blooming in the Mecklenburg Bay only since 2010, making the occurrence of the specific $C_{25}$ HBIs in sediments a potential time-marker for the year 2010. The same $C_{25}$ HBIs, found in the upper sediments from the Black Sea, may also be produced by *P. calcar-avis* in such settings and serve as time-markers for the 1920s, when *P. calcar-avis* was accidentally introduced in the Black Sea.

SESSION 3: PAST AND FUTURE CHANGES

## RECONSTRUCTING THE HISTORY OF COASTAL EUTROPHICATION AND QUANTIFYING TOTAL NITROGEN REFERENCE CONDITIONS IN BOTHNIAN SEA COASTAL WATERS

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Total nitrogen (TN) reference concentrations for the Gårdsfjärden estuary in the central Bothnian Sea, which receives discharge from an industrial point-source, have been estimated from diatom assemblages using a transfer function. The training set consists of 229 sheltered sites (combining surface-sediment diatom counts and water chemistry data provided by monitoring programmes) from Baltic Sea coastal areas, the Swedish west coast, Danish waters, Oslo Fjord, and the Netherlands (http://craticula.ncl.ac.uk/Molten).

Before 1920 there is a good ecological status with an assemblage dominated by benthic taxa, high diatom species richness, and low organic sedimentation with well oxygenated sediments. Many diatoms were epiphytic indicating that the sea floor in the estuary was covered with macrophytes. Diffuse laminations started to form in the early 1930s with fully developed laminations in the late 1940s indicating a deterioration in oxygen conditions and loss of bottom fauna. Discharge from the pulp mill peaked between the 1960s and 1980s and poor water transparency changed the available habitats and, consequently, dominant diatom life-forms with the establishment of a planktonic dominated assemblage.

The trend in reconstructed TN-values matches the history of the discharge from the mill, reaching maximum impact during the years of high discharge between 1945 and 1990. Monitoring data, dating back to 1980, can validate the diatom-inferred total nitrogen reconstruction, and our model performs well when measured TN is <400 µg $L^{-1}$ and the diatom analogue quality is fairly good. The reconstructed total nitrogen values of 260-300 µg $L^{-1}$ before 1920 could be considered reference nutrient conditions for Gårdsfjärden, even though the industrial history of the paper mill dates back to AD 1685. Diatoms are evidently a sensitive and early warning indicator to changes in nutrient input, but in Gårdsfjärden the most obvious change occurs when suitable habitats for epiphytes disappear.

Provided the requirements of quantitative reconstructions are met (Juggins, 2013), in addition to continuous sediment archives, good silica preservation, credible chronology and good diatom species analogues, diatom-inferred transfer functions can readily be used to establish reference nutrient conditions for the EU Water Framework Directive and HELCOM Baltic Sea Action Plan in other Baltic Sea coastal waters.

SESSION 3: PAST AND FUTURE CHANGES

## TEMPERATURE, DOC LEVEL AND BASIN INTERACTIONS EXPLAIN THE DECLINING OXYGEN CONCENTRATIONS IN THE BOTHNIAN SEA

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Hypoxia and oxygen deficient zones are expanding worldwide. To properly manage this deterioration of the marine environment, it is important to identify the causes of oxygen declines and the influence of anthropogenic activities. Here, we provide a study aiming to explain the declining oxygen levels in the deep waters of the Bothnian Sea over the past 20 years by investigating data from environmental monitoring programmes.

The observed decline in oxygen concentrations in deep waters was found to be primarily a consequence of water temperature increase and partly caused by an increase in dissolved organic carbon (DOC) in the seawater ($R^2_{Adj.}$=0.83) as well as inflow from the adjacent sea basin. As none of the tested eutrophication-related predictors were significant according to a stepwise multiple regression, a regional increase in nutrient inputs to the area is unlikely to explain a significant portion of the oxygen decline.

Based on the findings of this study, preventing the development of anoxia in the deep water of the Bothnian Sea is dependent on the large-scale measures taken to reduce climate change. In addition, the reduction of the nutrient load to the Baltic Proper is required to counteract the development of hypoxic and phosphate-rich water in the Baltic Proper, which can form deep water in the Bothnian Sea. The relative importance of these sources to oxygen consumption is difficult to determine from the available data, but the results clearly demonstrate the importance of climate related factors such as temperature, DOC and inflow from adjacent basins for the oxygen status of the sea.

SESSION 4: COASTAL SEAS AND SOCIETY

## BATHING WATER QUALITY AT THE GERMAN BALTIC COAST: LONG-TERM DEVELOPMENT, PROBLEMS AND CHALLENGES

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The first EU Bathing Water Directive (76/160/EEC) came into force already 1975 to prevent bathers from potential threats as pathogenic microorganisms and to protect public health. It has contributed to the improvement of recreational water quality until it was improved and repealed by the new directive (2006/7/EC) to meet the altering living standards of the general public. Based on research on most appropriate indicators (Cabelli et al. 1982; Balarajan et al. 1991; Saliba & Helmer 1990) the microbial indicators for pollution were reduced and specified to *Escherichia coli* and intestinal enterococci. Nonetheless, regulated observation of other pathogens such as *Vibrio*, *Salmonella* is lacking.

Although bathing water quality along the German Baltic coast is mostly classified as good to excellent, regional "hot spots" of pollution still cause beach closures because mandatory values cannot be reached. Especially shallow lagoons and estuaries with restricted water exchange often face these kind of problems. We present a long-term overview about bathing water quality along the German Baltic coast and its development after the change of directive with focus on still existing problem areas.

Furthermore, laboratory experiments were carried out to determine survival of the indicator organisms *E. coli* and enterococci under different salinity, transparency and light conditions, as well as a comparison of two established methods used for the monitoring of bathing waters: the membrane filtration (ISO 9308-1:2014) and the most probable number (ISO 9308-2:2012) method.

To support bathing water monitoring, own sampling data and inactivity rates were used for a model-based approach to predict microbial pollution within the Warnow Estuary following different scenarios as strong rain events or changing wind directions.

Existing risks and problems of the new directive are pointed out and briefly discussed as well as reflected in regards to climate change and future challenges such as higher water temperatures which may profit human-pathogenic microorganisms in this region.

SESSION 4: COASTAL SEAS AND SOCIETY

## BEACH MACRO-LITTER ON SOUTHERN BALTIC BEACHES

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Major objectives are to present a comprehensive dataset on beach macro-litter for parts of the southern Baltic Sea and to discuss if the methodology is fully applicable and a suitable monitoring method in the Baltic. We carried out a regular macro litter beach monitoring (OSPAR methodology, 4 time a year) on 35 beaches along the German and Lithuanian Baltic coast over 2-5 years. Additional experiments addressed the subjectivity of the field surveys and spatio-temporal variability on different scales. We observed no seasonality of the data and a monthly compared to a 3-monthly sampling resulted in 3 times higher annual item numbers. Along the Lithuanian coast, the average number of items per survey varied between 138 and 340 and along the German Baltic coast between 7 and 404, with a median value of 47. All data showed a very high spatio-temporal variability. Using the Matrix Scoring Technique we assessed beach litter sources. With 50% tourism and recreation was the most important source. 3D-transport simulations helped to explain the minor role of shipping as a source and, compared to the North Sea, the low numbers of items on German Baltic beaches. Floating litter had a short duration time in the western Baltic Sea and offshore drift dominated. Further, the common regular beach cleanings reduced the potential for local litter accumulation and translocation. We suggest a monitoring system on 14 Baltic beaches in Germany and 2 in Lithuania and provide cost calculations. The analysis of macro-litter in cormorant nesting material and the search for beached dead animals did not show any result. We can conclude that the macro-litter beach monitoring method is less suitable for Baltic beaches and should only serve as a complementary method in combination with others.

SESSION 4: COASTAL SEAS AND SOCIETY

## SELECTIVE FEEDING OF ARENICOLA MARINA INFLUENCES DISTRIBUTION AND BURIAL OF MICROPLASTIC PARTICLES IN MARINE SEDIMENTS

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Though marine microplastic particles are distributed on a global scale, the mechanisms of microplastic transport and accumulation in the marine environment are not fully understood yet. It is hypothesized that a large proportion of disposed plastic particles will eventually reach the sea floor. However, investigations on the further fate of once deposited particles received relatively little interest so far. This study provides first evidence for the burial of microplastic caused by the feeding activity of the polychaete *Arenicola marina*. Bioturbation rates were assessed in a long-term mesocosm experiment using differently sized particle tracers (luminophores with 130 µm mean diameter, microplastic particles with 500 µm and 1000 µm diameter, respectively). Downward transport rates were similar for all three tracer types despite of their different physical and morphological properties (size, shape, density) and reached up to ~1 mm·d $^{-1}$. Plastic particles were buried to a maximum depth of 20 cm. Most of the microplastic accumulated in sediment depths between 8 and 14 cm and was retained completely within these layers. The depth distribution of these accumulation zones corresponded to the observed depths where feeding activity of *A. marina* occurred. This concentration of particles was most probably due to the selective food ingestion of *A. marina* by discriminating large sediment and plastic particles. In accordance with this finding, a general increase of the medium grain size in all feeding layers could be observed after a time period of 240 days.

These results show that bioturbation processes can considerably affect the distribution of microplastic and underline the role of marine sediments as a potential sink for disposed litter. The permanent burial of plastic particles may reduce their accessibility for some marine organisms, but may also support a long-term conservation of these particles in marine systems.

SESSION 4: COASTAL SEAS AND SOCIETY

## THE FATE AND STABILITY OF BACTERIAL BIOFILMS ON MICROPLASTICS AFTER PASSING THE GUT OF INVERTEBRATES LIVING IN THE BALTIC SEA

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Microplastic (plastic particles ≤ 5 mm) pollution of aquatic systems has become of rising concern in the last decade. They do not only pose a threat to aquatic organisms, but also provide a surface for the colonisation by biofilm-forming microorganisms.

Because of their small size microplastics are susceptible to ingestion by aquatic organisms at the bottom of the food chain, and many aquatic invertebrates host viable potential pathogenic bacteria within their digestive system. We tested in laboratory feeding trials if the bacterial assemblages on polyamide and polystyrene became selectively modified during the passage through the gut of the filter-feeding bivalve *Mytilus edulis*, and the deposit-feeding polychaete *Arenicola marina*, especially with regard to pathogenic bacteria. We used 16S rRNA gene fingerprinting to compare bacterial assemblages before and after gut passage and to analyse the stability of the plastic-associated biofilms after egestion and subsequent incubation in seawater. After gut passage we found that the surrounding environment was an influential factor and served as a source for rapid bacterial recolonisation of the egested material. We could not detect an enrichment of potential pathogens on the polyamide or polystyrene particles after gut passage, but found that the presence of polyamide led to a reduction in species richness after 7 days. When polystyrene was present, the gammaproteobacterium *Amphritea atlantica* was highly enriched in the investigated biofilms, faeces and in the water independently of *A. marina*. The potential of polystyrene to serve as a vector for unusual bacteria to different habitats has therefore to be considered. Thus, in areas with high polystyrene pollution polystyrene might affect bacterial assemblages with yet unknown consequences for the respective ecosystem.

# Poster Session I

June 13, 2017

## P1 - Microbial loop annual variability through the water column gradients in the middle of the Gulf of Finland

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The aim of this study was to estimate the distribution, diversity and annual variability of the auto- and heterotrophic pico- and nanoplanktonic organisms (microalgae, bacteria, flagellates, ciliates) through the physical gradients (T, S, $O_2$, nutrients) in the deepest area (depth 110 m) of the middle GOF. The CDT profiling and samplings (interval 5 or 10 m) for nutrients, phytoplankton and microbiological analyses were performed from March till December 2016. The microorganisms were quantified by flow cytometry (BD Accuri C6) and qualified by epifluorescence microscopy (AO stained probes). Special attention was paid to the trophic relations between bacteria-algae and bacteria-flagellates. The bacterial attachment on algal detritus and the detritus aggregation was evaluated visually by microscope examination.

The expansion of the hypoxic bottom layer strongly affected the environmental conditions and the distribution of the microorganisms. The water column aerobic zone was the largest from May till late July (0-60 m). The surface mixed warm water layer increased from June to August and the thermocline was most sharpened and depressed in July. The halocline was located through the studied period at a depth of 60-80 m.

The abundance and heterogeneity of bacteria and nanoflagellates was influenced in great deal by the development of stratification, including upward and downward movement of the seasonal thermocline. The bacterial number was the highest in July during the filamentous cyanobacteria blooming with maximums just above the thermocline. The main consumers of bacteria from late spring till mid-summer were choanoflagellates (≥ 4 species). The flagellates probably not only control bacterial abundance but also affect the structure of bacterial community via size-selective grazing. The paradise of anaerobic bacteria and also anaerobic ciliates started below the depth of 80 m. The bacterial degradation of cyanobacterial filaments started very fast after the bloom started to decay, which in 2016 happened two times, first in early May and then again in the middle of July. Bacteria were very active to degrade the planktonic organisms. Two tendencies were observed during the bacterial degradation - destruction (mineralization) and progressive formation of aggregates.

## P2 - Decay modeling of E. coli bacteria in a shallow lagoon

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A 3D hydrodynamic model has been applied to the Curonian Lagoon to study the bacterial pollution where E. coli was used as indicator. E. coli are introduced into the water body through the sewage outfalls and the rivers. Through a field survey the E. coli inflows into the Curonian Lagoon were measured and then used as input to the numerical model. More model inputs were obtained through laboratory experiments, where the decay rate of E. coli was measured. The model has been calibrated and validated for the year 2015. After this, the model has then been run for a period of 12 years (from 2004 to 2015) to obtain a robust statistics for the pollution in the lagoon.

In this work attention is paid to the various environmental factors that govern the decay and survival of E. coli in lagoon waters. Especially the light shading by suspended sediments and phytoplankton presence have been taken into account. To this purpose a sediment transport model and an ecological model have been applied together with the hydrodynamic model. Differences with other simulations, where these factors have not been taken into account, have been highlighted.

The work was supported by BONUS project “Baltcoast”.

## P3 - MICRO-PLANKTON BIOMASS AND DIVERSITY IN THE VIETNAMESE UPWELLING AREA DURING SW MONSOON UNDER NORMAL CONDITIONS AND AFTER AN ENSO EVENT

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Investigating micro-plankton biomass and diversity under different climatological conditions is key to the understanding of cascading effects of climate change on nutrient cycles and biological productivity. Here we examined how changes in the nutrient concentrations in the coastal waters off Viet Nam influenced the distribution of micro-plankton communities, their biomass, and diversity during two disparate summers. Our micro-plankton and particulate organic silicate (PSi), carbon (PC), and nitrogen sampling took place in July 2003 during a weak southwest monsoon after an El Niño Southern Oscillation (ENSO) event when upwelling was reduced, and in July 2004 during normal upwelling conditions. Additional nutrient data were sampled in April 2004 and March 2005. Very low silicate ($SiO_4$) concentrations and $SiO_4$:DIN ratios characterized the source water mass for upwelling in July 2004, and dynamic $SiO_4$ to dissolved inorganic nitrogen ratios ($SiO_4$:DIN) mainly below the Redfield-Brzezinski ratio and DIN to phosphate ratios (DIN:$PO_4^{3-}$) below the Redfield ratio were a common feature off Viet Nam. Much higher particle concentrations and PSi/PC ratios during normal upwelling revealed major changes in the micro-plankton community structure among summers. Small dinoflagellates (10-20 µm) prevailed ubiquitously during reduced upwelling. During normal upwelling, the diatom *Rhizosolenia* sp. dominated the cell-carbon biomass in the silicate poor upwelling waters. *Trichodesmium erythraeum* dominated in the Mekong-influenced and nutrient depleted offshore waters, where it co-occurred with *Rhizosolenia* sp. Both species were directly associated with the much higher primary production (PP) and $N_2$ fixation rates that were quantified in earlier studies, as well as with much higher diversities at these offshore sites. Along the coast, the correlation between *Rhizosolenia* sp. and PP rates was less clear and the factors regulating the biomass of *Rhizosolenia* sp. in the upwelling waters are discussed. The very low silicate concentrations in the source water mass for upwelling and the offshore deflection of the Mekong river plume likely triggered the observed ecological differences in the micro-plankton communities off Viet Nam in the normal upwelling season compared to the post ENSO conditions.

## P4 - Natural phytoplankton communities as a source for dissolved organic matter and implications for carbon cycling in Roskilde Fjord, Denmark

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The role of phytoplankton in the dynamics of dissolved organic matter (DOM) in Roskilde Fjord (RF) and the effects of nitrate limitation was studied. To that end, changes in N:P ratios on community structure and consequently in quality and quantity of the DOM release were also addressed using controlled experiments with autumn and spring communities. Water with natural phytoplankton assemblage from RF was incubated under controlled conditions for 18 days, with or without 12 µM nitrate addition. Daily phytoplankton counts were performed by flow cytometry, with parallel chlorophyll a (Chla), humic- and protein-like DOM measurements. Nutrient analysis, dissolved organic carbon and characterization of DOM were performed on five occasions during each experiment, when larger changes in the fluorescence signal of Chla and/or DOM were observed.

In the autumn experiment, the community was initially limited by nitrate, with the highest phytoplankton biomasses observed in the units with nitrate addition. After addition of nitrate, a phytoplankton bloom (determined by a peak in Chla), developed dominated by diatoms and nanoflagellates. Humic- and protein-like DOM decreased during the initial three days in both treatments. This was followed by a slight increase in the humic-like DOM in the nitrate-added units, as opposed to the decrease in the control units, indicating production and consumption, respectively. At the onset, the community exhibited a high degree of heterotrophy, with a ratio of biomass between autotrophs to heterotrophs (mostly ciliates) around 0.3, which increased to 4 over time in both treatments.

In the spring experiment, nitrate was not limiting, and higher N:P ratios were observed, but no drastic differences were found between treatments. Formation of humic- and protein-like DOM during the bloom was observed. The dominating phytoplankton class was cryptophytes. After the bloom, a net decrease in DOM was observed in all experiment units, indicative of consumption and remineralization. Ciliates were also abundant in the beginning of the experiment, yet the biomass ratio of autotrophs to heterotrophs was high (2.5) and decreased (1) over time.

In conclusion, these results suggests that increase in phytoplankton biomass is linked to increases in the DOM pool and that the community composition is likely to influence the type of DOM produced. However, heterotrophs also play an important role in the DOM cycling, and can influence the quality of C exported.

## P5 - Phytoplankton diversity in Danish estuaries

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Phytoplankton analyses have been part of the Danish marine monitoring programs since 1989 and there is a significant amount of data covering a period of environmental changes. In this study, we present the first comprehensive analysis of phytoplankton diversity in Danish fjords and coastal areas. The monitoring methods used vary somewhat during the period due to various monitoring programs and we found significant differences between the consultants that provide data to the program. It has therefore been necessary to harmonize the data. Since both counts and sample volume varies, we have described species diversity with "rarefaction" estimates of counts of 200 and 400 prior to the analysis of relationships between diversity and the environment. The analysis showed significant spatial variation between water and a weak but significant negative relationship to the general level of eutrophication. Despite the fact that there were large differences in the composition of phytoplankton between stations and seasons, the species turnover was remarkably similar between stations over time. The integrity of phytoplankton was studied by comparing the seasonal and the annual variation in species composition and here there were clear patterns as discussed in relation to the hydrography of the stations

## P6 - Seasonal succession of cyanobacteria in the littoral of hypertrophic Curonian Lagoon and its driving forces

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Species diversity per sample varied from 20 to 53, decreasing in autumn. Abundance (in term of biomass) varied over a wide range, but rarely appeared below the level of intense bloom (>10 g $m^{-3}$). The maximal biomass recorded in August-September, minimal – in July.

During the summer period cyanobacteria was constantly dominant group of phytoplankton in terms of number: 80-99 % of the total number. Potentially-toxic species *Aphanizomenon flos-aquae*, *Microcystis aeruginosa*, *Microcystis wesenbergii*, *Planktothrix agardhii* and *Woronichinia compacta* contribute mainly into cyanobacterian total numbers (22 – 99 %, average 71 %). Cyanobacteria also absolutely prevailed every month in term of biomass, except May (22 % only), when diatoms provided the main contribution (55 %). Since June to November the share of cyanobacteria varied from 49 to 94 %.

The seasonal succession of leading dominant cyanobacterian taxa was marked: *Planktothrix agardhii* (May, 16 %) – *Microcystis* spp. (June, 33 %) – *Woronichinia compacta* + *Aphanocapsa planctonica* (July, 19 and 14 %) – *Aphanizomenon flos-aquae* (39 %) + *Microcystis* spp. (37 %) + *P. agardhii* (17 %) (August) – *Aph. flos-aquae* (38 %) + *Microcystis* spp. (27 %) (September). All these species considered as potentially-toxic.

During vegetation season water temperature and the content of nutrients favoured the dominance of cyanobacteria. The water temperature ranged from 7° C to 23° C (average 16° C for period). Water transparency by Secchi depth throughout the whole study period was very low, varying from 0,7 m to 0,05 m (0,4 m average), due to the high productivity of phytoplankton, as well as frequent wind-wave resuspension events. Minimal transparency (August) coincided with intensive cyanobacterial bloom, corresponding to the maximum of phytoplankton biomass and numbers. The stoichiometric ratio $N_{inorg}$:$P_{inorg}$ was maximal in May (27), and very low all other months (3-8), rising to 13-14 in August. It explains well the dominance of diatoms in May but only cyanobacteria – since June. It is known, Cyanophyta dominated when $N_{inorg}$:$P_{inorg}$[lt]25. The minimum level of stoichiometric ratio $N_{inorg}$:$P_{inorg}$ (4-7) favoured to mass development of 3 species belonging to Microcystis genus (33% of total phytoplankton biomass).

## P7 - Cellular mechanisms of phosphorus regulation in filamentous cyanobacteria

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Phosphorus is an essential nutrient and plays a major role in the metabolism of all living organisms. In the marine environment phosphorus is only available in a small amount and it is a limiting factor for the growth of phytoplankton. Filamentous diazotrophic cyanobacteria are also limited by phosphorus because they are able to overcome nitrogen limitation by nitrogen fixation from the air. In addition, diazotrophic cyanobacteria still grow when phosphorus is depleted in the water.

Beside other cyanobacteria species, *Nodularia spumigena* and *Aphanizomenon spec.* occur in the Baltic Sea where they form regularly huge blooms during the summer month. They can accumulate phosphorus intracellularly when it is available and use those storages under phosphorus deficient conditions. The change in the phosphorus content is reflected in the carbon to phosphorus (C:P) ratio. Until now it is still unknown how and where the phosphorus is incorporated or degraded in the cell and which cellular structures are involved. In the present study experiments with a natural community of cyanobacteria on the one hand and with a pure culture of the cyanobacterium *N. spumigena* on the other hand where preformed to find answers to those questions.

For field experiments samples of a natural cyanobacteria community were taken from different locations during the cruise M-117 with the RV Meteor in July and August 2015 in the Baltic Sea. In the laboratory experiments, conducted in 2016, a pure *N. spumigena* culture was used. In all experiments (cruise and lab) phosphorus in form of $PO_4^{3-}$ was added to the P-limited organisms. At defined times subsamples were taken to measure cellular components with a high phosphorus content and elementary functions in the cell metabolism of this communities like polyphosphates, phospholipids and ATP. First results showed that $PO_4^{3-}$ is decreasing in the water immediately after addition while the amount of polyphosphate is increasing. The polyphosphate content of the natural cyanobacteria community decreased again after some days while the ATP concentration increased when $PO_4^{3-}$ was completely depleted in the water.

This indicates that cyanobacteria store phosphorus first as polyphosphates and when conditions getting worst the polyphosphates are degraded and transferred to other cell structures to sustain the metabolism.

## P8 - Baltic filamentous cyanobacteria and picocyanobacteria growth characteristics at different environmental conditions simulated in laboratory experiments

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Over the past few decades, the world's coastal waters have experienced an increase in the number of harmful cyanobacterial and algal bloom events. The blooms of cyanobacteria, which develop each summer in the Baltic Sea, are composed of two different groups: the large, colony-forming filamentous cyanobacteria (e.g. *Nodularia spumigena*, *Aphanizomenon* sp., *Anabaena* sp.) and small-sized picocyanobacteria (mainly *Synechococcus*) (e.g. Śliwińska-Wilczewska et al., 2016). The knowledge of filamentous and picoplanktonic cyanobacteria functioning under various environmental conditions is still insufficient.

In this work, we examine the physiological response of different strains of cyanobacteria to variable environmental conditions within the range characteristic for the Baltic Sea. First, we collected picocyanobacteria (*Synechoccocus* sp. – three strains: red (BA-120), green (BA-124), brown (BA-132)) and filamentous cyanobacteria (*Nodularia spumigena*, *Anabaena* sp., *Aphanizomenon* sp.). The strains were isolated from the coastal zone of the Gulf of Gdansk (southern Baltic Sea) and maintained as unialgal cultures in the Culture Collection of Baltic Algae (CCBA) at the Institute of Oceanography, University of Gdansk, Poland. Next, we set laboratory experiments for each of the species simulating different environmental conditions, water temperature, salinity and light availability. In each case the following conditions were used: salinity of 3, 8, 13 and 18; water temperature of 5, 10, 15, 20 and 25 $^{o}$C; scalar irradiance (Photosynthetically Active Radiation, PAR) at water surface of 10, 100, 190, 280 and 370 µmol photons $m^{-2}$ $s^{-1}$.The conditions were altered in a systematic way in order to carry out 100 environmental scenarios for each of the phytoplankton species and to observe their responses in terms of the maximum growth rate, number of cells, pigments content, chlorophyll a fluorescence, photosynthetic efficiency and pH changes in inhabited medium. The data have been analyzed to derive the best statistical relationships that can be used in the numerical models simulating phytoplankton cycles in the Baltic Sea.

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## P9 - Is there a way back? Possible development of coastal water bodies during re-mesotrophication

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Anthropogenically induced eutrophication is for decades one major threat for coastal waters of the southern Baltic Sea and worldwide. Therefore, the EU-water framework directive aims at nutrient decreases. However, phytoplankton biomass did not respond on the nutrient reduction with less biomass. This reaction is surprising, because most point sources in e.g. German coastal waters were already reduced between 60 – 90% for nitrogen (N) and phosphorus (P). The underlying mechanisms are not well understood.

Therefore, growth and fertilisation experiments were conducted, as well as long-term data sets analysed in coastal water bodies of the southern Baltic Sea. This talk addresses different environmental factors, like non-point sources, species composition, and nutrient uptake behaviour that can have an impact on system recovery.

There was an imbalance of P concentrations and chlorophyll a, which depended on species composition. Chlorophyll a-concentrations in cyanobacteria-dominated inner coastal water bodies were sometimes 5-times higher compared to outer coastal water bodies with similar P concentrations. Inner coastal water bodies are often dominated by cyanobacteria, whereas the outer water bodies are dominated by diatoms and dinoflagellates. Cyanobacteria typically grow at low and even limited P concentrations, thereby forming blooms or continuously high biomass and, thus, increase turbidity of the system. An adaption of phytoplankton to the lowered nutrient inputs can explain the missing ecosystems reaction. Further, there were stochastic and permanent nutrient releases detected from adjacent land, which supported phytoplankton growth and therefore minimized the impact of reduced point sources.

These effects can influence ecosystem recovery and shall be included in management efforts. The following question arises: What happens when P concentrations are reduced further in the catchment area of inner coastal waters? It is possible that the most adapted phytoplankton species to low P levels, like cyanobacteria, become more and more dominating. A stronger reduction of N could also lead to higher abundances of cyanobacteria, particularly those capable of N-fixation, with their disadvantages of toxin production and increasing turbidity. It still remains debatable if the "good ecological state" is achievable for all coastal water bodies of the southern Baltic Sea.

## P10 - The impact of food web structures on re-mesotrophication in coastal water bodies

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All Baltic coastal water bodies are influenced by elevated primary production, due to decade long anthropogenic nutrient inputs. Not only the primary production, but also the depended consumers changed during the time course. There is still low improvement in water quality regarding Chlorophyll a and phytoplankton biovolume, even though the nutrient loads were already reduced in most German waters. Interesting enough other water bodies in the Baltic Sea and worldwide show less turbid water bodies at the same nutrient concentrations compared to some German ones. One cause for that can be the phytoplankton species composition. Dominating phytoplankton species in some German coastal water bodies are cyanobacteria, which elevate turbidity overproportional and may be an unfavourable food source for zooplankton.

This work investigated the influence of altered food webs in order to initiate re-mesotrophication. It was assumed that mesocosms with zooplankton domination would show lowered phytoplankton biomass during the period of two summers. Other mesocosms were controlled by zooplanktivorous fish (*Pomatoschistus* sp.). Surprisingly mesocosms with fish control had during two consecutive year's lower phytoplankton biomass than zooplankton dominated mesocosms and the origin system. Further, there was no nutrient increase in fish controlled mesocosms. It is possible that the control of zooplankton disturbed the nutrient recycling in the water column. Another cause can be the impact of gammarids on food webs and nutrient recycling. Fish controlled mesocosms had no gammarids at all, whereas zooplankton-dominated mesocosms had also high gammarid biomass (~9g $m^{-2}$ fresh mass). Those gammarids possibly controlled submerged macrophytes and epiphytes by grazing and therefore increased nutrient recycling.

This study suggests, that it is possible to re-mesotrophicate coastal water bodies with biomanipulation. Altered food webs can be a management tool to support the efforts of the EU-Water framework directive in order to reach the "good ecological state". However, it remains unknown how this biomanipulation can work on a whole system, what other resilience factors can occur and which effect invasive species have during the time of manipulation.

## P11 - Species composition, distribution and abundance of zooplankton (holo- and meroplankton) in the five deep basins of the Baltic Sea in June 2015

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The life and functioning of the Baltic zooplankton in a large extent depend on hydrological processes such as inflows from the North Sea and from the rivers of adjacent lands. Due to their relatively low tolerance to changes in environmental conditions, many zooplankton species are considered good indicators on various water masses. The presented studies were performed on samples collected in the Baltic Sea deep regions in June 2015, six months after the major Baltic inflow in 2014. We recorded the quantitative and qualitative composition of zooplankton community in the Arkona and Bornholm Deeps, in the Slupsk Furrow, and in the Gotland and Gdańsk Deeps. Forty-one species or genera of holo- and meroplankton (including early developmental stages of fish) were noted. The total zooplankton abundance ranged from 28 000 ind./ $m^3$ in the eastern part of the Arkona Deep to more than 100 000 ind./$m^3$ in the western part of the Arkona Deep and in the Gdańsk Deep. The species composition and distribution were influenced by the salinity gradient. On the one hand, we observed constant components of the Baltic zooplankton: marine species (e.g. *Pseudocalanus* spp., *Oithona similis*, *Parasagitta elegans baltica*, eggs and larvae of *Sprattus sprattus*) and brackish species (e.g. *Eubosmina* spp., *Eurytemora affinis*, *Acartia tonsa*). On the other hand, Atlantic species, e.g. *Calanus* sp., *Sagitta setosa*, that occur in the southern Baltic periodically, were recorded. The biological indicators of the salt water inflow were observed far eastward to the Gdańsk Deep.

## P12 - Distribution, diversity and structure of sublittoral hard-bottom communities along the physicochemical gradient of the Baltic Sea

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Sublittoral benthic habitats in the Baltic Sea are generally characterized by soft sediments. In this 'sea of mud and sand', stones, rocks and boulders represent island-like special habitats. Their hard surfaces are rare substratum, colonized by a variety of epibenthic species not found in the surrounding endofauna-dominated soft sediments. Sublittoral hard bottom habitats in the Baltic Sea arise patchy, vary in spatial extent and height and are sometimes covered by fine sediments. While relatively well-known in shallow water, rocky reefs in the circalittoral are very hard to detect and access. To our knowledge, the present study is the first to extensively describe distribution, diversity and community structure of epibenthic assemblages on deep hard substrata along the physicochemical gradient of the German Baltic Sea. Offshore hard-bottom habitats were investigated from Kiel Bight to Arkona Basin using image analysis. Benthic imagery was recorded using a downward-facing towed camera platform. More than 1000 images were analysed regarding macroscopic species richness as well as the community structure in terms of visual estimate of percentage cover of sessile invertebrates and macroalgae. Biological data for each image was linked to available physical and chemical environmental parameters and distinct epibenthic communities were identified. In general, hard substrata at the euphotic depth showed the highest species richness but lowest overall cover. Along the salinity gradient from high (25 psu) to low (7 psu) species richness was highest at western reefs and lowest in the Arkona Basin. Percentage cover was generally higher in the photic zone, on large hard surfaces as well as on surfaces in proximity to other hard-bottom communities.

## P13 - Quantification of the impact of benthos on the coastal filter using two mechanistic models in the Roskilde Fjord

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The coastal zones work as a "coastal filter" in which nutrients from land undergoes transformation and removal on its path to the open sea. The importance of benthic fauna for the biogeochemical processes, and ultimately the costal nutrient filter, were investigated in the Roskilde Fjord, Denmark. The ecological conditions were simulated by two mechanistic models; 1) the Swedish Coastal zone Model, which is a multi-basin model coupled to the Swedish Coastal and Ocean Biogeochemical model and 2) the FlexSem, which is a high-resolution combined box-model and 3-D model approach with unstructured mesh. Feeding, irrigation and particle mixing activities by benthic fauna were incorporated in the models and sensitivity analysis was used to assess the impact. The model results revealed that the activity performed by benthic fauna affected the biogeochemical processes (nutrient fluxes, denitrification) and pools (Chl a, sediment inventory of N and P and the pelagic pools of organic and inorganic nutrients) at least a few years until a new balance has been reached. The increased activity also resulted in an increased retention efficiency of N, whereas the retention efficiency of P decreased in the Roskilde Fjord. Apparently, however, the effect of benthic animals seems to diminish over longer (several years) time scales. The work is part of the BONUS COCOA (Nutrient COcktails in COAstal zones of the Baltic Sea) project.

## P14 - Details of particle reworking by macrozoobenthos on large spatial scales in the southwestern Baltic Sea

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Particle reworking by benthic macrofauna constitutes one of the bioturbation processes affecting benthic - pelagic exchange and is important for the understanding and assessment of sediment functions in aquatic ecosystems. We present data on the relation between benthic fauna and rates of bioturbation as assessed by measuring chlorophyll in the sediment and modeling these tracer profiles (Soetaert et al. 1996). The data were obtained at spatial scales of a meter to several hundred meters at six stations between Bay of Lübeck and Pomeranian Bay, Southwestern Baltic, an area with different sediment types and pronounced salinity changes from west to east. At each station, we surveyed local and non-local sediment mixing and along with the depth distribution of benthic macrofauna investigating up to 24 sediment cores.

Comparison of the information from individual cores, four cores within one multiple corer, 24 cores on the station scale and among stations themselves, revealed the following. Non-local mixing correlated significantly with abundance and biomass of the fauna (1959 – 112527 ind $m^{-2}$; 0.4 – 357 g dry weight $m^{-2}$). We identified main bioturbating organisms such as e.g. *Diastylis rathkei*, important for local sediment mixing, and *Arctica islandica*, *Limecola balthica*, *Nephtys hombergii* and *Scoloplos armiger* for non-local transports.

Spatial variability of bioturbation modes and bioturbation intensities was high and variability was similar between closely located sampling sites as well as across the southern Baltic Sea. Seasonally bioturbation varied just as much. Local mixing rates varied by a factor of 20 and non-local transport by a factor 6. Non-local transport accounted for 33 to 50% of the investigated area in the west and for 70 to 100% in the east. Mixing depths reached 7.1 ± 1.6 cm at stations in the west and 5.2 ± 1.7 cm in the east. The conspicuous difference in east – west distribution of local and non-local mixing associated with fauna, seemingly following salinity, cannot be explained.

## P15 - High biological particle and solute transport observed in the Pomeranian Bay sediments

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In the relatively shallow Pomeranian Bay (Southern Baltic), sandy sediments with abundant benthic macrofauna prevail (dominant species: *Marenzelleria* sp, *Mya aenaria*, *Hediste diversicolor*, *Limecola balthica*). In order to assess exchange of material between overlying water and sediment, we investigated the magnitude of particle reworking and solute transport in this sediment by benthic fauna using chlorophyll a and luminophores, as well as bromide ions, as particle and solute tracers, respectively. Using models to interpret tracer distributions in the sediment, we can compare the magnitudes of small scale/frequent (diffusion analogy) versus relatively large-scale transport modes (non-local) derived from both the short-lived attractive tracer chlorophyll a and the inert luminophore particle tracer as well as the solute tracer bromide.
We find that rates of particle reworking from a recent study are high and comparable to those from investigations 20 years ago, indicating consistency in the underlying processes. Solute and particle transport was higher than in most previous literature reports (surface a: 140 $yr^{-1}$; $D_b$: 1.07 ± 0.23 $cm^2\ yr^{-1}$). Both tracer experiments in the laboratory (bromide, luminophores), which exclusively depict animal activity, clearly show significant biological transport to ~10 cm sediment depth within 3 and 21 days, respectively. Chlorophyll a - depth distributions potentially include particle transport processes effective in situ, such as hydrodynamic sediment resuspension or benthic fishing activity. This tracer, too, indicates mixing within the uppermost 10 cm of the sediment. It reassures our conclusion that benthic fauna is largely responsible for particle reworking on short time scales of ~2-3 months in Pomeranian Bay.

## P16 - Effects of salinity on burrowing behavior and bioenergetics of the soft shell clam Mya arenaria

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Soft bottom habitats are predominant in the Baltic Sea, and bioturbators play a key role in the ecosystem functioning of the shallow Baltic water. Bioturbation facilitates the exchange of micro-organisms, nutrient and particles by increasing the sediment-water interface. The soft shell calm *Mya arenaria* is an important bioturbatorcommonly found in the Baltic Sea. *M. arenaria* habitats are strongly impacted by salinity fluctuations, especially in the South-western Baltic Sea. Furthermore, in shallow water habitats (such as off Hüttelmoor) the salinity fluctuations may be exacerbated by the terrestrial and/or submarine freshwater influx. Low and fluctuating salinities can negatively impact physiology and therefore the burrowing activities of soft bottom bioturbators such as *M.arenaria*. In this study, *M. arenaria* was acclimatedat normal (15 psu), low (5 psu) or fluctuating salinity (with daily shifts between 5 and 15 psu). The burrowing speed of clams and the number of times they can re-burrow after disturbance was determined. Tissue samples were collected to assess whether the salinity stress and/or the repeated burrowing cause bioenergetic stress in clams. The burrowing activity of *Mya arenaria* was strongly size dependent with larger clams being less able to re-burrow after the disturbance. The burrowing speed was not affected by acclimation to the constant low salinity (5 psu) but low salinity-acclimated clams were exhausted after fewer attempts to re-burrow than their control counterparts at 15 psu. We are currently investigating the effects of fluctuating salinity (5-15 psu) on burrowing behavior of clams and determining the energy status parameters in their tissues under different salinity and exercise regimes. These studies will provide insight into the potential effects of salinity on bioturbation potential of clams in the Baltic shallow waters and allow determining whether changes in the burrowing activity are associated with the energy deficiency of stressed clams. This research is supported by the Research Training Group 'Baltic TRANSCOAST' funded by Deutsche Forschungsgemeinschaft (DFG).

## P17 - Sediment and fauna living in it – Importance of functional diversity - Example from Gulf of Gdańsk

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Coastal biotopes of the Gulf of Gdańsk when compared to deeper zone of basin, are relatively diverse in terms of habitats, benthic fauna communities and thereby functions. To answer a question how different communities function and how functioning of macrozoobenthos is important for biogeochemistry at the water-sediment interface we have examined structural and functional diversity of macrozoobenthos in the gulf of Gdańsk. Our results demonstrate functional group classification of benthic invertebrates in this area accordance with their behaviour, physiology and biochemistry. On a basis of Biological Traits Analysis (BTA) and Functional Diversity (FD) index we compared the number of functions realized by fauna, how many of functions are rare or even very rare, and if functional diversity differs not only in case of quantity. To assess influence of fauna activity on sediments we have studied vertical distribution of benthic fauna and pore waters nutrient concentrations and calculated Bioturbation Potential Index (BPI).

In the Gulf of Gdańsk benthic fauna inhabiting soft bottom of the depth range from 2 to 50 m shows high similarity in terms of biomass structure and biological traits. But quantitative services for ecosystem functioning differ mainly due to difference in biomass and burial depth of macrofauna in different habitats. The deepest area of the Gulf of Gdańsk (below 68 m) is inhabited only by bentho-pelagic species living periodically in first cm of the sediment and all functions of benthic fauna are eliminated sharply.

## P18 - On the necessity of simplification when bioirrigation is treated as an ecosystem function

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Bioirrigation – the animal induced exchange of solutes between porewater and overlying water is a key process to evaluate the ecological function of sediments. As such it has pronounced implications for biogeochemical processes such as nutrient cycling and organic matter regeneration at the sediment water interface. Therefore, if the ecological function of sediments is of importance to society, it is unavoidable to understand how a changing environment will affect the irrigation activity of macrofauna. A shift in species composition e.g. from deep burrowing species to smaller, more opportunistic and shallow burrowing species will have large effects on ecosystem function. For a better understanding of transport and exchange processes between water and sediments in the German coastal sea the project SECOS Synthese addresses the assessment of these sedimentary ecosystem services that e.g. may be implemented into a sustainable and integrated coastal zone management. In this context of a better applicability of complex scientific data on pore water exchange and related effects for e.g. modelling purposes, a uniform scoring system on bioirrigation may be useful to compare community effects and describe seasonal or interannual variability in functioning of marine sediments.

To assess the potential for bioirrigation with an index, a theoretical approach founded on biological traits that represent behavior and ecological functionality of generic key species is used. In analogy to the particle related community bioturbation potential of Solan et al. (2004), context dependent life modes that affect the purposes of bioirrigation (feeding type, morphology of burrows, and burrowing depth) are combined with data on abundance and biomass of the respective species and are summed up to a community bioirrigation potential.

The condensation of scientific data to an index is inevitably accompanied with simplification. Therefore, a balance is needed between applicability in terms of abstraction and extrapolation on the one hand, and the precise mechanistic description of processes or activities leading to these processes (species specific investigations).

The presentation focuses on considerations of ecological traits relevant for bioirrigation purposes and their classification into a bioirrigation index. In this context, benefit and loss due to simplification and abstraction are discussed.

## P19 - Model-based assessment of the impact of seasonal hypoxia on macrobenthos and sedimentary organic carbon in shallow coastal areas of the Baltic Sea

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Eutrophication-induced hypoxia has become a major environmental problem jeopardizing the ecosystem of the Baltic Sea since 1950s. Evidence from field surveys indicates that across gradients from normoxic to anoxic conditions the diversity and abundance of benthic fauna are rapidly reduced. Dead zones in the off-shore deep waters of the Baltic Sea caused by persistent hypoxia have been long recognized. Until recent decades, seasonal hypoxia in shallower, near-shore areas has also become more prominent, which arouses growing concern for the associated benthic ecosystem.

Benthic macrofauna play an important role in the early diagenesis of organic carbon and nutrient cycling at the sediment-water interface through bioturbation. Bioturbation is the major process for vertical dilution of solid matter in sediments. It manipulates not only the redox reactions in the seafloor surface sediments but also the fluxes of oxygen, carbon and mineral nutrients between the sediment and overlying water. Thus, hypoxia affects not only the ecosystem but also the regional biogeochemical cycles.

In this study we present a model-based assessment of the impact of seasonal hypoxia on macrobenthos and organic carbon preservation in shallow coastal areas (water depth < 60 m) of the Baltic Sea. A mechanistic model is developed to quantify the mutual dependency between sedimentary total organic carbon (TOC) and benthic macrofauna. The model describes (i) the vertical distribution of infaunal biomass resulting from a trade-off between nutritional benefit and the costs of burial, with mortality caused by hypoxia taken into account, and (ii) the variable distribution of TOC being in turn shaped by bioturbation of local macrobenthos. In contrast to state-of-the-art diagenetic models, our approach resolves variations of bioturbation both in space and time, which depend on the macrobenthic community structure and biomass. The macrobenthos-TOC model is coupled to a 3D hydrodynamic-ecological model (ECOSMO) to estimate the temporal variation of macrobenthic biomass and TOC in shallow coastal seafloors which are subject to seasonal hypoxia between 2000 and 2015. Results indicate that the seasonal and decadal variation of macrobenthic biomass is on the order of magnitude of $10^3$ and $10^4$ tons, respectively. Its consequent impact on the sedimentary organic carbon budget is also quantified.

## P20 - Permeability effects in a coastal sand

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A typical coastal sea floor in the Southern Baltic Sea is covered with sands and inhabited by macrofauna such as *Mya arenaria* and *Arenicola marina*. Our aim is to quantify regulating factors for sea floor metabolism, specifically total oxygen uptake, as they constitute high influence on metabolic oxygen consumption by the seafloor in different ways. Sandy sediments themselves and their composition interact with pressure gradients affecting the distribution of oxygen in the sediment. A prerequisite for increased input of water and oxygen into the sediment (by organisms or physical processes) is the permeability of sediments. Factors like ripples and wave activity influence pressure gradients and advective processes. Depending on sediment composition and pressure gradients, pore space is flushed with oxygenated sea water increasing the availability of oxygen below the sediment surface and increasing availability of oxygen for bacterial processes. In addition to permeability, organic content and temperature influence sediment metabolism as well. Analysis of the sediment composition in our study area (Research Training Group "Baltic TRANSCOAST") shows the area to be permeable and thus susceptible to advective processes. To estimate the influence of pressure gradients on benthic exchange we use calibrated benthic chambers inducing advective pore water flow. First results indicate an increase of total oxygen uptake when advective flow is present. Within sediments, animals like *M. arenaria* and *A. marina* influence oxygen consumption. The influence of *M arenaria* is mainly based on the organism's respiration and the influence on oxygenation of the sediment is likely lower than that by *A. marina*. *A. marina* has a strong influence on the oxygen consumption of the sediments. In addition to respiration, pumping of oxygenated water through burrow and sediment oxygenates a larger volume of sediment, increasing availability of oxygen in the system. Both organisms occur in different numbers, thus we will quantify their influence for different abundances. On this poster we will estimate the orders of magnitude for the different factors through our own experimental results, previous experiments and literature values.

## P21 - Simulating the seasonal growth of Fucus vesiculosus in the Kiel Outdoor Benthocosms with a numerical boxmodel

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Warming and acidification of the oceans as a consequence of increasing $CO_2$-concentrations occur at large scales. Based on mesocosm experiments where we studied the single and combined impact of elevated seawater temperature and $pCO_2$ (1100 ppm) on the brown alga *Fucus vesiculosus* associated with its natural community (epiphytes and mesograzers) in all seasons (from April 2013 to April 2014), we developed a numerical boxmodel simulating the seasonal growth of *F. vesiculosus* in the Kiel Outdoor Benthocosms (KOBs). We consider nitrogen and carbon cycling in the KOBs and implemented relevant physiological and ecological processes. The model is forced with atmospheric and hydrographic data, which enables us to run model experiments under present and global change scenarios (e.g. warming, ocean acidification). We explicitly model DIN and DIC concentration in the water and *Fucus* growth as carbon and nitrogen increase. For instance, the following processes are implemented: (1) Storage of carbon and nitrogen assimilates, leading to a temporal decoupling of assimilation and growth. (2) Shading effects of epiphytes. (3) Grazing by *Idotea*, *Gammarus* and *Littorina* on both *Fucus* and epiphytes, but with species-specific rates and preferences. At present, the model is an exploratory tool to investigate whether all significant processes influencing the seasonal growth of *F. vesiculosus* are considered. We ultimately aim to develop a predictive model, which can be coupled to a 3D- high resolution western Baltic Sea numerical model. This will allow to observe the consequences of global change for the wellbeing and distribution of *F. vesiculosus* in the western Baltic Sea. Understanding responses of macroalgae and of the associated community is important because changing global temperatures and elevated $CO_2$ may affect the ecological role of *F. vesiculosus* as primary producer, carbon sink, water purifier, and ecosystem engineer in the coastal ecosystem of the Baltic Sea.

## P22 - Seagrass (Zostera muelleri) vulnerability and resilience: The threat of sediment burial

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Seagrasses are important, highly productive primary producers that provide a range of ecosystem services. Globally, increasing anthropogenic pressure in coastal regions has resulted in the reduced distribution and abundance of seagrasses. *Zostera muelleri* is recognised as a declining species in New Zealand. New Zealand's estuaries and coastal waterways suffer from sedimentation events, which have the potential to impact seagrass via smothering and light attenuation. This study examined the response of *Z. muelleri* to both one-off and repeated sediment burial events along an environmental gradient in situ.

In situ field experiments were performed at three sites in Tauranga Harbour, New Zealand, over a one-year period, in order to assess the spatial variation in responses to burial events and the subsequent recovery processes. Furthermore, particular focus was placed on the response patterns of the potentially sensitive stress indicator; Non-Structural Carbohydrate (NSC). A standard protocol was developed to ensure accurate and comparable NSC estimation in seagrass research, ultimately aimed at aiding the ability to generate vast overviews of seagrass ecosystem health across temporal and spatial boundaries. It is anticipated that the outcomes of this study will increase our knowledge of the vulnerability of seagrasses to burial events and their resilience to differing burial regimes. This information can then be used to aid in identifying areas that are at risk of losing seagrass due to sedimentation events and areas suitable for considering seagrass restoration attempts.

## P23 - Relating species biodiversity patterns to coastal habitat characteristics

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Coastal ecosystems are productive areas with a high habitat diversity hosting rich faunal communities. The characteristics of these species assemblages such as composition, abundance and their functional diversity, i.e. the composition and richness of different biological traits, provide information on the functioning and services of an ecosystem.

An extensive field study was conducted in order to get a better understanding of the connection between such organism assemblages and their environments i.e. their local habitats. Fish and benthic invertebrates were quantitatively sampled in four habitat types, namely bare sand, hard bottom, Zostera-, and Fucus-habitats around the Åland archipelago (Northern Baltic Sea). Species were identified and relevant biological traits were measured and assigned in order to examine how the habitats differ concerning species abundance, composition and dominance, and also to analyse whether the biological traits of species can be related to the specific habitat characteristics. Results indicate that habitats show a distinct pattern in fish and invertebrate biodiversity whereas vegetated habitats host higher abundances of mobile invertebrate species. The coastal ecosystem of the Åland archipelago has shown significant rates of change over recent decades, and further climate change-related alterations are expected for the future. Therefore, understanding the link between organisms and their environment is crucial for predicting consequences for the functioning of coastal ecosystems, especially within the context of climate change scenarios.

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## P24 - HIGH MAINTENANCE RESPIRATION MAY EXPLAIN SIGNIFICANT BASAL RESPIRATION IN A SUBARCTIC ESTUARY

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Oxygen levels continue to be an issue in the Baltic Sea and understanding respiration in the ecosystem is important to prevent hypoxic zone formation, and in addition to support proper strategies mitigating the $CO_2$ accumulation in the atmosphere. A majority of studies investigating oxygen consumption use seasons where production is at its peak. Here we aim to determine the basal level of ecosystem respiration during winter, using three-year-data in a sub-arctic estuary situated in the Bothnian Sea. The importance of maintenance respiration by the main consumers of oxygen, heterotrophic bacteria, is analysed as an explanatory process.

Carbon fixation in the estuary was low and accounted for ~20% of the yearly pelagic whole water respiration while accounting for 6% during winter time. Respiration during the lowest productive season was 45% (~40 mmol $m^{-2}$ $d^{-1}$) of the highest productive season respiration (~90 mmol $m^{-2}$ $d^{-1}$).

During low production conditions, the majority of bacterial respiration was due to maintenance respiration, occurring at a similar magnitude as when the respiration was mainly associated with growth. When respiration was associated with growth over 50 % of the bacterial specific respiration was due to maintenance respiration

The studied estuary was highly net-heterotrophic with a significant basal level of respiration, where allochthonous carbon was the main source of substrate. Furthermore, the impact of maintenance respiration on a larger scale may be even greater than previously thought, especially during low productivity as nutrient shortage elevated bacterial energy needs. One implication of these results is that nutrient reductions by water management may not necessarily result in reduced oxygen consumption in the estuary, but rather a shift from growth to maintenance driven respiration.

## P25 - Reconstruction of food web trophic positions and levels in the river-sea transitional zone of the Gulf of Riga using stable C and N isotope-ratio mass spectrometry

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Changes in stable isotope ratios (δ) are often used to determine energy flows, food web structures and pollutant biomagnification in both terrestrial and marine ecosystems. An increase in heavier isotopes can be observed towards top predators of food chains allowing time-integrated measurements of consumer diets as C isotopes allow discrimination between pelagic, littoral and benthic food sources but N isotopes can be used to calculate trophic positions (TPs) of members of food chains and webs.

The objectives of this study are to determine the seasonal and annual changes in stable C and N isotope ratios due to wide variability of various C and N sources throughout the year as well as calculate current TPs of heterotrophs in transitional estuarine waters of the Gulf of Riga thereby establishing an isotopic baseline of local organisms for future changes in food web structure.

115 samples of suspended material, sediments, mesozooplankton, benthic invertebrates and fish were collected during 6 cruises from May 2015 to November 2016. Dry homogenized samples were used in analyzes with a continuous flow isotope-ratio mass spectrometer for C and N isotope ratios. In addition, 2 mg sub-samples were analyzed with a combustion element analyzer to establish C:N ratio.

Distinct seasonal changes were observed in collected suspended material samples due to seasonal taxonomic changes in plankton and different terrestrial inputs. Preliminary analysis of $\delta^{15}N$ values in littoral and benthic predators and benthic omnivores' show that these values are in accordance with the results of previous studies, e.g., observed increase between trophic levels is 2 – 4 ‰. However, several discrepancies can be found in $\delta^{13}C$ values as many species don't follow the pattern of increase of heavier isotopes at higher trophic levels.

Main planktonic primary producers that affect δ values are dinoflagellates in spring and cyanobacteria in summer with their different fixation and discrimination of stable isotopes. Considering the feeding habits of rapid growth secondary producers and consumers, aforementioned seasonal changes influence their isotopic compositions as well.

This study was funded and is a part of State research programme 2014 – 2017 "The value and dynamic of Latvia's ecosystems under changing climate - EVIDEnT".

## P26 - Polyphosphates maintain chemotactic movement of Sulfurimonas gotlandica GD1T at substrate-limited conditions in Baltic pelagic redoxclines

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The central Baltic Sea is characterized by a practically permanent vertical transition zone between oxidized and reduced water bodies, the so called redox zone. Characteristically, high dark $CO_2$ fixation rates have been determined shortly below the chemocline, where the first appearance of sulfide occurs. There; dark $CO_2$ fixation is mainly driven by the chemolithoautotrophic and denitrifying Sulfurimonas GD17 cluster of the Epsilonproteobacteria, a key group for important transformations within the C-, N-, S-cycles of the accordant ecosystem. However, an overlap of nitrate and reduced sulfur is not necessarily present in redox zones of the Baltic Sea. This raised the question how these chemolithoautotrophic bacteria can survive in this system and how they gain access to the essential electron donor and acceptor for chemosynthesis.

We used *Sulfurimonas gotlandica* GD1$^T$, a model organism of the GD17 cluster isolated from a Baltic Sea redox zone, to answer this question. The hypothesis set by previous studies presumed that this species might be able to store catabolic components to survive times of nutrient starvation. Despite the early postulation of this theory, very few attempts in elucidating this question were made. Current study was undertaken to investigate presence of such substrate inclusions by using REM-EDX analyses on single cells of GD1$^T$ grown under different conditions and collected from environmental samples, which revealed an accumulation of substrates inside the cells. Compared to other chemolithoautotrophic bacteria GD1$^T$ does not store catabolites, like nitrate or sulfur, but phosphor in form of high-energy containing polyphosphate. Genetic analysis together with a new designed motility assay demonstrated that polyphosphate could be used as an energy reservoir to maintain chemotactic cell movement under nutrient-limited conditions. This energy storage could represent an important strategy for chemolithoautotrophic prokaryotes occupying eutrophic redox zones.

## P27 - In situ measurements record highly variable hydrogen sulphide concentrations in Gulf of Finland near-bottom water

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We present in situ measurement results on the vertical and temporal variability of $H_2S$ and $O_2$ concentrations, temperature and pH in week, hour and minute scales in the western Gulf of Finland in 2013–2014. The main focus is on the 60–100 m water depth range that contained 0.4–40 µM $O_2$ and 6.3–22.6 µM $H_2S$.

At stations where free gas was detected in the underlying sediments by acoustic surveys, the near-bottom $H_2S$ layer contained a more complex structure compared to stations devoid of gas. Local minima and maxima in pH often occurred near the upper $H_2S$ boundary (redox transition zone).

Except for the homogeneous, tranquil zone above the seafloor at some stations, substantial rapid changes in hydrographic conditions were common. Typically, a layer of marked temporal T variability was present atop or within the topmost $H_2S$ layers. The largest temporal changes were -0.44 °C / -10.8 µM $H_2S$ / +26 µM $O_2$ / -0.12 pH units within a week (at seafloor level), +0.18 °C / +7.9 µM $H_2S$ between casts (one hour) and +0.03 °C / -2.5 µM $H_2S$ per minute (high resolution logging). Abrupt changes in $H_2S$ concentration were recorded at two stations with free-gas-containing sediments. The T and $H_2S$-concentration changes were synchronous at several layers, reflecting the water movement. Fast Fourier transform analysis suggested contribution of low-frequency (<20 mHz) components to the $H_2S$ concentration changes.

We conclude that rapid changes occur in hydrographic conditions in near-bottom $H_2S$ layer in the northern Baltic Sea, especially at locations where free gas is present in the sediments.

## P28 - Seal-fisheries interactions in the Baltic Proper

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The rapid recovery in the Baltic seal populations since the 1980s, but particularly during the 2000s, has raised concerns in the fisheries sector, affecting stakeholders on multiple levels, from fishers to decision-makers and conservationists. The grey seal in the Baltic prey on some of the commercially most important fish species, locally conflicting with some fishing activities. As a result, the seal hunting was reinstated in 1997 in the region. However, we do not yet know to what extent the seals are competing with fisheries for resources in the whole Baltic Sea. Current population growth estimations, together with new data on the diet of grey seals in the region, have been integrated in an updated Ecopath with Ecosim model of the Baltic Proper. Moreover, the reduction of the winter ice extent in the Baltic Sea, which has been shown to have a negative effect on the breeding success of the grey seal, is being modelled under different future possible climate scenarios to reveal the impact of climate change in the seal populations. The biomass flows to the seals, as well as the extent in which the predator-fishery interactions modulate each other, are being investigated in order to evaluate the ecological significance of the seal-fisheries interactions. The outcomes of the model are expected to help provide recommendation to the fisheries management from an ecosystem approach.

## P29 - Pathological findings in intestines of grey seals (Halichoerus grypus) and harbour seals (Phoca vitulina) from the North and Baltic Sea associated with acanthocephalosis

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Grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina*) are the most common seal species in the North and Baltic Seas and final hosts of various parasites. Acanthocephalan infections are increasingly observed since the sample period started in 1998. In harbour seals the small intestine is infected with *Corynosoma strumosum* and/or *Corynosoma magdaleni*. Baltic grey seals often display severe *Corynosoma semerme* infections in caecum and colon associated with ulcers, thickened intestinal walls and inflammations as part of the Baltic Seal Disease Complex (BSDC), which includes no longer sighted lesions in the reproductive tract and endocrine system. Pathogenesis and correlation of acanthocephalosis with the intestinal alterations are unknown yet.

This study focuses on lesion differences and parasitic distribution in each seal species. Samples of infected grey seal (n=67) and harbour seal (n=257) intestines of all age groups and sexes, collected in Estonia and by the German and Polish monitoring system from 1998-2016, were taken for histopathology. Examined harbour seals mainly originated from the North Sea (n=246), grey seals from the Baltic Sea (n=55). Acanthocephalan intestinal distribution was recorded. The harbour seal sex ratio was almost equal (131 females/126 males), while male grey seals outnumbered the females (46 males/21 females).

Both species´ small intestines were mildly or moderately infected. Grey seals significantly showed more moderate and severe infections of the colon (n=18; n=13) than harbour seals (n=7; n=4). Current- (n=40) and previous-year born (n=39) harbour seals displayed a mural granulomatous eosinophilic, lymphoplasmacellular or catarrhalic enteritis. Especially infected perennial Baltic grey seals (n=17), but also younger animals (n=8) showed a chronic erosive/ulcerative, eosinophilic or lymphoplasmacellular colitis, tunica muscularis hypertrophy (n=10) and mural fibrosis (n=3).

*Corynosoma* spp. infections were not fatal in the sampled cases, but may affect the seals´ health negatively. Hypothetically, they induce the primary lesion, promoted by a pollutant-impaired immune system, particularly in the Baltic Sea. Not all infected seals displayed intestinal inflammations, but the lesions´ severity in Baltic grey seals stands out notably. This study´s findings indicate still prevailing symptoms of the BSDC and that acanthocephalans may be suitable seal health indicators, especially regarding the colon as target organ for Baltic grey seals.

## P30 - Spatial information in Maritime Spatial Planning across borders: Conciliating human activities and environmental values

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Maritime Spatial Planning (MSP) is an effective tool for building strategies and guiding actions that aim at conciliating human activities and environmental values in the spirit of the EU Marine Strategy Framework Directive. Cross-border collaboration – co-operation across national boundaries and between social, economic and environmental sectors – in MSP enables the examination of marine processes and human activities at the international scale. Moreover, MSP is a tool for informing and involving societies in the sustainable use of marine resources.

MSP relies on spatial information, highlighting the need for comprehensive high-quality spatial datasets with international coverage. However, no best practices have been established for the utilization of spatial information in cross-border MSP. Spatial data availability, quality and coverage on all sides of national borders need to be considered when gathering spatial information to be harmonized for common use. This requires a thorough review of the diverse source data in order to extract relevant and commensurable information. Furthermore, while most environmental information can be presented as spatial data without difficulty, some socio-economic information is challenging to conceptualize on a map for analysis.

Plan4Blue project aims at advancing cross-border MSP, examining the Gulf of Finland as a case area. One thematic work package of the project concentrates on producing practical guidelines for planners for the utilization of spatial information in a cross-border MSP process. The project involves both scientists and practitioners in Estonia and Finland and collaborates with Russian colleagues. This ensures a research-based and practice-oriented approach to smoothing the way for the official MSP processes in the countries of the Gulf of Finland and beyond. End-users of the project's results are involved in the project from the beginning.

We present preliminary results of an analysis of the optimal exploitation of spatial information. The presentation consists of summarized findings of reviewing previous MSP data management guidelines, overview of information extraction and harmonization from diverse source data, a summary of planners' spatial information requirements and data availability, and empirical review of the planners' needs for operational spatial data management guidelines.

## P37 - Sulphur isotope biogeochemistry of soils from an episodically flooded coastal wetland, southern Baltic Sea

Fernández Fernández, L.E.[1,2], Westphal, J.[1], Schmiedinger, I.[1], Kreuzburg, M.[1], Bahlo, R.[1], Koebsch, F.[3], and Böttcher, M.E.[1]

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Coastal wetlands are under dynamic impact both from fresh water and salt water sources, thereby experiencing temporarily sulphur-excess and -limiting conditions. In the present study, nine up to 10 meter long sediment cores from a recently rewetted fen (Hütelmoor, southern Baltic Sea) which has been under impact by episodic flooding with brackish waters were investigated (isotope) geochemically. The sites are positioned at different distances to the Baltic Sea coastline. The soils were analysed for the elemental composition (CNS), reactive iron and sedimentary sulphur contents, iron sulphide micro-textures, as well as the stable sulphur isotope composition of inorganic and organic sulphur fractions to understand signal development for the biogeochemical carbon-sulphur cycles in such a dynamic ecosystem.

We found evidence for the activity of dissimilatory sulphate-reducing microorganisms and the associated formation of pyrite with different textures (framboids, single euhedral crystals and clusters) and sulfurization of organic matter. Sedimentary sulphur fractions and their stable isotope signatures are controlled by the availability of dissolved organic matter or methane, reactive iron, and in particular dissolved sulphate and thereby from the relative position to the coast line and the given lithology. $d^{34}S$ values in the pyrite fraction vary in a wide range between -21 and +15 per mil versus VCDT, in agreement with spatial and temporal dynamics in the extend of sulphate-limiting conditions during the oxidation of reduced carbon.

Acknowledgement: This study is supported by the research training group BALTIC TRANSCOAST and the EU ERASMUS program

## P38 - Potential relationship between runoff from a coastal peat land on methane and nitrous oxide fluxes in shallow waters of the Baltic Sea

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Methane ($CH_4$) and Nitrous Oxide ($N_2O$) concentrations in the atmosphere have risen since ~1750 by about 150% and 20%, respectively and contribute significantly to the increased radiative forcing by greenhouse gases in the atmosphere, and thus climate change. Nitrous oxide additionally plays an important role for the transport of $NO_x$ to the stratosphere, and thus, stratospheric ozone depletion. Several locations of the Baltic Sea have been identified as sources for atmospheric $N_2O$ and $CH_4$, with strong oversaturations of $N_2O$ (up to 300%) and $CH_4$ (up to 20.000%) compared to atmosphere equilibrium concentrations. The marine trace gas production is mediated by microbial processes and depends mostly on external drivers such as temperature, $O_2$ concentration, and dissolved organic and inorganic material availability.

Within the DFG Research Training Group Baltic TRANSCOAST, we investigate the concentrations of trace gases in coastal waters and the surf zone adjacent to the shallow coastal fen Hütelmoor.A seasonal survey in 2016 revealed elevated concentrations of $CH_4$ (27.5 +/- 31.5; range: 5-161.6 nmol $L^{-1}$) in these shallow coastal waters (‹6m water depth). $N_2O$ was heterogeneously distributed and mostly close to atmospheric equilibrium concentrations (11.7 +/- 2.5; range: 4.8-16.4 nmol $L^{-1}$) in this area. The observed $CH_4$ accumulation in the bottom waters during stratified periods may be related to the absence of vertical mixing in connection to sedimentary sources. In contrast, well-mixed coastal water resulted in cross-slope gradients, with higher $CH_4$ concentrations at the coastline. The coastal zone is hydrologically connected to the peatland and marine sediments contain degraded peat layers due to ongoing erosion of the fen. We hypothesize, that the input of peatland-derived solutes via submarine groundwater discharge through those sediments supplies substrates to microbial activity and, thus, impacts the production and release of trace gases at our study site. We present data from a one-year cycle of the coastal area and relate them to abiotic factors like salinity, sediment properties and temperature.

## P39 - First insights into the distribution of polyphosphates in a coastal zone of the Baltic Sea and in an adjacent peat (the "Hütelmoor")

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Microorganisms can accumulate a surplus of phosphate to build intracellular polyphosphate (poly-p), which consists of up to thousand phosphate residues being linked by high energetic phosphoanhydride bonds. Polyphosphate accumulating microorganisms have been extensively studied in wastewater treatment plants and lake sediments, but their abundance and importance in other ecosystems is still unclear. In addition, little is known about the mechanisms and environmental factors being involved in the formation and degradation of poly-p, which can lead to alternating phosphate concentrations in the environment. The uncertainty about the contribution of poly-p to the phosphorus cycle and the responsible microorganisms being involved is mainly grounded in difficulties for poly-p quantification. With a recent improvement of a fluorometric method being based on the dye "DAPI", a better understanding of the distribution of poly-p in the environment can be achieved. First results are presented on poly-p concentrations in bottom waters of the Baltic Sea and in groundwater of an adjacent peat (the Hütelmoor). It is discussed how different salinity, oxygen or redox regimes may impact the distribution of poly-p in the environment.

## P40 - Groundwater flow and salinity distribution between a coastal peatland and the Baltic Sea

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Coastal peatlands are characterized by intense interactions between land and sea, comprising both a submarine discharge of fresh groundwater and inundations of the peatland with seawater. Nutrients and salts can influence the biogeochemical processes both in the shallow marine sediments and in the peatland. Submarine groundwater discharge (SGD) has been reported from several locations in the Baltic. The objective of this study is to quantify the exchange of fresh and brackish water across the shoreline in a coastal peatland in North-eastern Germany, and to assess the influence of a peat layer extending into the Baltic Sea.

The peatland with a size of 350 ha and a 3 km long shoreline was previously drained by a dense ditch system but is now undergoing a process of renaturation. A dune dike separates the peatland from the beach and is not maintained anymore. Below the peat layer, a shallow fine sand aquifer differs in depth and is limited downwards by glacial till. Borehole data along the beach provides information about the thickness and extension of the peat layer into the Baltic Sea. Water level and electrical conductivity (EC) are permanently measured in different depths at eight locations within the peatland. The water level in the peatland and the surrounding forest is close to or above ground level. First results indicate a groundwater flow direction towards the sea. Electrical conductivity measurements near the coastline indicate differences between 0.8 to 13 mS/cm in the sediment layers. EC fluctuates partially during storm events depending on the hydraulic gradient and the height and width of dunes. The groundwater flow between the peatland and the sea will be investigated experimentally using a numerical 2-D density-driven groundwater flow model.

## P41 - Hydrobiogeochemical and stable isotope characterization of ground waters in a catchment area for the southern Baltic Sea

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The evolution of ground waters in Mecklenburg-Vorpommern (MV; North-Eastern Germany), one of the catchment areas for the southern Baltic Sea, is controlled by different natural and anthropogenic factors. In the present study the hydrochemical and stable isotope (H, C, O, S) composition of shallow ground waters was investigated. A mass balance approach is combined with physico-chemical modeling to define the mineral dissolution/precipitation potential as well as the processes taking place during the ground water development.

The dissolved inorganic carbon system of the ground waters is controlled by the dissolution of biogenic carbon dioxide, the dissolution of (marin) carbonates and oxidation of anthropogenically introduced DOC and at a few sites biogenic methane. The sulfur isotope composition of dissolved sulfate indicates the substantial impact from the oxidation of sedimentary pyrite using oxygen or nitrate as electron acceptor. The combined results are the base for a quantitative reaction path analysis.

The composition of ground water is discussed with respect to its roe as source for fresh waters forming SGD at the Baltic Sea coast line and in a re-wetting peat area at the souther Baltic Sea coastal line (Huetelmoor).

## P42 - Groundwater discharge into the southern Baltic Sea: An open coastal interface

Lipka, M.[1], Schneider, J.[2], Schmiedinger, I.[1], Westphal, J.[1], Escher, P.[3], Sültenfuß, J.[4], Dellwig, O.[1], Winde, V.[5], and Böttcher, M.E.[1]

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Submarine ground water discharge (SGD) into coastal ecosystems is perceived as an important source of fresh water and solutes (nutrients, metabolites, trace elements) in marine biogeochemical cycles. Less is known about its significance for the German coastal zone. We present here the results of hydrogeochemical and stable isotope geochemical studies in an area that is affected by SGD into the southern Baltic Sea.

Anoxic groundwaters emerging as springs at the shore zone of the southern Baltic Sea are windows into the composition of subterrestrial ground water composition. They were investigated on a seasonal base for about five years.

The springs emerge in small pits yielding discharges of about to 10 L/min each. Surrounding sediments are sandy with gravels found at depth and corresponding high permeabilities. The positions of different springs on the shore zone were geostationary during the investigation period while their shape varied due to wind- and wave action. Water samples were analyzed for the concentrations of major and trace elements, pH, and the stable isotope ratios of water, DIC and sulfate. Newly formed precipitates in the stream bed were characterized via SEM-EDX and analyzed for their chemical and stable isotope composition.

The $^{2}H$ and $^{18}O$ contents of the spring waters indicate the ground water to originate from relatively young mixed meteoric waters. Dating by means of tritium and noble gases ($^{3}H$, $^{3}He$, $^{4}He$, Ne) yields an age of the spring waters of about 25-32a. The springs are hydrogeochemically characterized by dissolved Ca, Mg, Na, bicarbonate, and sulfate, mainly reflecting the water-rock interaction with aquifer material in the recharge area. The oxygen-free ground water is rich in dissolved iron (Fe) and phosphorous (P). The above ground draining streams degas carbon dioxide and take up oxygen in contact with the atmosphere. Iron(oxyhydr)oxide precipitates in the stream beds acting as a sink for dissolved phosphate, thus leading to the formation of SGD essentially free of dissolved iron and phosphate. Residues of Fe- oxidizing bacteria were found in the stream bed rust indicating an involvement of microbes to catalyze the dissolved Fe removal. The formation of Fe-phases in the subterranean estuary is also supposed to take place at depth thereby influencing the release of nutrients and metals into the Baltic Sea coastal ecosystem.

This work was supported by the BONUS+ project AMBER, the Leibniz IOW and the Graduiertenkolleg BALTIC TRANSCOAST.

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## P43 - Benthic carbon transformations and nutrient fluxes in the southern Baltic Sea: Dynamics in space and time

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Organic matter (OM) is mineralized in brackish marine sediments by microbial activity using different electron acceptors. Pore water profiles sensitively reflect the zones of dominant biogeochemical processes, net transformation rates and fluxes of dissolved species across the sediment-water interface. They are controlled by different factors like microbial activity, bottom water redox conditions, and availability of electron acceptors/donors. Microbial activity in the sediment leads to changes in redox conditions, formation of metabolites and may lead to the formation of authigenic minerals. For example, OM mineralization and reduction of FeOOH may lead to the release of phosphate into the bottom waters. Hypoxic bottom water conditions may enhance this process.

We present the results of a detailed biogeochemical investigation of modern surface sediments to study the processes and associated element fluxes in different areas of the southern Baltic Sea. Pore water and sediment samples of different substrate types were retrieved from short sediment cores that were collected with multi-coring devices. Pore water and bottom water samples were analyzed for metals, nutrients and metabolites concentrations (e.g., Mn, $SO_4$, $H_2S$, $PO_4$, DIC) to allow a modelling of steady-state volumetric transformation rates and element fluxes. Incubation experiments using intact sediment short cores were performed to obtain total nutrient fluxes. The gross microbial sulfate reduction rates were determined by the radiotracer method using sediment incubations.

Benthic element fluxes are controlled by sedimentary mineralization processes during early diagenesis, bottom water redox conditions and the transport processes at the sediment surface. Sediment formation conditions and OM contents mainly control early diagenetic process rates. Transport mechanisms determine the reflux of mineralization products into the water column. Advective fluxes induced by sedimentation events, macro zoobenthos and waves can affect the top sections of the sediment, thereby modifying shallow concentration gradients. Carrying out (non)steady state modelling of pore waters we were able to identify the impact of mixing processes and sedimentation events. In particular, the carbon isotope composition of DIC is found to be a highly sensitive tool for model parameterization, including the estimate of effective mixing activities.

The study is supported by BMBF during FONA-SECOS project, phases I and II, and Leibniz IOW.

## P44 - Fucus vesiculosus as a stable isotope (C, N, S) bio-monitor in an urbanised fjord of the western Baltic Sea

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The spatial variations in the elemental and stable carbon, nitrogen, and sulphur isotope composition of bladder wrack (*Fucus vesiculosus*) growing along the shore line of the semi-enclosed urbanized Kiel Fjord (western Baltic Sea) was investigated at more than 60 sites (Winde et al., 2017, IEHS). The analyses of the CNS stoichiometry and C and N stable isotope signature of *Fucus vesiculosus* displayed substantial differences between the north-western and the south-eastern parts of the Kiel Fjord. Different size classes displayed in part differences in C:N and C:S ratios, and the carbon isotope composition, reflecting the impact of the boundary conditions during growth. Whereas, the sulphur isotope composition was controlled by the assimilation of seawater sulphate, the carbon isotope composition reflected the difference in the composition of surface waters. The $d^{15}N$ values of the organic tissue tend to be an integrated monitor of anthropogenic impacts on the fjord. Results are compared to the composition of surface waters.

## P45 - Water and material exchange in a coastal transition zone of the southern Baltic Sea

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Submarine groundwater discharge (SGD) is an important pathway of dissolved element transport from the terrestrial to the marine environment. Little is known about the controls of this transport from landside to the Baltic Sea and vice versa, and the associated biogeochemical reactions at the seawater/ freshwater interfacial zone.
In the present study, we investigate water exchange and associated biogeochemical processes at the coastal fen of the nature reserve Heiligensee & Hütelmoor, southern Baltic Sea, which is the study area of the DFG research training group BALTIC TRANSCOAST. The compartments under consideration include the coastal water column and vertical pore water and solid phase profiles in sediments and soils along the coast as well as in the fen peatland.
Pore waters were retrieved via push-pull pore water lances. $^{224/223}$Ra isotope investigations in the water column are used for a general detection of benthic-pelagic water exchange. A focus of the investigations was set on the development of concentration gradients of redox-sensitive elements, nutrients and the stable isotope (O, H, C) composition. Physical parameters, major and trace elements have been included.
The study area displays a spatial and temporal heterogeneity in pore water compositions due to a complex lithology with permeable sands and impermeable peat layers. The tentative results of the hydrogeochemical and isotope investigations indicate SGD contributions in the NE of the study area.
The pore water´s carbon isotope composition of dissolved inorganic carbon indicates intense anaerobic oxidation of dissolved organic carbon and/or methane which may be influenced by the presence of below-ground peat layers. Dissolved sulphide accumulates already in shallow sediments (below 30 cm bsf) due to presumably high rates of sulphate reduction and/or pore water fluxes.
To quantify local pore water dynamics ('benthic-pelagic coupling') it is further planned to apply benthic seepage meters. Stationary pore water lances will complement the sampling at wells to allow for a flux determination of water and elements and analyses of the dominant biogeochemical processes.

## P46 - Stable isotope and trace element partitioning in recent carbonate-precipitating streams on Rügen Island, southern Baltic Sea

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Processes in the carbonate system of near-surface waters of the temperate climate zone are in particular sensitive to variations of boundary conditions associated with climate change. Calcium carbonate-saturated ground waters that emerge from springs may lose dissolved carbon dioxide to the atmosphere due to degassing. This leads to super-saturation of the aqueous solution with respect to several carbonates, including calcite. Stable isotope and trace element fractionation are of particular value to link these non-equilibrium processes to the formation mechanisms of calcite and the hydrodynamics of flowing streams. An example linking the past and present terrestrial and marine carbon cycles is found at the cliff coast line of Rügen Island: Fossil carbonate that forms the cliffs, is nowadays dissolved soil solutions and ground water. When these solutions emerge as springs, their dissolved carbonate system is in dis-equilibrium with respect to the recent Earth atmosphere. By following the chemical changes downstream it is found, that two regions of evolution can be differentiated: After an induction period, where only CO2-degassing takes place, a second stage is observed where calcite begins to form from the highly supersaturated solutions. At the bottom of the cliff, the carbonate stream water is finally entering the Baltic Sea mixing with the brackish coastal waters. In the present study, trace element and stable isotope (C, O) isotope fractionation was followed in several carbonate-precipitating streams. Major, minor and trace element concentrations and d13C and d18O values of carbonate solids and aqueous solutions where analysed as a function of the flow path. In addition, marine and older travertine carbonate samples were analysed for a comparison with recent precipitates. Sr/Ca and Mg/Ca ratios were lower in the newly formed calcium carbonate compared to the aqueous solution. The partition coefficients are larger than previous experimental close-to-equilibrium calibrations and indicate relatively fast calcite precipitation rates. The spring carbon isotopic composition indicates ground water evolution under conditions, essentially closed with respect to a carbon dioxide gas phase. The delta13C values of DIC increased along the flow path, due to preferential degassing of 12CO2. Travertine samples displayed a slight enrichment in 13C compared to the solution which is consistent with experimental and theoretical studies.

## P47 - The H and O isotope geochemistry of modern and paleo waters of the Baltic Sea: A water column and interstitial water study

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Variations in the stable hydrogen and oxygen isotope ($^{2}H/^{1}H$, $^{18}O/^{16}O$) composition of the modern water column was investigated on transects through the whole modern Baltic Sea to derive variations with salinity and the Baltic Sea water line.

In addition, interstitial waters extracted from long cores retrieved during IODP Leg 347 from sediment cores of the Baltic Sea were analysed to constrain the main hydrographic changes of the Baltic Sea from the late Pleistocene to modern time. Prior to its reconnection with the North Sea (through the Skagerrak-Kattegat connection), the Baltic Sea had evolved into a lake, with a brief interruption during the Yoldia stage. Upon reconnection with the open ocean, hydrologic and bottom water compositional changes in the Baltic Sea were dramatic. Current pore water profiles reflect these changes, further impacted by internal transport processes like diffusion and advection. Investigations were carried out at Sites M0059 (Little Belt), M0060 (Kattegat), M0065 (Bornholm Basin), and M0063 (Landsort Deep). Associated with a steep vertical decrease of salinity, a substantial shift towards an enrichment of the lighter stable isotopes in water is observed. The resulting shapes of the pore water gradients differ substantially due to different modern and paleo bottom water and sedimentation rates conditions. They allow to estimate the paleo-gradient in the stable isotope composition of Baltic Sea bottom waters.

## P48 - SECOS – The service of sediments in German coastal seas: the impact of sediment nutrient dynamics on coastal marine ecosystems

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Understanding the role of sediments in the biogeochemical cycling of elements in coastal waters can provide important insight into the functioning of marine coastal ecosystems. Marine coastal sediments provide ecosystem services through processes such as deposition of discarded material, transformation of eutrophic substances into non-reactive forms, e.g. nitrate removal via denitrification, burial of toxic substances, sediment stabilization, and regulation of biodiversity and production patterns. However, sediments can also support functions, which have a negative impact on marine coastal ecosystems, such as the production of hydrogen sulfide, emission of greenhouse gases, and negative effects on biodiversity. The SECOS II Synthesis project aims to quantify the sedimentary services for the German part of the Baltic Sea by applying a marine ecosystem service evaluation framework and spatially integrating natural scientific data, model simulation results and socio-economic aspects into an evaluation tool (Baltic Sea Atlas) that visualises the societal benefits and serves as a scientific basis for the implementation of major marine and coastal policies (Marine Strategy Framework Directive, Water Framework Directive, Habitat Directive, Maritime Spatial Planning Directive). In this presentation, we will discuss the approach within SECOS to modelling sedimentary services under changing environmental conditions and the impact this has on macrobenthos communities. We will describe the extension of the ERGOM ecosystem model to include a vertically resolved diagenetic model of sedimentary processes in the upper sediment layers. We will present the approach to parameter estimation and dealing with spatially varying bioturbation intensities, as well as our results from a high resolution (1nm) simulation. Future plans to configure climate change scenarios with perturbed atmospheric forcing will also be discussed.

## P49 - Benthic fluxes of nutrients and oxygen in the shallow coastal zone at the Puck Bay (Baltic Sea)

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The researches on the fluxes of nutrients ($NO_2^-$, $NO_3^-$, $NH_4^+$, $PO_4^{3-}$, $Si^-$) and dissolved oxygen (DO) were carried in the vegetation season 2015. Fluxes were calculated on the basis of incubation experiments. The cores of sediments for analysis were taken from 3 stations (2, 5, and 20 m depth) located in the outer part of the Puck Bay. In September sediments from Mytilus and Zostera beds were additionaly researched.

Concentrations of the organic carbon (POC) in surface sediments ranged from 0.39 to 70.3 mg $g^{-1}$ d.w. The lowest values (‹2.0 mg POC $g^{-1}$ d.w.) characterized sediments collected at the 2 and 5 m depth stations, the highest concentrations (›60 mg POC $g^{-1}$ d.w.) were observed in the sediments from the deepest station. During the vegetation season, there was an increase of POC and chlorophyll a concentrations observed. In March and June at the shallow stations, very low $C/N_{mol}$ proportion (‹6.5) showed high enrichment of nitrogen. In September the organic matter at this stations was reach in fresh algae material (C/chla ‹114). During vegetation season, at the deepest station, proportions $C/N_{mol}$ and C/chla were significantly higher (› 9.8 and ›2394, respectively) indicating the accumulation of degraded material.

Simultaneously, only at 20 m station a significant increase of fluxes of nutrients from sediments to the bottom water and consumption of oxygen by sediments were noticed. In September the fluxes of nutrients and oxygen ranged, averagely: 4.5 µmol $NO_2^-$ $m^{-2}$ $h^{-1}$, 26.9 µmol $NO_3^-$ $m^{-2}$ $h^{-1}$, 138.6 µmol $NH_4^+$ $m^{-2}$ $h^{-1}$, 3.2 µmol $PO_4^{3-}$ $m^{-2}$ $h^{-1}$, 355.0 µmol $Si^-$ $m^{-2}$ $h^{-1}$, -65.8 mg DO $m^{-2}$ $h^{-1}$. At the 2 and 5 m depth stations fluxes were lower, more variable and took different directions. Generally on the 2 m depth station the fluxes of nutrients were lower during the day than at night and often directed to the sediments. At the same time the production of oxygen was recorded.

At the Mytilus and Zostera beds, the fluxes of $Si^-$, $NH_4^+$ and DO exceeded the seasonal values of these substances. Average $Si^-$ fluxes from sediments with Zostera were 7-times higher than those without Zostera. Presence of Mytilus increased fluxes of ammonia from sediments into the bottom water by two orders of magnitude and the oxygen consumption rised more than 3.5 times. Large areas of the occurrence of these organisms will significantly affect the $Si^-$ , $NH_4^+$ and DO fluxes in reservoirs.

## P50 - Alkaline Phosphatase activity (APA) in plankton communities of a eutrophic lagoon: Is APA a marker for phosphorus demand?

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The Darß-Zingster Bodden Chain (DZBC) is a brackish tide less and shallow lagoon of the southern Baltic Sea. Until the 1990s, the whole Bodden chain was subject to substantial eutrophication for decades. As a result, a decline of macrophytes and the formation of dense phytoplankton blooms could be documented throughout the whole growing season. Since the early 1990s, the nutrient input was reduced by lower application of agricultural fertilizers and P-containing detergents as well as the implementation of waste-water treatment plants. However, the reduced nutrient loads did not decrease phytoplankton biomass in the DZBC.

The alkaline phosphatase activity (APA), which is interpreted as indicative for phosphorus (P) limitation conditions in phytoplankton communities, was always very high in the DZBC even under P repleted conditions. Long-term data sets between 1996 and 2016 were evaluated, and the correlation of APA to different abiotic and biotic parameters, like total P (TP), dissolved inorganic (DIP) and organic (DOP) P, carbon:nitrogen:phosphorus ratio, chlorophyll a, seston, particular organic matter (POM) and carbon (POC), bacterial abundance and succession of zooplankton community were tested. APA as absolute apparent maximal reaction velocity ($V_{max}$) was measured always at substrate saturation as well as at 12 increasing substrate concentrations in 2016 for substrate affinity ($K_M$) calculations of the enzyme mix.

Distinct peaks of APA occurred in spring and often also in summer. Surprisingly, APA declined from the hyper-eutrophic Saaler Bodden to the opening of the meso- to eutrophic Baltic Sea. Additionally, APA declined from 1996 through 2016, although the P loads decreased. We attempt detecting the organism, which might be responsible for the APA peaks and discuss $V_{max}$ as an indicator for P demand.

## P51 - Seasonal and diurnal variability of POC and DOC concentrations in the Baltic Sea.

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Concentrations of particulate organic carbon (POC), dissolved organic carbon (DOC) dissolved inorganic nitrogen (DIN), $PO_4^{3-}$, chlorophyll a (chl a) as well as pH were examined to assess their seasonal and diurnal variations in the Baltic Sea. Samples were collected at the Gdańsk Deep (54°44,730'N, 19°08,531'E) from several depths (1m, 10m, 40m and 90m) for 24h (2h resolution) during sampling campaigns in 2011 (May), 2014 (May) and 2015 (January, March, May, July, September, November). Pronounced seasonal variability was observed for all investigated variables. Both POC and DOC concentrations were significantly higher in the productive season (March-October) than in non-productive season (November-February). The increase of POC and DOC concentrations correlated well with phytoplankton activity reflected by chl a concentration. Strong diurnal variations of POC and DOC were detected only in May 2011 and March 2015, when the activity of phytoplankton was the highest. For both these sampling campaigns POC and DOC concentrations in the euphotic zone were respectively higher by up to 33% and 15% during the day time than during the night time. For other sampling campaigns diurnal variability of POC and DOC was much less detectable or, it was not observed at all for cold months (November and January).

Our results clearly show that apart from medium- (seasonal) and long-term (inter-annual) variability, POC and DOC can change significantly within hours. This should be taken into account for planning sampling campaigns and interpretation of existing (e.g. monitoring) data, especially those taken in productive seasons.

## P52 - Tracing DIC in marginal seas: A stable carbon isotope study

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The microbial mineralization of organic matter in marine sediments leads to the accumulation of dissolved inorganic carbon (DIC) and other metabolites into the interstitial waters. Pore water (PW) profiles sensitively reflect the zones of dominant biogeochemical processes, net transformation rates, and transport of dissolved species across the sediment-water interface (SWI). The biogeochemical processes create steep gradients in DIC and its carbon isotope composition. One boundary condition for transport processes in the sediment is defined by the composition of the water column (WC), which is under impact by physical mixing processes, biological activity and carbon dioxide exchange at the water-atmosphere interface.

We present here the results of detailed biogeochemical investigations of vertical WC and PW profiles from brackish marginal seas. The WC on a transect between the North Sea and the southern Baltic Sea as well within the Black Sea were investigated on three cruises with RV MS Merian. In addition, biogeochemical processes and associated element fluxes across the SWI were studied using PW and sediment samples retrieved from sediment cores collected with a multi-coring device. Water samples were analyzed for metals, nutrients, and metabolites concentrations as well as stable carbon isotope composition of DIC to allow a modeling of steady-state transformation, volumetric transformation rates and element fluxes.

The isotope composition of the DIC system shows a gradient between the North and the Baltic Sea, following the salinity during winter time. Element fluxes across the SWI depend on bottom water redox conditions, sedimentology and organic contents. Advective fluxes induced by sedimentation events, macro zoobenthos and wave action can affect the top sections of the sediment, thereby modifying shallow concentration gradients. By means of non-steady state modelling of PW profiles we were able to identify the impact of mixing processes and sedimentation events in the oxic part of the Baltic Sea. In the Black Sea anaerobic processes control the dynamics in $DI^{13}C$ under permanent euxinic conditions. A Keeling plot analysis was performed on PW to identify the $\delta^{13}C$ of DIC released upon oxidation of DOC or methane.

The carbon isotope composition of DIC is found to be a highly sensitive tool for understanding carbon cycling in the WC and sediments.

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## P53 - Structure and functioning of the acid-base system in the Baltic Sea

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Generally, four measurable variables are used to describe the acid-base system of seawater. These are: $pCO_2$, pH, total inorganic carbon ($C_T$, known also as DIC) and total alkalinity ($A_T$). All four variables interact and control the pH by set of equilibrium and mass-balance equations. In general the interrelationships between these four parameters facilitate the calculation of any two variables, when the two others are known. The pair most often used for studying marine $CO_2$ system is $A_T$ and $C_T$, because these variables are independent on temperature and pressure and behave conservative with respect to mixing. However, the use of $A_T$ and $C_T$ for the $CO_2$ system studies is not free from limitations. To obtain high accuracy for the calculations of pH and $pCO_2$ from measured or modelled $A_T$ and $C_T$, all dissociation constants and total concentrations of all non-$CO_2$ components of the acid-base system must be known. This requirement is approximately fulfilled with regard to ocean studies where the total concentrations of non-$CO_2$ acid-base components are there either negligible or can be approximated by a functions of salinity. However, this issue is more critical for coastal and shelf regions, where biogeochemical composition of seawater shows regional peculiarities.

In this context the brackish Baltic Sea can be considered as a very complex ecosystem, in which on one hand the low buffer capacity makes the seawater vulnerable to acidification, and on the other hand the sea is exposed to various anthropogenic influences which have the potential to change the acid-base system and consequently seawater pH. The goals of this study are to consolidate the existing knowledge on the structure and functioning of the acid-base system in the Baltic Sea, to point out the research gaps and to define challenges for the future research in this field. We took into consideration in our study both the general structure of the acid-base system and several local features of the Baltic Sea like e.g.: the existence of different $A_T$ vs. salinity regimes (including spatial and vertical distribution), so called ion anomaly, $A_T$ release from internal processes, organic matter contribution to $A_T$, mineralization of organic matter as a source of $CO_2$, short- and long-term variability of $CO_2$ system.

## P54 - High-resolution pCO2 measurements on a cargo ship in the Baltic Sea: Patterns and trends derived from a synoptic look at 13 years of observations

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Oceanic $CO_2$ measurements boomed during the past decades and are essential to quantify the oceanic uptake of anthropogenic $CO_2$ and the ongoing Ocean Acidification process. In the Baltic Sea, comprehensive investigations of the $CO_2$ system were initiated in 2003, when an automated $pCO_2$ measurement system was installed on a voluntary observing ship (VOS). By the end of 2015, the VOS FINNMAID had recorded 1600 transects between Lübeck and Helsinki, resulting in more than 2.5 million surface water $pCO_2$ observations. Here, we present for the first time a holistic view on the recorded data set, which allows to detect hitherto unknown regional and temporal patterns.

In contrast to the temperature-controlled $pCO_2$ variability in many oceanic regions, the $pCO_2$ dynamics in the Baltic Sea revealed to be dominated by biological processes. This biological control is directly related to regional patterns in the $pCO_2$ cycles: The seasonal $pCO_2$ peak-to-peak amplitude was found to regularly exceed 500 µatm in the north-eastern regions, whereas it typically remains below 300 µatm in the south-west. Likewise, the starting date of the spring bloom revealed regional patterns: In the southern areas it starts at the end of February, however, with around 2 weeks of interannual variability. In contrast, the spring bloom in the Gotland Sea starts a month later at the end of March, but reproducible within a few days each year. With respect to the $pCO_2$ progression throughout the year, we detected a bimodal pattern in the northern areas. This bimodal pattern is most pronounced in the Gotland Sea, indicating that the spring bloom is followed by a mid-summer nitrogen fixation period. In contrast, such distinct bloom events do not exist in the southern regions, for example in the Mecklenburg bight. Finally, we will demonstrate that a positive long-term $pCO_2$ trend that is attributed to anthropogenic emissions and clearly superimpose the seasonal $pCO_2$ cycle can at this stage not be determined from the available time series data. This finding is related to the (im-)possibility to currently identify Ocean Acidification in the Baltic Sea.

## P55 - Sea-atmosphere carbon dioxide fluxes at Utö in the Baltic sea

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Carbon dioxide is a key compound both in climate change and marine productivity. In the oceans, the sea-atmosphere carbon fluxes are driven by large-scale sea currents, while in coastal seas, such as the Baltic Sea, biological activity has a significant effect on the carbonate system. However, direct measurements of the aquatic carbonate system and especially the sea-atmosphere gas exchange are difficult to carry out due to waves, sea ice cover and sea spray that influence sensitive instruments. In addition, underwater instruments are exposed to biofouling.

In this study, we will present recent measurements carried out at the Utö Atmospheric and Marine Research Station located on the island of Utö in the Archipelago Sea. The measurements at this site include a full range of physical and biological parameters. A flow-through pumping system makes it possible to analyse water samples continuously. A flux tower has been erected on the shore to measure air-sea gas exchange.

The sea-atmosphere carbon dioxide fluxes are measured with a closed-path high-frequency infrared gas analyzer (LI-7000, Licor), which is equipped with a virtual impactor to protect it from sea spray. Dissolved carbon dioxide in the sea water is measured with an equalisation chamber together with an LI840A analyzer (Super-CO2, Sunburst Sensors).

The study of air-sea gas exchange focuses on a two-month period, 14 October – 14 December 2016. Approximately half of the time, the wind was blowing from the sea. The carbon dioxide concentration in the sea water exceeded the corresponding atmospheric concentration, thus causing a carbon dioxide flux from the sea to the atmosphere.

In addition to carbon dioxide observations, we also measured sea water pH (AFT-pH, Sunburst Sensors) during 5 July – 3 October 2016 and found that pH was linked to the carbon dioxide concentration of the sea water: an increment of dissolved carbon dioxide concentration causes acidification of sea water.

One objective of this research was to test the new measurement set-up, especially the carbon dioxide flux system in terms of its sensitivity to different perturbations, such as changes in ambient temperature and contamination of tubes by sea water, and the performance of the virtual impactor included.

## P56 - Recycling and burial of organic carbon in sediments of Eastern Gotland Basin, Baltic Sea

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The marine environment is important in the circulation of $CO_2$ due to 'biological pump' mechanisms. Shelf seas are believed to act as net sinks for anthropogenic $CO_2$ due to their high biological productivity driven by high nutrient inputs but it has also been suggested that inner estuaries and near-shore zones can act as sources of $CO_2$ to the atmosphere (Chen and Borges, 2009). Therefore, detailed studies of the carbon cycle in shelf seas and similar areas like the Baltic Sea, are warranted to improve regional carbon budgets (Kuliński and Pempkowiak, 2011). Biogeochemical processes in bottom sediments are important in influencing and controlling the fate of organic carbon and this is in turn reflected in the derived carbon budgets. Since burial in sediments and export to the North Sea are the main sinks of carbon in the Baltic Sea it is of great importance to understand these processes.

We present estimates of organic carbon recycling rates in the Eastern Gotland Basin (EGB), Baltic Sea from in situ measurements of benthic DIC fluxes using autonomous landers (Tengberg et al., 2004). These rates are further compared to organic carbon burial rates and accumulation rates with the aim to quantify the burial efficiency (i.e the amount of carbon preserved/amount of carbon deposited). Results from sites with oxygenated as well as anoxic bottom water are presented and the effect of the most recent Major Baltic Inflow (MBI) on carbon oxidation rates is elucidated (Hall et al., 2017).

This study provide a new estimate of an integrated benthic carbon mass balance in the Baltic proper, which has implications for existing Baltic carbon budgets.

## P57 - The characteristics of the carbonate system in the Odra River estuary (Poland)

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Estuaries are important regions for the global carbon cycle as transition zone between land, open ocean and the atmosphere. Studies on the carbon cycle and especially on the $CO_2$ system in the Baltic Sea are mostly focused in the open waters, while estuaries at the various river mouths are poorly investigated in this respect.

The aim of our study was to characterize the $CO_2$ system in the estuary of the Odra River - one of the biggest rivers entering the Baltic Sea. Water discharged by the Odra first enters relatively large (ca. 680 $km^2$) and shallow (mean depth ca. 3.8 m) Szczecin Lagoon, which is further connected to the Pomeranian Bay via narrow channels of three rivers: Dziwna, Swina and Peene.

During two RV Oceania cruises in May and November 2016 all four measurable parameters describing the $CO_2$ system ($A_T$, DIC, $pCO_2$, pH) were measured together with $O_2$, salinity (S) and temperature. Four characteristic sections were identified along the estuary: freshwater in the Odra River (S < 0.5 PSU), low saline water in the Szczecin Lagoon (S = 1 - 3 PSU), steep salinity gradients in the Swina River (S = 2 - 6) and Baltic Sea water in the Pomeranian Bay (S = 6 - 7 PSU). Along the salinity gradients large total alkalinity changes were observed in the estuary ($A_T$ amounted 2660 and 1910 µmol × $kg^{-1}$ in the Odra River and Pomeranian Bay respectively). The Odra River water was oversaturated with $CO_2$ irrespective of the season ($pCO_2$ of 1084 - 1350 µatm) - most likely as consequence of intensive mineralization of terrigenous organic matter. In the Szczecin Lagoon, $pCO_2$ dropped significantly down to 467 µatm in November and as low as 62 µatm in May. The latter was accompanied by $O_2$ saturation up to 122 % - inversely correlated to the distribution of $pCO_2$, which suggests that the $CO_2$ system in the estuary is controlled mainly by biological activity. The $pCO_2$ in the Pomeranian Bay waters was comparable to the values observed previously in the Baltic. Interestingly, this region was slightly undersaturated with $CO_2$ in November what may indicate the existence of a moderate autumn plankton bloom.

The obtained data significantly improve our knowledge on the structure of the $CO_2$ system in the Odra estuary and likely in other river mouths in the continental part of the Baltic Sea drainage basin. Further studies are required to resolve temporal and spatial variability, and to understand the importance of estuaries for the overall Baltic Sea carbon cycle.

## P58 - In situ and laboratory investigations on N2O production by microbial key players in the oxygen-deficient Baltic Sea basins

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Hypoxic zones in marine ecosystems are increasing due to enhanced eutrophication and global climate change. These oxygen minimum zones are considered as marine hotspots of nitrous oxide emission where elevated $N_2O$ concentrations are frequently measured. The Baltic Sea redoxcline offers the possibility to link $N_2O$ accumulation with the identity and activity of known microbial key players in the nitrogen cycle of the pelagic redoxcline. We examined the in situ $N_2O$ distribution in the redoxcline at 8 different stations in the central Baltic Sea in June 2016. $N_2O$ concentrations as high as 162 nmol $L^{-1}$ were detected at the Gotland Deep, where a transition from oxygenated inflow water to re-established anoxia was observed. Although sulfide is the main electron donor for chemoautotrophic denitrification in Baltic Sea redoxclines, it also inhibits the enzyme for nitrous oxide reduction (NorZ) to $N_2$ in the denitrification pathway, thereby resulting in $N_2O$ accumulation. The impact of sulfide on denitrification and $N_2O$ accumulation was investigated at in situ conditions, with water samples from the oxic-anoxic interface. Additionally, laboratory experiments using *Sulfurimonas gotlandica* GD1 as a representative of Baltic Sea chemoautotrophic denitrifiers were performed. Sulfide was spiked as the electron donor into both set ups at different concentrations ranging from 0-100 µM. The results revealed that the effect of sulfide on $N_2O$ production clearly differed between the stations and water depths but $N_2O$ accumulation generally increased with increasing sulfide concentration in both field and laboratory experiments. We conclude that disturbance of the denitrification process by increased sulfide concentrations might be an important mechanism for $N_2O$ accumulation in Baltic redoxclines as these are characterized by frequent intrusions and small-scale mixing events of different water masses.

## P59 - Zooplankton associated methane production: A process that influences methane gradients in oxic waters of the Baltic Sea

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Methane is a very powerful greenhouse gas. Its particular sources and sinks need to be identified and quantified for understanding the global carbon cycle. For the oceanic methane budget, semi-enclosed basins like the Baltic Sea play an important role due to high methane production rates in the sediments and fast ventilation of the relatively shallow water column. In the central Baltic Sea, the methane distribution is also characterized by strong seasonal and spatial gradients. During field studies in July 2012, we measured methane concentrations within the water column at two sites: the eastern Gotland Basin and the western Gotland Basin. We also studied the zooplankton distribution and its community composition. Further, we investigated the presence of methanogenic archaea in the shallow oxygenated water column. Finally, we conducted grazing experiments in the field to measure zooplankton associated methane production rates, to identify the potential impact of zooplankton on the methane dynamics in the central Baltic Sea. We observed a sub-thermocline methane enrichment within the oxygenated surface waters of the eastern Gotland Basin, but not of the western Gotland Basin. We found that this methane enrichment, correlates with the accumulation of zooplankton and its community composition. We also found methanogenic archaea belonging to the Methanomicrobiaceae at the depth of highest methane concentrations in the eastern Gotland Basin only. Hence, we suggest that zooplankton, in particular copepod-species-specific endosymbionts contribute to the methane enrichment below the thermocline.

## P60 - Study on different fractions of organic molecules in the Baltic Sea surface by spectrophoto- and spectrofluorometric methods

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The sea surface is a highly productive and active interface between the sea and the atmosphere. Sea surface films are created by organic matter from sea and land sources and they dissipate due to loss of material at the sea surface, including microbial degradation, chemical and photo chemical processes, and loss due to absorption and adsorption onto particulates. However the surface microlayer is almost ubiquitous and cover most of the surface of the ocean, even under conditions of high turbulence. A unique structure of the energy levels of the organic molecules results in a unique spectral distribution of the light intensity absorbed and emitted by the molecules. Hence, their absorption and fluorescence spectra may allow the identification of the sources of organic matter. Additionally, several absorption ($E_2$:$E_3$, S, $S_R$) and fluorescence (fluorescence intensities at peaks: A, C, M, T, the ratio (M+T)/(A+C), HIX) indices help in describing the changes in molecular size and weight as well as in composition of organic matter.

Investigations included the region of Gulf of Gdańsk, along a transect from the Vistula River outlet to open sea. The fluorescence and absorption measurements of the samples collected from a surface films and a subsurface layer (SS, a depth of 1 m) during three research cruises in Gulf of Gdańsk, the Baltic Sea allowed to assess (i) decreasing of two terrestrial components (A and C) contribution with increasing salinity (~1.64% and ~1.89 % in SML and 0.78 and 0.71 % in SS, respectively) and increasing of in-situ produced components (M and T) with salinity (~0.52% and ~2.83% in SML and ~0.98% and ~1.87 % in SS, respectively), (ii) component T revealed the biggest relative changes along the transect from the Vistula River outlet to Gdańsk Deep, both in SML and SS (about 18.5 % and ~12.3 %, respectively), (iii) the ratio E2:E3 points to discrete changes in molecular weight/size, effected by photobleaching, while (iv) HIX index reflects the humification/condensation processes more sensitively and effectively in SS.

Surface active molecules (surfactants) may affect the penetration depth of solar radiation or gas exchange hence research on the influence of surfactants on the sea surface properties become an important task, especially in coastal waters and in vicinity of the river mouths or in less urbanized and more natural and pristine region, like Arctic.

## P61 - Impact of the Medjerda sedimentary fluxes on the morphodynamic equilibrium of the northern coast of the Gulf of Tunis (Medjerda-Raoued coast), Tunisia.

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The reconstruction of the Paleo-geomorphological context of the new Medjerda delta was the subject of this study. The study area is the new mouth of the Medjerda River which leads to the El-Hissiane coastal region, Gulf of Tunis. A core drilling mission was carried out on the new delta in August 2014. Two sedimentary cores CEM 1 (1.68 cm) and CEM 2 (80 cm), CEM 3 (42 cm) and CEM 4 (48 cm), the central zone of the deltaic front, the levee area, the swamp area and the current shoreline. The methodological approach focuses on the multi-proxy approach performed on the sedimentary archives collected. The chronological study is based on the 210Pb / 137Cs method. The collected sedimentary archive consists of two well-marked sedimentary units. A basal part consisting of sandy sediment. A summit part characterised by a clay layer intercalated by silty levels. The change of sedimentary layers marks the establishment of a new delta on an old sandy beach. The silty levels mark small marine weather events that hit the coast of the Gulf of Tunis. The geochemical study shows variable concentrations of chemical elements (Fe, K, Al, Rb, Nb, Cr, Ti, Ba, Ca, Sr, Zr). Principal component analysis (PCA) shows that these chemical elements are grouped in 3 poles. A terrigenous pole, a marine pole and a third pole. The evolution of the geochemical signature shows an increase in terrigenous elements with the implementation of a new delta associated with a decrease in the contents of the marine treasures. The chronological method affirms that the speed of sedimentation is very important and that the progradation of the new delta has been under fluvial dominance since 1939. The presence of a more sedimentary layer constituted sediments probably revised during a strong flood. The new delta of the Medjerda passed through two radical geomorphological phases: a phase of progradation followed by an erosion phase. Under the effect of the anthropization of the river, the new delta has experienced several forms of degradation due to the reduction of the sediment load associated with the erosive action of the marine hydrodynamic agents.

## P62 - Estimation of erosion volume rate of the Baltic Sea shores

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Geological structure of the Baltic Sea shores as well as abrasion action of the sea varies very much. The literature overview permits to collect characteristics of erosion rates for different shore segments. The maximum input of sediments is expected from the southern and eastern Baltic shores, where the average erosion rate constitutes to 1.0 – 1.5 m per year, while practically the erosion has happened during stormy events and may reach up to 10-20 m per year at the particular small segments of the shore. Extrapolating the data on volume rate for some specific study areas on the rest of the Baltic shores we estimated the gain of the movable material from the southern and eastern shores that gave about 5 million $m^3$ per year.

## P63 - Spatial variability of the coastal retreat along the Russian part of the Vistula Spit during 2002-2014 by results of instrumental monitoring and satellite images analysis

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The data of instrumental measurements and satellite images were used to reveal the variability of the shoreline retreat at the accumulative dissipative sandy shores of the South Eastern Baltic. The retreat was identified by changes in location of dune edge.

Basing on the ground-based monitoring data for 2002-2015 the 3 coastal segments were distinguished: the stable segment to the north of the Strait of Baltiysk, the eroded 4-km segment to the south of the Strait of Baltiysk (with maximum erosion rate up to 2 m/year); the remaining area of the Russian part of the Spit (21 km) with an alternation of stable, eroded and accumulative segments. The alongshore variability in particle size distribution (mostly medium sand) is most likely associated rather with the latest wave processing than with long-term dynamic processes.

Images of satellites OrbView-3 for 2004 and 2005 years (spatial resolution 1 m/pixel) and Pleiades for 2014 year (spatial resolution 0.5 m/pixel) were used. The lines of the foredune edge for 25 km northern part of the Vistula Spit (from the Polish-Russian border to the Strait of Baltiysk) for 2004-2005 and 2015 were digitized with the step of 10 m and compared. Introducing the level of confidence ± 1.5 m per 10 years, we considered that eroded, stable and accreted parts of the shore have the total length 15.4, 4.9, 5.2 km (60.4%, 19.1%, 20.5%). The average (10 years) erosion rate for the marine shore on the Russian side of the Vistula Spit is 0.6 m/year, and accretion rate is 0.3 m/year.

The alongshore variability for the rate of coastline retreat (positive-negative) was in the range of 20-1800 m. The revealed quasiperiodic interchange of eroded and accretive segments with the length scale of 100 – 2000 m pointed out the weakness of existed network of ground-based monitoring. It is recommended to use satellite monitoring with verification of results by instrumental measurements at limited number of transects.

The picture of spatial interchange of the eroded and accretive segments couldn't be permanent during long time, otherwise the shore would be very much meandering, but it is not a case in reality. Therefore, the obtained 'picture' has to be moved along the shore in a scale of decades (10th of years) to keep the aligned shore morphometry.

One can say that obtained spatial distribution of the rate of retreat/advance of the coastline reflects the 'turbulence' in the cumulative impact of the dynamic shore-formed factors.

## P64 - A PARAMETRIC MODEL TO DETERMINE THE BATHYMETRY IN SHALLOW COASTAL ZONE USING DIGITAL AERIAL PHOTOGRAPHS OF THE SELECTED SECTION OF THE DZIWNÓW SPLIT

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Bathymetry data (maps) for the coastal zone are being applied to analyze the morphology of the coast. That maps are usually created based on echo sounding measurements. In the shallow coastal zone the quality and accuracy of data is insufficient. Studying of these places by using echo sounder or sonar is unprofitable. Green LIDAR scanning can solve the problem, but it is still an expensive method.In studies of the coastal zone digital RGB aerial photographs are used - mainly for preparing orthophotomaps. The authors decided to use this fact in order to build a parametric model for mapping the bottom of the Baltic Sea shallow coastal zone (the Dziwnów Split).So far, in the 60's, researchers in the USA (Musgrove, 1969) and Russia (Zdanowicz, 1963) developed the first method of bathymetry determining from aerial panchromatic (black-white) photographs. This method was adapted for the Polish Baltic coastal zone conditions by Furmańczyk in 1975. In 2014 we have returned to this concept using more advanced techniques of scenes recording and image processing and by using the digital vertical aerial photographs. The high-resolution image (10 $cm^2$ / pixel) is technically a big matrix containing values of the grey level in the individual spectral bands.The proposed model is based on the image pixel values and relative depths measured In situ in selected checkpoints (beach, shoal and depth region). As a result, the relation of the pixel brightness and sea depth is defined. Parameterization here comprises a dynamic adaptation of known depth to the range of pixel brightness and determination of the optimal bathymetric curve. In the next step, the depth calculations for the whole scene are done. Note, the algorithm requires numbers of adjustments resulting from, e.g., vignetting effect or distribution of light.We have developed the algorithm with correction formulas and created a final model in MATLAB software. It allows one to obtain 3D bathymetry visualization for a specific region from a digital color aerial photograph. The model enables to determine the bathymetry of the most dynamic areas in the marine coastal zone up to 3-4 meters depth with a relatively good accuracy. Comparing the digital bathymetry maps - obtained by proposed method - in the following periods, one can develop differential maps, which reflect the movements of the sea-bottom sediments. This can be used to indicate the most dynamic regions in the examined area.

## P65 - The role of weak storms in the development of the natural and protected coast of Dziwnow Spit

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Morphodynamic changes along dune coasts are usually considered as they were caused by high intensity impact factors as storm surges, which usually lead to significant beach and dune erosion. However, the short-term changes caused by non-extreme hydrodynamic conditions are not sufficiently investigated, especially their comparison in the natural and protected coast. This research focuses on a comparison of changes caused by weak (significant wave height [Hs] ‹ 2.5 m) storms along a dune coast of Dziwnow Spit. The studies were carried out along two 2-km-long sections of the southern Baltic coast, where one of section is a natural coast and the other is a protected area. Several real-time kinematic (RTK) GPS surveys were carried out from June to December 2012. The surveys included cross-shore profiles measured from the dune foot to a water depth of 1 m. The profiles were spaced at constant 100 m intervals. In addition, hydrodynamic data, in form of offshore significant wave height from WAM model and water level from tide gauge in Dziwnow were collected. Using statistical method of Ward's hierarchical cluster analysis, the groups of hydrodynamic conditions were identified. Coastal changes were analysed using two well-known parameters: shoreline displacement and volume changes, which several statistical parameters were calculated for. The analysis confirms that both natural processes: erosion and accumulation take place with relation to the shoreline displacement and the volume changes in all groups of hydrodynamic conditions on both the natural and protected coast. The proportion of these changes depends on the hydrodynamic conditions and the type of the coast. The studies proved that on the one hand the coast protection system, in form of groynes, fulfils its protective function in some classified groups of hydrodynamic conditions but on the other hand, it also shows that groynes lose their protective function as soon as conditions become more severe.

## P66 - Hydro-meteorological conditions of coastal erosion in the southern Baltic seashore in Poland

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The problems of research concerns the spatial and temporal variability of meteorological and marine conditions during the last century within the Southern Baltic coastal zone. The short-term and seasonal dynamics together with long-term tendencies and changes of climatic and marine conditions have a decisive impact on the Baltic coast erosion and its landscape transformations. The occurrence of storm surges, intensive atmospheric precipitation and snow melting (among others) lead to geo-morphologic changes of this marine coastal zone, mainly due to the occurrence of marine abrasion and slope erosion-denudation processes. Moreover, the climatic conditioning through thermal phenomena and precipitation affects the lively nature and its processes. The paper covers the characteristics of the main hydro-meteorological components which determine the landscape transformations within the Southern Baltic coastal zone: sea level, thermal conditions and icing of marine waters, atmospheric precipitation, snow cover, air temperature, wind speed and direction.

The analysis of hydro-meteorological conditions determining the landscape transformations within the Southern Baltic coastal zone covers the following issues:

- dynamics of thermal-precipitation changes

- occurrence of wet and dry periods,

- variability of thermal and growing seasons

- variability of temperature and icing of marine waters

- dynamics of storm highs and lows

- intensity of abrasion within cliff and dune edges

- extreme hydro-meteorological phenomena and their role in the transformation of marine coastal areas.

## P67 - Hydro-meteorological seasonality of landslide processes of the Pomeranian Bay cliff coast (Southern Baltic)

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Functioning of the contemporary morphogenetic system of the Pomeranian Bay cliff coast is mainly conditioned by the structure of climate seasonality. Seasonal variability of landslide processes should be associated with course of the weather and hydrological conditions during the year. Landslide processes are often initiated by several factors. The intensity of the landslide process is determined mainly by the scale and intensity of such factors as storm surges and precipitation. In situations of extreme storm surges and high precipitation dramatically increases the risk of massive landslides causing threat to the infrastructure and population of coastal areas. In order to effective prediction of the adverse conditions it is necessary to understanding the morphogenetic seasonality of specific types of weather.

The main object of the research was to determine the seasonality of storm surges and rainfall characterized by a specific morphogenetic potential. To solve the problem of the research statistical analysis of meteorological and hydrological conditions of the period 1973-2010 were conducted

The study showed that the greatest probability of storm surges causing landslides occur in the period from November 2 to February 14. In this season, the frequency of storm surges amounts 7.7%.On the other hand, the highest intensity of precipitation can be observed most often in the summer from June 10 to July 19 with a frequency of 25%. It was also determined that the seasons of high precipitation and storm surges will never overlap. But there is one period when during the highest sea activity we can observe increased precipitation and it occurs from November 2 to December 31. This season should be considered as a period of the highest risk of landslide processes occurrence.

## P73 - Providing best estimates of major inflow events by use of a multi-model ensemble approach

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The Baltic Inflow is a frequently reoccurring event, where salt-rich water masses from the North Sea enter the Baltic Sea. These water masses have an impact on the flora and fauna of the Baltic Sea but might also affect the stratification and geostrophic currents of the surface waters. The last major inflow event has been detected in December 2014, which was predicted by ocean forecasting models and also reflected in the data collected at measurement stations.

In the framework of the Copernicus Marine Environment Monitoring Service a multi-model ensemble (MME) approach has been developed to provide a best estimate for such severe events over a wide area, especially in regions where comprehensive and gapless observations are lacking. With the aid of the MME, which is based on several independent forecast products of the North and Baltic Sea, also the uncertainty between the forecasting models can be distinguished, providing an added value to modellers and users of a single-forecast. The MME is calculated for the following physical parameters: 2D salinity and temperature at the sea surface and the bottom, 2D sea surface currents, vertically integrated water transports across BOOS and NOOS (Baltic- and North West Shelf Operational Oceanographic System) transects, and sea surface height at 24 stations along the coast of the Baltic Sea. The MME for temperature and salinity are further validated using satellite and in-situ data at offshore stations.

We will present the method of how inflow events can be detected in e.g. bottom salinity, transports and sea level and will show some results of the last major inflow event in 2014. In addition, we will give some estimates of uncertainty which go along with such forecasts.

## P74 - Numerical simulations of North Sea saline water spread into the central Baltic Sea after Major Baltic Inflow 2014

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In this work spread of saline water after Major Baltic Inflow in December 2014 is discussed. To perform numerical simulations of hydrodynamics in Baltic Sea Princeton Ocean Model (POM) (Blumberg et al 1987) was used. The initial salinity field was estimated based on data at the beginning of the inflow at Darss Sill and Arkona Basin and the long term monthly averaged data in the remaining part of Baltic Sea. The wind conditions were adopted according to Coamps model output operated at the Interdisciplinary Centre for Mathematical and Computational Modelling (ICM), Warsaw (Jakubiak and Hodur 2011). As the result the times in which the saline water reached the different areas of Baltic Sea was estimated and compared to available measured data.

Blumberg A. F., Mellor G. L., 1987, A description of a three-dimensional coastal ocean circulation model, pp.1–16, [w] Three-dimensional Coastal Ocean Models, N. Heaps (Red.), Am. Geophys. Union, 4, 208

Jakubiak, B. and Hodur, R.M., 2011. Experiments with a land-surface model coupled to a high-resolution NWP system, Proc. "Earth Observation for Land-Atmosphere Interaction Science", Frascati, Italy, 3–5 November 2010. ESA SP-688, January 2011, 6 pp.

## P75 - Assessment of long time series of atmospheric circulation patterns forcing inflows of saline water to the Baltic Sea

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Sporadic inflows of saline waters are very important to maintain the salt balance and favorable conditions for life in the entire Baltic Sea. At other times the Baltic Sea water exchange with the North Sea through two narrow and shallow straits is highly restricted and due to the high fresh water runoff from the catchment area, outflow conditions are generally dominating. Inflow events, which carry enough saline water into the Baltic to reach the bottom of the central basins, are called major Baltic inflows (MBI). During the last 4 decades, the number of MBI-s per decade has gone down from 4-5 to only one, what has generated hypoxia in large volumes of the Baltic deeps. The trigger of a Baltic inflows lies in the atmosphere and the direct atmospheric forcing consists of two phases: at first high pressure with easterly winds lasts over the Baltic Sea region, what is followed by strong westerlies. The intensity of the event depends on the persistence and strength of both phases and how closely these come after each other. There are also some anomalies in the atmospheric circulation during the whole season with the event compared to mean situation, but these results are not so distinct. At the same time for prediction of MBI-s longer term factors that favor the MBI-s are very important. The other source of predictability lies in the upper atmospheric levels as the signal of transformation in the atmospheric circulation starts from up. That means that if we want to detect or even predict MBI-s from atmospheric forcing side we should be flexible and capable to describe atmospheric circulation in the whole atmospheric column with varying resolution in time and space. This sounds as a classical synoptic climatological task. Availability of more than century-long reanalysed time series gives us opportunity to study the variability of atmospheric forcing of MBI-s and other inflows during the whole period of their detection. Our main task could be summed up as: what is the scale of the atmospheric forcing of MBI-s and inflows in general in time and space? To answer this question we perform a number of sensitivity studies with various atmospheric circulation classifications, varying the size of the area of that is classified, the altitude of pressure field, the period that is classified. This all helps us to get a better understanding why the occurrence of the events is so variable and brings us towards detection of the events from the atmospheric parameters.

## P76 - Numerical hydrodynamic modeling Major Baltic inflow using INMOM model

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The results of the simulation of Major Baltic Inflow 2003 and 2014 years with the help of numerical simulation model of the North and Baltic Seas, realized on the basis INMOM model. To improve the spatial resolution of the model region in the narrow Danish straits was created spherical grid area with two poles. Irregularity of grid area was set so that the steps to the space in the Danish Straits reached 300-700m in sea waters reach up to 4-6 km. Vertical were set 25 irregularly distributed over the depth σ-levels. The number of grid points of the area was 720x628. The initial and boundary conditions of temperature and salinity were set according to the reanalysis http://marine.copernicus.eu/. In the liquid boundaries of the North Sea were set amplitude and phase of the 8 main tidal harmonics. For currents flow condition has been set. As forcing were set weather data reanalysis WRF model (2002-2003 y.) and ERA (2014-2015 y.). The modeling results were compared with measurements of temperature and salinity at Station Darss Sill. The comparison results showed that the model realistically describes the features of the water dynamics and salt, heat flows during Major Baltic Inflow.

## P77 - The dynamics of water overflowing the Słupsk Sill after the inflow 2014

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Inflowing waters of the Major Baltic Inflow (MBI) in 2014 overflowed the Słupsk Sill with periodic plum-like scheme. The period of plums varies from days up to two weeks. During the overflowed process the halocline raised by 15 meters but the consequences due to vertical mixing was observed in whole water column. This work focus on the data collected during four months of mooring measurements deployed at the Słupsk Sill as well as on the data acquired with towing CTDO probe before and after mooring deployment.

## P78 - Does sea ice influence Baltic inflow dynamics?

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Salt water inflows remain one of the most important research topics for salinity changes in the Baltic Sea, yet their dynamics are still not fully understood. In this study we investigated whether sea ice cover influences the intensity of salt water inflows. We used a three-dimensional coupled ice-ocean circulation model for the Baltic Sea with a novel ice model that takes the impact of the weight of sea ice on the sea level elevation into account. The simulated time period is 1949 to 1989. Our sensitivity studies have shown that changes in salinity correlate with changes in ice cover. Colder conditions cause lower salinity nearly evenly distributed over the whole model domain. However, this leads to a strong gradient regarding the relative changes from North to South. We think that the main contributors are the manipulation of wind stress and surface pressure in areas with a thick ice cover. These effects seem to influence the sea level and influence the intensity of salt water inflows. This leads us to the conclusion that sea ice also contributes to the mean salinity in the Baltic Sea, though only being present in the Northern part.
According to the second Assessment of Climate Change in the Baltic Sea region sea ice cover in the Baltic Sea is projected to continue to shrink. Our studies show that global warming might not only influence air temperature in the North but also influence the mean salinity in the Baltic Sea.

## P79 - Turbulent mixing and methanotrophic bacterial activity within the dense gravity current of the Major Baltic Inflow 2014/2015

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The Major Baltic Inflow (MBI) 2014/2015 was classified as the third largest inflow since 1880. Despite the importance of MBIs for the Baltic Sea, direct measurements of an inflow entering the central Baltic Sea have been rare due to logistical constraints. For the MBI 2014/2015, high-resolution turbulence microstructure data, biogeochemical data, and microbiological data have been acquired inside the gravity current just entering the Gotland Basin. Results show that the vigorously turbulent interface between the oxic near-bottom inflow and the sulfidic ambient water is a location of important biogeochemical and microbial transformations. In addition to these ship-based measurements, the Gotland Deep Environmental Sampling Station (GODESS) has been deployed in the center of the Gotland Basin. The GODESS was, in addition to standard sensors, equipped with a temperature microstructure package, allowing the measurement of turbulence parameters over several months. The mooring was able to capture the arrival of the MBI. The main inflow reached the central basin in a front-like pattern with a vertical structure of cold oxic intrusions interleaving with the sulfidic ambient waters. These large-scale temperature variabilities are, however, not reflected in an increase of temperature microstructure. This surprising result indicates that, after the detachment of the MBI from the basin boundary, during its way into the central Basin, turbulence levels decreased to those typically observed during a stagnation period. This finding underlines the importance of mixing at the basin boundaries.

## P80 - Impact of natural oxygenation on sedimentary nitrogen loss and recycling in the Baltic proper

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At the end of 2014, a major Baltic inflow (MBI) brought oxygenated, salty water into the Baltic proper and reached the long-term anoxic Eastern Gotland Basin by March 2015. During two expeditions in July 2015 and April 2016, two newly oxygenated sites were visited in addition to permanently oxic and anoxic sites. The same stations had been visited in 2008 and 2010, but the now oxygenated stations were then anoxic. Here nitrogen (N) and oxygen fluxes were measured *in situ* using a benthic lander. Whole core, slurry and *in situ* incubations with labelled nitrogen ($^{15}N$) were conducted to measure denitrification, anaerobic ammonium oxidation (anammox) and dissimilatory nitrate reduction to ammonium (DNRA) rates. The MBI gave rise to bottom water nitrate ($NO_3^-$) concentrations of about 10 µM at the newly oxygenated sites, where the $NO_3^-$ concentrations previously had been lower than 0.5 µM (Hall et al., 2017). The increased availability of $NO_3^-$ initiated DNRA (0.06-0.53 mmol $m^{-2}$ $d^{-1}$), which retained N in the system, and denitrification (0.05-0.16 mmol $m^{-2}$ $d^{-1}$), which removed N from the system. The MBI created a second oxycline at 140 m in the water column, a potential environment where denitrification could also have taken place. By combining our measured rates with literature values for the water column, denitrification in newly oxygenated areas was estimated to remove 12 % of the total N input, although this assumed the MBI oxygenated the entire Baltic proper below 140 m depth. This study shows that the MBI has had a major influence on the nitrogen cycle in the Baltic proper.

## P81 - Changes of mercury species concentrations in Baltic Sea waters during the Major Baltic Inflow of winter 2014/2015

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It is especially important to better understand the marine mercury cycle in areas showing low oxygen concentration, because in these environments certain bacteria groups transform divalent mercury to neurotoxic methylmercury (MeHg). Subsequently, MeHg is accumulated in the food chain posing health risks to higher trophic level organisms.

During stagnation, Baltic Sea deep water shows oxygen consumption that is not replenished because of steep density gradients causing reduced vertical transport. At low oxygen concentration, other compounds (nitrate, Mn(IV), Fe(III), sulphate) are used to enable microbial mineralization processes. Some iron and sulphate reducing bacteria are known to cause MeHg production. Episodically, almost in decadal intervals, salty and thus heavy North Sea water is supplied to the deep Baltic Sea basins by meteorological controlled sea level differences in combination with strong westerly winds. These inflow events supply oxygen to the Baltic Sea deep waters that suffered during long stagnation period under oxygen consumption and built up of anoxic and sulfidic conditions at depth. Such an event happened during the time of the study.

The mercury species MeHg, dimethylmercury and elemental mercury and additionally total mercury (Hg-tot) were analysed on three campaigns in March 2014, March 2015 and July/August 2015 in various water layers of the Baltic Sea deeps. Thus, dramatic changes of the mercury concentration distribution could be recorded. The inflowing water changed the precondition of mercury transformation and major amounts of accumulated mercury were removed, likely attached to particles. Based on the Hg-tot and MeHg depth profiles of the Gotland Sea deep station, the inventory for Hg-tot was 900 ± 450 nmol/m² in March 2014 and 300 ± 150 nmol/m² in July/August 2015, indicating a loss of 600 ± 420 nmol/m² of total mercury in 17 months. This corresponded to about a decade of atmospheric Hg deposition in that area (~50 nmol/m²yr). The deep-water inventory for MeHg was about 230 nmol/m² in March 2014 and 20 nmol/m² in July/August, respectively, resulting in a loss of 210 nmol/m², roughly one third of Hg-tot. Based on the investigated stations along the thalweg of the Baltic Sea for three campaigns, the propagation of the mercury removal is shown and the potential consequences are discussed.

## P82 - The Baltic Sea Anoxic Situation Index – How to assess the anoxic situation with one value

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As a brackish water body, the Baltic Sea suffers from areas of low oxygen concentration, up to the point of anoxia with significant concentrations of hydrogen sulphide. Assessing the state of a large body of water can usually only be done in estimations, based on spatially distributed measurements. To approximate the degree of anoxia and euxinia in the deep basins of the Baltic Sea based on HELCOM monitoring data, the Baltic Sea Anoxic Situation Index (BAXI) has been developed. The unit-less value resulting from the developed formula is a relative measure meant primarily for comparison purposes. Its goal is to increase when the amount of dissolved oxygen (DO) in the monitored area decreases, thus showing the seasonal and decadal variability. For the anoxia estimation, measurements of the DO concentration at predefined monitoring stations are used. If available, hydrogen sulphide concentration measures and their corresponding water depths are also considered.

Advantages of the BAXI are the formula‘s conciseness, that no assumptions about linear relations of area to volume of the water body are made and the additional use of hydrogen sulphide concentration values, to better approximate the degree of anoxia. Compared to other indicators for the assessment, the BAXI is robust against incomplete data sets and takes all available monitoring data into account.

The index was visually validated by using a visualization tool developed for scientific outreach purposes in which hypoxia and anoxia water bodies were modelled and can be interactively explored in 3D. A timeline visualizes the BAXI for the monitoring data acquired within the regular monitoring cruises of the IOW. Even though validation is not easy, the index was found to relate sufficiently well to the ground truth data, and also to the annual hydrographic-hydrochemical assessments of the Baltic Sea condition.

## P83 - Classifying spectral wave energy distributions in coastal archipelagos

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Wind generated surface waves are important for many coastal processes. In shallow water the longer waves are involved in interactions at the bottom, while shorter waves are a factor to consider in e.g. air-sea interaction. The distribution of energy between waves of different length is commonly described by the so called wave spectrum. The properties of the wave spectrum is quite well known for general open sea conditions, where it often – in the absence of swell – has one distinct energy maximum. The regular shape of the open sea wave spectrum opens up possibilities to quantify the wave energy distribution with the help of statistical parameters, such as the significant wave height and the peak wave period. However, this approach is not adequate in to describe the wave field at more complex coastal areas where the waves are generated by different fetches, and further mixed with attenuated longer waves propagating towards the shore. To identify systematic patterns in the seemingly unstructured wave fields we used wave measurements from 20 different locations in the Helsinki coastal archipelago. We were able to quantify wave energy distributions for different types of locations that were mainly classified based on the level of exposure to the open sea waves. The key finding is that the longer waves are not swell that are unrelated to the local part of the wave field, but waves generated further out from the shore by the same atmospheric system. The resulting energy distribution is therefore a systematic balance based on the unique fetch conditions and sheltering properties of the coastal location in question. We identify four different types of coastal conditions and show that the energy distribution for places with the similar geographical properties resemble each other. The systematic classification of typical energy distributions for archipelago areas will have consequences for both scientific and engineering studies by enabling a more accurate assessment of the wave impact in archipelagos.

## P84 - Effects of the wave-induced forcing on a circulation model of the Baltic Sea

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This study addresses the coupling between wind wave and circulation models on the example of the Baltic Sea. This topic reflects the increased interest in operational oceanography to reduce prediction errors of state estimates at coastal scales. The effect of wind waves on model circulation model is investigated using a high-resolution NEMO v3.6 model forced with fluxes and fields obtained from the wave model WAM. The additional terms accounting for wave-current interaction that are considered in this study are the sea-state dependent energy and momentum fluxes as well as different parameterizations of the Stokes-Coriolis force. The individual and collective role of these processes is quantified and the results are compared against the NEMO stand-alone model, as well as against in-situ and satellite measurements. The effects of including the sea state effects on the Baltic Sea vertical mixing and dynamics are illustrated for the cases of several extreme events. The importance of considering the wave-induced processes into the hydrodynamical models for various Baltic Sea model applications is demonstrated.

## P85 - Formation of strong offshore flows in the Southern Baltic coastal zone – observations and numerical modelling

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In the overall system of coastal zone currents of Southern Baltic Sea occasionally seaward-directed jets are formed. They originate within the surf zone and broaden outside the breaking region. The typical hydrodynamical background is the convergence of two opposite directed longshore flows (feeder currents, resulting from the longshore variability of wave induced set-up). Resulting offshore flow is called rip current. It may cause bar erosion and if the phenomenon lasts long enough then a channel is formulated. This so-called energy window is a potential place for the emergence of next rip current which deepens the channel (feedback mechanism). The observations confirmed the occurrence of this phenomenon in Polish coastal zone (Furmańczyk 2001, Szmytkiewicz 2003), moreover field studies allowed to determine the wave conditions, in which the seaward-directed flow emerged (Schönhofer 2014). Within the research presented herein field studies were conducted in the vicinity of Lubiatowo village, where a field laboratory of the Institute of Hydro-Engineering of the Polish Academy of Sciences is situated. According to measured (with the use of free-floating GPS transmitters) data one irregular offshore flow was observed, which had some features characteristic for rip current. Moreover, seaward-directed jets in the presence of a break in the bar in the study area are reconstructed by numerical modelling with the use of XBeach model. Several test cases for variety of wind wave direction and steepness are considered. Based on these simulations wind wave conditions conductive to the formation of such flows are specified and compared to these described by Schonchhofer (2014). Additionally, based on wave model WAM generated data, the incidence of such favorable conditions together with their seasonal variation is estimated.

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## P86 - Assessment of extreme current velocities and parameters of wind waves in the vicinity of Kotlin Island, the Gulf of Finland

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Research of the Kotlin Isle (KI) coastal dynamics has shown that most part of western shore is actively eroded. Rates of coast retreat reaches 1.2-1.6 m/year, being maximal values for the Eastern Gulf of Finland (GoF). Geological and geophysical studies reveal factors controlled coastal dynamics. Thickness of Holocene marine sands within beaches and dunes is less than 1-2 m. Large areas of near-shore bottom, covered by boulders and pebbles are represented by glacial till outcrops. It causes sediment deficiency, which lead to active erosion. Coastal relief is low, and during severe storms, sand beaches and foredunes are affected by waves. Nowadays the Coast Protection Program of St. Petersburg includes sand nourishment together with groins construction. Determining the optimal configuration and location of the bank protection installations on the coast requires information on the extreme water level, current velocity and wind waves.

Calculations of extreme current velocities were performed using a three-dimensional hydrodynamic model of the eastern GoF. Extreme wind wave parameters were estimated using SWAN wind wave model on different grids including a 25m grid covering the west coast of KI. To calculate the maximum possible values of current velocities and wave parameters, the period of maximum severe flood on December 26-28, 2011 was chosen. Calculations were performed under prescribing at the open western boundary of the model domain hourly values of the water level observed at the station "Shepelevo", and at the eastern boundary, Neva River water discharge. At the boundary with the atmosphere hourly fields of meteorological parameters from HIRLAM model have been set.

Calculated maximal modules of current velocity are 20 - 70 cm $c^{-1}$ off the southern coast of KI, 30 - 90 cm $c^{-1}$, off the northern coast, and on KI end are greater than 100 cm $c^{-1}$. Significant wave height calculations were performed for the three coastal protection options: 1) unprotected artificial sandy beach, 2) the beach, protected by breakwaters, and 3) the beach protected by groins and breakwaters. Analysis of wave heights off the KI coast showed that in the case of beach protected by breakwaters (option 2 of coastal protection), wave height near the coast is markedly reduced in comparison with the unprotected beach (option 1). However, in the case of beach with breakwaters and groins (option 3) strong changes in significant wave height near the coast are not marked.

## P87 - Particle transport model sensitivity on wave-induced processes

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Different effects of wind waves on the hydrodynamics in the North Sea-Baltic Sea are investigated using a coupled wave (WAM) and circulation (NEMO) model system as part of the Geesthacht Coupled cOAstal model SysTem GCOAST. The terms accounting for the wave-current interaction are: the Stokes-Coriolis force, the sea-state dependent momentum and energy flux. The role of the different Stokes- drift parameterizations is investigated using a particle-drift model. Those particles can be considered as simple representations of either oil fractions, or fish larvae. In the ocean circulation models the momentum flux from the atmosphere, which is related to the wind speed, is passed directly to the ocean and this is controlled by the drag coefficient. However, in the real ocean, the waves play also the role of a reservoir for momentum and energy because different amounts of the momentum flux from the atmosphere is taken up by the waves. In the coupled model system the momentum transferred into the ocean model is estimated as the fraction of the total flux that goes directly to the currents plus the momentum lost from wave dissipation. Additionally, we demonstrate that the wave-induced Stokes-Coriolis force leads to a deflection of the current. During the extreme events the Stokes velocity is comparable in magnitude to the current velocity. The resulting wave-induced drift is crucial for the transport of particles in the upper ocean. The performed sensitivity analyses demonstrate that the model skill depends on the chosen processes. The using of a coupled-model system reveals that the newly introduced wave effects are important for the drift-model performance, especially during extremes. Those effects cannot be neglected by search and rescue, oil-spill, transport of biological material, or larva drift modelling.

## P88 - 3D MODELING VS OBSERVATIONS FOR THE GULF OF RIGA: EFFECTS OF VARYING RIVER DISCHARGE, WAVES AND TIDES

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Baltic Sea has been extensively studied in recent decades. However, the Gulf of Riga has got slightly less attention. There are still some modelling discrepancies, especially, concerning stratification properties which can get rather sensitive in certain periods of the year. Latvian Institute of Aquatic Ecology and Marine Systems Institute perform regular monitoring including profiling which is complemented by additional near coast observations at 10 locations and occasional FerryBox data. There are also SST data in days of clear skies which provides excellent reference to upwelling events. These data are compared with modelling results of HBM 3D ocean circulation software with atmospheric forcing by DMI HIRLAM model for time period 2014-2017. Nested set-up is applied where territorial water of Latvia and Gulf of Riga have finer resolution of 1 nm, whereas other part of Baltic Sea have rough resolution - 2 nm. Outer wet boundary conditions are placed at Zealand (west) and Åland (north) islands to exclude Bothnian bay. Wet boundary conditions are obtained from DMI ocean model, whereas wave field is obtained from DMI WAM forecasts. Particularly interesting is the influence of varying river run-off: both seasonal variability and annual changes. For example, year 2015 was particularly dry resulting in increased salinity afterwards. Lowered Daugava river run-off brought visible changes in profile measurements in southern part of Gulf of Riga, but alteration of water exchange through Irbe strait minimises the effect of varying river discharge. The importance of wave effect in wind drag is studied basing on comparison with water level measurements. The influence of waves is prominent only when wave orbital velocity is comparable with magnitude of wind. Tidal effects are negligible in Baltic proper but diurnal oscillations are somewhat visible in Gulf of Riga and Gulf of Finland where the amplitude can reach few centimetres.

Fourier analysis of water level observations is compared with modelling results where tidal potential is accounted by actual ephemerides. The correlation is good, but its role in exchange of waters between Gulf of Riga and Irbe strait is low. Recent decade did not have substantial ice cover in Gulf of Riga but Suur (Virtsu) strait usually has a short period with fastened ice. Despite most of the water exchange occurs through Irbe strait between Gulf of Riga and Baltic proper, conditions in Suur strait can influence water level dynamics in mooring stations.

## P89 - A NUMERICAL APPROACH TO ANALYSE THE PERSIAN GULF AS AN INVERSE ESTUARY IN CONTRAST TO THE BALTIC SEA

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The Persian Gulf and the Baltic Sea share a lot of common features such as mean depth, surface area and are both semi-enclosed seas, separated by narrow straits to the ocean. The climate in the Baltic Sea region is humid and the drainage basin is large which leads to a fresh water runoff out of the Baltic Sea. This corresponds to an estuarine circulation. The climate in the Persian Gulf region is the opposite. The whole region is very arid with an evaporation rate of up to 1.4 m/y. Because of that there is an outflow of very saline and thus dense water at the bottom and an inflow of Indian Ocean Surface Water which corresponds to an inverse estuarine circulation. The dense bottom water is of special interest since it could feed Indian Ocean intermediate or deep waters with long residence times, leading to a sequestration of atmospheric properties such as the greenhouse gas $CO_2$.

In this study the transports through the Strait of Hormuz connecting the Persian Gulf to the Gulf of Oman are computed, based on a 1 nm simulation using the 'General Estuarine Transport Model' (www.getm.eu), and compared to the transports of the Baltic Sea. For analysis, the total exchange flow (TEF) theory is applied and discussed. In addition, the overturning circulation of the Persian Gulf is presented.

## P90 - Where to put it? How to relocate the „permanent“ observation station "Darss Sill"?

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The deep water ventilation of the Baltic Sea depends crucially on the inflow of saline, oxygen rich water from the North Sea. These events are difficult to observe due to their intermittent character and short duration of 5-15 days. Thus, a high temporal sampling is required in the order of some hours. Like often in oceanography such long-term and high resolution observations are sparse. One of the rare exceptions is the permanent observation station “Darss Sill” (in the western Baltic Sea) in the direct pathway of the inflowing water masses.

Due to the increased demand of offshore wind energy, potential offshore constructions sites would require a relocation of the “Darss Sill” station. To investigate possible new locations, we conducted a site assessment to quantify the observational skill at the present location and possible alternative places. To assess the skill of potential new observation stations, we set up a eddy resolving (grid resolution 200m) full baroclinic model of the western Baltic Sea with the General Estuarine Transport Model (GETM). The model integration period covers 35 years (1980-2015).

Based on the model output fields, we computed spatial maps of autocorrelation time scale, spatial correlation length, days with salinities larger than 17 psu , consecutive days with salinities larger than 17 psu, reconstruction error of: a) Major Baltic Inflows (MBIs), b) cumulative salinity distributions, and c) total exchange flow. Additionally, we computed the standard deviation of the above mentioned fields. To construct a cost function to find suitable new locations, we aimed for maximising the correlation temporal and spatial correlation length, days with salinities larger than 17 psu and minimising the reconstruction error and the standard deviations. This optimisation procedure also included a Monte Carlo analysis. Here, we varied the individual weights of the computed maps provided to the cost function.

The optimisation indicate that the present location of station Darss Sill is well chosen. However, a shift of 8-12 km towards the Northeast could give further improvement in representing the water exchange between the North Sea and the Baltic Sea. Although we cannot recommend a relocation from a scientific point of view, subtitle alternative locations exist.

## P93 - The impact of extreme meteorological and hydrological events on the dynamics of cliff coast retreat (Pomeranian Bay - Southern Baltic)

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In the last 30 years it showed a significant retreat of the Southern Baltic Sea coast, both in the cliff coast and the dune coast. The paper presents the intensity of retreat of moraine cliffs of the Pomeranian Bay during the period 1984-2015, using the measured values of the rate of the cliff crown retreat on the Wolin Island. The dynamics of cliff retreat is referenced to extreme meteorological and hydrological conditions that generate geomorphological changes of the sea coast. There is determined the time variability of extreme storm surges which decide about the intensity of the cliff abrasion. Research also show the dynamics of extreme precipitation and snow melt, which determine the dynamics of slope erosion processes, eg. Landslides cliff. In addition, there is presented a model of the initiation, evolution and decay of geomorphological forms which occur on the cliff slope, on the basis of sequential photographic documentation. The study also report a quantitative relationships between the dynamics of extreme meteorological and hydrological conditions and the intensity of the loss of sediment of the cliff coast.

## P94 - Impact of early spring weather conditions on the characteristics of the CIL on field data 2004-2008

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Data of temperature and salinity of the waters of the Baltic Sea in May and July were analysed to study the influence air of temperature in March on the characteristics of the cold intermediate layer (CIL). The in-situ environmental monitoring data obtained under the program "LUKOIL-KMN" held in May and July of 2004-2008 in South-Eastern part of the Baltic Sea was used for the analysis. The following parameters were selected for the study: temperature, salinity, depth of the core of cold intermediate layer, depth of the upper boundary of gradient sublayer of the CIL. The air temperature was taken from the open information source Gismeteo [https://www.gismeteo.ru].

Comparison of the core temperature of the CIL, measured in May and July, and air temperature in March demonstrated a great correlation which confirms the importance of the March climatic conditions in determining the characteristics of CIL. In addition, the relations of early spring climatic conditions and belonging to the specific winter water mass sublayer are being studied.

## P95 - Reproduction of thermohaline structure of the cold intermediate layer in Southeastern Baltic by the CMEMS reanalysis.

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A comparison of field data of formation of the cold intermediate layer (CIL) of the Baltic Sea was made. Vertical profiles of temperature and salinity obtained in the south-eastern Baltic in May, July from 2004 to 2005 (54°52' N, 19°20' E) were compared with similar data of modelling in the same period. The data of hydrophysical measurements was collected in 4 expeditions on the research vessel "Professor Shtokman". We use the physical reanalysis provided by CMEMS (http://marine.copernicus.eu). The reanalysis is carried out for the period of 1989 – 2014 by means of HIROMB with multivariate data assimilation [1]. The field data used for comparison are not included in the reanalysis data base.

We pay attention to the elements of the CIL structures that may form under the action of different mechanisms [2]. If the boundaries of the CIL are defined as maximum absolute value of water temperature gradient across the vertical [3], one may allocate 2 the main elements of the CIL structures in the salinity field - homogeneous and gradient sublayers [4].

Comparison of natural and simulated data showed that the model reproduces both the homogeneous and the gradient sub-layers of the CIL. The volumes of waters for each sub-layer are not reproduced exactly. In comparison with the same field data, gradient sublayer of the CIL according to the model data was located higher on each of the considered profiles. But this inconsistency does not interfere with an overall positive conclusion about reproduction of internal (structural) elements of the CIL thermohaline structure of the Baltic Sea by the CMEMS reanalysis.

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## P96 - Variability of the Cold Intermediate Layer of the Baltic Sea in spring 2006

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The cold intermediate layer (CIL) is clearly identifiable in vertical structure of the Baltic Sea waters after the formation of seasonal thermocline in spring. During spring period, the CIL, from one side, has already been formed, and from the other - not yet significantly changed by external influence of the particular-year spring conditions. This make it possible to clarify mechanisms and processes involved in the CIL formation. The aim of this work is to analyse the variability of the Baltic CIL properties along the main axis of the sea -- from the Arkona Basin to the Gulf of Finland -- during spring 2006. We examine the combined data set from cruise No 76 of r/v "Professor Shtokman" (AB SIO; 23 April – 4 May 2006; the Gulf of Finland – the Gotland basin) and cruise No 11/06/05 of r/v “Gauss” (IOW; 4-12 May 2006; Kiel Bight – northern Gotland basin). It is found that both location of the CIL boundaries and properties of the major part of its waters vary along the axis of the sea incoherently; its thickness, minimum water temperature (the core of the CIL) and the depth of its location, water salinity in the CIL core vary considerably. Thus, the CIL as a whole is not the result of large-scale intrusion of waters from a particular Baltic sub-basin, like, e.g., the Levantine Intermediate Waters in Mediterranean. Vertical temperature profiles within the CIL are all extremely heterogeneous either, excluding vertical winter-time convection from the set of possible mechanisms responsible for the Baltic CIL formation. We conclude that the heterogeneity of the CIL as a whole speaks in favour of its formation by a combination of local and large-scale transport processes.

Investigations are supported by the Russian Science Foundation, project number 15-17-10020.

## P97 - Longitudinal transformation of estuarine transport controlled to mixing controlled nutrient, oxygen and detritus dynamics in the Gulf of Finland

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Nutrient and phytoplankton dynamics in the western part of the Gulf of Finland are determined by water-mass exchange with the Baltic Proper and in the eastern part by nutrient load via River Neva. Along the thalweg vertical stratification changes from permanent layered structure to a frequently mixed water column. Due to this phenomena, there is strong benthic and pelagic coupling in the eastern part whereas the western part has limited bottom and surface connection. Although different factors determine and control nutrient and phytoplankton dynamics, the response in the Gulf of Finland is qualitatively similar, being dominated by seasonal cycling of biogeochemical parameters.

We modelled the Baltic Sea (including Gulf of Finland) using circulation model GETM coupled with biogeochemical model ERGOM. Model results of a 40-year simulation (1966-2006) were analysed.

Our results show that in the upper layer the seasonal cycle of phytoplankton, nutrients and oxygen concentrations is uniform along the thalweg. Nutrient concentrations increase from early winter due to degradation of benthic organic matter until a new spring bloom of diatoms starts. In the eastern part river discharge of nutrients increases the level of nutrients there compared to the western part of the gulf. The phytoplankton biomass in relatively high throughout the summer as diatoms are replaced with dinoflagellates and cyanobacteria. Simultaneously part of the dead organic matter originating from phytoplankton is deposited to the bottom, increasing benthic detritus pool. In the eastern part the benthic nutrient and detritus seasonal cycle is similar to the surface layer. In the western part below the halocline saline low-oxygen and nutrient-rich water is transported from the open Baltic Proper to the Gulf of Finland in spring and early summer. This results in the highest nutrient concentrations and the poorest oxygen conditions by the end of August. The central area of the Gulf of Finland is a region where estuarine transport control of nutrient, oxygen and detritus dynamics changes gradually to mixing controlled nutrient, oxygen and detritus dynamics.

## P98 - From Bornholm basin till Northern Baltic Proper: plankton, benthos and hydrophysical conditions in August-September 2016

Ezhova E.[1], Paka V.[1], Karaseva E.[2], Chechko V.[1], Krechik V.[1], and Polunina J.[1]
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During 45 day-cruise (02.08–16.09.2016) of ABIORAS r/v "Academic Strakhov" 3374-miles route, covered the main part of Baltic Proper – from Bornholm Basin till northern Baltic Proper, was passed with 348 stations sampled. Hydrophysical, geological, geophysical and biological works and also specific sampling in the dumpsites of chemical munitions (in frame of MODUM project were done. The detailed survey of water structure through the southern and central areas of the Baltic Sea along the transects with a spatial resolution of 2-3 nautical miles was performed. Analysed data point out the assimilation of waters of the last major North Sea inflows starting in December 2014. It was concluded, the environmental situation corresponds to the onset of stagnation phase. Benthic data are in accordance with this conclusion. It was shown the absence of macrozoobenthos in the Gdansk Deep at 100 m depth, but its presence at the southern slope of the Western Gotland basin at depths 112-119 m, where macrofauna was represented by polychaetes, indicating aerobic environment. In the Eastern Gotland macrozoobenthos, represented mostly by polychaete *Scoloplos armiger*, was marked in two of ten sampling sites (112-124 m) only. Benthic data of the cruise fixed the same spatial limits of *S.armiger* distribution as in 1984-1992. Deeper and in more northern location this species- indicator of lower border of macrofauna distribution, was absent. Ichtioplankton was represented mostly by cod and sprat. Roe and larvae of cod were met over 80 m depths in South Baltic and over 140–200 m in Gotland basin. Cod roe was not detected in northernmost parts of study area, between 58 and 59° N. The average number of cod larvae was the highest during the modern period of observation, probably indicating the successful survival during embryonic development and at early larval stages. Over the last 25 years, the average number of cod roe in the Gdansk basin for the third time (after 1994 and 2003 – years of former major inflows) sufficiently exceeded the long-term average level.

## P99 - From Arkona till Northern Baltic Proper: plankton, benthos and hydrophysical conditions in August-September 2016

Ezhova E., Paka, V., Karasiova E., Krechik V., Chechko V, Polunina J.[1]
[1]*Atlantic Branch of P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences*

During 45 day-cruise (02.08–16.09.2016) of ABIORAS research vessel "Nikolay Strakhov" 3374-miles rout, covered the main part of Baltic Proper – from Arkona basin till Northern Baltic Proper, was passed with 348 stations sampled. Hydrophysical, geological, geophysical and biological works and also specific sampling in the dumpsites of chemical munitions (in frame of MODUM project) were done.

## P100 - Hydrophysical conditions in the southern and central parts of the Baltic Sea in August-September 2016

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In August-September 2016, the 32th cruise of the r/v "Academic Strakhov" took place. Detailed survey of water structure in the southern and central parts of the Baltic Sea had been carried out. To get quality data from thin bottom layer, each cast should reach the bottom. To meet this requirement, instead of the advanced technique of the underway measurements with U-tow probe, densely spaced (2-3 n.m.) casts from the drifting ship had been carried out. Quasi free-falling CTDO probe was used for this purpose. Special attention was payed to accuracy of estimating the minimum bottom oxygen concentration. To avoid great mistake due to slow response of the oxygen sensor, the hold for 30 sec was made before recovery after the probe reached the bottom.

The situation with the last MBI's (December 2014) water propagation was obtained. Besides, the survey with 1 n.m. spacing between casts was carried out in the Słupsk Sill area to check whether the gravity current at the entrance into the Słupsk Furrow had been formed or not. The blocking of salt Bornholm water overflow across the sill was revealed. The probable reason of the temporal blocking was an uplift of the sea surface level at the eastern coast of the sea because of long-lasted westerly winds.

Measurements at long transects were interrupted from time to time to carry out special investigations of internal waves, near-bottom currents, and microstructure. In the centre of the Bornholm Deep, where the dumpsite of chemical munitions is located, the 60m long moored thermistor string was installed along with the up-looking RDCP. Quasi-inertial internal waves were registered which probably may induce the near-bottom motion capable to stir up non-consolidated muds, which rather often could be contaminated with warfare gases. During observations the inertial waves were registered, however bottom currents were weak that time. Evidences of turbulence mixing were found at an amount of points by microstructure sound "Baklan". In conditions of blocking of the Słupsk Sill overflow, no turbulization of bottom layers was observed anywhere. Dissipation rates of order of $10^{-8}$ W/kg were measured everywhere at depths of propagation of numerous thermohaline intrusions.

## P101 - 40 Years of ecological research in the Darß-Zingst Bodden Chain, a shallow lagoon at the Southern Baltic

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The Darß Zingst Bodden Chains is a coastal lagoon system at the German Southern Baltic coast. Four consecutive water bodies are connected by narrow streams. Thus, the 4 water basins receive different freshwater portions and show a salinity gradient. The whole system is heavily eutrophicated. The salinity gradient is accompanied by a eutrophication gradient. The coastal lagoons are very important posing as habitats for various species (incl. migratory birds) and protecting the open Baltic from nutrient influxes, but are also used by man in various ways.

The State Agency (Wasserwirtschaftsdirektion Küste, today Mecklenburg-Western Pomeranian Agency for the Environment, Nature Conservation and Geology) investigated always hydrological issues (ice cover, morphology, eutrophication and toxic substances, like pesticides and heavy metals). In the 1960s, the Maritime Observatory of the University Leipzig began investigating hydrological issues of the complex water body for scientific purposes. Scientist of the University of Rostock (Dept. Biology) participated in the research cruises and programmes also in that time.

Since the late 1940s, biologists in Rostock started to include the flora and fauna of coastal areas into their teaching and research programs. In the late 1960s, many Rostock biologists turned their focus onto matter cycling of coastal lagoons including, biogeochemistry, matter cycling, microbiology, plant physiology, marine botany, zoology etc. In September 1977, the Biological Station in Zingst was opened as a teaching and research platform. A monitoring program was started in 1969 for the Zingster Strom on a daily basis: chemical data, especially nutrients. Some biological parameters date back to that time: phyto- and zooplankton, macrophyte covers. Monthly sampling cruises investigate hydrochemistry, plankton and seston nowadays.

## P102 - A STUDY ON HYDROGRAPHY AND WATER QUALITY ALONG A GRADIENT IN HIMMERFJÄRDEN BAY IN SPRING

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Future climate projections indicate a decrease in sea ice cover and an increase in precipitation in the Baltic Sea. Increasing terrestrial run-off will emphasize its role in controlling the water quality in coastal waters. Here we examine the role of weather conditions and hydrology on water quality in a Baltic Sea coastal gradient, considering both physical (temperature, salinity, mixed layer depth, presence of sea ice) and bio-optical properties of sea water (Secchi depth, suspended particulate matter (SPM), and coloured dissolved organic matter (CDOM)). We use chlorophyll-a concentration (Chl-a) to study how these factors affect the timing of the spring bloom. The study area included five sampling stations along a 60 km transect from the head of Himmerfjärden bay towards the open sea, southeast of Stockholm, from January to May with main focus on two years, 2014 and 2015. Both winters were exceptionally mild. According to SMHI data, sea ice occurred in Himmerfjärden for 12 days in 2014 and only for 1 day in 2015. The spring 2015 was warmer with 20% higher precipitation and 40% more runoff than 2014. During both springs, we observed clear spatial gradients of decreasing concentrations of Chl-a and SPM, turbidity and absorption of CDOM, from the innermost bay towards the open sea. At the innermost site the CDOM absorption was on average 0.9 $m^{-1}$ and at the outermost 0.4 $m^{-1}$. Chl-a concentration was on average 3.9 µg/l at the innermost site and 1.4 µg/l at the outermost and SPM concentration 2.6 mg/$m^3$ and 0.7 mg/$m^3$, respectively. Correspondingly, Secchi depth increased towards the open sea, from 2.7 m at the innermost to 9.1 m at the outermost site. We also observed a later spring bloom maximum in the inner bay, a pattern confirmed when studying a longer time series. The later bloom in the inner bay may result from a poorer light climate due to higher CDOM absorption and SPM concentration, a different species composition, or the nutrient inputs associated with terrestrial runoff. The results suggest that the mixed layer depth may influence the annual variability of the spring bloom timing. This case study suggests that water quality in coastal waters is sensitive to changes in river runoff and stratification.

## P103 - Estimating the quality and usability of the 3D hydrodynamic model COHERENS as a part of a water quality model system in the Archipelago Sea

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Many coastal sea ecosystems are highly stressed by human impact. Maritime spatial planning is a way to improve the health of such ecosystems and to use the sea in a sustainable way. This needs integrated systems with long-term observations and coastal modelling. A water quality model system has recently been developed for the Archipelago Sea. It will be used to evaluate the effects of changes in e.g. point nutrient sources or water protection measures in the catchment.An integral part of that system is a high-resolution 3D hydrodynamic model which provides the physical forcing for the water quality model. The high-resolution hydrodynamic model is nested with a coarser-resolution Baltic Sea model to get the boundary conditions. Here we evaluated the performance of the coastal hydrodynamic model and its usability as a part of the water quality model system. We also used the model to study transport of passive tracers in and through the Archipelago Sea.

We compared the simulated temperature and salinity fields for years 2006-2015 to observations from coastal monitoring stations and research cruises. In addition, measurements with higher temporal resolution for summers 2013-2015 were available from FMI's marine research station in the Utö Island. The model captured well the seasonal cycle of surface temperature, but tended to overestimate the bottom layer temperature in the inner archipelago. Also, in some areas it could not describe the vertical stratification in full detail. Comparison with the Utö data showed that the model overestimated salinity at all depths, but in July 2014, the model was able to simulate advection of warmer and less saline water at deeper layers.

The simulation of tracer discharge from a river showed that the tracer concentration was high only in the shallow river estuary. In deeper areas of the inner archipelago, the concentration decayed rapidly due to horizontal spreading and vertical mixing. Our results indicate that the Archipelago Sea may be even more vulnerable to the background load from the open sea than to the load from the catchment. The simulations showed that transport of substances through the Archipelago Sea varies considerably from year to year. In some years, the net transport is from the Baltic Proper towards the Bothnian Sea and in other years it is the opposite, depending on the prevailing wind conditions. Thus, long-term monitoring and long model simulations are necessary to better evaluate the effects of changes in loading sources.

## P105 - Remote Sensing of Coastal Upwelling and Its Seasonal Variability in the SE Baltic Sea

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Coastal upwelling is a very common process in the Baltic Sea, especially during the warm season from April to September. Even though the spatial scale of upwelling is not very large, its high frequency of occurrence makes it a key physical process in some of the Baltic Sea coastal regions.

In this study we analyse satellite sea surface temperature (SST) measurements together with in situ monitoring data to study the seasonal variability of the coastal upwelling and its properties off the SE Baltic Sea coast.

Altogether during the study period in 2000 – 2015, 69 coastal upwelling events were registered in space-borne MODIS data. The analysis of upwelling favourable meteorological conditions shows a clear seasonal pattern: during summer months when the vertical stratification of water column is at its strongest, shorter upwelling-favourable wind events are required to induce an upwelling event (e.g. approximately 2 days in June and July), while in early spring and autumn favourable northerly winds should persist for about 4 days. The analysis of upwelling parameters also shows clear seasonal patterns related to seasonal variations of water column stratification.

## P106 - Seasonal features of marine data assimilation using satellite SST products from Copernicus Marine Service

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Presently both the forecast models and the satellite observations are of high resolution, resolving mesoscale eddies, fronts, filaments etc. We used the HBM model applied for marine areas near Estonia, including the Gulf of Finland and Gulf of Riga, with 0.5-mile grid step. Remotely sensed SST data were obtained from Copernicus Marine Service, which multi-sensor product is built from bias-corrected L3 mono-sensor products at the resolution 0.02 degrees.

Analysis of SST forecast errors relative to remote sensing data revealed several seasonal features. During the spring warming period, surface layers of "free" forecast (without data assimilation) warms in the open sea faster than is observed, both by the remote sensing and Ferrybox data. At the same time, forecasted coastal temperature increase is slower than observed change. During autumn cooling period, the forecast-observation differences have opposite behaviour.

We applied two assimilation methods – Optimal interpolation (OI) and Successive corrections (SCM). Comparison of assimilated model run with free run shows reduction of error and lower bias. Differences are analysed with respect to wind forcing and heat fluxes, both as time series and spatial patterns, in order to obtain guidance for improvements in model set-up and selection of data assimilation.

## P107 - Numerical modelling of hydrodynamics and sediment transport in the Gulf of Gdańsk

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The magnitude and direction of bedload transport in the Gulf of Gdansk in extreme weather conditions is investigated. Since there is a lack of sufficient amount of in-situ data of bedload transport in the area of interest, the only way to assess the magnitude and direction of bedload transport in this large area characterized by complex bottom topography and hydrodynamics is to use on integrated approach. This requires modelling of waves, currents, the critical bed shear stress and bedload transport magnitude, with a due consideration to the realistic bathymetry and distribution of surface sediment types. In order to estimate the maximal possible bedload transport hydrodynamic conditions during an extreme theoretical storm is investigated. Such storm condition defined based on 138-year NOAA data is assumed, namely stationary wave field for a northerly wind of 30 m/s (Cieślikiewicz et al. 2016). For such condition the wave-induced bottom shear stress is estimated. At the same time, the resultant current-induced bottom stress is calculated, based on the wave field. Next, the total wave- and current-induced bed shear stress is calculated, as is the bedload transport. The SWAN model (Booij 1999) was used to define wind-wave fields, whereas wave-induced currents were calculated using the Kołodko and Gic-Grusza (2015) model, and the magnitude of bedload transport was estimated using the modified Meyer-Peter and Müller (1948) formula. The calculations were performed using a GIS model. The results obtained are innovative. The approach presented appears to be a valuable source of information on bedload transport in the coastal zone.

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Cieślikiewicz W, Dudkowska A, Gic-Grusza G (2016)Port of Gdansk and Port of Gdynia's exposure to threats resulting from storm extremes. JPSRA 7(1): 29–36

Kołodko J, Gic-Grusza G (2015)A note on the vertical distribution of momentum transport in water waves. Oceanol Hydrobiol Stud 44 (4): 563–568. doi: 10.1515/ohs-2015-0053

Meyer-Peter E, Müller R (1948) Formulas for bed-load transport. Proceedings of the 2nd Meeting, IAHR: 39–64, Stockholm, Sweden

## P108 - Influence of lateral submesoscale turbulent transport on generation of salinity minima in the thermocline

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The density of water is controlled in first approximation by both its salinity and temperature. Heating up upwelled highly saline water that moves offshore and mixes with the surrounding less saline water can result in a reduced density whereby retaining higher salinity levels. Thus permitting the ocean surface mixed layer to have a higher salinity than the water masses just above the thermocline, while still maintaining a stable vertical density distribution.

The generation of these thermoclinic salinity minima relies heavily on the interplay between atmospheric heat input and submesoscale mixing processes. Using a 2d, upwelling permitting, model setup and a corresponding idealised 3d model we try to characterise the tip off points under which salinity minima become possible.
We are in particular interested in the impact of lateral mixing processes (resulting from eddies) in comparison to vertical processes (due to unstable vertical layering of water masses through Ekman transport).

## P109 - Direct evidence of double-diffusive mixing in the Baltic Sea

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Diapycnal mixing in the Baltic Sea is presently understood as the result of small-scale shear instabilities in the turbulent bottom boundary layers and in the stratified interior of the main basins. This interpretation of mixing ignores, however, a class of double-diffusive mixing processes that may occur in regions where the stable vertical salinity gradient characterizing the Baltic Sea is partly compensated by an unstable temperature gradient. Under these conditions, diffusive-convective instabilities may develop, ultimately resulting in a characteristic "staircase" structure in temperature and salinity profiles. Here, first direct evidence for the relevance of this process in the Baltic Sea is presented, based on an extensive data set from the Bornholm Basin obtained in summer 2016. Using densely-spaced shear and temperature microstructure observations from different measurement platforms, well-defined series of diffusive-convective staircase patterns were identified on the top of warm intrusions originating from the neighboring Arkona Basin. Typical thicknesses of the nearly perfectly mixed convective layers were found to be of the order of a few tens of centimeters, separated by thin interfaces of only a few centimeters thickness. Similar data from autonomous ocean gliders, equipped with turbulence sensors, provided additional information about the lateral structure of the staircase patterns. Estimates of the vertical heat fluxes across the layer interfaces suggest time scales of days to weeks for the mixing between warm intrusions and ambient waters, indicating that double-diffusive instabilities constitute a key mixing process during our observations, challenging the traditional view of shear-induced mixing.

## P110 - Numerical simulation and features mixing of stock currents on the example of inflow of water from the Vistula Lagoon into coastal waters of the Baltic Sea through the Baltic Straits

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It is well known that one of the main sources of pollution of sea areas is river runoff, which in addition to various types of carcinogens it carries a significant amount of nutrients, which can then lead (and leads) to the process of "flowering" of water in the reservoirs and seas. It is obvious that this problem requires the fullness of understanding of the basic features of stock currents for different seasons of the year.

The aim of this work is to study the characteristics of inflow of the Vistula Lagoon waters to the Baltic Sea through the Baltic Straits (Baltiysk, Kaliningrad region, Russia) using numerical modeling.

It is known [Simpson J.E., 1987, Gritsenko V.A. and Chubarenko I.P., 2001] that the etymology and the dynamics of stock currents in the Baltic Sea are wide and varied. They are generated by river runoff, water exchange with bays and fjords, wind effects, storm mixing, periodic inflows of the North Sea waters, winter cooling, etc. Obviously, small linear and temporal scales of these currents require consideration of the horizontal inhomogeneity of the density field of water, an essential unsteadiness of all processes, the Earth's rotation and a number of others, which makes it very difficult to use both analytical approaches and 3d modeling. 16 modelling sceneries with different initial parameters were calculated using this model.

Analysis of the modelling results allowed to obtain the following results:

1) good qualitative correlation between modelling result and satellite observations;
2) changing the characteristic parameters of model ($u_0$ and $\Delta\rho_0$) has weak effect on vortex formation for constant width ($h_0$) of the current;
3) due to the lack of boundary conditions the difference in structure between model and real currents were found;
4) significant bending of streamlines and transition of stock current to the longshore current due to interaction between these currents were found [Gritsenko V.A. and Chubarenko I.P., 2001].

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## P111 - Increasing spatial resolution in a Baltic Sea circulation model: On getting more than one bargained for.

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Mitigation and adaptation to climate change call for reliable tools capable of projecting into a warming future. Among the tools currently developed are ocean-circulation models, and among the approaches to make them more reliable is the increase in spatial resolution. Recent advances in computational resources have rendered eddy-permitting resolutions of the Baltic Sea possible. Here we report peculiarities encountered as we started to resolve meso-scale processes with the circulation model MOMBA.

## P112 - Analysis of Annual Mean Circulation in the Gulf of Finland Simulated with a High Resolution Hydrodynamic Model

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We studied circulation patterns in the Gulf of Finland with a high-resolution 3D hydrodynamic model setup. The configuration was based on the NEMO model and had 0.25 NM horizontal resolution and vertical resolution of 1 m. Our simulation of the years 2012-2014 revealed high year to year variability in the circulation. For example, in 2012 the mean circulation in the model was cyclonic, resembling more the traditional long term mean circulation patterns described already by Witting and Palmen in the early 20th century. On the other hand, in 2013 and 2014 a clear cyclonic pattern did not emerge. The persistency of currents in the Gulf of Finland is known to be low, with high variability in time and space. This was clearly demonstrated by our results.

Upwelling related coastal currents, river runoff and wind forcing were further analysed. Several strong upwelling related coastal currents were present in the results on both northern and southern coast of the Gulf. Although the Gulf of Finland receives large amounts of fresh water, most notably from the river Neva, the inter-annual variations in runoff did not have a significant effect on the variations in the mean circulation patterns. The effect of wind forcing on the circulation in the Gulf was also considered. We found that annual differences in wind forcing contributed to the modelled circulation patterns.

## P114 - Towards understanding of charophyte ecology in the estuarine environment: case study in the Curonian Lagoon

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The distribution and abundance of 5 charophyte species was studied in relation to the abiotic and biotic environmental factors in eutrophic estuarine lagoon. Relationships were assessed using multivariate statistical analysis. All species were recorded along the eastern shore of the lagoon, whereas *C. contraria* was found on the western part. In comparison to former distribution of charophytes, there was increase of vegetated areas and their maximum depth in the estuarine part of the lagoon, where the dominant species *C. contraria* became even more widespread both with the depth and area.

Spatial distribution of charophytes in the lagoon was mainly explained by abiotic factors such as near-bottom salinity and wave exposure. Typical brackish water species (*Chara baltica* and *Tolypella nidifica*) were restricted to the areas with mean water salinity above 0.4, whereas typical freshwater species (*Nitellopsis obtusa*) was mainly found in the areas close to riverine outflow. Relatively low importance of water transparency for the species occurrence and especially their abundance in the lagoon could be explained either by a stronger effect of other environmental factors or limited spatial and temporal resolution of Secchi depth measurements and absence of other estimates restricting light availability for plants. The wave exposure and its indirect factors (bottom slope and median diameter of sediments) better explained the distribution of charophytes than the water transparency. This can be explained by relatively shallow and large lagoon, where waves most likely limit the maximum extent of charophytes by detaching them from sandy substrate and resuspending sediments, especially along the eastern coast. Respectively, the most of the species (especially *C. baltica* and *C. aspera*) showed preference to relatively shallow areas, usually at < 1 m depth. C. contraria was the single species related to the habitats with relatively high wave exposure perhaps due to morphological adaptation by partly ecorticated (subgymnophyllous) form. The results of multivariate regression trees indicated the interaction effect of bottom slope, salinity and wave exposure on charophyte distribution, highlighting complex influence of abiotic factors. It seems that the biological factors were structured in respect to the abiotic factors emphasizing the stronger effect of later ones.

## P115 - Ocean Acidification causes subtle responses in foundational macroalga Fucus vesiculosus

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Ocean Acidification (OA) is one of the most severe environmental changes expected to occur in the ongoing Century. Although effects of OA on calcifying organisms have been extensively studied, responses of photosynthetic organism such as macroalgae are not as well known. In addition to pH changes, OA will also alter carbon availability, which has been suggested to elevate photosynthesis rates in marine macrophytes. However, many macroalgae possess carbon concentrating mechanisms, which can be operated with energetic cost to import carbon from seawater. The utilization of these mechanisms depends on light availability and photosynthesis rates, as individuals growing under intensive light may become carbon-limited as they deplete the inorganic carbon pool from seawater. Thus, the increase of free dissolved $CO_2$ with OA could reduce the reliance on CCMs in high light, or facilitate photosynthesis in low light through increased $CO_2$ diffusion. In addition to carbon physiology, OA has been suggested to increase the susceptibility to photoinhibition under high irradiance. Thus, the expected response of macroalgae against OA will depend on light environment.

In experiments manipulating light and pH via $CO_2$ bubbling, we examined the responses of foundational macroalgae *Fucus vesiculosus* during two seasons, winter and summer. In contrast to some previous experiments, OA did not affect *F. vesiculosus* growth in either season. Photosynthesis rates, measured as maximum electron transport rate through photosystem II were unaffected in summer but showed minor decline under the most extreme acidification scenario in winter. OA caused increased photoinhibition (lowering of Fv/Fm) under high irradiance treatment in summer, but not in winter.

Acidification caused declines in chlorophyll content under high irradiance, but only in winter. OA also changed the elemental ratios by lowering nitrogen content, and increasing carbon content under low irradiance in both seasons, suggesting that the individuals were able to gain carbon more efficiently with lower nitrogen investment in low-light conditions because of increased carbon availability.

Our results suggest that OA may trigger subtle responses in foundational species such as Fucus, which may have implications for associated species and higher trophic levels.

## P116 - Impact of submerged vegetation on matter fluxes in shallow coastal lagoons of the Baltic Sea

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Brackish shallow lagoons are dynamic habitats characterized by steep environmental gradients and strong seasonal variability driving the extension of submerged vegetation. Anthropogenic stressors such as eutrophication may cause a complete disappearance of submerged vegetation in shallow brackish lagoons, while the ecological role of submerged vegetation on the structure and function of the food webs in these lagoons is barely understood. While there is an extensive research on the lower (phytoplankton and zooplankton) and higher (fish stocks) trophic levels, astonishingly few investigations address the trophic link between these both. The project aims to quantitatively compare the Darss-Zingst Bodden chain and the West-Rügensche Bodden chain, two shallow lagoons that differ considerably in their eutrophication status. Further, the project aims to identify the trophic importance of submerged vegetation in the lagoons food web. In both lagoons, the biomass and production of phytoplankton, zooplankton, macrophytes and the faunal community will be seasonally measured in combination with environmental characteristics such as light and nutrients during the field campaign in 2017. We will use C and N stable isotopes as trophic markers to characterize the trophic structure of each lagoons food web separately and compare the sources, preconditions and fate of nutrient pulses. Preliminary results of the on-going field campaign will be presented.

## P117 - Peat in the Baltic Sea as a unique hard substrate for macrophytes

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The nature reserve "Heiligensee and Hütelmoor", located at the German Baltic Sea coast, protects a peatland complex including coastal fens and a peat bog. In the past the area has undergone drastic changes, caused by natural processes as well as by anthropogenic impacts. Sea level rise in combination with flooding events led to a continuous reduction of the fen area. As a result, part of the fen became covered by beach and dune systems, while the sea-exposed peat is today providing a unique kind of hard substrate for macrophytes. Peat layers can be found in some sections at the beach and in the shallow coastal waters until about 2 m water depth, illustrating the dynamics of the coastline. As part of the project Baltic TRANSCOAST, field investigations of taxonomic composition, biomass, coverage and seasonality of the macrophytes growing in our study site on peat as well as on adjacent hard substrates are performed. Typically, phytobenthic communities on hard substrates are dominated by attached algae, while rooted phanerogams and charophytes increase proportionally with decreasing substrate size (silt and mud). First demographic recordings show that there are distinct differences in the species composition, biodiversity and biomass between the sea-exposed peat and adjacent cobble and pebble substrates. On this poster we want to introduce peat as a new kind of hard substrate for algae growth, showing the influence of substrate on a local scale and estimating the key factors influencing species composition and productivity through the results of our field study and literature values.

## P118 - Heavy metal concentration and oxidative stress level in the macrophytes of the Baltic Sea

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In the Baltic Sea ecosystem, several fish species and molluscs have been used as biomarkers of oxidative stress, there is less information regarding macrophytes as key species of coastal habitats. The aim of this study was to examine spatial differences in the activity of enzymes Glutathione - S transferase (GST), glutathione reductase (GR) in connection with macrophyte community diversity and heavy metal (Hg, Cd, Pb, Cu) concentrations in the littoral of the Gulf of Riga, Finland and Bothnia bay at 7 stations. The Bray-Curtis cluster analyses of stations with macrophyte communities' main groups biomass (Chlorophyta, Phaeophyta, Rhodophyta) revealed that Tvaerminne, Mersrags and Hanko habitats are rich with *Fucus vesiculosus* biomass (460,0, 338,0 and 302,0 mg dry weight/$m^2$). At stations Rauma and Klamila *F. vesiculosus* biomass lowered– 137,0 and 137,0 mg dry weight/$m^2$, but at Saulkrasti habitat (eastern part Gulf of Riga) only 57,0 mg dry weight/$m^2$. Enzyme activity results for the GST are as follows: the highest activity in 2009 and 2010 in *Fucus vesiculosus* was found in Saulkrasti habitat - 587 and 490 nanomoles / min / mg protein, and the minimum activity – Mersrags and Klamilla (2010) habitats - 105.0, 100.0, 104.0 nanomoles / min / mg protein respectively. GR activity also shows the maximum value for *F.vesiculosus* at Saulkrasti and Klamilla habitats in 2009 - 607.0 and 403.0 nanomoles / min / mg protein, thereby producing increased environmental stress effects on macrophyte populations in the investigated habitats. There is no clear trend in oxidative stress level in the Gulf of Riga between 2009 and 2015. According to PCA and correlation analyses positive correlation was obtained between red algae oxidative stress and heavy metal concentration levels in the Gulf of Riga.

## P119 - Lack of ciliate community integrity in transitional waters: a case study from the SE Baltic Sea

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Salinity is a major factor controlling species distribution in estuarine systems. Most aquatic organisms are adapted to life in either marine of fresh waters. As a result, the saltwater–freshwater mixing zones are characterized by low biodiversity. Although the low biodiversity in brackish waters is well documented, it is unknown how communities are formed and how stable are they in small–scale interface between the freshwater and brackish environments, such as coastal lagoons and inlets of estuaries.

The Baltic Sea, one of world's largest brackish water environments, is particularly well suited for studies aiming to understand these processes at different spatial and temporal scales. We used ciliates inhabiting transitional waters in the Curonian Lagoon to explore diversity fluctuations in pelagic microbial communities experiencing frequent brackish water intrusions. We found that, similar to the reported patterns for multicellular zooplankton and benthos, a reduced ciliate diversity in brackish conditions was also apparent. During the brackish water intrusions (23% of all sampling occasions), the community presented a mixture of fresh- and brackish water taxa with no specific component unique to the area facing frequent intrusions. Moreover, in the mixed community, freshwater <0.5) and low salinity (0.5-2) ciliate assemblages were identical to those observed at the reference limnetic site, with a similar seasonal succession pattern. In the mixing area, the brackish/marine taxa (*Mesodinium rubrum*, *Strombidium conicum*, *Stobilidium caudatum*, *Tintinnopsis kofoidi*, *T. baltica*, *T. sp*., *Glaucoma sp.* and *Helicostomella subulata*) occurred only during the brackish-water (>2) conditions, while freshwater taxa (20) occured in the entire salinity range observed during the study period (0-7). These findings suggest that in the brackish water–freshwater mixing zones of lagoons and inlets of the South-Eastern Baltic Sea, the organization of ciliate communities is the result of mixing of fresh and brackish waters with temporal and spatial variability related to the water residence time and hydrography.

## P120 - Assessing phenotypic plasticity of salinity tolerance in Temora longicornis

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Copepods of marine origin dominate the zooplankton in the open Baltic Sea and are important mediators of environmental change in the Baltic food webs. The ability of copepod populations to cope with future environmental change will depend on the species' capacity to acclimatize and adapt to changing conditions, including the projected decrease in sea surface salinity. However, the physiological, ecological and evolutionary responses of copepods to salinity are not fully understood. Using the marine copepod *Temora longicornis* as a model species, we compared the effects of salinity on vital rates and physiological plasticity of different populations originating from the Kattegat (25 PSU) and the Baltic Sea (7-8 PSU). We found significant differences in life history traits among these populations. While the salinity tolerance was generally broad, the Kattegat population was significantly less tolerant to low salinity (S<10) compared to the Baltic populations. Common garden experiments using full-sib clutches split across a salinity gradient of 8-20 further revealed that the higher tolerance of the native salinity in the Baltic population results from genotype variation and local adaptations as a result of selection rather than a broad physiological plasticity ('euryhalinity') of the species. This adaptation has relevant implication for the understanding of the environmental control of the species' dynamics, diversity and the copepod mediated energy flow, both now and in future as a further decrease in salinity is projected.

## P121 - MICROBIAL FOOD WEB COMPONENTS IN RELATION WITH EUTROPHICATION/ANTHROPOGENIC GRADIENT

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Microbial food web components, their size classes and species composition have been investigated in different Baltic Sea sub-regions since 80-ies in relation to the eutrophication and anthropogenic stressors. Ciliate population analyses were conducted by inverted microscopy, picocyanobacteria, flagellate counting and cell measurements – by epifluorescens microscopy with DAPI staining for DNS as well as partly by flow cytometry.In the case with ciliate communities their biodiversity is close related to the seasonal succession and eutrophication level/trophic state index. Ciliates are represented by organisms with different functional role in their communities (autotrophy, heterotrophy, mixotrophy). One of the key species of the ciliates – Mesodinium rubrum with autotrophic endosymbionts could perform remarkable diurnal migrations as well as fast reaction on nutrient concentration by forming red tide phenomenon close to the river input area.

Long term investigations (1999 – 2016) of pico and nanoplankton in parallel with macrophyte ecological investigations and mapping in the Gulf of Riga according to HELCOM recommendations reviled close relations for both communities. In the eastern part of the Gulf of Riga with mean values of trophic state index 5.13 and Secchi depth 2.0 m both by density and biomass nanoplankton is dominating. In the west coast transect with trophic state index 4.75 and Secci depth 2.95 m mainly picocyanobacteria are prevailing. Correlation and PCA analyses by PRIMER 6 software with environmental factors, macrophyte production, pico and nanoplankton values illustrate closer relations of microbial food web elements with environmental factors and Phaeophyta biomass and distribution.

## P122 - Hybridisation between Baltic blue mussels (Mytilus edulis, M. trossulus): Disentangling reproductive barriers from environmental adaptation.

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Secondary contact between blue mussels of the *Mytilus edulis* species complex usually leads to the formation of stable mosaic hybrid zones - except for the *M. edulis* - *M. trossulus* hybrid zone in Northern Europe, where a *M. trossulus* hybrid swarm is populating the Baltic Sea. Despite pervasive gene flow between Baltic *M. edulis* and Baltic *M. trossulus*, mussels maintain genetically and phenotypically distinct entities, which could be explained by both weak reproductive barriers and adaptation to environmental conditions (e.g. low salinity).

Performing full-cross fertilisation between mussels from the Mytilus transition zone - putatively Baltic *M. edulis*, Baltic *M. trossulus*, and intermediate hybrids - we tracked fertilisation success, larval survival and growth under different salinities, which now enables us to disentangle the proportion of adaptation to salinity conditions from possible reproductive barriers between the Baltic *M. edulis* and Baltic *M. trossulus* in the early life stages of these mussels. The genotyping of the parent mussels is performed right now and will be correlated and discussed in the context of the strong parent-combination depending differences we found in fertilisation success. Larval survival and growth under local (transition zone at 11 PSU), western (13 PSU), and eastern (9 PSU) salinities will also be analysed.

This ongoing research will allow us to estimate to which proportion the observed introgressive hybridisation is adaptive and a precondition to colonise low salinity marine environments.

## P123 - Assessing the exposure of migratory pike-perch (Sander lucioperca L.) to cyanotoxins using stable isotopes

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The presence of cyanobacterial toxins in commercial and recreationally important fish poses a human health concern. Improving our understanding of the factors which determine algal toxin levels in fish is complicated by uncertainties in feeding habits and exposure, especially among migratory fishes sharing freshwater and coastal brackish water habitats differing substantially in nutrient concentrations and intensity of algal blooms. We analysed cyanobacterial hepatotoxins (microcystins and/or nodularin) in migratory and resident pike-perch (*Sander lucioperca* L.) individuals of commercial size (›30 cm) to test the hypothesis that resident fish in the hypereutrophic freshwater Curonian Lagoon would exhibit higher toxin concentrations relative to migratory individuals returning from the Baltic Sea. For the first time in the Baltic Sea basin, the stable isotopes of sulphur ($\delta^{34}S$) were used to differentiate freshwater and marine end-points (-0.2 to 18.5 ‰, respectively) and to distinguish resident and migratory individuals among fish captured from the freshwater lagoon. Contrary to our prediction, hepatotoxin concentrations were similar among migratory and resident individuals suggesting that habitat choice did not appreciably affect exposure. The 10- fold variability of concentrations among all individuals does not seem to be related to trophic positions (estimated by $\delta^{15}N$) nor body condition (fat content), however it was negatively related to body length. Human health risks are often assessed based on mean toxin concentrations for a population, while our study indicates that significant number of individuals can contain concentrations close to or exceeding the threshold value of tolerable daily intake even though the population mean does not.

# Poster Session II

June 15, 2017

## P128 - Proliferation of the use of unconformities in stratigraphic subdivision of the Baltic Sea basin

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There is a recent move in the Baltic Sea region, Finland in particular, toward using unconformities to subdivide the deglacial to present sedimentary fill of Baltic Sea Basin (BSB) into *local and regional* allostratigraphic units. Räsänen et al. (2009) described the combined use of allostratigraphy and lithostratigraphy (CUAL) approach, which uses unconformities as the primary (allo)stratigraphic subdivision criteria, whereas lithostratigraphic units can be used for complementing lithostratigraphically mappable features in the allostratigraphic framework. CUAL approach is particularly suited for Quaternary glacial strata that have high lithologic variability and frequent unconformities because of the often opposing and delayed effects of the ice-margin advance and retreat, differential glacioisostatic uplift, and glacioeustatic sea-level change. This novel stratigraphic approach is an internationally compatible alternative to the traditional practice of classifying sediments according to the archaic Baltic Sea stages.

Recently, Tsyrulnikov et al. (2012) identified 9 lithostratigraphic units and assigned them to 3 allounits in the Gulf of Riga. Virtasalo et al. (2014) recognized 3 alloformations that include 6 lithoformations and 3 allomembers in the western Gulf of Finland. Virtasalo et al. (2016) formally defined the unconformable *base of the brackish-water mud* as a BSB-wide allostratigraphic boundary, which is erosional and covered by a patchy thin silt-sand sheet in shallow areas, and sharp and possibly erosional in deep areas. Hyttinen et al. (in press) described 2 alloformations with the lower unit subdivided into 2 lithoformations in the Ångermanälven River estuary. Bendixen et al. (in press) identified 3 allounits with the middle unit further subdivided into 3 allounits in Kattegat. Jensen et al. (in press) defined 5 allomembers and 5 lithostratigraphic units above sedimentary bedrock, and assigned them to 4 alloformations in Bornholm Basin. Ojala et al. (in press) showed how the unconformable base of brackish-water mud aids urban planning in the Helsinki metropolitan area.

More studies are required to identify and characterize additional unconformities in BSB. Once a sufficient number of local and regional unconformities have been identified, the allostratigraphic approach will permit reconstructing the depositional history of BSB in an unprecedentedly coherent and detailed way. This presentation summarizes the recent activities and provides an outlook for future studies.

## P129 - The brackish phase of the Yoldia Sea stage in the open Baltic basin in time and space

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The Yoldia Sea stage, c. 11 700 to 10 700 cal. yr BP, can be subdivided into two freshwater phases with a short brackish-water phase in between. This stage in the history of the Baltic Sea was important as the open connection with the North Atlantic enabled marine organisms to immigrate into the basin, which are today considered glacial relict species. The short brackish phase is further an invaluable chronological marker for the open Baltic setting in a clay sequence almost barren of radiocarbon datable macrofossils and very low organic carbon content.

The maximum duration of the brackish phase has been estimated to 350 years, traditionally dated to c. 11 300 to 10 950 cal. yr BP, although some records indicate it only lasted some 70–120 years. This duration is based on the cross-correlation of several geographically spread clay varve sequences recording fragments of this stage. The drilling during the IODP Expedition 347, Baltic Sea Paleoenvironment has provided us with a long and continuous sediment record (Site M0063) from the deepest basin of the Baltic Sea, the Landsort Deep, covering the entire Yoldia Sea stage.

Diatom stratigraphic analyses are the most successful proxy to pinpoint the sudden marine water inflow in the open Baltic Basin during the Yoldia Sea stage. Diatom analyses from the Landsort Deep, North Central-, Eastern Gotland- and the Bornholm Basin will be presented and compared. In the Landsort Deep, situated closest to the inlet area, diatoms were very abundant during the short brackish phase, but the initial and final freshwater phases of the Yoldia Sea stage were devoid. Diatom concentration indicate that primary production was high but species richness was very low with only a few taxa present. The North Central Basin show a similar trend as the Landsort Deep, while in the Eastern Gotland Basin a freshwater assemblage is recorded in the final phase.

The diatom stratigraphies indicate that the Landsort Deep shows an environment with higher salinity and a longer duration of the brackish phase than the other sites investigated from the open Baltic proper. The onset is dated by clay varve chronology to c. 11 470 cal. yr BP (10 532 varve yr BP) in the Landsort Deep and 11 340 cal. yr BP (10 404 varve yr BP) in the Eastern Gotland Basin, a delay of approximately 130 years. In the southern Baltic Sea, only few benthic brackish taxa are recorded indicating a much more shallow setting than today.

## P130 - Radiocarbon dating of coastal Late Holocene Baltic Sea sediments

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A total of 59 radiocarbon dates have been performed on 38 macrofossil samples and 21 bulk sediment samples from sediment cores from 9 sites along the western coast of the central Baltic Sea. The aim of the study was to establish reliable chronologies and investigate the difference between radiocarbon ages derived from macrofossil samples and the bulk sediment samples from the same level in the cores. The selected sampling sites represents both closed and open coastal conditions.

The mean difference between the two types of dated material varies between 540 and 2025 radiocarbon years with a mean difference of 872±389 years.

It is clear from our results that a key factor controlling the difference between the two types of material dated is the geographic location and geological conditions of the land surrounding the sampling site. Sites surrounded whit easily eroded and redeposited sediments displays older bulk sediment radiocarbon ages than sites surrounded by bare bedrock.

It can be concluded that it is impossible to predict the difference between the radiocarbon ages derived from bulk sediment samples and those derived from macrofossil samples the later should be used whenever possible.

## P131 - Middle and Late Holocene climate forcing on the open Baltic Sea: a diatom stratigraphical investigation from IODP Expedition 347 sediment core M0063 Landsort Deep

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This project aims to investigate the role of climate-driven processes on the open Baltic Sea during the Middle (8.2-4.2 cal ky BP) and Late (4.2 cal ky BP-present) Holocene. The objectives of this study are to determine the history, timing and duration of Middle and Late Holocene Baltic marine inflows and its implications for changing salinity, and to identify high primary productivity events.

During IODP Expedition 347 'Baltic Sea Paleoenvironment', a laminated sediment core with extremely high resolution Middle and Late Holocene sequences from Landsort Deep, the deepest sub-basin in the Baltic Sea basin, has been retrieved. Diatom stratigraphy, using both relative and absolute abundance, is used to reconstruct salinity and primary productivity changes during the Holocene and to investigate climatic and oceanographic mechanisms behind these changes. Together with a depth-age model, an assessment of climate-driven natural variability in the Landsort Deep is made.

Future plans include identifying triggers and timing of high primary productivity events and the return to low productivity during the Littorina Sea in high resolution, and to assess the relative importance of natural climate forcing versus anthropogenic forcing on environmental change of the Baltic Sea.

## P132 - Regional climate change and onset of farming in Northern Germany and Southern Scandinavia

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In Europe, the transition from hunter-gatherer-fisher based communities into societies mainly relying on farming was spread from the southeast towards the north and west during the Holocene. In central Germany, farming was adopted at ~7500 cal. yr BP, whereas the shift is evident at ~6000-5500 cal. yr BP in northern Germany and southern Scandinavia. Consequently, farming techniques were available for more than a millennium. Some studies argue that climate change might have played a role in the onset of farming in those areas. The aim of this study is to reconstruct the mid to late Holocene sea surface temperature (SST) evolution in the Skagerrak to document potential regional climatic impacts on changes in human economy. We compare our results to a record of human settlement activity in northern Germany and southern Scandinavia. Prior to ~6300 cal. yr BP, warm SSTs are documented throughout the Skagerrak, suggesting dominance of North Atlantic sourced water inflow providing mild climatic conditions. Between ~6300 and 5400 cal. yr BP, i.e. concomitant with the shift in human economy, SSTs in the NE Skagerrak dropped by ~5-6ºC, as also documented in mean annual air temperatures in central South Sweden, although less pronounced. The regional cooling suggests outflow of colder Baltic Sea water only affecting the NE Skagerrak and central South Sweden. Probably, numerous severe winters reflecting a continental-dominated atmospheric circulation pattern prevailed over the region. These changes most likely caused a gradual restriction in natural food sources, in particular from the marine realm. We thus suggest that hunter-gatherer-fishers were forced to adopt farming strategies to counter-balance this environmental stress. Our results indicate that regional changes in oceanography probably amplifying North Atlantic climate change in the western Baltic were an important factor that played a role in the adoption of farming in northern Germany and southern Scandinavia.

## P133 - Paleodynamics of the Curonian Spit eastern coastline during the Holocene according to GPR data

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The Curonian Spit in Lithuania is one of the most unique places in both cultural and geological terms. Spit composed of aeolian deposits, characterized by the phase activity. During the Holocene active and passive periods of dune formation were interchanging. Quiet periods, when dune surface used to be covered by vegetation and soil layer used to be formed, were regularly changed by aeolian activity periods during which the soil has been destroyed or covered with a layer of new sand. Thus, the buried soils (paleosols) were formed. These soils have significantly different lithological and physical characteristics from the aeolian sand – this allows to use ground penetrate radar (GPR) survey for their identification and mapping. The Curonian Spit is included into the UNESCO list of cultural heritage monuments, thus consequently GPR (non-invasion method) was used to detect the paleosols.

The study was focused on the eastern half of the Curonian Spit, along the western coast and Curonian Lagoon. The aim was to determine dunes paleodynamics during the different Holocene periods and to reconstruct paleoshore-line. Radiocarbon ($^{14}C$) dating of the detected paleosols helped to identify quiet dune formation stages and active periods (dune's transgressions toward lagoon).

## P134 - Late Glacial and Holocene history of the Southern Baltic Sea level changes as recorded in the deposits of the sedimentary basins Mrzeżyno area

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Late Glacial and Holocene stages in the development of sedimentary basins that existed within the Samowo paleochannel were constructed based on multidisciplinary studies of sediments. Data from granulometry, lithology, plant macroremnants, non-pollen microfossils, diatoms, cladocera, molluscs and ostracods provided a foundation, based on which local environmental conditions were reconstructed. Palynology and radiocarbon dating provided age control. Bioindicative properties of both plant and animal remains, as well as differences in sediment lithology, enabled discrimination between 37 sedimentary series, associated with each phase of the study area development, especially with changing hydrological conditions. The evolution of this area as recorded in sediments, progressed from a Late Glacial through early Holocene lacustrine-marshy basin characterized by considerable water level and salinity fluctuations, with short-lived marine incursions, especially in the middle part of the Holocene, through dynamic fluvial environment events, a late Holocene biogenic environment, to the youngest aeolian accumulation processes. In the present study, an attempt was made to link the various stages in the development of this area, influenced both by local and regional environmental changes, and the associated habitat condition changes.

The Rega river estuarine system was an area subject to multiple changes in environmental conditions due to sea level fluctuations forced by climatic changes. At the same time, many of these changes were imprinted over this area for a considerable time. This study results show that the southern Baltic Sea level was forced predominantly by climatic factors. High sea level can be associated with positive thermal anomalies, whereas low sea level periods reflect the cold periods of the Bond cycles (Bond et al. 1997). Cool periods are often associated with elevated aeolian activity, which is further invigorated during southern Baltic low-stands. Riverine series F2 through F5 can be linked with low-stand periods. In some cases, it is challenging to precisely and unambiguously determine the riverine series time of deposition.

## P135 - Reconstruction of Holocene changes in redox conditions on Bornholm and Gdansk Basins reflected by the geochemical data

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The poster will present the reconstruction of changes in redox conditions in Holocene for the marine sediments from the bottom of the Bornholm Basin (-gravity core M86-1/24, φ 55°22.648, λ 15°21.802, 98 m depth) and Gdansk Basin (gravity core P475/12, φ 54°49.39, λ 19°11.14, 105 m depth). To prepare the age model of selected sites, calibrated age AMS14C was completed with high resolution in Poznań Radiocarbon Laboratory. All radiocarbon ages were calibrated using OxCal 4.2 software and the Marine13 calibration curve was applied. Results were given in cal. BP years. No reservoir correction has been used. The results of radiocarbon dating in both cores were based on *Macoma* sp. shells and present age from the present day to more than 7,500 years cal. BP. Core samples were also analysed to determine the changes in their chemical composition. The total organic carbon (TOC) analyses were performed at 2-cm resolution by using the Rapid CS cube – ELEMENTAR analyser at the University of Szczecin Laboratory. Analysis of total carbon (TC) and total nitrogen (N) was done separately by using Vario MAX analyser from Elementar at 2-cm resolution as well. Analyses of elements (Fe, Mn, Cu, Zn, Ni, Ti) were determined by XRF - an X-ray fluorescence scanning by "ITRAX" system at the Leibniz Institute for Baltic Sea Research in Warnemünde. Analysis of changes in the chemical composition of deposits in a stratigraphic sequence allowed us to identify periods of increased supply, changes in salinity and delivery of better oxygenated water from the North Sea. T. Neumann in his article "Geochemical records of salt-water inflows into the deep basin of the Baltic Sea" used the Mn/Fe ratio as a good indicator of the redox conditions in water as a good historical observation of salt water ingression. Taking into account the above, we used inter alia the Mn/Fe ratio in order to determine the periods of varying oxygenated water for both locations. For Bornholm Basin periods of significant reduction in water oxygenation were recorded between 5100 - 3550 years calBP, 1300 - 600 years calBP and 80 years calBP till now. In the same time for the Gdansk Basin, there is no data evidence which clearly shows variability in water oxygenation. However, the deficit of oxygen in this area was much stronger in comparison with the Bornholm Basin.

## P136 - Sedimentary authigenesis of iron and manganese sulphides in Holocene sediments of the Landsort Deep: Textural and sulphur isotopic evidence

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The texture and stable sulphur isotope composition of iron and manganese sulphides were investigated in the water column and in up to 5 m long sediment cores from the central Landsort Deep, western Baltic Sea. The sediments were deposited during the Holocene brackish phase of the Baltic Sea. In the modern anoxic part of the water column, very minor abundances of single crystals or proto-framboids of pyrite were observed. These are transported to the surface sediment acting as nuclei for further crystallization. In the sediments, the distribution patterns of framboidal pyrite is consistent, with a dynamic history of the dominating weakly-euxinic conditions with regular oxidation events of the sulphide-bearing part of the water column. When compared to the sulphur isotope composition of dissolved sulphide in the water column, the signatures found in mackinawite and pyrite indicate formation under conditions essentially limited wrt dissolved sulphate below the sediment-water interface. The surface texture together with a strongly zoned sulphur isotope patterns of concretionary authigenic MnS indicates slow growth in a sulfidic pore water gradient that developed towards a system increasingly limited in dissolved sulphate. From a physicochemical point of view, manganese-calcium solid-solutions should form in the pore waters instead of MnS. We argue, that the inhibitory effect of enhanced phosphate on the carbonate system is responsible for this thermodynamic paradox.

## P137 - Leibniz SAW-Project "BaltRap": The Baltic Sea and its Southern Lowlands - Proxy-environment interactions in times of rapid changes

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With this conference contribution, we intend to present the recently started Leibniz-SAW "BaltRap network" that aims at integrating high-resolution marine (Baltic Sea sediments) and terrestrial (lake sediments and tree rings from north-eastern Germany and northern Poland) proxy archives to comprehensively understand the impact of rapid climate change in the southern Baltic Sea region (SBSR) and to distinguish between natural and human forcing.

Considering the wide range of temporal and spatial scales involved in shaping system dynamics, we expect significant differences in the response time and magnitude of the considered environmental records. Beyond instrumental observations only a rigorous proxy development, testing, and application tailored to the different bio- and geo-archives based on precise and accurate chronologies will enable us to address the following main goals: 1. Comprehensive understanding of the environmental responses and response times of marine and terrestrial/limnic systems to gradual changes, major climatic transitions, and short-term climate oscillations during the Holocene; 2. Integration and precise synchronization of the various proxy records from brackish/marine and terrestrial/limnic systems in the SBSR to grasp the entire range of interactions between the Baltic Sea and its adjacent terrestrial systems; 3. Distinction of natural variability from the increasing influence of human societies in the later Holocene (particularly in the last century) to better project 21st century dynamics.

## P138 - Changes in the Diatom/Dinoflagellate ratio during the 20th century

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The Diatom/Dinoflagellate index (Dia/Dino index) is a core indicator for assessing the ecological status of the Baltic Sea within the scope of the Marine Strategy Framework Directive (MSFD). It reflects the dominance patterns in the phytoplankton spring bloom. In order to operationalize this indicator, conditions for the good environmental status (GES) have to be defined. The first half of the 20th century is considered as an unimpaired reference, as suggested by an example of nutrient data. Historical data sources of the pre-eutrophication period were exploited. The early phytoplankton data reveal diatom dominance in the spring blooms, i.e. a high Dia/Dino index, in all regions of the Baltic Sea. Therefore, a Dia/Dino index › 0.5 marks the GES for this indicator in the Eastern Gotland Basin. In Kiel Bay and Bay of Mecklenburg, the Dia/Dino index is constantly very high, confirming a previously suggested GES border of 0.75. Recent monitoring data revealed a sudden decrease of the Dia/Dino index especially in the period from 1989-1991 indicating a worsening of the environmental status. This is, however, not related to eutrophication but probably to climate change.

## P139 - Future warming might alter trophic relations in the plankton food web

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The combined effects of climate change, i.e. rising water temperature and increasing $pCO_2$ concentration, on natural phytoplankton communities are to a large extent still unclear. Especially in the Baltic Sea, phytoplankton community composition and biomass vary strong between seasonal bloom events. In that way responses in the phytoplankton system to climate change might differ to a large extend between such events.

We conducted two mesocosm experiments with a natural autumn and a summer plankton community of the Baltic Sea. The results showed a temperature-induced earlier bloom-time and a time-dependent decrease by more than half in phytoplankton carbon with increasing temperature in the autumn bloom. Moreover, the results of the summer study provided evidence that warming enhances the grazing pressure of copepods and can alter trophic relations between phytoplankton and their grazers in the pelagic food web. Further they suggest that warming effects can be translated to the next higher trophic level by switching a summer plankton community from a bottom-up to a mainly top-down controlled system. This was reflected by a significant decrease in phytoplankton carbon and an increase in zooplankton abundance under warming. Instead, both experiments showed that increasing $pCO_2$ concentrations seem to affect natural phytoplankton communities only minor.

## P140 - SPATIOTEMPORAL VARIANCE IN ZOOPLANKTON SAMPLING – A FIELD STUDY

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We studied the spatial and temporal variability of sampled zooplankton abundances in the Hanko archipelago, in the Gulf of Finland. Long-term time-series of zooplankton monitoring data have been collected from the same area.

Our goals are threefold: 1) we want to investigate the repeatability of sampled zooplankton abundance between replicated samples, 2) we estimate spatiotemporal variance components within the same sampling season and area, and 3) we aim to recognize the most important environmental covariates which can be used for correcting sampling bias.

The experiment was conducted during the summers of 2015 and 2016, at three locations outside of the Hanko peninsula in the Gulf of Finland along a gradient from sheltered to exposed stations. Each station was sampled twice in June and August with three replicates each. The sampling method was in accordance with long term study praxis from the same site. The analysis of the data will be finalised in March 2017.

The repeatability of the sampling events and the spatiotemporal variation are predicted to have important implications for monitoring efforts and for the usability of long term data. In upcoming studies, we hope to use this quantitative information to approximate the level of observation error variance in existing monitoring data, to facilitate further state-space modelling of long-term trends and population dynamics.

## P141 - Long-term changes in the zooplankton community in the offshore and inshore South-East Baltic (SEB)

Polunina Ju.[1]

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In zooplankton of the inshore (Vistula lagoon) and in the offshore SEB waters the diversity and abundance of warm-water species increased during last 100 years, opposite the ones of cool-water species. We recorded alien species cladocerans from the Ponto-Caspian basin *Cercopagis pengoi*, *Evadne anonyx*. It could be regarded as a result of climate change in the Atlantic Ocean basin represented by an increase of average surface water temperature ca 2°C in the Gdansk basin (1990-2000).

In the Vistula Lagoon the number of freshwater species decreased and new brackish water species appeared this changes were caused by anthropogenic regulation of salinity regime in 1911-1914. The assemblages of dominant species, presented by euryhaline copepods (*Euritemora affinis*, *Acartia* spp.) is constant for many years, marking the stability of main factors, including food resource, important for zooplankton.

In the Curonian Lagoon, sufficient changes of zooplankton structure were marked: the increase of large-sized crustaceans ratio between dominant species; the increase the average body-size of plankton animal; the increase of food particles size consumed by the dominants. The significance of the species consuming larger food particles is increased in zooplankton. It is a consequence of the composition and structure changes of the suspended matter and phytoplankton as a result of increase trophic level of the lagoon.

## P142 - Temperature variability in the Baltic Sea since 1850

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The detection of trends in a system with large decadal variability such as the Baltic Sea is very difficult, but nevertheless important in order to understand whether there are systematic changes in the drivers and how the Baltic Sea system responds to these changes.

The 2m air temperature rise in this area during the last decades amounts to 0.3K per decade, which is significant higher compared to most other coastal seas in the world. In this study a first attempt to systematically analyse detailed temperature variability from 1850-2009 in the Baltic Sea has been done using two long-term model setups as well as observations. The Modular Ocean Model coupled with the Ecological Regional Ocean Model (MOM-Ergom) and the Swedish Coastal and Ocean Biogeochemical model coupled to the Rossby Centre Ocean circulation model (RCO-Scobi) both forced with the same high resolution atmospheric forcing fields have simulated the physical and the biogeochemical variability of the whole Baltic Sea for over 150 years.

The variability in the Baltic Sea temperature is very diversified both in time and space. The trends at the bottom area do not vary much throughout the year and are mainly driven by Major Baltic Inflows which bring warm but salty and thus denser water from the surface to the bottom regions of the Baltic Sea. Thus, the highest temperature rise can be found at the bottom of the Bornhom Basin which amounts to 0.25K per decade since the 1960s. In contrast the changes in surface temperatures are highly dependent on the seasonal cycle of the air temperature. The largest trends in the SST can be found in summer in the Bothnian Bay due to the ice-albedo effect. In winter and spring the highest effects can be seen in the southern areas close to the German and Polish coasts.

Hence, the aim of this study is to detect systematic changes in water temperature in the Baltic Sea and to find out which atmospheric and related changes are the most important drivers, considering the air temperature but also wind, precipitation, sea level pressure, humidity, net precipitation, saltwater inflows and runoff. We also want to find out, why the rise in the sea surface temperature is so large compared to the trends in other coastal areas in the world.

## P143 - Are there SST regime shifts in the south-eastern Baltic Proper?

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This study is aimed to determine whether the regime shifts can be detected in the sea surface temperature in the south-eastern part of the Baltic Sea. For this purpose, we used long-term (1960-2016) air temperature and sea surface temperature data sets. The Sequential Regime Shift Detector (SRSD) software package was used to identify shifts in these time-series. In both time series were detected one significant ($p < 0.05$) regime shift, in 1989, which separates two climate regimes 1960-1988 and 1989-2016. This shift can be characterized with increase of 1.1-1.3$^0$C annual mean air temperature and increase of 1.1$^0$C annual mean sea surface temperature. The paper describes the peculiarities of the regime shift in hydrological regime in the south-eastern Baltic Sea and its possible relations with North Atlantic Oscillation index.

## P144 - Towards disentangling effects of a warming climate on the Baltic Sea: simulations with the eddy-permitting circulation model MOMBA

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The challenges of a warming climate are yet to be understood. This applies to both global and local scales. Here we present simulations with a recently-developed high-resolution ocean-circulation model of the Baltic Sea aimed at disentangling the effects of different climate-related drivers such as sea level rise, wind increase, surface warming and enhanced rainfall. The focus is on the dynamics of the link between the North Sea and the Baltic Sea in a changing climate.

## P145 - The assessment of the trends and non-stationarity of the thermohaline structure oscillations in the Baltic Sea

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This paper presents the variability of temperature and salinity in the Baltic sea from 1989 to 2013 which were investigated in the stationary approach and taking into account the non-stationary of processes. Over the last two decades in the Baltic Sea was indicated the increasing trend in water temperature as a whole at 1-2 °C in the active layer, and about 1 °C below the pycnocline layer. Estimated salinity trends in the obtained series showed a tendency to decrease the salinity of the surface layer, and its rise in the deep layer. The variance is about 1 ‰. Comparison the dispersions of the original series and the dispersions of stationary approximation showed the proximity of these values. This result indicates that seasonal variations make a decisive contribution to the total dispersion of long-term temperature oscillations. The dispersion of series salinity estimated thus, on the contrary, shows that the seasonal component makes a less significant contribution to long- term oscillations in this parameter, and the dominant role is the inter-annual component. The annual harmonic amplitude of water temperature variations in the surface layer is much higher than the amplitude of its overtones and has a significant positive trend, which indicates an increase the intensity of seasonal temperature fluctuations in recent decades. The evaluation phase of the annual harmonic suggests that the onset of its maximum since 1989 has shifted to 1 month - from July to August. Evaluation of the annual harmonic amplitude and its overtones in saline fluctuations in the surface layer indicate approximately the same their contribution to the seasonal variability of salinity. At the same time, the negative trend evident in inter-annual changes of the amplitude of the annual harmonic. While inter-annual changes in the semi-annual harmonics pronounced the positive trend. The annual harmonic amplitude in salinity changes in the deep layer is far more than amplitude of its overtones. Well expressed positive trends in inter-annual changes of the annual harmonic and its semi-annual and third-of-the-annual overtones, which indicate an increase in the amplitude of salinity fluctuations in recent decades. The contributions of advection, vertical turbulent diffusion and components of the freshwater balance in the changes of heat and salt in the Baltic Sea in different timescales ranges were estimated on the basis of physical-statistical analysis.

## P146 - Variation in pyrite sulphur concentration in sediments of the Gdansk Deep during the last 200 years

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Nutrient-driven eutrophication has led to increased input of particulate organic matter to the bottom of the Baltic. A large amount of organic material encourages microbial activity and oxygen consumption in bottom waters. The most important pathway of organic matter oxidation in anoxic marine sediments is sulphate reduction which produces hydrogen sulphide. Hydrogen sulphide reacts with iron to form sulphide minerals (particularly pyrite), ultimately reducing the availability of iron for primary producers.

In this study, temporal variations in concentration of pyrite sulphur (TRS – total reducible sulphides) and sulphur present in the form of FeS, $Fe_3S_4$ and $H_2S$ (AVS – acid volatile sulphides) were investigated in sediments of the Gdansk Deep. Additionally, total and HCl– extractable iron (reactive Fe) was quantified, and the age of the sediment was determined. Concentrations of hydrogen sulphide, sulphate, and total Fe and Fe(II) were analysed in pore water. These are the first results of pyrite sulphur concentration in sediments of this part of the Baltic.

Concentration of AVS in sediments of the Gdansk Deep deposited before 1920 is relatively low and stable. AVS concentration increases over the following years. TRS is characterized by substantial increase of its concentration after 1990, with the maximum in the late 1950s. The highest concentration of TRS is observed after extremely strong inflows from the North Sea when concentration of sulphate in bottom water increases. Oxygen is rapidly consumed during aerobic mineralization of organic matter, while high availability of sulphates enhances the bacterial reduction and production of hydrogen sulphide. Sulphate reduction stimulates pyrite formation as the reaction with dissolved sulphide is the main pathway of iron mono-sulphides conversion to pyrite. Concentration of TRS changes similarly to the North Atlantic Oscillation index. However, the similarity is much clearer for the period before 1990 than for the following years.

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## P147 - Linkage between the vertical stratification and current oscillations in the Gulf of Finland

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Vertical structure of currents in the Gulf of Finland is a composition of processes that appear in a large range of spatial and temporal scales. Kinetic energy spectra of currents usually reveal the energy maxima at a broad semi-diurnal frequency band, broad diurnal frequency band and/or low-frequency seiches band. We hypothesize that frequency composition of kinetic energy spectra is related to the vertical stratification and flow structure; i.e. in the case of sheared flow, the dominating oscillations might occur at different frequencies in different layers. The data from five bottom-mounted ADCP deployments in the deeper parts of the gulf from summer 2010 to spring 2014 were analysed. Vertical stratification is described based on CTD casts acquired close to the location of current measurements.

The observations revealed that location of current shear maxima was strongly linked to the pycnoclines. For instance the location of current shear maxima followed the deepening of seasonal thermocline during autumn convection. Current shear maxima were absent only in the case when seasonal thermocline and quasi-permanent halocline vanished. Such cases with the duration of a few weeks occurred during winters 2011/12 and 2013/2014 when strong SW winds reversed estuarine circulation, which led to the collapse of stratification and barotropic flow system.

The kinetic energy spectra of currents were strongly dependent on vertical stratification and current shear. The spectra in the periods with weak shear and strong wind forcing were dominated by current oscillations coinciding with different modes of seiches. During the periods with the multi-layered flow, spectral peaks in current spectra suggested the presence of seiches, inertial oscillations, and semidiurnal tides. Current velocity spectra for both analysed summers 2010 and 2011 revealed the same energy peaks, but they occurred in different depth ranges. In summer 2010, seiches had higher energy from surface to 60 m depth while in summer 2011, they had higher energy below 50 m depth. The frequency range of semidiurnal tides and inertial oscillations was present in the whole water column in summer 2010 while in 2011 summer it was distinguishable only in the upper 50 m.

The role of observed current oscillations in vertical mixing which could alter the residual circulation pattern in the Gulf of Finland and similar estuarine basins (revealing both stratified and weakly stratified conditions) is discussed.

## P148 - Interannual and decadal changes of storm surge events and sea ice occurrence on the south-western Baltic Sea coast

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Long-term sea level and sea ice data records on the German Baltic Sea coast reveal that i) extreme water level variations appear regularly but ii) sea ice does not form regularly every winter. However, both may cause economic and ecological impacts when they appear, and need therefore to be investigated and predicted. In order to minimize the consequences of storm surges (i), their impact on potentially endangered regions have been investigated for the past 50 years and predictions of their recurrence probability have been calculated, which was found to vary regionally between 5 and more than 50 years. Sea ice (ii) occurrence and its changes have been analysed for the same period, from 1960 to 2010. As the year to year variability is large we subdivided the 50 years into three overlapping 30 year periods (1961-1990, 1971-2000 and 1981-2010) to look for any trends. In the southern and western Baltic, there was a clear decrease in the total frequency of ice occurrence. Other parameters like begin and end of the ice season, ice thickness, etc. did not show such clear signal and also showed larger regional differences. The ice conditions mainly changed in accordance with the changes in air temperature in the same period, although some changes could have also been influenced by other factors like the deepening of fairways.

## P149 - Variability of the structure of coastal currents and wind surge at the northern shore of the Sambian Peninsula, the Baltic Sea: numerical modeling results

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The main task was to estimate the locations of the most probable sites of the active coastal erosion at the open marine shore of northern part of the Sambian Peninsula (South-Eastern Baltic, Kaliningrad Oblast, Russia) for different wind directions. The 2-dimensional numerical model set-up was applied to study the spatial structure of coastal currents. Calibration was made using the data for Lubiatowo Field Station, Poland. The greatest concern was to storm winds of the northwest and western directions (maximal frequency). It was shown that contribution of drift component to the resulting currents at the northern shore of the Samian Peninsula is remarkably higher than it is commonly assumed. Drift component in the total current remains noticeable even in a zone between the shoreline and the depth of the first wave breaking. This component makes up to 50% of the observed current for the longshore winds and not less than 20% for winds at 45 degrees to the longshore direction. Outside the zone of wave transformation, the wind-induced drift plays the major role. The maximum wind surge for winds of west and north-west directions (0.3-0.5 m and higher at winds greater than 20 m/s) happened at the shore segment from the Svetlogorsk to the southern part of Curonian Spit (to the north-east of Zelenogradsk), where speeds of currents at the marine border of the zone of wave transformation can reach 0.7-0.8 m/s for wind speed up to 20 m/s. It was found for the winds from North-West quarters that the zone of current divergence appears at the same coastal segment that forms conditions for removal of water to the deep sea from the coastal zone.

## P150 - Comparison of the January 2017 storm surge with long-term severe storm events in the Odra mouth area (the southern Baltic Sea)

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Storm surges in the coastal waters of the Pomeranian Bay are associated with low-pressure systems travelling over the Baltic Sea. They result in the intrusion of the Bay's brackish waters into the Szczecin Lagoon, which raise the water level there and in the downstream Odra branches. The storm events are recorded irregularly, mostly from November to February. At the Pomeranian Bay coast, the level of 100 cm above the mean sea level (amsl) in Świnoujście was reached or exceeded during 31 storm surges in 1993-2016. The highest sea level of 183 cm amsl was recorded on 4 November 1995 (only 13 cm lower than the highest level ever recorded in Świnoujście on 10 February 1874). The heaviest storm surge in the Szczecin Lagoon and in the lower Odra channels was recorded on 15 October 2009, when the maximum water level of 125 cm amsl in Trzebież was only 12 cm lower than the highest level ever recorded there (on 31 December 1913).The extensive storm surge that occurred at the southern coast of the Baltic Sea on 4-6 January 2017 was induced by the movement of a deep low-pressure system, known as Axel, from the North Atlantic across Scandinavia over the central part of the Baltic on 4 January (975 hPa in the centre). Then it progresses further south-east over the north-eastern part of Poland. At the Pomeranian Bay coast, it resulted in a sea level rise up to 140 cm amsl in Świnoujście during the night of 4 January. The alarm level was exceeded during 38 hours. The storm surge induced wind-driven water backflow into the Szczecin Lagoon and the lower Odra channels and penetrated as high up the river as Bielinek. The almost 70-cm rise in water level posed the flood threat for the low-lying coastal areas around the Szczecin Lagoon and those adjacent to the downstream Odra channels. Comparison of this surge with all severe storm events recorded in the period of 1993-2016 allowed to classify it as the fourth highest surge in the system of downstream reaches of the Odra River and the Szczecin Lagoon in the analysed period.

## P151 - Sea level rise and its impact on sediment dynamics along the south-eastern Baltic Sea coast

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South-eastern Baltic Sea coasts consist primarily of easy erodible soft sediment and are very sensitive to large hydrodynamic loads. Development of these coasts is controlled mainly by waves due to almost non-existing tides. In addition to the wave action shores are also influenced by sea-level changes. Relative sea-level rise occurs due to more frequent and intense storms with increased wind speeds, that also increases sea surges, the possibility of floods and coastal erosion risk. Climate change forecasts predict the increase in global temperature that is linked to global sea level rise and increase in the frequency and magnitude of storm events. The coasts of south-eastern Baltic Sea are experiencing increased wave heights, frequency and changes in wave direction that together with global and storm-driven sea-level rise are placing increased pressure on the shoreline and therefore erosion might occur in previously dynamically stabile coastal areas.

Water level measurements along the Latvian coast are available since the end of 19th century, in this study is used data starting from 1960s. All coastal hydrological stations from 1960-2016 show a strong annual average water level rise trend with most rapid increase in Gulf of Riga. The trends slopes of annual maxima of water level exhibit even more remarkable increase in this region and may reach up to 10 mm/year. These data are coupled with a reconstructed wave-driven sediment transport for 1970 to 2007. We analyse combination of sediment dynamics, wave action and sea level rise impact on coastal zone changes. The aim of the analysis is to examine any changes in annual mean and maxima sea-level and investigate any relationships with changes in sediment flux along the coast.

Sediment dynamic data were calculated with Coastal Engineering Research Council method using wave data from third generation wave model WAM Cycle 4 and adjusted geostrophic winds for from the Swedish Meteorological and Hydrological Institute 1970–2007. Sea-level data were obtained from Latvian Environment, Geology and Meteorology Centre.

## P152 - Wind wave climate of the Baltic Sea following the results of modelling by SWAN

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The long-term simulated wind wave data for 1979–2015, time period of the Baltic Sea were used to examine the properties of wind wave climate. The wave parameters were calculated using the SWAN spectral wave model with a regular mesh (0.05°). NCEP/CFSR (~0.3°) input wind forcing was used. The simulated data were compared with instrumental data of the Sweden buoys (SMHI) and statistical errors were estimated. As input wind fields the NCEP/CFSR reanalysis was used. The results of numerical simulations were compared with the results of numerical modelling, based on other unstructured mesh with spatial resolution from 250 m to 10 km and on other input wind fields (NCEP/NACR). It was revealed, that for the Baltic Sea simulations have less significant errors with regular mesh and with data of NCEP/CFSR reanalysis. The simulated maximum significant wave heights, periods and the quantity of storm situations were calculated. The wind wave climate of the Baltic Sea has very instable character with its typical (10–12 years) time intervals of the increase and of the attenuation of the wind wave intensity.

## P153 - Dangerous sea level rises in the Gulf of Finland: instrumental measurements and numerical modeling.

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Analyses data of hydrometeorological processes in the Gulf of Finland during the dangerous level rises, caused floods in St. Petersburg. It is shown that the dangerous level rises is a complex multifactorial polycyclic process. The dominant contribution to this process make mesoscale (73%) and synoptic (65%) fluctuations, while multiyear and seasonal oscillation contributions is much lower (from 5 to 25%). Based on automatic bottom stations data, ship measurements and reanalysis data, shown that in periods of dangerous sea level rises in the Gulf of Finland is maintained stable stratification and well expressed baroclinic component in the current. Cross-correlation analysis between the tangential friction of wind and currents indicates a pronounced non-stationarity statistical relationship between these processes during periods of floods. Using numerical experiments on hydrodynamic model INMOM investigated the spatial structure of low-frequency waves, forming a dangerous level rises in the Baltic Sea. Estimated amplitude and phase characteristics of flood waves. These results show that the low-frequency waves, forming dangerous sea level rises are progressive-standing waves, the nodal area which is noted more often in the open Baltic and antinodes in the east of Gulf of Finland, the Gulf of Riga and in the southwest of the sea.

## P154 - Hazardous SWL fluctuation at the Klaipeda Harbour, Lithuania

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Increase of storminess is one of the major signs of climate variability. High wind velocities are main driver of water mass hydrodynamic and evoke hazardous water level changes in closed basins. The purpose of this study is to determine hazardous SWL changes and meteorological conditions that evoke them in the Klaipeda Harbour at the SE part of the Baltic Sea.

To achieve this objective, SWL was measured the 4Hz frequency with the Wave Recorder LM2 (PTR Group Ltd, Tallinn Estonia) in the Dange river mouth, Klaipeda harbour, November 2016-January 2017. Meteorological data for the research period was obtained from the Lithuanian hydro meteorological service, Klaipeda station.

SWL changes with the amplitude of more than 50 cm were observed more than 20 times during this research. When the front side of a cyclone is approaching SE Baltic Sea coast stronger South Westerly winds reach Klaipeda. After the active low moves forward and the wind direction changes to the North West in the Klaipeda harbour hazardous SWL changes are observed. Different intensity of hazardous SWL change (up to 120 cm) was observed depending on the cyclone wind speed in the Klaipeda Harbour.

## P155 - Wave set-up in the urban area of the City of Tallinn, Estonia

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A devastating flooding is usually a result of the interplay of several drivers that simultaneously contribute to the water level rise. Wave-induced set-up is a strongly nonlinear phenomenon that results in a rise in the mean water level at the waterline. This phenomenon is added to the joint effect of all other factors responsible for high water levels. The contribution of wave set-up to the formation of devastating coastal flooding may be substantial; therefore it is essential to identify the typical shapes of probability distributions of this driver.

We explore the shape of probability distributions of wave set-up heights and alongshore variations of this shape in the vicinity of city of Tallinn in the Gulf of Finland, the eastern Baltic Sea. Wave properties are modelled using a triple nested version of the WAM model, with a resolution of the innermost grid about 0.25 nm (about 470 m). The model is forced by one-point open-sea wind data from Kalbådagrund for the period of 1981–2016.

Empirical distributions of wave set-up heights systematically match an inverse Gaussian (Wald) distribution along the entire study area. This appearance signals that extreme set-up events are more probable that it could be expected from the probability of occurrence of severe seas. The established qualitative shape is invariant with respect to the coastline orientation and to the properties of local wave climate.

## P156 - Extreme statistics of the sea level oscillations on the Russian coast of the Baltic Sea

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The long-term sea level data from 17 tide gauges on the Russian coast of the Baltic Sea were used to examine the statistical properties of extreme sea level. The duration of observations was varied from 30 to 185 years (at Kronstadt tide gauge). To avoid the impact of long-term level trends due to global sea-level rise and vertical tectonic shifts, we used detrended sea level data series. It is shown that the extreme sea level value distributions of return period for short tide gauge records are well approximated by the Gumbel distribution. The longest data series (Kronstadt, St. Petersburg and Vyborg) have shown a significant deviation from the Gumbel distribution for the rarest events. The maximum values of extreme rises/ebbs of 100-year recurrence were observed in the Gulf of Finland. Statistical analysis of the sea level data series reveals that positive surges (rises) occurred more probable than negative surges (ebbs). The maps of distribution of the extreme sea level values for Russian coast of the Baltic Sea with different returned period (10, 20, 50, 100 year) were created, they based on the results of this statistical analysis. The extreme characteristics of the regular periodic sea level oscillations (astronomical tides, seasonal sea level variations, and pole tide) were researched. The extreme range of regular periodic sea level oscillations can reach 80–90 cm in the head of the Gulf of Finland, it is comparable to the critical height of sea level rise during floods in the Neva Bay (160 cm above zero Kronstadt tide gauge). In our research, we presented the maps of the extreme range of the seasonal sea level oscillations, astronomical tides, and pole tide in the Baltic Sea.

## P157 - Wave hindcast statistics in the Gulf of Bothnia

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Wave models are efficient tools in simulating past and future wave conditions. The quality of the Baltic Sea wave models has been shown to be good in open sea areas and even near coastal areas and archipelagos, if measures are taken to account for unresolved islands at the used resolution.

Earlier studies have also shown that in the open sea areas, the quality of the wind forcing is the main factor in the accuracy of the wave model results. The operational wave forecasts in the Baltic Sea utilise wind forcing from high-resolution numerical weather prediction systems. Many of the present wave hindcasts and reanalyses are based on using wind fields collected from operational forecasting systems. They have been shown to give an accurate description of the Baltic Sea wave conditions, but the heterogeneous quality of the wind fields (due to the changes in the forecast system), and the temporal extent of the hindcasts (NWP systems with good quality and resolution are available only starting from c. 2000 onwards) have been discussed as limitations of these hindcasts.

For a long time, the resolution and quality of the atmospheric reanalyses has limited their use in the Baltic Sea. Nowadays, there are downscaled reanalysis products, such as the RCA4-ERA interim produced by SMHI, that give us possibility to do wave model hindcasts using wind forcing with adequate horizontal temporal resolution. Furthermore, the seasonal ice conditions, that are important for the wave reanalysis, can be calculated with an ice-ocean model using the same atmospheric forcing, thus providing a compatible forcing dataset. We evaluate the quality of wave hindcast made for the Gulf of Bothnia using wind forcing from RCA4-ERA interim and ice concentrations from SMHI's Nemo-Nordic model of Baltic & North Seas. We use data from wave buoys and satellite altimeters to evaluate the quality of the model results.

The wave hindcast is used to evaluate the extreme wave conditions in the Gulf of Bothnia and to calculate the wave-generated oscillatory velocities at the seabed to estimate the exposure of sediments to wave action.

## P158 - Sea level probability forecasts for the Finnish coast

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The probability forecasts of meteorological phenomena are increasingly used by the operational weather services. We present a sea level probability forecast method which is used to predict the sea levels on the Finnish Coast for the next 10 days. The 10-day sea level forecasts are useful for the marine traffic and for the coastal protection against sea floods. The cargo ships optimize their route plan and loading using the forecast information. In case of sea level extremes, the authorities are better prepared to prevent flooding damage at the coast.

The sea level modeling system consists of two components. The first component models the internal sea level variations of the Baltic Sea, which are calculated with a barotropic sea level model that treats the Baltic Sea as a closed basin. The second component models the variations in the total water volume of the Baltic Sea due to wind-induced water exchange through the Danish Straits. These variations are calculated from the daily means of the zonal wind component at (55 N, 15 E) of the preceding 60 days. Thus the second component includes the future change in the mean sea level of the Baltic Sea.

The surface wind field and air pressure, obtained from the ensemble prediction system at ECMWF, are used as the atmospheric forcing for the sea level model. There is a control forecast and 50 perturbed forecasts for 10-day forecast lengths. From the ensemble of sea level forecasts, the likely range of sea levels and exceedance probabilities of fixed levels can be evaluated statistically for any location in the Baltic Sea. The quality of the sea level forecasts is assessed by comparing the results with Finnish tide gauge observations. Preliminary results show that the water volume variations in the Baltic Sea are accurately described by the sea level forecasts. Compared to the present operational sea level forecasts at FMI, the probability forecasts have longer temporal extent and confidence ranges are added to the sea level forecast.

## P159 - Storm surge modelling in the southern Baltic Sea using the high resolution PM3D model

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Storm surges are among the most dangerous natural phenomena affecting many low-lying coastal areas of the world. In the southern Baltic Sea they pose the flood threat for coastal areas, polders, and areas adjacent to rivers. In the study, the new parallel version of three-dimensional hydrodynamic model of the Baltic Sea (PM3D), developed at the Institute of Oceanography, University of Gdańsk in Poland was applied to calculate sea level fluctuations along the southern Baltic coast in 2010-2015. The tool was based on the coastal ocean circulation model known as the Princeton Ocean Model. The open boundary was located between the North Sea and the Skagerrak. Two grids differing in spatial resolution were used: one with 1 NM spacing, applied to the region including the Baltic Sea and the Skagerrak, and the other with 0.5 NM spacing employed in its southern part. Nesting of the 0.5 NM grid into the 1 NM grid resulted in a much better approximation of the coastline and the area's bathymetry, hence in a better correlation between the calculated and the observed distributions of water levels.The correlation coefficients for relationships between numerical simulations and hourly readings from the sea level stations located at the southern Baltic coast increased to over 0.93. On the other hand, the RMSEs decreased to below 0.09 m and over 92% of readings were reproduced by the PM3D within a range of ±0.15 m. Model quality tests involving 2010-2015 storm surge events showed a good fit between the modelled and observed distributions of data. In the cases of high-amplitude and rapid water level fluctuations the model generated relatively good simulations, properly predicting the timing and extent of maximum values with errors usually not exceeding 0.15 m. During the analysed surges, the best fit between the numerical calculations and readings from the sea-level gauges was obtained for Ustka and Gdańsk, only a slightly worse agreement being shown for Sassnitz. The adequate approximation of sea-level variations by the PM3D makes it a reliable tool for storm surge simulations. As the PM3D involves parallel calculations, the computation time of simulations was reduced considerably, thus allowing to apply the high-resolution grid also to the operational version of the model available within the SatBałtyk System (http://satbaltyk.iopan.gda.pl).

## P160 -Evolution and improvement of the CMEMS-Baltic Sea forecast products during the last two years

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For the Copernicus Marine and Environmental Service (CMEMS – marine.copernicus.eu), the Baltic Sea Near Real Time Forecast Products are provided two times per day for Physical and Biochemical parameters by a consortium of these five institutes: the Danish Meteorological Institute (DMI), the Federal Maritime and Hydrographic Agency (BSH), the Swedish Meteorological and Hydrological Institute (SMHI), the Marine Systems Institute of Tallinn University (MSI) and the Finnish Meteorlogical Institute (FMI).

Since 2009, with the first MyOcean project, this consortium develops an ocean circulation model, the Hiromb-Boos-Model (HBM). Once a year, all developments of the model system are made operational to create a new version of the forecast products. For this procedure, the quality of the forecasting product is tested and published in technical reports. These reports present an analysis of the statistical values and a comparison between the new version and the current version of the operational product. The main focus is put on timeseries over a period of one to two years, but recently a further focus is put on specific events, such as storm surges or salt water inflows.

During the last two years it emerged, that there has been a great improvement in forecasting these specific events. Meanwhile, the analyisis of the longer time series remained at the same reliable quality. To achieve a better forecasting product many tools have been developed - both in the examined coupled forecasting model HBM-ERGOM (improved turbulence scheme, better description of sea ice, spatial variable atmospheric deposition and N/P-ration) and in the comprehensive validation programs (tools for standardised event based analysis).

This poster shall give a detailed overview about the quality improving progress of the whole Baltic Sea-forecasting system of CMEMS during the last two years.

## P161 - HBM-PDAF assimilation system in the North and Baltic Sea: recent implementation and results

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The operational service at the BSH bases its model systems on the 3D baroclinic circulation model HBM (HIROMB-BOOS Model), which provides the basic information for a couple of downstream services, like e.g. the sea level prediction and storm surge warning service for the German coast, or oil spill forecasting and search-and-rescue applications.

With the aim of improving the forecast skill, an ensemble data assimilation (DA) system was built by coupling of HBM and the parallel data assimilation framework (PDAF) for the North and Baltic Seas. Testing and validating the DA system with both satellite sea surface temperature (SST) and temperature-salinity profiles have shown a significant improvement of the forecast quality during the DeMarine project.

Within the framework of the Copernicus Marine Environment Monitoring Service (CMEMS), the DA system has been further developed and transferred to the latest releases of both HBM and PDAF. Currently, SST from the Advanced Very High Resolution Radiometer (AVHRR) is assimilated in the HBM-PDAF system on a pre-operational basis at the BSH. The AVHRR data is processed, gridded and quality controlled by the BSH satellite data service. We plan to extend the assimilation system to include more observations (e.g. T/S profiles, Ferry Box data, altimeter data, or satellite image of ice cover), and further plan to transfer the assimilation system into operational mode at the BSH.

The comparison of the free model runs and the runs including assimilation over one year period shows obvious changes in the temperature by the DA system in the whole Baltic Sea. The changes can be found not only at the surface but also in the whole water column. The validation of the results with independent MARNET observations confirms the improvement of forecasting system with assimilation. The new progresses in the HBM-PDAF system and the recent results of the comparison and validation will be presented.

## P165 - Bathing water quality on Lithuanian coast: microbial pollution and algal blooms

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Coastal waters are important ecosystems from the ecological and the economic perspective and provide many valuable ecosystem goods and services. Still those ecosystems are exposed to the environmental pressures, mainly related with anthropogenic activities as an urbanisation, extensive agriculture, sewage discharge and recreation. Those activities can result in an increase and exposure to pollutants from different sources.

According Bathing Water Directive (2006/7/EC) bathing water quality are monitored using two indicators: E. coli and intestinal enterococci. Algae or cyanobacteria should be investigated and their acceptability and health risks determined when tendency for proliferation is observed, especially when the bathing waters are classified as “good”, “sufficient” and “poor”. Stakeholders are also indicating algal blooms as one of the main concern in the beach areas, because they cause bad smell, bathing discomfort and potential toxicity. On the other hand the thresholds of microbial indicators do not give any information about the pollution source and possibilities to predict and avoid the potential risks.

Our study objective was to indicate the hot spots on the coastal beaches of Lithuania where the microbial pollution and intensive algal blooms are observed. Using different approaches we also provide the tools for microbial pollution and algal source tracking. With the 3D hydrodynamic transport model we indicate possible fate and transport of microbial pollution in the area. The host source and toxicity of E. coli could be revealed using the molecular methods. Remote observation method could be useful tool for the assessment and prediction of transport and accumulation of the algae. The synergistic use of methods (molecular, Earth Observation and modelling) opens new insights in sustainable water quality monitoring of key recreation places on Lithuania coast.

Work resulted from the BONUS BaltCoast project was supported by BONUS (Art 185), funded jointly by the EU and Research Council of Lithuania. Activities related with algal blooms investigation were supported by EOMORES – the EU H2020 research and innovation programme project under grant agreement No. 730066.

## P166 - Microcystins in the shallow lagoons of South-Eastern Baltic and its influence on fish species

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Curonian and Vistula Lagoons of the Baltic Sea are semi-enclosed shallow eutrophic-hypertrophic basins (Alexandrov S., 2010), two largest lagoons of the Baltic Sea. The measured average and maximal contents of total microcystin in the Russian part of the Curonian lagoon are significantly higher than in neighboring Lithuanian part of Lagoon (Sigitas Sulcius et al,2015), due to natural specific of the basin (Smirnova M.,Ezhova E.,2015). The total content of cell-bound microcystins reaches 4719 µg/g dry weight, extracellular – 290 µg/l (Ezhova E, Lange E., Russkikh Y. et al, 2014). In the Vistula Lagoon not numerous determinations of microcystins were done, however the measured content of cell-bound toxins was also rather high – 268 µg/g dry weight (Russkikh J., Ezhova E. et al., 2012).

The observation of harmful algal blooms (HAB) with proved presence of microcystins and its toxic effect on aquatic biota are regular in the region since 2010. Humane and vertebrate disease, caused by consumption of fish – rhabdomyolysis or Haff disease (Haffkrankheit), was first identified in Europe in 1924 in the Vistula Lagoon, former Frischen Haff. Recent study of 2008-2011 Haff disease outbreaks in Siberia have shown, microcystins are the etiological factor of the disease and the most probable reason is the appearance of toxins during HAB of cyanobacteria Microcystis aeruginosa [Ubugunov L.et al,2013]. It is well known, microcystin-LR is a potent inhibitor of eukaryotic protein serine-threonine phosphatases 1 and 2A in vitro (Honkanen R.E. et al,1990; MacKintosh C. et al,1990) and in vivo (Runnegar M.T.C et al,1993) and its effect on eukaryotic cells is universal.

For detailed description of the effect of high natural microcystin content on vertebrate animals as well as to clarify whether first historical cases of Haff disease (1924-1931) associated with microcystin's influence, laboratory tests on model fish species – Poecilia reticulate, were done.

100 % lethal effect of natural undiluted and 4-times diluted water, collected during late-fall 2016 HAB crisis in the Curonian lagoon, was shown. The results of the study explain well the regular mass fish kills in both lagoons.

## P167 - Presence of Vibrio spp. in bathing waters of the Baltic Sea: current status, knowledge gaps and future investigations

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*Vibrio spp*. are common aquatic bacteria causing severe infections of humans and animals. These organisms inhabit surface waters throughout the world and highly depend on specific conditions concerning salinity and water temperature. Infections by pathogenic *Vibrio spp*. are mostly attributed to raw shellfish consume or to a direct wound exposure to warmer seawater containing these organisms. Although the number of illness cases of *Vibrio spp*. infections increased throughout the years around the Baltic Sea no actual directive exists controlling potential outbreaks. Moreover, at regional level only low attention is paid to this problem. The objective of this study is to compile information about the presence of *Vibrio spp*. along the coast of the Baltic Sea, as well as their diversity, spatial and temporal distribution, in order to define knowledge gaps with regard to potential vectors, sources and risks that have to be addressed in the future.

## P168 - LONGITUDINAL MONITORING OF SURFACE WATER QUALITY

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Water quality in surface water (rivers, lakes) depends on complex processes in catchment and in water body itself. Conventional monitoring of water quality is based on sampling and further analytics of constituents in the laboratory. Thought extended monitoring engages automatic sampling or on-line sensors, its results are discrete and describe the water quality in a singular point or profile. Quantification of matter input (especially from diffuse sources) and transformation processes in the water body requires increasing of spatial and temporal resolution of water quality observation. This can be achieved by application of longitudinal boat-based online measurements.

The mounting of an online analyzer system, including spectrometer, positioning device, sensors (pH, temperature, conductivity, COD, nitrogen compounds, turbidity, chlorophyll-a, etc.), flow measurements (ADCP), sediment sonar, on the boat enables to depict comprehensive water quality features in longitudinal profile of a river.

Such system has been developed on low cost basis and applied on the river Tollense, which catchment is in the west of Pomerania and belongs to the basin of the Baltic Sea. The measurement system for orthophosphate, nitrate, ammonia, pH, redox potential, dissolved oxygen, COD, BOD, and positioning was assembled and mounted on a boat. Four measurements campaigns have been performed on a 28 km segment of the river in March, Mai, August and December in order to observe the water quality at different seasons. To validate the boat measurements, grab sampling has been performed in parallel.

The measurement data show conformity of the water quality according to the expected state of this specific river. For example, in winter period higher nitrate concentrations were observed on the river stretches receiving tile drainage flows from arable land in the vicinity. In the vegetation period the phosphate was found under detection limit, because of incorporation into algae and water plants, which are typical for low land rivers. Moreover, the measurements have revealed unknown matter inputs of nitrogen and phosphate accompanying by conductivity change.

Although the construction of such measurement system is logistically and technologically challenging, its application delivers valuable results, which can be applied as in practice, as well as for scientific purposes, e.g. modeling of water quality formation processes.

## P169 - A METHOD TO DEFINE THE EXTENT OF COASTAL WATERS FROM SATELLITE DATA

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Total suspended matter (TSM) can be used as an indicator for coastal water extents and can be retrieved reliably from Medium Resolution Imaging Spectrometer (MERIS) data. In this study, full resolution MERIS data from summers 2009-2011 were used to investigate the Baltic proper region and explore the extent of coastal waters. For this region, MERIS images show the effect of Coriolis forces causing anti-cyclonic circulation and the impact of atmospheric Rosby waves, which cause large eddies primarily in the southern Baltic, extending to approximately 130 km offshore.

A MERIS composite image of the Baltic Sea from early June 2011 was then used to evaluate the extent of coastal influence via TSM patterns. This time of year was selected because TSM patterns should not be influenced by cyanobacteria blooms. The averaged TSM data from early June 2011 were used to extract transects approximately perpendicular to the coast spanning from coastal to offshore waters. Several coastal transects in the NW Baltic proper (Swedish coastal areas), the Eastern and South Eastern (Latvian and Lithuanian coast) and Southern Baltic proper (Polish coast) were defined for analysis. The transects from each selected area were used to define the approximate extent of coastal waters (in km) using locally defined thresholds for open sea waters.

The TSM distribution along the transects varied over the regions. For example, transects from the NW Baltic Sea were best described by polynomial equations whereas the transects in the SE coastal areas were best described by logarithmic equations in areas of high resuspension. These varying trends indicate different hydrological regimes that are either primarily driven by diffusional distribution processes (NW Baltic Sea) or by local wind exposure (Southern Baltic).

The results of the study demonstrate that ocean colour remote sensing provides important information to understand the dynamics of Baltic Sea waters. The data can also be used for monitoring the extent of coastal waters. The approach described here can be applied to any coastal water body influenced by TSM. The method is also generic and can be applied to any ocean colour sensor providing reliable TSM data, such as ESA's Ocean Land Colour Instrument (OLCI) on Sentinel-3.

## P170 -Water quality assessment in the eutrophic Curonian Lagoon with support of Hyperspectral Imagery

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The Curonian Lagoon is naturally productive water basin that has been impacted by the undesired processes of both eutrophication and climate change. Nowadays the lagoon is considered to be hyper-eutrophic with recurring spring diatom blooms followed by summer cyanobacteria blooms. Cyanobacteria blooms are a major concern in this region because the chlorophyll-a concentration can be extremely high (up to about 200 mg $m^{-3}$) and, under specific climate conditions, can be associated with a surface accumulation of algae. The successful validation of satellite remote sensing data over the hypereutrophic Curonian Lagoon retrieving water quality parameters (Giardino et al., 2010, Bresciani et al., 2012, Vaiciute et al., 2012) opened a new insights for the understanding of whole lagoon functioning and water quality changes. However, the additional use of airborne hyperspectral sensors can be very useful tools for monitoring such productive and optically complex waters. The high spatial and spectral resolution obtained with airborne hyperspectral instruments makes it possible to develop water quality retrieval algorithms suitable for optically complex waters, which may subsequently be used with current and future satellite sensors. Three APEX missions have been performed in the Curonian Lagoon on 01/09/2016 and 02/09/2016 under EUFAR project COOLAPEX. Simultaneously water quality parameters were collected (chl-a, phycocyanin, CDOM, TSM). The aim of this study was to develop the algorithms for retrieval of water quality from APEX hyperspectral data. We found a good agreement between in situ measured and APEX derived chl-a concentration ($R^2$=0.94, N=11). Also a good agreement was found between phycocyanin concentration measured in situ and retrieved from APEX data ($R^2$=0.89, N=7) as hyperspectral data provides the enhanced information suitable for estimating the secondary pigments of phytoplankton. Our study confirmed the significance of the spatial aggregation of APEX pixels and sampling time span for the validation results.

Work resulted from the 7FP project INFORM under grant agreement No. 606865 and EOMORES – the EU H2020 research and innovation programme project under grant agreement No. 730066.

## P171 - Human pathogen detection accord to IMO Ballast Water Management Convention in three main port of Latvia

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Invasive aquatic species present a major threat to the marine ecosystems, and shipping has been identified as a major pathway for introducing species to new environments. The effects of the introduction of new species have in many areas of the world been devastating. The IMO Ballast Water Management Convention("International Convention for the Control and Management of Ships' Ballast Water and Sediments" adopted in 2004, entry into force in 8 September 2017) aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments. HELCOM-OSPAR protocol. According IMO regulation D-2 of the Convention and to HELCOM-OSPAR protocol that supplements the Convention human of pathogens (intestinal enterococci, *Escherichia coli* and *Vibrio cholerae*) are of special concern.

Sampling of human pathogens was performed in spring and summer in three main Latvian ports in 2015 to detect abundance of *E. coli* and intestinal enterococci. Sample analysis and processing followed the EU Bathing Water Directive 2006/7/EC - for presence and abundance detection of *E. coli* ISO 9308-3 method and for intestinal enterococci detection ISO 7899-1 method was used. *Vibrio cholerae* was not monitored because it require specialised laboratory and in EU Bathing Water Directive 2006/7/EC there is no *Vibrio cholerae* detection method mentioned. According to IMO Conventions Regulation D-2 intestinal enterococci concentrations in should be less than 100 cfu per 100 milliliters and *Escherichia coli* less than 250 cfu per 100 millilitres.

Results showed that the amount of human pathogens in Port of Riga and Ventspils was found in highest concentration during summer maximum of HAB, but in Port of Liepaja amount of human pathogens were higher during spring. In general the highest human pathogene amount was detected in Port of Riga that could be explained by more intense ship lines and higher density of boats, motorboats and yachts. For further conclusions more data is necessary.

This work was supported by National Research Program 2014-2017 "The value and dynamic of Latvia's ecosystems under changing climate" (acronym EVIDEnT) and Joint Lithuanian – Latvian - Taiwan cooperation program project 2015-2017 "Development of the ships' ballast water management system to reduce biological invasions" (acronym BALMAN).

## P172 - Identification of cyanobacteria in a eutrophic inner coastal lagoon at the Southern Baltic coast

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Cyanobacteria are found in habitats worldwide with different sizes, forms and features. Picocyanobacteria such as Synechococcus and Prochlorococcus dominate the oligotrophic oceans. Eutrophic shallow brackish waters are dominated by other picocyanobacteria, which mostly form colonies. For monitoring purposes, these colony builders are usually determined by morphological features of the colonies. However, the huge plasticity of this feature requires the application of molecular genetic methods. A biphasic approach of culture dependent and culture independent methods was applied to samples of the Darß-Zingst Bodden Chain, a eutrophic inner coastal lagoon of the Southern Baltic Sea. The 16S rRNA phylogeny of isolated strains as well as clone sequences indicate a strong dominance of Cyanobium species. Morphologically, Aphanothece dominated the phytoplankton by up to 90 % abundance. While Aphanothece spp. belong to the Chroococcales, which are able to produce toxins and may fix nitrogen, Cyanobium belong to the basal alpha-picocyanobacteria, which have no special abilities. The discrepancy between morphologically determined Aphanothece-like species and genetically determined Cyanobium may be found in other eutrophic and shallow habitats too. This bias will have consequences for indicator species identification and risk assessment.

## P173 - Monitoring of marine biofilm formation dynamics at submerged solid surfaces with multitechnique sensors

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Biofouling phenomenon on artificial and biotic solid substrata of varying hydrophobicity was studied in the Baltic Sea brackish water (Gulf of Gdansk) during a three-year period. Biofilm biovolume, substratum coverage, area to volume ratio, spatial spreading, mean thickness and roughness, fractal dimension in 2D determined as a function in time from confocal microscopy (CLSM) data were used to mathematical modeling of a marine biofilm under steady state conditions. The analyses revealed that different biological components in the biofilms (bacteria, micro-algae and ConA-stained EPS) followed different dynamics in time. A clear change was observed from a heterotrophic system dominated by bacteria to an autotrophic system enriched in diatoms. Photosynthetic properties (photosynthetic energy storage ES, photoacoustic amplitude and phase spectra) of biofilm communities exhibited a seasonal variability as indicated by a novel closed-cell type photoacoustic spectroscopy PAS system. The relationships between contact angle, contact angle hysteresis CAH, adhesion and marine biofouling were determined with an automatic captive bubble solid surface wettability sensor assigned for *in-situ*, on-line and quasi-continuous measurements of permanently submerged samples (Pogorzelski et al., 2013; 2014). The wettability parameters evolution allowed the particular biofilm structural states (from conditioning film to macrofouling) to be identified. Knowledge of three-dimensional structure of the biofilm, and the distribution of species concerned is crucial in managing and preventing uncontrolled colonization of great practical value for undersea engineering constructions. A multistep approach involving chemical, wettability, photoacoustic and microscopy techniques can be used to assess ecological features of microperiphytons, and as robust indicators for marine bioassessment. Short generation time, sessile nature and fast responsiveness to environmental conditions make biofilms suitable as a monitoring tool in Baltic Sea eutrophication studies (in progress).

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## P174 - Two non-indigenous dreissenids (Dreissena polymorpha and D. rostriformis bugensis) in a southern Baltic coastal lagoon: changes in population size and structure of an "old" and a "new" immigrant

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*Dreissena polymorpha* and *D. rostriformis bugensis* are freshwater Pontocaspian bivalve species, at present widely distributed in Europe and North America. The dispersal of *D. polymorpha* (the zebra mussel, an "old" immigrant") in Europe began at the turn of the 18th and 19th centuries, whereas expansion of *D. rostriformis bugensis* (the quagga, a "new" immigrant") in Europe started as late as in the 1940s. In the Szczecin Lagoon (a southern Baltic coastal lagoon), the quagga was recorded for the first time in 2014 and found to coexist with the zebra mussel, a long-time resident of the Lagoon. As the two species are suspected of being competitors where they coexist, it was of interest to follow quagga population's dynamics in the Lagoon. Three sites of quagga's occurrence (in the northern, eastern, and south-eastern part of the Lagoon) have been sampled monthly since May 2015 to determine abundance, biomass, and size structure of both the quagga and the zebra mussel. In summer 2015, the northern site showed the quagga to vastly outnumber (and outweigh) the zebra mussel, the quagga individuals being in addition much larger than those of the zebra mussel. The dreissenid assemblages at the two other sites were dominated by the zebra mussel, both in terms of abundance and biomass. It was therefore concluded that the new immigrant started colonising the Lagoon from the north. In summer 2016, the abundance ratio of the two species at the northern sites changed markedly in favour of *D. polymorpha*, still dominant at the eastern and south-eastern sites. As, however, the quagga population at the northern site showed a high contribution of large individuals, its biomass dominated over that of the zebra mussel. In addition, in contrast to the preceding year, the quagga samples collected in 2016 contained a high proportion of empty shells (dead individuals). Moreover, the size distribution of live quagga showed no distinct peak of smaller length classes which would have evidenced the appearance of new generations and hence a progressing population growth. It may be then concluded that, at least at present, the zebra mussel, an "established" immigrant, remains a stronger player of the two dreissenids.

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## P175 - Should the alien species be protected? The case of Chara connivens in the Baltic Sea with particular reference to Poland

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The first reports on the presence of *Chara connivens* P. Salzm. ex A. Braun 1835 in the Baltic Sea area could be published thanks to Dr. C. Baenitz's talks on this species and on other rare and new plants found in Königsberg and Danzig, respectively, given to the Assemblies of the Prussian Botanical Society in the early 1870s. As it was shown by H. Luther more than one hundred years later, the scientific society at the end of the 19th century was well aware of the fact that *C. connivens* was introduced to the areas of both harbor cities as a ballast plant - wet sand was commonly used as a solid ballast at times of sailing ships. The species' protection status in the countries around the Baltic, as well as its status in the Red Data lists of endangered plant species (including HELCOM Red Lists), are critically reviewed. In Poland for example, *C. connivens* is strictly protected. It was also classified as extinct (EX) even in the 21st century – in spite of data (published by Pliński et al. in 1978) showing that the species was then quite common and even abundant in the western, Polish part of the Vistula Lagoon in the 1970s. Its presence by the southern coast of the lagoon was reported in recent years. Moreover, it was also found to inhabit sheltered bays in the Szczecin Lagoon, the water body where this alien plant has never been recorded before. The available historical and recent records are compared and the contemporary distribution of this alien charophyte in the Polish coastal waters is presented. While *C. connivens* was not reported again from Königsberg/Kaliningrad, and the long-cited original habitat in Gdańsk, "Loch an der Westerplatte", does not exist for more than a hundred years, another coastal habitat visited by Baenitz (present-day Ptasi Raj Lake by the Brave Vistula mouth) still supports charophyte communities, as it was shown in 2012. Further detailed research in this coastal lagoon would confirm if *C. connivens* is still present there. Owing to the presented facts, it is suggested that this species as non-indigenous, is deleted from the Red lists and is not protected any longer anywhere in the Baltic Sea region.

## P176 - Identification and distribution of invasive polychaete species complex Marenzelleria spp. in Lithuanian marine area

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First records of invasive polychaete *Marenzelleria* sp. in Lithuanian waters date in 1990. At first, it was identified as *M. viridis*, later as *M. neglecta*, however an application of molecular methods showed that both of these species are present in the Baltic. Furthermore, another species was detected – *M. arcia*. In this study, we investigated species composition of *Marenzelleria* spp. complex in Lithuanian marine waters from shallow coastal sandy bottoms down to muddy hypoxic sediments below halocline. We used polymerase chain reaction (PCR) based restriction fragment polymorphism (RFLP) markers that discriminate between these three species. In total, 89 individuals sampled at 10 sites were analysed (4.5-60 m depth range). Results of PCR-RFLP analysis indicated the presence of all three species currently known for the Baltic Sea: *M. viridis*, *M. neglecta* and *M. arctia*. The model of the occurrence of these species in Lithuanian marine area was created. Environmental predictors were depth, sediment types, near bottom orbital velocity, current velocity, salinity, oxygen concentration, Secchi depth, temperature, topographic features. Maximum entropy (MAXENT) modelling method was used as it deals with low number of presences really well. The most important environmental factors for *M. artia* were sediments, wave generated orbital velocity and temperature: this species preferred deep sandy and muddy areas below summer thermocline and unaffected by waves. The most important environmental factors for *M. viridis* and *M. neglecta* were sediments, salinity and wave generated orbital velocity. These species preferred shallow sandy bottoms tolerating lower salinity and extreme wave exposure. *M. viridis* and *M. neglecta* occurred always together and were present from the shallowest sites (4.5 m) up to 40 m depth. *M. arctia*, on the other hand, was present deeper than 30 m and at depths ›50 m were the only species present of *Marenzelleria* genus.

## P177 - Detection of regime shifts in the zoobenthos assemblages in the south-eastern Baltic Sea near Lithuanian coast

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This paper examines long-term patterns in the macrozoobenthos assemblages (co-occurring species) in the southeastern part of the Baltic Sea for the period of 1981-2016. Co-occurring species group has been allocated in different environmental regime areas: deep zone Gotland Basin 90-120 m, medium deep monitoring station (47 m depth, aleurite), and coastal monitoring stations (14 m depth, fine sand). The Sequential Regime Shift Detector (SRSD) software package was used to identify shifts in the time series of abundance and biomass of each species (*Oligochaeta spp.*, *Pygospio elegans*, *Bylgides sarsi*, *Scoloplos armiger*, *Marenzelleria spp.*, *Monoporeia affinis*, *Ostracoda spp.*, *Saduria entomon*, *Pontoporeia femorata*, *Macoma balthica*, *Cerastoderma glaucum*). The benthic assemblages are a reliable indicator of climatic changes in the environment. Their reaction manifested itself in the changes of abundance and biomass of certain species, and changes in species composition (ratio between boreal and arctic species). Significant ($p < 0.05$) regime shifts were detected among glacial relict species, bivalves, opportunistic worms, and invasive *Marenzelleria spp*. The long-term characteristics changes of the quantitative macrozoobenthos are related to climatic changes.

## P178 - Developing new indicator variables for marine habitat monitoring based on mm-scale bathymetry and multi-frequency acoustic scatter

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In this study, we improve the remote marine habitat monitoring of macrobenthic organisms by combining mm-scale laser-line scanner and multi-frequency acoustic scatter data. Towards this purpose, a new autonomous lander system has been developed. Remote sensing of the seafloor is required to obtain a comprehensive view of the marine environment. It allows for analysing spatio-temporal dynamics, monitoring of natural seabed variations, and evaluating possible anthropogenic impacts, all being crucial in regard to marine spatial planning as well as the sustainable and economic use of the sea. One aspect of ongoing remote sensing research is the identification of marine life, including both fauna and flora. The monitoring of seafloor fauna – including benthic communities - is mainly done using optical imaging systems and sample retrieval. The identification of new remote sensing indicator variables characteristic for the physical nature of the respective habitat would allow an improved spatial monitoring. A poorly investigated indicator variable is mm-scale seafloor microtopography and -roughness, which can be measured by laser-line scanning and in turn strongly affects acoustic scatter. Two field campaigns have been conducted offshore Sylt Island in 2015 and 2016 to measure the microtopography of seafloor covered by sand masons, blue mussels, and oysters and to collect multi-frequency acoustic data. The acoustic data and topography of the blue mussel and oyster fields are currently being analysed. The mm-scale microtopography of sand mason covered seafloor was transformed into the frequency domain and the average of the magnitude at different spatial wavelengths was used as a measure of roughness. The presence of sand masons causes a measurable difference in roughness magnitude at spatial wavelengths between 0.02 m and 0.0036 m, with magnitude depending on sand mason abundance. This effect was not detected by commonly used 1D roughness profiles but required consideration of the complete spectrum. The influenced spatial wavelengths correspond to acoustic frequencies of 75 kHz and 400 kHz in water that are common for acoustic monitoring purposes. The available results indicate that the development of habitat-specific indicator variables, e.g. related to abundancies of sand masons or mussels, is possible and that remote sensing may assist the monitoring of benthic habitats in the future.

## P179 - Recent findings about benthic non-indigenous species in the Polish coastal waters

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Relatively low species richness of the benthic communities in the Baltic Sea makes them highly vulnerable to alien species introductions. Throughout the time numerous non-indigenous species have been introduced to the Baltic Sea mainly due to shipping activities. Some of these species such as *Palaemon elegans* and polychaete from genus Marenzelleria are nowadays commonly found in the Baltic Sea. Since 2010 several new alien species have been recorded in the Polish coastal waters among them: bivalves the Conrad's false mussel *Mytilopsis leucophaeata* and the Atlantic rangia *Rangia cuneata* and crustaceans the oriental shrimp *Palaemon macrodactylus* and *Melita nitida*. *M. leucophaeata* has been recorded in relatively low densities at one site in the Gulf of Gdańsk since 2010 (Dziubińska 2011). In 2016 the species was recorded in the Vistula Delta where the bivalves were more abundant and significantly larger than in the Gulf of Gdańsk. In 2014 two species were found in the Vistula Delta: *R. cuneata* and *P. macrodactylus*. The Atlantic rangia was found previously in the Vistula Lagoon in 2010 (Rudinskaya & Gusev 2012). For the oriental shrimp it was the first record in the Baltic Sea (Janas & Tutak 2014). For both species, the spread to the open part of the Gulf of Gdańsk or the Baltic Sea has not been observed yet. *M. nitida* was recorded for the first time in samples collected from the Port of Gdynia in 2014 (Normant et al. 2017). In 2016 it was recorded also on artificial offshore structure outside the port area.

## P180 - Shipworms, destructive invaders to the Baltic Sea

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Wooden groyne systems at the Southwestern Baltic Sea coast are traditionally an important coastal protection facility, but become regularly infested and destroyed by the invasive wood-boring bivalve *Teredo navalis* since the early 90ies. The groynes made from soft wood had to be renewed regularly in short intervals and today mainly hardwood of tropical origin is used, causing substantial maintenance costs and a negative ecological footprint. Furthermore, *T. navalis* is threatening wooden shipwrecks and other maritime related constructions of high archaeological value. For a long time, the occurrence of *T. navalis* was supposed to be mainly limited by low salinities. Recently, possible range expansion of this invasive species into marine regions of lower salinities than predicted before is discussed. The particular abiotic conditions in the Baltic Sea with a horizontal salinity gradient from west to east give a favourable opportunity to study *T. navalis* at its distribution border. *T. navalis* was therefore monitored at its distribution boundary in the Baltic Sea over a period of five years. At seven different stations along the prevailing salinity gradient at the Mecklenburg-Western Pomerania coast, larval traps were installed regularly, while at the same time water temperature and salinity were measured continuously on an hourly basis. Correlations between measured abiotic parameters and infestation density of *T. navalis* have been tested. The results did not confirm range expansion of *T. navalis* for the German Baltic Sea Coast, locating the actual distribution border at the west coast of Rügen. The salinity and temperatures within the groyne systems vary between the years investigated, and slightly alter the most eastern infestation border in the Baltic Sea. Temperatures seem to have a higher effect than expected, which is a striking result with respect to global warming.

## P181 - Marenzelleria arctia (Polychaeta: Spionidae) in the South-Eastern Baltic Sea (Russian EEZ)

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First appearing in the Baltic Sea in 1985, by the beginning of the 1990's several polychaetes of Marenzelleria genus colonized the whole Baltic Sea. It is considered now, that *Marenzelleria* spp. species group in the Baltic Sea is represented by *M. neglecta*, *M. arctia* and *M.viridis*. While *M. viridis* occurs in the Sound, southwestern areas and in the east, where it co-exists together with other two species, *M. neglecta* inhibits whole south-eastern Baltic and Eastern Baltic, including Eastern Gotland Basin, Gulf of Riga and Gulf of Finland and. *M. arctia* was found only from the northern sub-basins, where could occur together with one of the two other species. Further studies have shown, Gulf of Finland is inhibited mostly by *M.arctia*.

The revision of polychaete samples from the Russian South-Eastern Baltic (2001-2016) let to assign all regional findings of mass alien Marenzelleria species, earlier identified as *M. neglecta*, to other species, *M. arctia*. The map of *M. arctia* biomass distribution in the Russian EEZ till 70-m isobath is produced. The pattern of *M. arctia* spatial distribution is characterized by a low abundance (mean annual biomass 1,21 g $m^{-2}$, max 8,0 g $m^{-2}$) and temporal consistency. Biomass maxima are located along the coasts, at the sandy-silt beds. In the Vistula Lagoon no one exemplar of *M. arctia* was recorded, only *M. neglecta* is present in the lagoon environment.

## P182 - Species diversity of polychaete worms from XIX to XXI centuries in the Vistula lagoon, Baltic sea

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Since the late 19th century to the end of 1980's in the Vistula Lagoon (former Frischen Haff) the only polychaete species, *Hediste diversicolor*, is dwelling. In the late 1980's a large-scale invasion of North-American spionid *Marenzelleria neglecta* (earlier identified as *M, viridis*) occurred, the worm has become the dominant component of zoobenthos in the whole lagoon. Since mid-1990's, we recorded three more polychaete species: Baltic species *Streblospio benedicti* and *Manayunkia aestuarina* and alien *Alkmaria romijni*. Recently, in 2013-2014 in the Lagoon another 2 species were unintentionally introduced: *Boccardiella ligerica* and *Laonome cf. calida*. Thus, nowadays 7 polychaete species are constant inhabitants of the lagoon: aboriginal *Hediste diversicolor*, *Streblospio benedicti*,*Manayunkia aestuarina*, and aliens *Marenzelleria neglecta* (1987), *Alkmaria romijni* (mid 90s of XX century), *Laonome cf. calida* (2014), *Boccardiella ligerica* (since 2013 in the Polish part of Lagoon, since 2016 in Russian). *H. diversicolor*, *S. benedicti*, *M. aestuarina* are distributed locally, in the most saline north-east lagoon areas, where average annual salinity is 4-6 PSU. *A. romijni*, *B. ligerica* and *L. cf. calida* are spread very locally, within very space-limited areas. *M. neglecta* is widespread over the lagoon.

The average numbers of *H. diversicolor* in the area it inhabits was 135 ind.$m^{-2}$, biomass 8.5 g $m^{-2}$, *M. neglecta* (in the north-eastern, Russian part) – 302 ind.$m^{-2}$ and 4.2 g $m^{-2}$, *M. aestuarina* – 516 ind.$m^{-2}$, *S. benedicti* – 113.7 ind.$m^{-2}$, *A. romijni* – 26 7 ind.$m^{-2}$, L. cf. calida – 186 ind.$m^{-2}$ and 0.13 g $m^{-2}$, *B. ligerica* – 520 ind.$m^{-2}$ and 0.27 g $m^{-2}$. The reasons of a gradual increase of polychaete species diversity in bottom fauna of Vistula Lagoon is discussed. We consider, main reasons are the changes of the set of ecological conditions, driven both by anthropogenic and natural forcing factors, and unintentional introduction through ballast water and sediments from ballast tanks of dredging ships.

## P183 - DNA BARCODING AND POPULATION GENETIC STRUCTURE ANALYSIS OF THE COMMON SHIPWORM TEREDO NAVALIS IN THE BALTIC SEA

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The common shipworm *Teredo navalis* is one of the most widespread marine wood-boring bivalves of the world and probably one of the most cost-incurring marine invertebrates. First reports on *T. navalis* for the Baltic Sea date back to the year 1835 followed by periodic mass occurrences during the last centuries. As recently as 1993 a stable, reproductive population in the south-western part has been known. Little is known so far whether *T. navalis* was absent between the mentioned mass occurrences or survived in cryptic populations. This leads to the question if the periodic mass occurrences are reflected in the current distribution and in the population structure of this species. The conceivable existence of a self-contained brackish water Baltic Sea population separated from a marine Atlantic Ocean population is a second concerning question.

Therefore, samples were collected from the North Sea and along the salinity gradient from the Skagerrak as the entrance area of the Baltic Sea to the eastern distribution border of this species at the west coast of the island Rügen. For a reliable molecular-taxonomic identification a specific COI (cytochrome c oxidase subunit 1) primer pair for *T. navalis* was developed. Using the COI barcoding approach for species identification, *T. navalis* was verified as the only teredinid species in the proper Baltic Sea. Subsequently, various population genetic indices including haplotype diversity, $F_{st}$ values and an AMOVA analysis were applied. To visualize the distribution of haplotypes at the different sampling sites a median-joining network was calculated. In addition, the past demographic structure of *T. navalis* was analysed, among others by calculating Tajima´s D and Fu´s F values.

The results showed a higher genetic diversity within the Baltic Sea than outside and no decrease along the salinity gradient. The 'star-like' haplotype network displayed no population substructures or differentiated demes. Finally, all computations and analyses could not reveal neither differentiated populations nor a separated Baltic Sea population. Together with the results from the calculated past demographic structure, it can be assumed that a sudden demographic expansion of this species took place without any signs of neither a bottleneck nor a founder effect for the Baltic Sea. The results support the assumption of a panmictic population in the Baltic Sea with unhindered migration of individuals as well as a high gene flow between the various sampling sites.

## P184 - Invasive round goby (Neogobius melanostomus) of South-Eastern Baltic: morpho-genetic features of populations and dispersal pathways

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The results of the morpho-genetic study of the invasive round goby (*Neogobius melanostomus*) from the South-Eastern Baltic Sea are given. Specimens from the Vistula Lagoon and Russian part of the Gulf of Gdansk were investigated. Eight meristic and 44 morphological (plastic) characters were measured for 67 round goby individuals. Specimens with lower numbers of vertebrae and branched rays in pelvic fin vs species diagnosis were revealed. Analysis of mitochondrial cytochrome c oxidase subunit I (COI) and cytochrome b (cyt b) gene fragments polymorphism were performed for 15 and 7 specimens respectively. Low level of the sequences' polymorphism was revealed. All specimens were the carriers of the same haplotype of the COI, widespread in round goby populations from the Black Sea basin. For cytochrome b sequences two haplotypes, differentiated by one nucleotide substitution (p-distance = 0.6%), were identified. Sequences COI and cyt b of the round goby from Kaliningrad region were closely related to haplotypes of specimens from the Black Sea basin.

Joint analysis of own, GenBank and literary data allows definitely to reject one of existing hypothesis of natural and vessel-mediated round goby spreading through river and canal water-ways of Europe. Basing on the molecular-genetic data we also rejected as probable vessel-mediated invasive rout of *N. melanostomus* to Baltic region from the Caspian Sea through the Volga River and the Volga-Baltic Waterway. We conclude the native area of round goby sub-populations from study area is western part of the Black Sea; the vector of invasion is connected with vessels (ballast water transport) and invasion rout to the Baltic Sea pass around Europe through the Marmara, Mediterranean and Atlantic Ocean.

## P185 - Do non-indigenous species monitoring methods optimization is possible? Example from the in the eastern Baltic Sea ports monitoring results

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Marine biological monitoring in Latvian waters is part of HELCOM on-going sampling program of zooplankton, phytoplankton and soft-bottom benthic invertebrates. It is clearly recognized that at present monitoring program does not cover all areas and organism groups where non-indigenous (NIS) species could be found. Following of national, regional and international conventions and legislations requirements, Latvia is started to develop a targeted monitoring program for all non-indigenous species including also marine organisms. First step was taken conducting dense baseline survey in three largest Latvian ports with goal to test applicability of different sampling methods in ports of Liepaja, Ventspils and Riga based on HELCOM-OSPAR Port Survey Protocol. Study gave a good overview of new species occurrence and NIS distribution in largest Latvian ports. Moreover, important conclusion was several proposals to modify and adapt separate sampling methods for eastern Baltic Sea port environment. For example, regarding fouling organisms the difference between species assemblages on plates at different depths was not significant in any studied Latvian port as the depth of Latvian ports is not big. Therefore it is recommended to decrease the number of plates for the monitoring of NIS species to economy the resources. Regarding mobile epifauna HELCOM-OSPAR protocol recommending only one sampling time in late summer/autumn, however our results showed that sampling in spring gives additional results to non-indigenous species list. During this study we compared obtained information on NIS occurrence from previous port surveys and routine biological monitoring program done in vicinity of large rivers. First conclusions show that in some monitored parameters, for example phytoplankton and zooplankton, optimization could be possible. The study presents and discussing biological results from routine monitoring in Latvian waters and port surveys. This work was supported by the State Research program „The value and dynamic of Latvia's ecosystems under changing climate – EVIDEnT" (2014 - 2017) and joint Lithuanian – Latvian - Taiwan cooperation program project "Development of the ships' ballast water management system to reduce biological invasions – BALMAN" (2015-2017).

## P186 - Non-indigenous species in the Baltic Sea: Fouling studies and new records in Latvian ports

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In recent years, several marine non-indigenous species (NIS) lists have been produced for many Baltic Sea countries but still little is known about the diversity and distribution of fouling NIS in Latvian waters. We conducted two-year (2014-2015) survey in the three largest ports of Latvia to assess NIS diversity on different hard substrate types, constituting the first fouling assemblage study for the port of Liepaja, Ventspils and Riga.

A survey of fouling organisms on different hard substrates was performed using settlement plates and scraping samples based on methodology as it is described in HELCOM - OSPAR protocol.

The study results showed that environmental conditions in all ports regarding physico-chemical parameters are similar. In these ports non-indigenous species accounted for 60-99% of the total benthic invertebrate biomass and we found eight non-indigenous (*Amphibalanus improvisus*, *Dreissena polymorpha*, *Gammarus tigrinus*, *Pontogammarus robustoides*, *Palaemon elegans*, *Chelicorophium curvispinum*, *Obesogammarus crassus*, *Sinelobus stanfordi*)and two cryptogenic species (*Mya arenaria*, *Cordylophora caspia*) of which *C. curvispinum*, *O. crassus*, *S. stanfordi* were detected for the first time in the Latvian estuary waters. At the moment invasive nature has been found in one of the non-indigenous species that was first found in the estuary waters in Latvia - freshwater shrimp *C. curvispinum*, because it is the dominant species that reduce native species richness.

Our study showed that non-indigenous species and the proportion of major Latvian ports are similar.

The study developed within the „The value and dynamic of Latvia's ecosystems under changing climate – EVIDEnT" (2014-2017) and joint Lithuanian – Latvian - Taiwan cooperation program project "Development of the ships' ballast water management system to reduce biological invasions –BALMAN" (2015-2017).

## P187 - Phytoplankton monitoring of non-indigenous species in the three main ports of Latvia

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Transport by ballast waters has been known as one of the largest vectors for non-indigenous aquatic species invasions, therefore ports are the main and initial areas of their distribution and development. As port areas are not included in national monitoring programs in Latvia, three biggest Latvian ports- Liepaja, Ventspils and Riga were survived to assess occurrence of non-indigenous species (NIS). Phytoplankton is one of the biological parameter recommended by HELCOM/OSPAR guidelines. Thereby sampling of phytoplankton were performed in spring and summer in all three ports during 2014 and 2015 to test the applicability of monitoring methods for collection and detection of phytoplankton NIS. Few modifications were made regarding phytoplankton methods. Results from our study indicate, that integrated sample of 0-5m water column would give more precise quantification for phytoplankton as well for chlorophyll a determination in the ports of Latvia than one pooled or separately analysed phytoplankton samples. Only one NIS – dinoflagellate *Prorocentrum cordatum* were detected in phytoplankton samples of ports Ventspils and Liepaja, while in Riga no invasive phytoplankton species were found. The highest biomass of *P. cordatum* reached 1050 mg $m^{-3}$ and composed even 84% from total phytoplankton biomass during autumn, year 2014 in port Liepaja. Future perspectives for phytoplankton monitoring in port areas were assessed based on comparison of phytoplankton data from port survey and phytoplankton results from annual National monitoring program.

This work was supported by National Research Program 2014-2017 "The value and dynamic of Latvia's ecosystems under changing climate" (acronym EVIDEnT) and Joint Lithuanian – Latvian - Taiwan cooperation program project 2015-2017 "Development of the ships' ballast water management system to reduce biological invasions" (acronym BALMAN).

## P188 - The seasonal structure of phytoplankton community in the Gulf of Riga in 2016.

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Annual dynamics of phytoplankton community was investigated in transitional waters of the Gulf of Riga within the high frequency sampling (14 times in March - November) and linked to environmental factors in year 2016. After mild winter without ice appearance and increased precipitation in February spring bloom started already at the second part of March dominated by diatoms - mostly Thalassiosira baltica, however no expressed peak of diatoms was detected. The observed maximum of spring biomass was 9265 mg/$m^3$, i.e., twice higher than long-term (1993-2015) maximal value. In the decline phase of bloom dinoflagellate Peridiniella catenata and mixotrophic ciliate Mesodinium rubrum took over the diatoms. The concentrations of inorganic nutrients indicated phosphorus limitation during the whole spring bloom period. The summer succession varied greatly as different taxonomic groups were present, favoured by optimal DIN:DIP ratio from river runoff waters (rainfall in July and August was 50 – 70% higher than normal) and without substantial bloom of cyanobacteria. During autumn after the bottom-up mixing with increase of available inorganic nutrients, diatom T. baltica was dominating again. In this study particular attention was paid to the development and cell size distribution of ciliate M. rubrum. The highest biomass of M. rubrum was recorded in spring composing up to 63% of total phytoplankton biomass and with dominance of big size specimens (›27 µm). During summer period second peak of ciliates was detected in August, however having significantly smaller body size then.

Apparently, in 2016 phytoplankton succession during spring and particularly in summer was controlled by freshwater inflow due to increased precipitation.

## P189 - Microphytobenthic flora in a shallow lagoon of the Southern Baltic Sea

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The Darss-Zingst Bodden Chain is a shallow lagoon of the Southern Baltic Sea in Germany. This lagoon is characterised by a high phytoplankton biomass, which form a huge photosynthetic benthic boundary layer on the top of the sediment. Therefore, a true microphytobenthos community was not expected. However, some typical large benthic diatoms occurred in net (>55 µm) plankton samples. Therefore, the microphytobenthic flora, especially benthic diatoms were collected and studied after cleaning with Hydrogen peroxide and washing the top sediment layer by using light and electron microscopes (SEM and TEM). This was done also with epiphytobenthos from important submersed macrophytes (Charophyta).

A total of 65 species in 33 genera were recorded from all samples (sediments and algae). Abundant diatomspecies in sediment samples were: *Pseudostaurosira brevistriata* (Grunow) D.M.Williams & Round, *Pseudostaurosiropsis geocollegarum* (Witkowski) E.A.Morales and *Staurosira construens* var. venter (Ehrenberg) P.B.Hamilton. *P. brevistriata* and *S. construens* var. venter are cosmopolitan species. On the other hand, P. geocollegarum was only reported as an abundant species in sediments from coastal shallows of Puck Bay in Poland (Witkowski et al. 1995). The common morphological features of these species are araphid and linking spines, which join frustules together in a ribbon-like colony. Compared to the attached diatoms on *Chara baltica*, the benthic diatoms occurring in sediments were relative small and it was difficult to find out their specific features by using light microscope. Therefore, particular attention was paid to small diatoms which have been probably overlooked before.

To reveal difference of species composition and dominance of diatom taxa, more samples will be seasonally collected from various sites at different salinities along the lagoon and investigated further.

## P190 - Fish biodiversity monitoring in the German part of the Pomeranian Bay

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A monitoring of the demersal fish assemblage has been conducted in the German part of the Pomeranian Bay every September between 2003 and 2015. This investigation is a cooperation of the University of Rostock and the Thuenen Institute of Baltic Sea Fisheries. Samples were taken using two types of benthic trawls combined with a special small beam trawl. The most important fishes hydrographic parameters were measured at every monitoring station. Abundances, biomasses and length distributions were estimated for all species caught. For the most abundant species random samples were taken in order to study their feeding ecology. Between 25 and 30 different fish species were recorded every year. The species composition is a mixture of marine, diadromous and freshwater fish. The most prominent change observed was the increasing appearance of the non native Round Goby (*Neogobius melanostomus*). Results will be presented especially concerning the species diversity within the monitoring area and study period. The temporal development of the fish assemblage might reflect the environmental state in the monitoring area.

## P191 - Digital Imagery – a new tool for the German Seabirds at Sea monitoring program

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Seabirds are important elements of the marine ecosystem. More and more frequently, they face restrictions in their natural habitat due to human activities. To ensure an effective protection of these important top predators, it is essential to record population densities as well as spatial distribution patterns. The abundance and distribution of seabirds in German waters has been recorded within the German "Seabirds at Sea" (SAS) monitoring program since 1990 (North Sea) and 2000 (Baltic Sea). The SAS monitoring is performed by means of internationally standardised observer-based line transect counts with ship or aircraft. Since 2004 the program is conducted within the framework of large-scale monitoring initiatives financed by the provincial and federal governments. All SAS data recorded during the past decades were collected in a database and have since become a comprehensive dataset, containing invaluable seabird abundance and distribution data.

In recent years new aircraft-based digital approaches are increasingly used to assess seabird occurrence. This development was driven by the expansion of the offshore wind energy and the flight ban on observer-based surveys within wind farm areas due to safety reasons.

We give an introduction to the observer-based ship and aircraft SAS methods, as well as an inside view on the digital approaches. Furthermore, we compare the advantages and disadvantages of the different survey methods. With regard to the consistency of long-term datasets, we highlight the necessity of parallel application of the different methods for the assessment of trends in seabird population numbers and distribution patterns.

## P192 - Reconstruction of long-term variability of the Baltic Sea ecosystem characteristics using SPBEM model

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The aim of this study is the reconstruction of long-term variability of ecosystem components in the Baltic Sea using St.-Petersburg Baltic Sea Eutrophication Model (SPBEM) for A1B climate change scenario, obtained from the data of numerical experiments on global climate ECHAM5/MPI-OM model. The simulations were carried out for the period of 1961-2010 aa. Analysis of simulations allowed to identify the main trends in inter-annual and seasonal variability of water temperature in the photic layer, salinity, concentrations of nutrients, biomass of three dominant algae species and primary production, as well as inter-annual variability of hypoxic areas for different Baltic Sea sub-basins. It is shown that the variability of biological characteristics for the considered period is largely caused by the climate change, associated with increase of photic layer temperature. Model results do not contradict observational data. The consistency between the characteristics correctly reflects the reproducible internal connections and interaction in marine ecosystem. The basic features of long-term variability of ecosystem components will be discussed.

## P193 - Effect of nutrient load reduction in the North and the Baltic Seas on Skagerrak-Kattegat area ecosystem parameters.

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The ecosystem model NEMO-Nordic-SCOBI was applied to the Skagerrak – Kattegat area to investigate the variability of ecosystem indicators. Two sensitivity runs were performed to investigate possible effects of the Baltic Sea Action Plan (BSAP) and a river loads reduction scenario on the Skagerrak - Kattegat area. Modeled sea surface salinity, temperature and dissolved inorganic phosphate are in good agreement with observations. At the same time, the model has a bias for dissolved inorganic nitrogen and dissolved silicate during the winter season in certain areas of the investigated region. Overall, the model results are of sufficient quality to warrant confidence in the conclusions of this study. Results from the two sensitivity studies show a decrease of sea surface nutrient concentrations during winter in both regions. In the Skagerrak area the decrease is due to reduction in river nutrient loads in the North Sea. In the Kattegat area there is a decrease of dissolved phosphate due to the implementation of BSAP. At the same time, in both scenarios, no significant changes were observed for near bottom oxygen or surface layer Chl-a.

## P194 - Model estimation of the nutrient emission and retention for the Pregolya River basin (South-Eastern Baltic) according to climate change and socio-economic development scenarios

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The Pregolya River being the transboundary water course is the largest river that flows into the Vistula Lagoon of the Baltic Sea bringing nutrients from Polish and Russian sides of the catchment. The screening/monitoring (2014-2016) in all major streams of the Pregolya River within the Kaliningrad Oblast (12 points) allow to estimate the total nutrient emission at the point of the bifurcation of the river into two arms amounted to 2334 tons of total nitrogen and 280 tons of total phosphorus per 2015.

Water discharge at the outlet sections were assessed using 3 HYPE model installations for (a) the catchment area of the Pregolya River upstream the division into the arms, (b) the catchment area of the downstream Pregolya flowing to the Vistula Lagoon, the catchment area of the Deyma arm flowing to the Curonian Lagoon. Nutrient emission and retention was estimated using FyrisNP model calibrated by results of screening monitoring.

Using climate scenarios for atmospheric forcing (2041-2060, projections CanESM2_RCA4, CM5A-MR_WRF, CNRM-CM5_RCA4, MPI-ESM-LR_CCLM, increase in temperature and precipitation, but with different intensity), the calibrated HYPE model for the Pregolya River catchment showed that the increase in precipitation does not always lead to an increase in the river runoff. This nonlinearity is associated primarily with an increase in temperature and therefore, in evaporation. Moreover, simulations showed an increase in the river runoff only in two (out of four) scenario solutions. This suggests that environmental conditions in the Pregolya River basin are very sensitive to emerging combinations in the couple of "temperature-precipitation", so the projection for the river water runoff is highly dependent on uncertainty in projection of atmospheric parameters.

Socio-economic scenarios included the scenario Business As Usual (preservation of the 5-years trends (2010-2014) in the development of agriculture and population), Documented Future scenario (official plans of the socio-economic development issued by regional Polish and Russian authorities) and Good Agricultural Practice scenario (changes only for the Russian part of the catchment assuming that good practice already implemented in the Polish part). Results showed that variations in nutrient emission due to climate changes are comparable to those caused by socio-economic development using best agricultural practice recommendations and nowadays HELCCOM limits in fertilization.

## P195 - Nemunas River watershed modeling for the assessment of the export of land based nutrients to the Curonian Lagoon

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Nemunas River is a major contributory that discharges into the largest European coastal lagoon – Curonian Lagoon. It is not only important for changing and governing its mass balance, but it is also bringing nutrients and sediments into the lagoon. Nemunas River basin is shared by Belorussia, Lithuania, Poland and the Russian Federation Kaliningrad oblast. Agriculture has a significant impact on the status of water bodies in the Nemunas River basin. Chemicals that enter the river from agriculture and fish ponds are a major source of pollution. It is important to be able to model nutrient and other biogeochemically significant dissolved substance contributions that are altering and influencing the ecosystem in view of a better understanding of the dynamics of the Nemunas River and the Curonian lagoon. SWAT (Soil and Water Assessment Tool) was used for hydrological modelling of Nemunas River as it has gained international acceptance as a robust interdisciplinary watershed modelling tool. The result of this study is a fully functioning, calibrated and validated hydrological model with sediment and nutrient dynamics of the Nemunas River basin, which was used to explore the effects of climate change and water management scenarios, and assess the impact of those scenarios in terms of land based nutrient export to the Curonian Lagoon. Future studies could involve coupling this model with ecological models for a better understanding of the dynamics in the study area and other relevant regions.

## P196 - THE LOICZ BUDGET APPROACH REVEALS ALTERNATING NUTRIENT SINK-SOURCE ROLE OF THE HYPEREUTROPHIC CURONIAN LAGOON

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The specific role of shallow and large lagoons as coastal filters or biogeochemical reactors, and their contribution to mitigating eutrophication remains frequently questioned. Since lagoons are highly heterogeneous environments and receive seasonally variable loads of nutrients and organic matter, their whole ecosystem metabolism can shift temporally and/or spatially. This study aims to identify the role of eutrophic lagoon in modulating nitrogen (N), phosphorus (P) and silica (Si) transport along the terrestrial-sea continuum. The specific questions addressed are: 1) how N, P and Si net budgets vary interannually; 2) how nutrient budgets vary between two hydrologically different areas in the lagoon; 3) whether the estuary acts as a nutrient sink or source. To answer these questions, we produced black box budgets of N, P and Si for the Curonian Lagoon (Lithuania/Russia) for 2013-2015, using the LOICZ (Land-Ocean Interaction in the Coastal Zone) budget methodology. The lagoon was divided into two boxes representing its northern and southern sections that differ in water residence time and sediment composition. This approach allowed being more precise in evaluating synthetic ecosystem functions as net ecosystem metabolism (NEM) and net $N_2$ fluxes (N-fixation- denitrification). The first indicates if the system is a net producer or consumer of organic carbon while the second indicates which process is dominating between N-fixation and denitrification. The obtained results show that filter or bioreactor functions varied among sites and years without clear trend. For DIN the sink/source role changed between sites and between different years. For DIP and DSi the lagoon generally acted as a net sink. The NEM as an estimation of difference between system production and respiration in the Curonian Lagoon indicated that the lagoon was mainly autotrophic because of high primary production rates. In the study period, the two areas of the lagoon had opposite net $N_2$ fluxes on annual basis. The smaller transitional area was a relevant source of N via N-fixation while in the larger confined site denitrification was dominant and the $N_2$ budget was negative. Results from this study should stimulate further research on factors regulating nutrient retention or release in eutrophic estuaries, including climate anomalies, watershed features, the ecological stoichiometry and the occurrence of algal blooms. We believe that our results may stimulate similar research in other SE Baltic Sea lagoons.

## P197 - Curonian lagoon fish stocks model: ECOPATH/ECOSIM approach

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The Curonian lagoon is the largest coastal lagoon in Europe providing more than 95% of inland commercial fish landings in Lithuania. Decrease in commercially important fish stocks and shift in fish community have proven that traditional assessment and management of fish stocks is outdated and incapable to assess the impact to whole ecosystem, therefore application of ecosystem based fishery management models is necessary. Measure and predict the response of fish stocks to exploitation it is necessary to understand how the direct and indirect effects of fishing interact. We used an ECOPATH with ECOSIM approach to describe the relationship between the main species and overall fishing mortality and to try to understand how fishery affects fish stocks communities and entire ecosystem. ECOPATH model includes key and most important fish species in the Curonian lagoon: six fish species, piscivorous birds, bivalves, macrozoobenthos, phytoplankton, zooplankton and detritus. Because fishing and predation are size-selective processes, we use multi-stanza approach for commercial fish species in the lagoon, splitting each fish species to three different age groups: juveniles, pre-commercial and commercial size. The structure of the model is discussed and mixed trophic impact analysis was undertaken to determine the direct and indirect effects of biomass changes within and between groups in the system, due to effects of fishery.

## P198 - MODELLING THE IMPACT OF A MUSSEL FARM ON THE WATER QUALITY

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The modular infrastructure MOSSCO (Modular System for Shelves and Coasts) was enhanced by a mussel farming module that allows the scenario-dependent simulation of spatially explicit water quality parameters for a given mussel density and farm location. The component computes the loss of phytoplankton due to filtration, as well as the release of dissolved inorganic nutrients (ammonium & phosphate), fast-sinking detritus (both depending on the phytoplankton uptake) and the consumption of oxygen.

Combining the component with a 3d-ecosystem model consisting of ERGOM and GETM allowed estimating the impact on the water quality, e.g. the change of secchi depth or bottom oxygen concentration. It was applied to different mussel farm scenarios in the western part of Oder Lagoon, using the specific filtration and nutrient release rates of *Dreissena polymorpha*, known from previous field experiments.

The poster will focus on (i) the constituents of the mussel farm component and; (ii) its application to different scenarios in the western part of Oder Lagoon.

## P200 - SmartSea - The Gulf of Bothnia as resource for Blue Growth

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Blue Growth is a long term strategy of the European Union (EU) to enhance the sustainable growth of the maritime sector. Our surrounding seas have been drivers for the European economy for a long time, and they still have great potential for further exploiting of natural resources and economic growth. Especially if the growth can be achieved in an environmentally sustainable way, benefits are obvious. It has been estimated that improvement of the state of the Baltic Sea would until 2030 create 900 000 jobs in the whole Baltic Sea area, mainly in Blue Tech, tourism, real estate and building businesses (Dahlgren et al. 2015).

However, coastal seas already experience pressures like off-shore construction, shipping, pollution, eutrophication, over-fishing, and climate change. In order to obtain sustainable Blue Growth, it is necessary to localize and assess the current maritime activities, estimate their growth potential, and investigate their present and future effects on each other and on the marine environment.

The pursose of the SmartSea project is to support the growth of commercial marine activities in the Gulf of Bothnia (GoB) region, in the northern Baltic Sea. The GoB is an essential resource in terms of fish farming and wind power, for example, and it is also possible to make use of the geological resources of the GoB. Moreover, the rapid growth of the commercial marine activities and the consequences of the climate change may lead to conflicts between the different activities and harm the marine ecosystem of the GoB. The project aims to identify these risks and find solutions for the sustainable use of the sea. The project has already produced new detailed information e.g. on seabed structures and sediment dynamics in the GoB. The end products of the SmartSea project will include e.g. MSP Toolbox used in maritime spatial planning, spatial estimation of the effects of climate change to GoB region, and guidelines for the sustainable use of marine mineral resources and seafloor deposits.

SmartSea project is funded by the Strategic Research Council of Academy of Finland, grant No: 292 985. The project will last for 2015-2020 and its funding totals nearly 8 million euros. The project partners are: the Finnish Meteorological Institute (coordinator), the Finnish Environment Institute, Natural Resources Institute Finland, GTK, VTT Technical Research Centre of Finland, the Universities of Helsinki and Turku, and the Swedish Meteorological and Hydrological Institute.

## P201 - Transboundary transitional waters of the Baltic Sea: Environmental assets or liabilities?

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The Article 2(6) of the Water Framework Directive (WFD) defines "transitional waters" as "bodies of surface water in the vicinity of river mouths which are partially saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows". According to WFD CIS Guidance Document No. 5 (p. 20): "If salinity measurements exist, the outer boundary should be drawn where the salinity of the transitional water is usually substantially lower than the salinity of the adjacent coastal water." Hence, the availability of a strong fresh to marine water gradient is the key feature determining an aquatic area as transitional one.

This simple criterion, however, causes some confusion regarding whether or not a water body should be designated as transitional. For instance, due to a strong salinity gradient caused by freshwater flows, the whole eastern part of the Gulf of Finland could be classified as transitional waters. Yet, designating of a vast marine area as transitional waters would cause needless overlapping of the WFD with the Maritime Spatial Planning Framework Directive. Naturally, neither Finland, nor Estonia have designated their parts of the Gulf of Finland as transitional waters in the WFD terms. Some of the Baltic transboundary aquatic areas are divided by their status in different countries. For instance, Poland has designated its part of Szczecin Lagoon as transitional waters, whereas the German part of the lagoon is designated as a coastal water body.

Differing management policies in the countries sharing the same aquatic area, could be seen as a liability leading to resource depletion, decline in water quality, and ecosystem degradation. Yet, if properly addressed, the transboundariness of transitional waters could be seen as an asset facilitating international collaboration. For example, the trilateral cooperation between Denmark, Germany, and the Netherlands in the management of the Wadden Sea is instrumental in promoting environmental cooperation among the North Sea countries.

We have scrutinized all cross-border coastal areas of the Baltic Sea in order to elicit transboundary transitional waters, and to build their database. The results of our survey show that there are nine transitional water bodies along the Baltic Sea coast shared by two or more countries. In the presentation, we present their typology and highlight their main physiographic, environmental, and management features.

## P202 - Application of GIS for aesthetic valuation of coastal habitat ecotones: a case study from the Curonian Spit, Lithuania

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The Curonian Spit is the largest barrier spit with the longest and highest shifting coastal dunes along the Baltic Sea fringe. For choosing an optimal dune management model, it is essential to evaluate their aesthetic appeal for tourists, among other aspects. Due to the climate change, the shifting dunes of the Curonian Spit are rapidly overgrowing with brushwood and forest, and the acreage of dune/brushwood/forest ecotones, whose aesthetic valuation is complicated, is quickly expanding.

In order to assess the aesthetic appeal of the most common dune and forest habitats and their ecotones we have applied a paired comparison method by presenting pairs of photos to a representative group of randomly selected visitors (n=990). These photos represented the combinations of nearview habitats and their backgrounds (eg. White dunes with a Mugo pine plantation in the background, mature Scots pine forest with Grey dunes in the background, etc.). After ranking all present habitat combinations by their aesthetic appeal, a raster GIS layer has been created where a ranking-based aesthetic appeal value has been assigned to each plot, i.e. to a pixel with the resolution of 5x5 m, depending on the habitat type.

In the second stage of the analysis, a total aesthetic value (Z) was calculated for each plot by integrating the aesthetic values of the surrounding eight plots, thus simulating the nearview visual experience of visitors. In the case of the ecotones between two habitats, the total aesthetic value of each plot is calculated as a function of the integrated aesthetic values of the nearview and background habitats available from the results of the paired comparison.

Taking into account information on the habitats in the adjacent plots and the ones next to them, the calculation algorithm considers the width of the nearview habitats to the background, which depends on their visual clearness: from 0 m (no background) in the case of a young Norway spruce stand or a Mugo pine plantation to 150 m (30 adjacent pixels) in the case of open White dunes with a forest in the background.

The results of the calculation have been verified by comparing the total aesthetic values of various plots (Z) established using the GIS with those assessed on the spot in the same locations by randomly selected respondents (n=300). The verification confirmed the validity of the suggested method for aesthetic valuation of coastal habitat ecotones.

## P203 - Construction of "iconic buildings" on reclaimed coastal areas: can it be sustainable?

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When in 2011 "Gazprom" acquired a plot of land on the north bank of the NevaBay of the Gulf of Finland with a total area of 140,000 m$^2$ for construction of «LakhtaCenter» business-centre, it was just a large stock of sand. The entire site is located within the reclaimed area, artificially formed in 1960-1970. Thus, the construction of the LakhtaCenter does not involve the destruction of any historical landscapes or ecologically valuable coastal biological communities. This was also confirmed by UNESCO World Heritage Committee when in 2012 it found no negative impact on the historical panorama of Saint-Petersburg.

The Lakhta Center complex will consist of an 86-storey «Tower» of the office center 500 m high, with 3 underground floors, an atrium and a stylobate part. The total area is 385,000 m$^2$. The «Tower» is expected to become the tallest building in Russia and in Europe making it the new symbol of Saint Petersburg: its new «Iconic building».

The analysis of the coastal zone state together with geophysical, geological and hydrobiological studies of the underwater area of the north coast of the NevaBay showed that the area of construction is the most stable biotope in the region and the project has no additional geoecological risks to the coastal zone. In fact, the natural intensive growth of cane *Phragmites australis* to the west of the considered coastal zone will help stabilize the beach making this project favorable for shoreline stabilization and formation of balanced coastal ecosystems.

At the same time, the most appropriate solution for coast protection on the territory of Lakhta Center is considered the creation of artificial beaches along with facilities for beach retention. The use of vertical seawalls as a sole method of coast protection should be limited, as they can cause rapid and irreversible erosion of beaches due to wave reflection. Creation of a promenade with permeable strengthening of a slope type at the bottom is seen as the most reasonable on the considered section of the coast.

Construction of the Lakhta Center «Iconic building» and the associated infrastructure on the artificially formed territory should represent a new idea in urban planning in the coastal zone.

## P204 - Effect of the construction of the new Bronka port in the Neva Bay on the diversity of waterbird community

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The avant-port «Bronka» is constructed in the southwestern part of the Neva Bay near the Flood Protection Barrier of St. Petersburg, in the area of higher aquatic vegetation "thickets", important for water bird nesting and relief on Spring and Autumn migrations. The avant-port includes the multipurpose sea transhipment complex, the operational water area and approach channel. Total cargo turnover of the Bronka port will make 1.9 million TEU and 260 thousand vehicles a year. Construction of the port started in January, 2011. At this time, 48 species of water birds, 665 nesting pairs and 12,537 migrants were registered. In 2015, the I$^{st}$ stage of construction was completed. The hydrotechnical and dredging works have been annually increasing the content of suspended matter in water. To date, the total amount of 384.6 million RUB of the environmental payments have been quarterly made to the Federal Budget in order to compensate the negative environmental impact due to water pollution by suspended matter. Also, the new Nature Protected Area (NPA) «Southern Coast of the Neva Bay» was organized as a compensation action at the territory adjacent to the Avant-port. Field ornithological studies showed that species diversity and number of nesting water birds at the territory of NPA «Southern Coast of the Neva Bay» did not change dramatically. 848 nesting pairs and 11 700 migrants were registered. The territory of wetland, adjacent to the construction area, continues to play an important role as a biotope for nesting of number of water birds, and for short stay of migrating species in spring and autumn. The hydrotechnical and dredging works did not have a significant negative effect on transit migrants. Thus, the environmental impact of construction of the Bronka port corresponds to the project predictions, is limited in space (as local) and time (as short). In order to make the assessment of the possibility of avant-ports' perspective development in the Eastern part of the Gulf of Finland, a complex study of the higher aquatic vegetation «thickets» are suggested. The results of the programme implementation will make it possible to predict with confidence the scenarios of further actions during the development of port complexes in the Neva Bay and Eastern Gulf of Finland.

## P205 - Local coastal governance developments in Latvia: science-policy integration governance for rural municipalities

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Coastal systems are not only complex systems, but are to be treated as social-ecological systems (SES), being based on complementary studies and further on policy-planning-management of interconnected and balanced triple-bottom-line dimensions of natural, socio-cultural, economic and also mandatory governance resources. Those resources and their developments of Latvia's 500 km long coastline are neither satisfactory studied nor adequate governance applied, particularly since dominantly most of mentioned coastline territories belong to small rural municipalities characterized by very low regular population density, low administration capacities and, in turn, very long coastline with increasing pressure on coastal environment within limited national supervision context.

The EU BONUS BaltCoast project partner countries apply the System Approach Framework (SAF). The Latvia case study area is Salacgriva rural municipality. The known governance approaches and scenarios (CGS) studied are as follows: business-as-usual (BAU as minimum of requirements defined by legislation); strengthening the top-down approach and related instruments; bottom-up approach based on stakeholders' nodes/networks innovations/initiatives; collaborative governance approaches and scenario. Looks like that no one of the traditionally known CGS can be realized in a full scale in the current local municipal conditions even in the municipality known as pioneering one in many governance activities and instruments applied. Eventually thus the Collaborative CGS shall be further studied, applied and tested, complementary incorporating useful instruments of other discussed CGS.

Elaborated and discussed Collaborative CGS proposals comprise also the following set and sequence of coastal governance implementation tools as current national ICM innovations: coastal governance thematic; municipal coastal collaborative monitoring programme, involving wide part of citizens report, based on cross-disciplinary science-policy studies with extensive stakeholders participation science approaches; municipal coastal sustainability indicator system with bottom-up part; coastal thematic planning spatial plan; set of complementary governance instruments. All these tools to be ICM disciplinary developed shall be integrated with and within mandatory municipal development planning documents.

## P206 - Potential conflicts between conservation of underwater maritime heritage and future developments of marine spatial use in Russian Economic zone in South-Eastern Baltic Sea

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The development of the marine resources use may influence the ecosystem, social and economic aspects. Russian Economic zone in South-Eastern Baltic (Russian EEZ) is affected by the multiple types of the sea usage. The most spatially significant are fishery, military usage, communication and navigation, and mineral resources exploration. Anthropogenic effect of in these activities was estimated for marine ecosystem only in Russian EEZ. Areas of archeological potential were determined during reconstruction of ancient shore levels and build-ups formed 10,500-6,500 years ago. Analysis of areas convenient for settlement, fishing, wind protection (paleo-estuary and adjoining coasts; areas of gulfs, which deeply penetrate into the land; crenellated shoreline areas, small islands with accumulative coasts, situated not far from the main land; areas of spits) allowed to range the regions as per their archeological potential. Determination of underwater areas of archeological potential allowed to specify zones where further extension of sea resources development may result in loss of objects of cultural heritage. Most of these zones are situated north-eastward the Sambian Peninsula and along the Vistula Spit within 40 m isobath. Only few types of sea resources usage significantly affect the objects of cultural heritage. First of all they are the ones that actively deal with the sea bottom - mining, potential wind farms, dumping, anchorage, oil perspective area. Combining areas with archeological potential and locations of the present and future sea resources development revealed conflict zones between these usages. Conflict of interests between economic development and conservation of maritime cultural heritage can be negotiated by inclusion of essential measures on preliminary exploration of the areas with high archeological potential before the start of the new marine infrastructure, mining projects and other economic developments.

## P207 - Population connectivity and the importance of the network of marine protected areas for conservation of marine habitat forming species

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Marine protected areas (MPAs, in EU Natura 2000 network) are essential elements for long term viability and protection of key habitats and species. The effectiveness of MPAs depends on population connectivity patterns between protected and non-protected areas. This study assessed the population connectivity across a network of protected and non-protected areas based on population genetics of blue mussel (*Mytilus* sp.). Microsatellite DNA markers were used to measure genetic diversity and describe genetic structure of Lithuanian blue mussel populations as well as estimate contemporary gene flow among six locations within and outside Lithuanian MPAs.

The results of the genetic diversity analyses indicated medium to high levels of polymorphism and no population size bottlenecks were detected. The analysis of population structure lets us identify four genetically distinguishable groups, however clustering of populations did not coincide with geographical location of populations. Analysis of population structure and gene flow between populations led to preliminary conclusions that Lithuanian blue mussel populations are genetically structured and contain two source populations – within southern and outside northern offshore MPAs. There is also one highly differentiated and isolated population within the coastal MPA.

The estimation of population structure and analysis of gene flow revealed that the patterns of genetic connectivity reflect in the genetic structure of populations. Moreover, intensive but unidirectional gene flow (from offshore to coastal populations) could assist in recovery of coastal populations after major decline of blue mussels since 2010. Thus, connectivity analysis of MPAs and nearby habitats within the Lithuanian Baltic Sea area revealed the importance of MPAs on surrounding coastal ecosystems, their vulnerability to NIS, resilience and potential role in restoration of the native key-habitats.

## P209 - Leibniz ScienceCampus Phosphorus Research Rostock: Towards sustainable phosphorus management

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Phosphorus (P) is an essential plant fertilizer, but - when present in excess - it is also a disruptive element in freshwater and marine water bodies such as the Baltic Sea. Foreseeable limitations in mineral P resources supply and the need for closing nutrient cycles strengthen the demand for sustainable and more efficient use, recycling and recovery of P.

Phosphorus enters inland waters, estuaries, and the sea via various routes. In all ecosystems, P undergoes constant transformation and thereby intervenes in numerous biogeochemical processes. A final destination of this valuable chemical element is the anoxic deep Baltic basins and sediments. P acts from cellular levels to impact of entire ecosystems, e.g. large-scale cyanobacteria blooms in the Central Baltic Sea during summer. Accordingly, P studies in the Leibniz ScienceCampus Phosphorus Research Rostock range from microscale measurements to ecosystem modeling. The aim of environmental P investigations is to better understand P fluxes and cycles and to establish effective protection and rehabilitation measures.

The Leibniz ScienceCampus Phosphorus Research Rostock ('P-Campus') brings together the expertise of around 90 scientists from the University of Rostock and 5 Leibniz Institutes, thus creating the basis for a comprehensive exploration of P, its numerous chemical compounds and effects. Its aims are to promote long-term research cooperation in order to establish the scientific foundations for various P-related processes in the terrestrial, agricultural, limnic and marine environment; to search for new approaches to sustainable P management; and to develop advanced technologies for the use of P. The P-Campus encourages interdisciplinarity in its topics, projects, and methods.

Research foci of the P-Campus are P cycles and fluxes in the environment, sufficiency and efficiency of P use and P recycling, and synthesis of and with P containing compounds. Additionally, the development of advanced analytical methods in P research as a cross-sectional task serves and stimulates the above-mentioned research clusters.

Scientists working in the framework of the P-Campus consider a broad scale of interactions between human activities and the status of the Baltic Sea ecosystem. We strive to ensure that the results achieve the policy beyond the boundaries of science to develop the necessary legislative measures and to support their implementation at national and international levels.

## P210 - Phosphorus from source to sea – Integrated phosphorus and water resources management for sustainable water protection (PhosWaM)

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Despite depletion of phosphorus (P) rock reserves, undesired amounts of P are still 'wasted' causing environmental problems, especially in aquatic systems. The goal of the researchers and practice partners involved in the project PhosWaM is to enlarge the knowledge base with regard to the sources, transport routes, and transformation processes of P compounds in waterways. Process and modelling studies are supplemented by studies of measures such as controlled drainage, filter systems for small sewage treatment plants, and the opening of piped watercourses. Proposals are to be drawn up for optimising the monitoring plans and action programmes regarding P to fulfil the requirements of the EC Water Framework Directive (WFD), the EC Marine Strategy Framework Directive (MSFD), and the Baltic Action Plan (BSAP). The focus of the investigations is on the Warnow River Basin, the brackish Unterwarnow estuary, and the adjacent coastal waters of the Baltic Sea. At 3,324 km², the Warnow and Unterwarnow are the second largest German catchment area that drains into the Baltic Sea. The region is mainly agricultural, and its hydrologic balance has been strongly altered by anthropogenic influences. The entire flow path from the source to the sea is considered, because management decisions in the river basins affect the P-loads into the sea.

Project aims are:
· Quantify emission sources such as drainage-, groundwater- and erosion paths as well as small sewage treatment plants with the help of modelling
- Model the impact of measures and altered hydrological conditions on phosphorus losses
· For various arable crops, assess the risk of agricultural phosphorus losses into water bodies by means of field trials and by using a phosphorus index
· Examine how various phosphorus fractions contribute to water pollution and how they change along the course of a waterway
· Develop and test measures to reduce phosphorus inputs and/or control phosphorus retention
· Develop an overall concept for improving phosphorus retention
· Develop recommendations for regional and national planning authorities

## P211 - Phosphorous removal potential of small Waste Water Treatment Plants in the sub-catchments of the Baltic Sea

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The Phosphorous load from catchments is a significant driver of marine ecosystem eutrophication and has to be mitigated by P source control in the catchment. Independent from sources portioning, point sources can be more easily targeted for control and management than diffuse impacted by complex watershed matter flows. Various MFA studies identified rural waste water treatment plants ([lt] $10^4$ PE) as significant P emission source in the German sub-catchments of the Baltic Sea. Compared to larger WWTP, enhanced P removal lead to more elevated per capita costs here and can legally only be enforced via an ambient water based perspective according to WFD. This study proposes a concept to efficiently reduce P emissions from WWTP by combining enhanced P removal with low cost measures and prioritizing WWTP for more strict effluent standards by applying a complementary set of criteria.

As case study, the Warnow catchment in Mecklenburg-Vorpommern (Germany) is chosen where small treatment plants without P-discharge limits annually emit 12 tons of P (76% of total WWTP emissions in the catchment). For these facilities, two modification options are proposed: reducing sludge retention time, combined with introducing Bio-P for activated sludge systems, and/or chemical precipitation for the remaining plants.

Prioritization of plants is based on four evaluation criteria. In the K1 the complete elimination of WWTP emissions by means of chemical precipitation is considered against riverine load under assumption of ambient water quality. The potential of biological P-removal enhancement assessed with a technological mass-flow model is included in the criterion K2, counting possible P-reduction load in the relevant water body by solely operational modification of treatment technology. As third criterion K3 the capita costs for complete P elimination for all (biologically and/or chemically) are calculated. The K4 criterion describes the impact of P-elimination on receiving water quality. The modeled riverine P-concentration after technology modification is compared to the recommended values for the “good” ecological status of the river. Higher concentrations ratio reveals higher ecological relevance. The final score of each WWTP is calculated by the sum of direct ranking values of each criterion. This way, rural plants with highest potential to reduce riverine concentration and P-load to the Baltic Sea can be transparently identified.

## P212 - How much phosphorus is in the sediments of the Darß-Zingst Bodden Chain (DZBC)? - meaning of physical sediment properties

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The determination of total phosphorus (TP) pools in sediments is a common tool to estimate the eutrophication potential of sediments, which may release phosphorus to the overlying water column by remineralisation and desorption processes. Based on weight specific TP contents it was a longtime assumption that phosphorus accumulates in fine grained organic rich sediments in the deeper areas of the Darß-Zingst Bodden Chain (DZBC) as well as in the Baltic.

In the framework of the joint research program BACOSA the sediments in the DZBC from two different water depths (0.5 and 2 m), representing the two main sediment types, were analysed. At the 0.5 m station, sandy sediments with less organic matter content (LOI < 5 %) occur. Whereas at the 2 m station the sediments are muddy with high organic matter content (LOI > 5 %). The TP contents related to the sediment dry weight differ markedly with higher TP contents of 10.9 µmol $g^{-1}$ DW at the 2 m station in comparison to 3.2 µmol $g^{-1}$ DW at the 0.5 m station. The relation to sediment dry mass does not consider the water content in the sediment. This led to the assumption that organic matter and TP contents are correlated. But the picture change if TP was displayed as volume specific concentration. The TP concentrations on both stations are similar with 3.6 mol $m^{-3}$ at the 2 m and 4.8 mol $m^{-3}$at the 0.5 m station and does not correlate to mud or organic matter content in the sediments. This shows that TP is deposited at the shallow site with sandy sediments at least to the same extend than in muddy sediments.

According to this findings literature data of TP amounts in the different sediments from the DZBC and Baltic Sea are review and recalculated as volume related TP concentrations considering the dry bulk density of the different sediment types. The recalculation results in similar or even higher TP concentrations in sandy than in muddy sediments and contradict the assumption of P-accumulation in deeper basins. It emphasizes the meaning of physical sediment properties for interpretation of P-pools and mass balances.

## P213- -PHOSPHORUS COMPOSITION ALONG THE RIVER WARNOW AND ITS CATCHMENT - PRELIMINARY RESULTS

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In the frame of environmental Phosphorus (P) monitoring in fresh as well as in marine waters the concentration of total phosphorus (TP) and soluble reactive phosphorus (SRP) are analysed over long time periods. But this gives less information which amount of P finally contributes to eutrophication processes. Besides SRP, dissolved and particulate phosphorus are constituents of the nutrient loads entering coastal seas like the Baltic Sea via rivers.

In the framework of the joint research program PhosWaM the concentration of different phosphorus fractions (dissolved, particulate, organic, inorganic) and their spatial and temporal variation in the water are analysed at 22 stations along the river Warnow as well as at 16 stations in different inlets from the catchment area. At 4 additional stations the influence of lakes is analysed.

Preliminary results show a slight increase of TP concentration in upstream direction in the Warnow mediated by an increase of particulate phosphorus (PP). In contrast, the SRP concentration is almost constant along the stream pond. The lake outlets show higher TP concentration than in the inlets, mediated by an increase in dissolved fractions (DP, SRP), indicating a release of phosphorus from lake sediments. At all stations the SRP concentration decreases towards the winter months.

These preliminary results indicate the complexity of phosphorus dynamics in the river ecosystem and eutrophication processes. Further analysis of different P-fractions in the Warnow and its catchment should give deeper understanding of P-sources, transformation and eutrophication potential and should lead to sustainable environmental management.

## P214 - Phosphorus cycling in the Warnow estuary: Concentrations, transformation, retention and bioavailability

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Coastal waters of the southern Baltic Sea are still subject to a high level of eutrophication with phosphorus (P) as one of the most driving forces. The BMBF funded project "PhosWaM" aims to study P concentrations, fractions and transformations from the source to the sea. Here we present first results from the Unterwarnow, the brackish transition area between the catchment of the river Warnow and the coastal southern Baltic Sea. Since August 2016, water samples are taken at twelve stations along the Unterwarnow on a monthly resolution. Samples originate from surface and bottom waters, and if present also from the halocline. Reactive phosphorus is measured in the filtrate and the unfiltered samples immediately. Later on, concentrations of total phosphorus and dissolved and particulate phosphorus are determined.

In addition, short cores are analysed seasonally at four sites to study sedimentary P cycling and potential release from the pore waters into the water column. Pore water is extracted from each core by rhizons in 1 cm-steps. Pore water concentrations of P, Fe, Mn, and major ions are analysed by ICP-OES while nutrients and $H_2S$ are determined by an autoanalyser and spectrophotometrically, respectively. After cores slicing, the sediments are freeze-dried and homogenized. The concentrations of total and easily extractable P are measured along with further elements like Ca, Fe and Mn by ICP-OES.

First results indicate that the different P fractions in the water column decrease in direction to the Baltic Sea. For example, in August total reactive phosphorus decreased from 4 µmol $PO_4^{3-}$ $l^{-1}$ to 1 µmol $PO_4^{3-}$ $l^{-1}$ at the surface. During summer, bottom water concentrations are usually higher than at the surface whereas in winter the water column is more intensively mixed and concentrations are similar.

In the series of surface sediment samples, we observed distinct differences along the Unterwarnow transect. Loss on ignition (LOI), as a rough indicator of organic matter content, decreases from ca. 31% to less than 5% near the mouth of the Unterwarnow. In contrast, the mobile P fraction amounts to ca. 40% of total P, mainly bound to ferric oxides, at the beginning of the Unterwarnow, whereas up to 95% are observed in the river mouth.

Finally, we expect an improved knowledge about the different P fractions in the Unterwarnow and the role of this system as source or sink for P allowing recommendations for effective management strategies.

## P215 - Retention and release of Phosphorus from lake and river sediments in the Warnow River catchment (Baltic Sea) during different seasons

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Rivers and lakes play a crucial role for the retention of phosphorus (P) emissions from agriculture and municipal wastewater. How much of the emitted P finally enters the Ocean depends on many factors. Especially the exchange of P between sediments and the water column is of particular importance.

The ReWaM-Project PhosWaM investigates the processes and pathways influencing the P-transport from the catchment of the Warnow River to the Baltic Sea. Strategies will be developed that should help to reduce the amount of P exported from the catchment, and increase the P retention in the rivers and lakes to overall reduce the P-inputs into the Baltic Sea.

The presented sub-project deals with the exchange of phosphorus between sediments and water column in four lakes, two rivers and two smaller streams in the Warnow River catchment. The aim is to investigate under which conditions river and lake sediments act as source or sink of phosphorus, and how the P-retention in rivers and lakes can be improved. We will present fluxes of different P compounds between sediments and water column, measured in incubation experiments with intact sediment cores and calculated from the concentrations of phosphate, total phosphorus, and labile phosphorus. Sampling took place at different seasons during three sampling campaigns in 2016 and 2017.

## P216 - Determination of atmospheric phosphorus deposition in the German part of the Baltic Sea

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As one of the main driving nutrient parameters for eutrophication, the land based input of phosphorus into the Baltic Sea is strictly controlled and monitored by its riparian countries. In contrast, the phosphorus deposition from the atmosphere is assumed to be mostly from natural sources, therefore no frequent monitoring of emission and deposition exist. As it is known that atmospheric deposition is not negligible for the eutrophication of marine systems, a constant background input of 15 kg P/km²/y was assumed by HELCOM for the establishment of the phosphorus reduction target of the Baltic Sea Action Plan. Based only on punctual measurements for the Baltic Sea, this deposition rate was revised to 5 kg P/km²/y, which corresponds to a total input of 2200 tons.

As verification of this deposition rate is needed, Germany has initiated a monitoring program on 2 onshore and 2 offshore stations over the period of at least one year. The onshore stations are located at the Leibniz Institute for Baltic Sea Research in Warnemünde (IOW) and at the Biological Station of the University Rostock in Zingst. The offshore stations are the FINO2 station near Kriegers Flak and the MARNET Arkona buoy, both in the Arkona Basin. While the onshore stations measure both dry and wet deposition, the offshore stations only measure wet deposition due to possible contamination of dry deposition with faeces from bird populations around the offshore stations. Onshore samples were taken every 3 days for dry deposition and after every precipitation event for wet deposition. Offshore samples were refrigerated stored on a weekly basis until collection.

First analyses of taken IOW station samples showed high variability with precipitation and ranges for dissolved inorganic phosphate from 3.2 µg P/m²/d to 206.9 µg P/m²/d for dry deposition and 0.22 µg P/m² to 32.0 µg P/m²/d per precipitation event for wet deposition were measured. For total phosphorus magnitudes from 14.3 µg P/m²/d to 221.8 µg P/m²/d were measured for dry deposition and 27.6 µg P/m² to 842.3 µg P/m² per precipitation event for wet deposition. Recent data are combined with long term data from Zingst and indicate that the contribution of atmospheric phosphorus deposition could be higher than assumed by HELCOM.

## P217 - A ONE-YEAR HIGH RESOLUTION MONITORING OF P CONCENTRATIONS FROM DIFFUSE SOURCES AND CHANGES ON THE WAY TO THE BALTIC SEA

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Phosphorus (P) as an essential and limiting factor for primary production is a major contributor to eutrophication of rivers, lakes and seas, such as the Baltic Sea. Most of this P is coming from diffuse sources of agricultural origin. Studies and surveys often focus on total phosphorus (TP) and/or orthophosphate for risk assessments; however, particulate phosphorus (PP) makes out a big part of the TP entering surface water bodies. To reconstruct the quantity and composition of the phosphorus reaching the Baltic Sea one needs to look at the sources and the transport path.

The Warnow, the second biggest German river draining into the Baltic Sea, is situated in an agriculturally dominated catchment representative of northern Germany. Our study was conducted in the Zarnow sub-catchment. During the discharge period Nov. 2015 – Apr. 2016 weekly, and during the summer May 2016 – Oct. 2016 biweekly water samples were taken from a tile drain, drainage ditch and surface close groundwater (3-4m) from the same agricultural field, four stations along the river Zarnow and two along the river Warnow. Samples were analysed for soluble and particulate reactive (SRP, PRP) and non-reactive (SNP, PNP) P. Reactive components consist of mainly inorganic P. Spatial and temporal variations were found.

TP inputs from tile drain were below 2µmol/l. Ditch inputs exceeded 3µmol/l in 3 months of the monitoring period. Groundwater might be an important source with TP values of 5,1 +/- 2,8µmol/l. Tile drain and groundwater differ markedly, as tile drain is dominated by soluble (›70%) and groundwater by particulate components (≥90%).

Down the river Zarnow, TP increased towards the mouth in the first months. However, starting in May, maximum TP values were reached in the middle of the Zarnow already. This might be a typical seasonal picture. The TP threshold value set in accordance with the EU WFD (3,2µmol/l) was exceeded in 56% of measurements. The Zarnow was dominated by reactive P most of the time.

In the river Warnow clear seasonal changes can be observed: In March and April SRP decreased to detection limit along with PNP increase, visualising a spring bloom. Generally, TP is fluctuating less in the Warnow, perhaps because of the larger catchment area. The EU WFD TP threshold was exceeded in 38% of measurements. In conclusion, the exceeding of the EU WFD threshold illustrates the need for further P reduction. Reduction measures should be launched in the small rivers and in groundwater.

## P218 - P-EXPORT PATTERNS FROM ARTIFICIALLY DRAINED AGRICULTURAL LAND

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Phosphorus (P), a major plant nutrient, is frequently responsible for the eutrophication and ecological disturbance of rivers, lakes and seas such as the Baltic Sea. Leaching losses from agricultural soils can be a substantial source of P-inputs into water bodies. Drainage systems shorten the residence time of water in the soil and the effect of tile drainage on P-losses is controversially discussed.

The aim of the present study was to investigate the magnitude and the dynamics of P losses at our long-term agricultural field site 'Dummerstorf' (Mecklenburg-Western Pomerania). In a small, intensively artificially drained lowland catchment of the brook Zarnow, a tributary of the river Warnow, the dynamics and the extent of total phosphorus (TP) and dissolved reactive phosphorus (DRP) concentrations as well as the discharge were monitored at three spatial scales (drainage plot: 4.2 ha, ditch: 179 ha, and brook Zarnow: 1550 ha). Investigations covered two winter seasons from November to April. Water samples at all scales were taken automatically using ISCO-samplers every six hours and merged into daily samples for laboratory analysis. Water level was recorded automatically every 15 minutes. On the basis of weekly manual measurements of stream flow, rating curves were developed to derive daily discharge data.

Mean TP (DRP) concentrations were 0.045 (0.017) mg $l^{-1}$, 0.056 (0.019) mg $l^{-1}$, 0.057 (0.015) mg $l^{-1}$ at the drainage plot, the ditch, and the brook during discharge period 2015/16. Results indicate that the threshold value for a good ecological status with respect to TP, which is 0.1 mg $l^{-1}$ TP in Germany, was mostly being fulfilled. TP and DRP concentrations showed strong fluctuations during the discharge period with minima of 0.004 mg $l^{-1}$ TP and 0.000 mg $l^{-1}$ DRP, and maxima of 0.307 mg $l^{-1}$ TP and 0.176 mg $l^{-1}$ DRP, respectively. This could be attributed to flow conditions with lower concentrations during baseflow and higher concentrations during high flow periods. The majority of P losses occurred during five storm events accounting for 25% precipitation of the entire season. During these events, 15-77% TP and 48-68% DRP of the total seasonal loads were leached at the three spatial scales.

Due to the dynamics of P losses caused by the altered hydrology of the investigated catchment, we conclude that artificially drained areas should be taken greater into account for risk assessment and for deriving management strategies to reduce P losses.

## P219 - Validation of the new Sentinel-3 satellite altimetry data in the Baltic Sea basin

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Sentinel-3 is a new ESA ocean mission equipped with a Synthetic Aperture Radar Altimeter (SRAL) designed to measure water levels, significant wave heights, and wind speeds with very high resolution. The unprecedentedly high resolution will allow precise observations of wave heights and other parameters very close to the coast. The Baltic Sea is characterized by very complex geometry, and the wave climate research will significantly benefit from the high spatial resolution of Sentinel-3 data. Sentinel-3 mission was successfully launched in February 2016 and started to produce ready to use operational stage data in December 2016. Here we present the status of the up to date collected data from Sentinel-3 altimetry covering the Baltic Sea basin. We present a cross-validation of significant wave heights, wind measurements, and water levels extracted from the Sentinel-3 altimetry data with available in-situ measurements for the Baltic Sea basin, using a pipeline previously developed for the validation of CRYOSAT-2, ENVISAT, ERS-1/2, GEOSAT, JASON-1/2, SARAL, and TOPEX/POSEIDON regional data. We discuss the derived uncertainty in the Sentinel-3 data, study biases and temporal biases between the satellite and in-situ data, and the effect of distance from the coast and ice concentration to the measurement errors in the data.

## P220 - WAM validation with satellite altimeter observations in the Baltic Sea

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Wave models are often validated against in situ wave buoy observations, the most accurate wave measurements available. In the Baltic Sea however, the buoy network is relatively sparse considering the spatial variability of the sea and its wave conditions. Furthermore, there are presently no operational wave buoy measurements available from the Eastern Gotland Basin and in the northern part of the Baltic Sea the measurement period is limited by the seasonal ice cover. Satellite altimeters provide more comprehensive spatial coverage over the entire sea but the data is more prone to uncertainties for example due to proximity of land or ice.

This study will evaluate satellite altimeter data suitability for wave model validation in the Baltic Sea and develop methods for fast and effective estimation of operational forecast model accuracy. We use altimeter significant wave height observations from 7 satellite missions for the period 2006-2015 to evaluate the accuracy of 2 NM WAM hindcast dataset. Spatial data mining and geographic visualization techniques will be applied for identifying the accuracy of the modelled gradients in the significant wave height field from the coastal areas towards the open sea.

## P221 - Polarisation of upwelling radiance above the sea surface - modelling and measurements

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The subject of our study is the directional distribution of polarisation of upwelling light over the sea surface. The use of polarisation allows, under certain conditions (different directions of measurements relative to the direction of the Sun), to reduce the amount of light that comes from redundant surface reflections. It helps to obtain more accurate measurements (for example, the colour of the sea) for the water-leaving radiance. In addition, the state of polarization of the water leaving light may include some information about the constituents of sea water.

Polarisation of light can be expressed by so-called Stokes vector S, which includes four elements traditionally denoted as $[I\ Q\ U\ V]^T$. These elements denotes in sequence: total intensity, intensity of light polarised parallel/perpendicular to reference plane, oblique polarisation and circular polarisation. The latter is negligible in natural conditions (atmosphere and sea water). The single quantity that characterises how much a beam of light is polarised is the Degree of Linear Polarisation: $DoLP = (Q^2+U^2)^{0.5}/I$.

Our research is based on two methods: modelling made using Monte Carlo algorithm and measurements. Measurements are made with polarisation imaging camera PolarCam, produced by 4D Technology, equipped with Fujinon fish-eye lens. It uses special monochrome CCD array in which the neighbouring cells, instead of recording different colours (like in ordinary camera), are equipped with micropolarisers of four directions (0, 45, 90 and 135 degrees). This allows us to obtain elements I, Q and U of Stokes vector.

The measurement results show us the observed angular distribution of the Degree of Linear Polarisation above the surface of the sea. However, only modelling results allow distinguishing the surface reflected photons from those that have been scattered in the see depth. We present polar plots of both and indicate the regions where polarisation of water leaving radiation is higher than polarisation of reflected radiation. In addition to that, we study the influence of the atmosphere on the possibility of remote sensing of polarised water leaving signal.

## P222 - AEROSOL DIFFUSIVITY IMPACT ON THE POLARISATION OF UPWELLING LIGHT AT THE TOP OF ATMOSPHERE

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Our research focuses on the impact of aerosols on the polarisation of light measured at the top of the atmosphere. We are interested in using polarising filters during remote measurements. We analyse the polarisation state of light that reaches the top of the atmosphere. This signal consists of three main components. These components are a scattered light in the atmosphere, the light reflected from the surface of the sea and the light coming from the depths (scattered under the surface).

Information about how many photons reaching the top of the atmosphere derived from the mentioned components comes from our method. It is based on the Monte Carlo algorithm (by Jacek Piskozub) which tracks not only the direction of the scattering and the place of absorption of virtual photons, but also the state of their polarisation during each interaction. Results of modeling are shown in form of polar plots.

Polarisation formed in the atmosphere as a result of molecular scattering (Rayleigh scattering) turns out to be the strongest contribution to the measured degree of polarisation at the top of the atmosphere (TOA). It is therefore a factor that interferes in obtaining information from beneath the sea surface. However, the polarisation pattern derived from molecular scattering has a predictable shape depending on the position of the sun. The maximum value of the polarisation depend on the amount of aerosol which can be described by the Aerosol Optical Thickness (AOT).

At the top of the atmosphere, you can also see the strong polarisation signal derived from the direct sun reflection on the wavy surface of the sea. It forms a ring in the polar plot with an extension in the area of direct sun reflections. The weakest contribution to the polarisation comes from the water-leaving signal. It is visible mainly on both sides of the reflection.

## P223 - The hydrography of the Bothnian Sea seen from a glider

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The hydrography of the Bothnian Sea, a semi-enclosed basin in the Baltic Sea, differs considerably from that of the other basins of the Baltic Sea. The salinity stratification and deep-water conditions there depend on the water exchange with the Baltic Proper through Åland Sea and Archipelago Sea and on the river runoff. The deep-water conditions in the Bothnian Sea have so far been good, but some indication of change towards worse has been reported. Our aim is to study the water exchange processes and as the beginning of a longer study, we did a survey of the temperature, salinity and oxygen fields in the southwestern Bothnian Sea in autumn 2016 with a Slocum G2 shallow sea glider.

We did a one month long glider experiment from 6th September to 6th October 2016. The glider route was round 700 km long and we got nearly 5000 vertical profiles along eleven sections. The location of the sections was designed so that one followed the southern end of the basin along the 50 m bottom contour, another one followed roughly the deep trench of the basin and the other nine sections grossed the trench. By this we tried to catch the areas of waters flowing from the Baltic Proper and to follow them inside the basin keeping our observations in the Finnish EEZ.

Our interest was in the slow, large-scale processes rather than in rapid short scale variations. We consider that our glider route served that purpose rather well. The data gives indication that the inflow from the Åland Sea turns to the right along the southern edge of the Bothnian Sea. Our section that describes the incoming water seems to be too short to confirm that fully. Elongation of the section towards the archipelago would have been beneficial.

The glider showed to be a useful tool for this kind of research. However, the huge amount of data requires careful processing and interpretation, which is a challenge. Charting of the hydrography of the southeastern Bothnian Sea with a glider in 2016 was successful. We will continue our measurement campaigns in spring 2017 with a two weeks R/V Aranda cruise accompanied with one or two gliders that will be used to make more detailed observations in sea areas that we expect to be important for the water exchange between the basins.

## P224 - Application of Argo Floats in hydrographic observations in the Bothnian Sea

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Argo floats have been routinely used to monitor the hydrography of the upper 2000 m layer of the oceans since the year 2000. Today the global system consists of about 3800 active floats. Most of them drift freely in deep-ocean far from shores, and they provide frequent data from remote areas rarely visited with scientific vessels. The collected data helps to better understand the state and variability of the upper ocean, to enhance remote sensing data and serves as input to climate models.

The Finnish Meteorological Institute began to operate Argo floats in the Baltic Sea in 2011 and Finland is now a partner in Euro-Argo RI. FMI's Argo floats are continuously operating e.g. in the Bothnian Sea and Gotland basin, in the Baltic Sea Proper. The characteristics of the Baltic Sea are challenging for the Argo floats. The basin is small and shallow and has highly varying bottom topography. The water has generally low salinity and density, but is often strongly stratified. Furthermore, the northern sub-basins have seasonal ice cover. All these restrict the use of the usually freely floating Argo floats and increase the need for piloting them actively.

After six years of operations, we can look into the Argo float data from the Bothnian Sea and estimate its representativeness and assess the feasibility of such monitoring in a shallow small sea area. We discuss several important questions. 1) How well a single float and furthermore, its single profile can describe the hydrography of the surrounding basin? 2) What part of the water column can we capture without increasing too much the risk of losing the float to the bottom? 3) Where in the Bothnian Sea would it be the most beneficial to deploy the floats to a monitor the physical and biogeochemical properties of the basin, b) to study the water exchange between Bothnian Sea and the Baltic Sea Proper and c) to best supplement the existing monitoring network?

In any case, we can state that extension of the global Argo array to the Baltic Sea has given a lot of useful new data that would not be possible to get easily by other means. We are also happy to mention that unlike the one use practice in the oceans, we retrieve, check and fix, and redeploy the Argo floats used in the Baltic Sea.

## P225 - Assessing near-bottom velocity field using an experimental particle image velocimeter

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Several experiments were conducted in the coastal zone of Tallinn Bay during years 2009 - 2015 to assess the conformity of measured bottom boundary layer velocity profiles with theoretical shear stress model. During the first series of measurements an acoustic Doppler velocimeter (ADV) with turbidity sensor was used to monitor near bottom velocity and turbidity levels. The second measurement series involved a particle image velocimeter (PIV) which was used to record sediment particles moving above the seabed. Surface waves were recorded using pressure based wave buoy. Along with measurements sediment and water samples were collected and analysed in the laboratory against sediment concentration and grain size distribution in the water. Wind parameters, as background data, were obtained from coastal weather stations.

Simultaneous measurements of near bottom velocity (19 cm from the bottom), wave height and period enabled to calculate the boundary layer velocity profiles using a simplified Nielsen model.

It is shown that the boundary layer can extend 1 – 10 cm from the bottom depending on the bottom type and wave activity. Calculated shear velocities and turbidity measurement results were compared for validation. PIV-sonde allowed direct measurements of velocity profiles up to the height of 70 cm from the bottom. Maximum velocities found using video frame analysis showed a great diversity at heights of 20 – 70 cm from the bottom but decreased consistently from 20 cm down to 2 cm – closer to the seabed it was not possible to measure due to high resuspension of sediment. The height of the wave boundary layer was 10 - 20 cm and the bed roughness found by extrapolating near-bottom velocity profiles remained between 0.1 – 3 cm, the roughness calculated by grain parameters (D50) was between 0.04 – 4 cm. The experimental PIV-sonde made possible to obtain unique data for assessing the conformity of theoretical velocity profiles with the real velocity distribution in the bottom boundary layer.

## P226 - ADCP DATA PROCESSING AND CURRENT MEASUREMENTS IN THE FINNISH ARCHIPELAGO SEA

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Sea currents transport heat and substances between coastal and open sea and between Baltic Sea basins. In order to understand e.g. water exchange between basins and through that to evaluate the present and future changes in the state of Baltic Sea, it is important to have knowledge of the currents, preferably through measurements. Real-time current measurements can also give valuable support for ship navigation in the areas of strong currents. Bottom moored ADCP provides us with sea current magnitude and direction profiles from some meters above seabed to near the surface. Such measurements give us valuable information on local currents and can be used for validation and assimilation of ocean circulation models that can provide us a broader understanding of the sea area.

FMI has large amount of ADCP datasets from the northern Baltic Sea basins. The measured datasets have several uncertainties that require automated and manual processing tools to ensure good quality data. In this work the different factors affecting the accuracy of the ADCP measurements are studied and quality assurance methods are developed using as an example one specific dataset from the Archipelago Sea. The aim is to develop common practices and quality assurance methods to be automatically used on all FMI's ADCP measurements.

The current measurements used in this study were done in the Archipelago Sea between June and November, 2013. The observation site was at a crossing of two trafficked ship routes that is known to have strong currents time to time that can affect navigation. In this area there are also ongoing projects that aim to develop modeling tools to analyse the spreading and distributions of materials and our data may be used in these cases for model validations.

The summer thermocline changes vertical current structure of the measured area. Currents are stronger near the surface than on the bottom but the maximum values are located near thermocline. Preliminary results show change in directions in these two levels. Prevailing currents near the surface are towards southwest and vary largely in all other directions. In the bottom layer currents are mainly on the axes between northwest and southwest following bathymetry of the area. Strongest currents seem to occur during the autumn after the thermocline has disappeared. These currents are mainly towards north-northeast with magnitudes over 40 cm/s and reach through the whole water column. The average velocity of the area is around 7 cm/s.

## P227 - Electrochemical pHT measurements of TRIS buffered artificial seawater samples in the salinity range 5-20

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Oceans act as a carbon sink, as they absorb $CO_2$ leading to a decrease in pH. Hence, precise and comparable measurements of the oceans pH are of fundamental importance for studies on the anthropogenically driven climate change. In order to assure comparability of pH measurement results, internationally accepted pH standards are inevitable. Currently the only agreed standards are TRIS (2-amino-2-hydroxymethyl-1,3-propanediol) buffered artificial seawater solutions based on DelValls and Dickson (1998) in the high salinity range (20-40), whose pH values have been measured using an electrochemical setup comprising so called Harned cells. This setup represents a primary pH standard. However, in oceanographic practice $pH_T$ is measured with spectrophotometric systems using indicator dye m-cresol purple (mCP). Such systems are calibrated using the above mentioned standard solutions. As mCP is poorly characterized in the lower salinity range predominant in the Baltic Sea, a collaboration project between the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) and the Physikalisch-Technische Bundesanstalt (PTB) (see also abstracts submitted by Müller et al. and Rehder et al.) was initiated. The $pH_T$ values of TRIS buffered artificial seawater solutions have been measured in the salinity range 5-20 (and additionally 35) in the temperature range 5-45 °C. PTB has used an electrochemical Harned cell measurement setup and IOW has measured absorption spectra of the indicator dye mCP of the same TRIS buffered artificial seawater solutions. The Harned cell measurement results allow for the first time the reliable calibration of $pH_T$ measurement devices, e.g. spectrophotometers in the low salinity range and hence traceability of those $pH_T$ values to a primary standard.

We will present details of the electrochemical measurements and how they have been linked to the subsequent spectrophotometric results of IOW.

## P228 - Updating pH measurements in brackish waters: Characterization of the indicator dye m-Cresol purple based on newly available TRIS buffers

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Ocean acidification, as a consequence of the uptake of anthropogenic $CO_2$ by seawater, has been recognized as a global threat to marine ecosystems. Accordingly, the Marine Strategy Framework Directive claims to track this process. In oceanic environments acidification rates in the order of 0.002 pH units $yr^{-1}$ were successfully determined by means of spectrophotometric measurements, indicating that in principle this technique meets the required levels of precision, accuracy and long-term traceability. However, the required dissociation constant and extinction properties of the applied pH indicator dye m-Cresol purple (mCP) were poorly characterized for salinities below 20, because buffer solutions with a well-defined pH were not available. Consequently, pH measurements could not be used to properly determine the $CO_2$ system in the Baltic Sea with an uncertainty comparable to open ocean applications.

Here we present for the first time extensive characterizations of mCP for the salinity range 5-20 and temperatures from 5-45°C. The basis for this dye characterization are TRIS buffers in the same salinity and temperature range that were recently produced in cooperation of IOW and Germanys metrological institute PTB (see also abstracts submitted by Rehder et al. and Bastkowski et al.). This new dye characterization should be used in future research, but can also be applied to re-evaluate previous spectrophotometric measurements. Due to the fundamental chemical principles of the method it is only applicable for a limited pH-range, which in turn depends on the salinity. We will present a comprehensive analysis of the uncertainty patterns of the method for the full spectrum of pH-S-conditions typically encountered in the Baltic Sea. In summary, we will demonstrate that with the progress made over the last three years in the framework of the project BONUS PINBAL, spectrophotometric pH measurements can now be applied in brackish water systems without major uncertainties. The achieved quality of the measurements allows to include pH in the computation of other $CO_2$ system parameters and to follow the dynamics of a potential acidification process in almost all waters of the Baltic Sea.

## P229 -Baltic Sea forest ecosystems: challenges and opportunities for the EU Forest Strategy

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Coastal forests in Baltic Sea region form not only a complex demographic but also geopolitical landscape, with boreal region covering around 60% along the coastline and islands around the Baltic Sea and Gulf of Bothnia, and the rest attributed to a Continental and Atlantic forest regions. These multifunctional ecosystems not only contribute to the local and regional economy through their multi-functionality but play an important role in minimising the impact from the coastal erosion and flooding. The increasing demand for forest products and significant societal and political changes and policies has prompted reformed EU Forest Strategy to shift toward a sustainable management of the forest ecosystems. Yet, its adoption continues to be one of the major challenges at the national and regional levels, especially in relation to a forest conservation and stakeholder engagement. The balance between the national needs and wants becomes blurred and one of the key arguments here is that it remains to be seen how well the strategy is applied to the coastal forest regions and toward achieving a good environmental status of the Baltic region and beyond. Case studies of Finland, Poland and Croatia all provide insight into the lessons that need to be learned.

## P230 - Land cover change as a consequence of natural and human impact: SE Baltic Sea region example

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Main task of this research is to make suggestions for further research on land cover change and to use land cover change analysis as indicator of micro-climate change in example of Lithuanian Baltic Sea coastal zone.

Coastal zones are among those areas that have been subject to intense human pressure due to their natural resources. As a transitional zone, between land and sea, coastal zones hold some of the most valuable and productive habitats on earth. Huge amounts of energy circulate in these zones, which attracts all sort of human interest and activities (Rivis et al, 2016; Schlacher et al., 2014; Bicknell et al., Sperb et al., 2006). A large number of population lives near the coastal zone.

Analysis on the land use and land cover change as a consequence on human livelihoods as well as on the environment is a matter of concern for sustainable development and management of natural resources. The Baltic Sea and coast is one of the most vital natural resources of Lithuania. Only a small part of the Baltic Sea coast belongs to Lithuania (~91 km.) and almost half of it belongs to the National park area and Natura 2000 or other prohibited area (State Cadastre of Protected Areas, 2014).

Retrospective analysis of land cover dynamics and its driving force has been undertaken using satellite images of Landsat5 TM year 1989, Landsat5 TM year 2000 and Landsat8 TM year 2014 and 2016 with 30 m spatial resolution of Lithuanian Western part. Analysis of building's geodatabase (year 1997 and 2016) applied on orthophoto of Lithuanian Western part was made in order to identify socio-economic change and its difference's impact to nowadays land cover change. In detail statistical, mathematical analysis of ongoing processes have been made using national statistical data and in field trips of most areas of interest. Results showed that during research period landscapes in terms of agriculture, urbanization and human behaviour had changed the most. Further research will be carried out in terms of micro-climate change evaluation.

## P231 - Influence of hydraulic modification of the Vistula Lagoon in XIX century on sedimentation

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The layer of shells found in 10 sediment cores in the northern part of the Vistula Lagoon is interpreted as a finger print of hydrological modification of the lagoon system. The hypothesis is proved by different carbon concentration, sediment colors and dense in two parts of the core divided by shell layer. The cut off the Nogat River, the northern branch of the Visla River delta, which had happened in 1916, started new period of natural evolution of the lagoon. This drastic event initiated by humans changed the river dominated environmental conditions to the marine dominated ones.

## P232 - THE HISTORY OF LAND USE ON THE WOLIN ISLAND DURING 17TH-21ST CENTURY

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The poster describes possibility of using historical cartographic materials in a process of tracing the remnants of the past landscape on the Wolin Island. The aim of this study was to analyse changes in the land use on the Wolin Island from the end of 17th century to the present. Understanding of previous land cover changes is important for the interpretation of modern landscapes. On areas with long histories of human settlement (e.g. Wolin Island) the study of landscape must consider the relative influence of past land use. During the past centuries humans have changed the Wolin Island environment. This happened because of significant intensity of land use change and natural causes. The article discusses e.g. cadastral maps 1:8333 from 1692-1709, topographic maps 1:25000 (Meßtischblatt) from 1870-1945, topographic maps 1:10000 from 2000-2003 and lidar data from 2011. The results may provide a base for the search for factors which could influence the structure of land use on the Wolin Island.

## P241 - Modeling of suspended particles propagation, released from the dumpsites of chemical weapons in the Baltic Sea

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Lagrangian approach based on the consideration of motion of individual particles due to the mean currents, turbulence, and gravitational settling was applied to predict the propagation of substances in the sea. Pathways of suspended particles were calculated on the base of current-velocity and eddy diffusivity data obtained by the Princeton Ocean Model. Formulas for calculation of particles' displacement applied in the present investigation are described in detail in (Zhurbas et al., 2010). Trajectories of Lagrangian particles released from the near bottom sources at a distance of 1cm from the bottom in the Bornholm Basin, Gdansk Deep and Eastern Gotland Basin Dumpsites were calculated. The period of calculations presented in the study is first four months of 2012. The four-months period is considered to be long enough to obtain a picture of the dispersion of particles around the source, to reveal the areas of their transit and "capture", and to investigate the hydrodynamic processes affecting particles' propagation. Verification of model calculations of particles' trajectories has been implemented by the comparative analysis with trajectories of real drifters released from the surface and deep layers in the shelf zone of the southeastern part of the Baltic in summer of 2015 and 2016. Having analysed the horizontal and vertical displacements of Lagrangian particles released from the dumpsites one may summarize that during the whole period of calculations about half of trajectories didn't extend outside the deeps they started from. These trajectories were passing in the vicinity of the bottom. Concentrations of toxic agents are expected to be high in these areas for several months. Some trajectories show that the influence of near inertial internal waves on particles' propagation can be significant. Some particles were trapped by near inertial waves in some locations and remained within a distance of several kilometers for several days. Another half of particles, which spread outside the deeps, passed long distances, their vertical positions changed considerably – from the near bottom to the surface layer. Toxic agents corresponding to these particles are expected to be distributed in wide areas of the Baltic and not to produce high concentrations.

## P242 - Spatial distribution of arsenic in bottom sediments of southern Baltic Sea

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Arsenic is an element ubiquitous in all environmental components, however 70% of arsenic input to the Baltic Sea comes with surface runoff and results from on-land anthropogenic activity (the use of pesticides, coal burning, mining and smelting processes). Additional source of arsenic in the Baltic deeps is the Chemical Weapon dumped on the sea bottom after the II World War.

Arsenic is assumed toxic to plants, animals and humans and is considered as a potential carcinogen. It disrupts enzymatic processes in cells, causes cell walls breakdown, inhibits mitochondria functions, affects proteins formation by its high affinity to sulfhydryl groups, inhibits phosphate insertion to DNA, affecting transmission of genetic information. Chronic exposure to elevated arsenic concentrations can cause disturbance in nervous system and heart diseases. It is also assumed that bladder and lung cancer may be caused by chronic arsenic poisoning. As fish and seafood are the main sources of arsenic in human diet it is very important to investigate the marine environment for arsenic concentrations.

Between the years 2012-2017, during several research projects, number of 350 surface sediments samples were collected in the area of southern Baltic Sea, including areas of: Gulf of Gdańsk with Gdańsk Deep, Słupsk Furrow, Poland's Exclusive Economic Zone along the polish coastline, Bornholm Deep and Gotland Deep including chemical weapons dumping areas. Total arsenic concentrations in the samples were measured and additional sediments properties were examined. Obtained results of arsenic concentrations ranged from 0.1 $\mu g \cdot g^{-1}$ in sandy sediments to 24.5 $\mu g \cdot g^{-1}$ in muds. Levels of arsenic correlate significantly with iron concentration in the sediments, amount of organic matter and grain size.

The considerable number of samples allowed to extrapolate the results and develop a map of arsenic concentrations in sediment for a large area of southern Baltic Sea. This kind of visualization of concentrations clearly exposes patterns of arsenic distribution over the bottom of the Baltic.

## P243 - UDEMM: ÖkoToxEMM – Toxicological and Environmental Monitoring of the emission of pollutants from munition in the sea

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*1. Introduction:* Dumped ammunition after World Wars 1 and 2 into the sea is a worldwide problem for shipping, installation of offshore wind farms and the aquatic ecosystem in general. To address this problem the project RoBEMM designs a fully automatic delaboration unit for conventional munition in the sea. In parallel, the UDEMM project (start March 2016) aims to control the release of toxic substances (mainly trinitrotoluene, TNT) during the process of dismantling conventional ammunition. In ÖkoToxEMM, a part of UDEMM, we will establish the mussel *Mytilus edulis* as a bio-indicator system for harmful compounds leaking from corroding ammunition. This system will be used as a long-term monitoring program for the safety of the marine ecosystem as well as to optimize the prototype during the delaboration process.

*2. Objectives:* Deployment of mussels at ammunition dump sites before, during and after the delaboration; Development of an analytical method to quantify explosives and their degradation products in mussel samples; Optimization of the delaborator to minimize environmental contamination; Installation of a long-term biomonitoring program of explosives using *Mytilus edulis*; Establishment of a risk-assessment for humans and the environment

*3. Materials & methods:* For biomonitoring we use the mussel *Mytilus edulis* domiciled in the Baltic Sea. Routine measurements of explosives and their degradation products will be performed by HPLC with UV-detection and validated by GC-MS/MS.

*4. Results:* For the deployment of mussels we used self-made moorings. We placed mussels directly at ammunition dump sites and successfully developed an HPLC-method as well as a GC-MS/MS method to detect TNT and important TNT metabolites.

*5. Conclusion:* The ÖkoToxEMM project develops an effective long-term biomonitoring system for the detection of explosives in mussels and during the dismantling of ammunition. Up to date, no long-term biomonitoring program exists for these kinds of pollutants.

## P244 - High-frequency multibeam echosounder as a tool for monitoring ammunition dump sites in shallow waters

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Ammunition in coastal waters of the Baltic Sea is a current topic, which has been neglected for a long time. After the Second World War, besides unexploded ordnance, an estimated amount of 300.000 tons of conventional underwater ammunitions has been dumped in nearshore areas all along the Baltic coastline. Insufficient knowledge exists about the exact number, location and transport processes of dissolved and particulate matter induced by currents as well as sediment rearrangement. The often close proximity to the shore and therefore to popular tourist sites and beaches makes it necessary to predict decay and movements of the mines itself, but also of the explosive material as TNT or gun cotton.

The purpose of this study is to develop an adequate monitoring procedure that enables long-term observation of known dumpsites and predictions about the mobility and transport of the ammunition bodies induced by currents as well as sediment rearrangement. Within the BMBF funded UDEMM project (https://udemm.geomar.de), two explicit mine sites in the area Kolberger Heide have been chosen for detailed monitoring. During several surveys the sites were mapped with a 400 kHz multibeam echosounder system, which is one of the most effective tools to map the seafloor. Mines and sediment properties were identified on basis of high resolution bathymetry and acoustic backscatter. Additional visual surveys with a towed underwater camera system were conducted to identify the ammunition bodies. The first site consists of a pile of around 70 anchor mines, with 150 cm diameter each. The second study site is an area of five connected former explosion craters. At least 60 ground mines and torpedo heads, varying in size from 100 to 250 cm length, have been deposited in and around these craters. Geographic-information-system based morphometric derivatives were calculated and the position and orientation of each object was mapped. Repeated surveys over the year provide comparable data sets in different seasonal states. Together with ADCP-based current measurements predictions about movement and relocation of the ammunition bodies shall be made.

## P245 - Sedimentary geochemistry of Fe, Mn and REEs in an acid sulphate soil impacted estuary, northern Baltic Sea

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The development of acid sulphate soil (ASS), which occurs in many low-lying coastal areas, liberates large quantities of acidity and toxic metals, causing serious ecological damage to recipient watercourses. The Vörå creek, which is located in the mid-western coast of Finland, is one of most heavily ASS impacted streams in Europe [1-3]. Our recent studies examined the solid-phase distribution and speciation of Fe, Mn and REEs in a 3.5 m long sediment core and three samples of suspended particulate matter collected in the Vörå-creek estuary by combining chemical extractions and X-ray absorption spectroscopy (XAS) [4-6]. Reactive Fe (defined via extraction with 1M HCl) was high throughout the core (52–68%) and strongly dominated by Fe(II) complexed by organic matter, with the remaining Fe(II) occurring as mackinawite. Iron is thus sulphidised to only a limited extent, which is explained by the brackish-water conditions (i.e. low in sulphate) and the abundant input via the creek of reactive Fe(III) pools dominated by Fe(III)-organic complexes and 2-line ferrihydrite. The most striking feature of Mn in the sediment core is two Mn-enrichment zones where there are strong fine-scale variations in Mn concentrations with peaks episodically reaching up to 10-25 $g \cdot kg^{-1}$ and 6.7-12 $g \cdot kg^{-1}$, respectively, in a manner similar to Mn concentrations in the settling materials sampled close to the coring site [2]. Taking into account this feature as well as the fact that Mn is transported via the creek as dissolved Mn, it is proposed that i) the Mn distribution pattern in the core is largely inherited from the settling materials; and ii) the huge fine-scale variation in Mn concentrations is regulated by biogeochemical conditions optimal for massive Mn oxidation, including a high Mn load transported via the creek and strong activities of Mn(II)-oxidising bacteria. Despite that metal (Fe/Al) oxyhydroxides and organic matter are abundant in the estuary and have the capacity to scavenge REEs, they played an overall minor role in capturing and carrying the REEs. Instead, the REEs were bound via inner-sphere complexation on phyllosilicates (clay minerals).

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## P246 - Occurrence of PPCPs in riverine run-offs and the German Baltic Sea

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The occurrence of pharmaceuticals and personal care products (PPCPs) in the marine environment is of great concern. They are ubiquitous contaminants and can be used as anthropogenic indicators for pollution of the marine environment. Their unknown fate and the effect on the marine environment and especially its organisms, is of mayor scientific concern. In this study we determined the emergence of eight pharmaceuticals and eleven ultraviolet filters (UV-Filters) in 5 rivers/streams (Oder, Vistula, Warnow, Barthe, Mühlenfließ) discharging into the Baltic Sea. Furthermore the occurrence of the PPCPs in close beach proximity was investigated. Two pharmaceuticals (sulfamethoxazole, salicylic acid) and two UV-Filters (2-phenylbenzimidazole-5-sulfonic acid, octocrylene) were detected in the water of all sampled rivers, with concentration ranging from 0.6 ng/L to 836.3 ng/L. In all rivers the PPCP concentration decreases towards the Baltic Sea. The Oder was most polluted river, only small stream Mühlenfließ showed higher degree of contamination. The antibiotic sulfamethoxazole was detected at comparable concentration along the coast, which leads to the assumption of stable concentration in beach proximity. Along the coast UV-filters appeared in varying concentrations, leading to the conclusion that the direct input into the marine environment plays a bigger role than the indirect input.

## P247 - Preliminary results of monitoring studies on macrophytes in the area of brine discharge from the creation of gas storage caverns (Puck Bay, Baltic)

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The coastal zone of the Puck Bay, located in the area protected within Natura 2000 network, is subjected to the influence of two media – wastewaters discharged through a collector of the sewage treatment plant in Dębogórze and brine effluent discharged by means of a pipeline as a result of construction of the underground gas storage UGS Kosakowo. The results of the monitoring studies conducted in 2009, 2012 and 2015 have shown that after 40 years, macrophytes (*Zannichellia palustris*) were again noted in the area (2012). They occur in small amounts, but slightly increase their bottom coverage. It indicates the improvement of the environment state in the area being under pressure of two media, and also points indirectly, that environmentally friendly technical solutions were applied for discharge of the effluents.

## P248 - INFLUENCE OF SURFACTANT CONCENTRATION AND TEMPERATURE GRADIENTS ON SPREADING OF CRUDE-OIL AT SEA

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Spreading kinetics measurements were carried out on crude oils at natural surfactant-containing sea water of well-controlled thermo elastic surface properties in laboratory conditions. It was found that oil lens expansion rates, predicted from the classical surface tension-driven spreading theory, were higher by a factor of 6-9 than those experimentally derived for natural seawater. Previously, in order to explain such a discrepancy, the initial spreading $S_o$- entering the lens radius –time dependence was exchanged with the temporal spreading one $S_t$ dependent on the surface viscoelasticity of water phase (Boniewicz and Pogorzelski, 2008). Now, natural surfactant concentration and temperature gradients perpendicular to the surface were shown to drive fluid flow at the surface microlayer as a result of the classic and thermal Marangoni phenomenon. The balance of interfacial forces was written as: $-\mu_L dU/dZ=d\gamma/dT \cdot dT/dx+d\gamma/dC \cdot dC/dx$ where: $\mu_L$ is the dynamic viscosity, U- the velocity, Z and x axes oriented perpendicularly and horizontally to the main flow direction, T, γ, C are the temperature, surface tension and concentration of surfactants. Marangoni effects (scaled with the Marangoni number) can be made dominating over buoyancy-effects (quantified with the Rayleigh number Ra) for most liquids in liquid layers with thicknesses of millimetres. Surface tension gradients induce the Benard-Marangoni instability and formation of the cell-like flow. Computations performed on model oil-natural seawater systems, shown that concentration dγ/dC are several times lower than thermal dγ/dT (Boniewicz and Pogorzelski, 2016), which could significantly slow down the spreading process of oil spills under an evaporative cooling condition.

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## P249 - Real time in situ oil-spill monitoring using FerryBox system equipped with UV-fluorometer

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The Baltic Sea, with its high maritime traffic has increased probability for oil pollution occurrence. Spatial distribution of detected oil spills show that they are most probably noted on major ship routes, which leads to idea to monitor oil in water with Ships Of Opportunity (SOOPs). UV (Ultra-violet) fluorescence is highly sensitive and straightforward method to determine oil-based aromatic compounds in seawater, in lab and on field. In-situ field operable UVfluorometers are nowadays compact, robust and sensitive - up to 0.001 µg/L. Compact FerryBox system developed by TUT Marine Systems Institute is used on board ferries M/S ROMANTIKA and M/S BALTIC QUEEN. During GRACE project, UviLux (Chelsey Instruments Ltd) UV-fluorometer is intended to be used for monitoring oil compounds in surface layer of the open sea. With excitation wavelength at 360nm and emission at 450nm, UviLux sensor detects the concentration of polycyclic aromatic hydrocarbons (PAHs) in water. In parallel, basic seawater properties are recorded by the same system in real time – temp, salinity, turbidity, $O_2$ and $pCO_2$ concentration. Such system enables automated asset for detection and monitoring of oil spills on fairways, where occurrence of oil spills is highest.Preliminary results show reliable operation of the FerryBox system equipped with UviLux oil sensor. Measurements in manual regime in five harbours on Estonian coast, showed average PAH concentration (in terms of Carbazole) varying from 0,016-0,037 µg/L, with max values up to 0,074µg/L. UviLux sensor integrated into FerryBox system for over two months on Tallinn-Stockholm fairway showed max values of PAH concentration up to 2,6 µg/L and remarkable variability. Drawback of FerryBox-based oil detection system was high sensitivity to biofouling.Study summarises the operational experience gathered from tests of the FerryBox systems equipped with UV-fluorometer, showing its potential as an oil-spill detection and monitoring tool. Repeated tracks of ferries allow to obtain statistics of oil compounds in water in different sea areas. Especially important is monitoring of small spills, which stay undetected with conventional remote sensing methods, but are most numerous and detectable only with in situ measurements.

Present study is under H2020 project GRACE (InteGrated oil spill Response ACtions and Environmental effects) focusing on comparing and evaluating the effectiveness and effects of different oil spill response methods in a cold climate.

## P250 - Tidal zone monitoring for marine litter at beaches of the Baltic Sea and the Warnow River

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Marine litter is a growing problem which causes damage in oceans and seas all around the world. For a better protection of the marine environment, the European Union (EU) developed the Marine Strategy Framework Directive (MSFD) which requires the Good Environmental Status (GES) of the marine environment until 2020. Therefore, it is necessary: "to develop monitoring methods for the identification and trends in the amount of litter washed ashore and / or deposited on coastlines, including analysis of its composition, spatial distribution and where possible source" (MSFD–2008/56/EC). At the Leibniz Institute for Baltic Sea Research in Warnemünde (IOW) a tidal zone monitoring method was developed, which gives information about litter (micro, meso and macro) that originate from sea / rivers. The method was tested at different beaches along the German and Lithuanian Baltic Sea coast and at beaches of the Warnow River (Germany) using a sieve (with 2 mm mesh size) on an area of always 10 m². We present the results of the pollution of the beaches (accumulation zone) along the Baltic Sea and the Warnow River after high water and stormy events in terms of composition, size and spatial distribution. Furthermore, a matrix scoring technique was used to estimate the potential sources of litter. We describe the usability of the method as a secondary (additional) method used after stormy events or high human activities besides a regular monitoring at the beach to measure the amount of sea / river-based litter. Created for volunteers (with the ease of use) this method provides the opportunity for a quick identification of the amount, composition and sources of marine litter even when a regular beach cleaning is proceed.

## P251 - Microplastics and associated vector properties in the Baltic Sea

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While the global distribution of microplastics (MP) in the marine environment is increasingly being studied, the microbial life on these plastic particles is far from being understood. We carried out an in situ experiment to explore the microbial colonization of MP along an environmental gradient. Polyethylene (PE), polystyrene (PS) and wooden pellets were incubated for 14 days at 7 stations with various degrees of anthropogenic impact, located in the estuary of the river Warnow (Rostock, Germany), the coastal Baltic Sea and a sewage treatment plant. The biofilm communities were compared to the corresponding water communities (free-living and particle-attached fraction), applying high-throughput 16S amplicon sequencing. Generally, significant differences were found between free- and attached-living communities. The experiment revealed further that the relevance of the substrate for microbial colonization depended on the environmental conditions. For instance, plastic-specific communities solely developed in areas with high salinity and low nutrient concentrations. Particular attention was given to potential pathogenic members in these plastic-associated biofilms. We discovered no enrichment of potential pathogens on MP and assume that the vector function of MP for potential pathogenic microorganisms is negligible. Our study closes research gaps in the field of MP-associated biofilms, in particular representing the first-time comparison with communities on natural particles. The results facilitate an understanding of the composition and spatial variability of MP-associated microbial communities in the Baltic Sea and can serve as basis for future research on the role and potential threats of these communities.

## P252 - Microplastics in marine bottom sediments (the Baltic Sea)

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Fifty four samples of bottom sediments were collected in the coastal zone and the deep-sea area of the Baltic Sea Proper at the stations from 3 m to 215 m depth during expeditions of 2015-2016. Among the samples, different types of mud, slightly gravelly muddy sand, sandy mud, and sands are present. In order to extract microplastic particles (1-5 mm), the analysis of samples was carried out by modified NOAA method, using for quality control the adding of artificial reference particles (ARPs) to marine sediment sample before the extraction procedure. Several samples (16) were treated by the standard NOAA method. The analysis showed that not all microplastics objects float up during the separation, some amount of microplastics remain in the sediment. Reasons are such as biofouling, the presence of fuel oil / paraffin, which create a sticky film. For better and more complete extraction of microplastics from the samples, the repetition of the separation steps was used, and the washing of muds and mud sands through a cascade of filters. Preliminary analysis shows that the concentration of microplastics is: from 0 to 194 items per kg DW for particles, from 0 to 1117 items per kg DW for films, and from 0 to 2239 items per kg DW for fibres. Minimum values correspond to the results of the analysis of samples that were obtained predominantly with the standard method of NOAA. The research is supported by the Russian Science Foundation, grant number 15-17-10020 (project MARBLE).

## P253 - The new Instrument development for suspended material sampling and in-situ microplastic detection

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Invading of microplastics in marine environment is known as a recent ecological threat. Existing methods of microplastic detection require sampling activities and laboratory treatment, but such approach is very expensive to illustrate a wide scale of patterns of microplastic migration. We undertake activities to develop the instrument called PLEX (PLastic EXplorer), which was designed for on-line sampling of suspended material from surface and bulk seawaters with In-Situ microplastic detection. PLEX poses a highly efficient pass-through filter equipped with a rotary pump, intake and outtake manifolds. A sampling filter and an optical in-situ detector are mounted on the outtake manifold for detection of microplastics and further laboratory control. Feld tests of PLEX and laboratory tests of optical detector have been maintained by now. The test data concerning bulk sea water sampling and optical detector calibration will be presented at the conference.

The research is supported by the Russian Science Foundation, grant number 15-17-10020 (project MARBLE).

PERMANENT PRESENTATION AT THE ATRIUM

## BALTIC EARTH - EXTENDING THE KNOWLEDGE OF THE REGIONAL EARTH SYSTEM IN THE BALTIC SEA REGION

Reckermann, M., Meier, H.E.M., Rutgersson, A., Aigars, J., Berger, F., Dailidienė, I., Haapala, J., Kulinski, K., Lehmann, A., Myrberg, K., Omstedt, A., Partasenok, I., Post, P., Rehder, G., Schrum, C., Smith, B., Stendel, M., Weisse, R., Zhuravlev, S.

The goal of Baltic Earth is to achieve an improved Earth system understanding of the Baltic Sea region with a holistic focus encompassing processes in the atmosphere, on land and in the sea, as well as processes and impacts related to the anthroposphere. A Baltic Earth Science Plan was established in 2016, with a definition of core research questions, so-called "Grand Challenges". They are currently:

- Salinity dynamics in the Baltic Sea
- Land-Sea biogeochemical linkages in the Baltic Sea region
- Natural hazards and extreme events in the Baltic Sea region
- Sea level and coastal dynamics at the Baltic Sea
- Regional variability of water and energy exchanges in the Baltic Sea region
- Multiple drivers for regional Earth system changes in the Baltic Sea region

The Grand Challenges are intended as flexible, regularly updated research topics and will be dealt with by specific working groups. Additional working groups deal with "Regional Climate System Models", "Scenario Simulations for the Baltic Sea 1960-2100", "Outreach and Communication" and "Education". The human impact shall be assessed at all levels, wherever reasonable. New Grand Challenges and modifications of existing ones can be implemented by the international steering group and the working groups, by using assessments of existing research and knowledge, and the open discussions at conferences and workshops. Baltic Earth is internationally embedded, collaborating with similar regions in Europe and the world. Baltic Earth intends to provide a "service to society" in the respect that assessments on specific topics provide an overview of knowledge gaps, and the communication with different stakeholders may help to identify open scientific questions relevant for society. A major tool of communication and collaboration within the scientific community and outreach beyond is the organization of meetings, seminars, workshops and conferences on specific topics. Baltic Earth is committed to educational activities with the establishment of regular Baltic Earth Summer Schools, the first two of which took place in 2015 and 2016. Every two years, the Baltic Earth community comes together at a dedicated Baltic Earth Conference, the first of which took place in Nida, Lithuania, with the grand topic of "Multiple drivers of Earth system changes in the Baltic Sea region". The Second Baltic Earth Conference will be in Helsingør, Denmark, in 2018. This presentation will provide the background and an overview of the recent activities of Baltic Earth.

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