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BALTIC SEA DAY 2021

Baltic Sea Centre | Stockholm University

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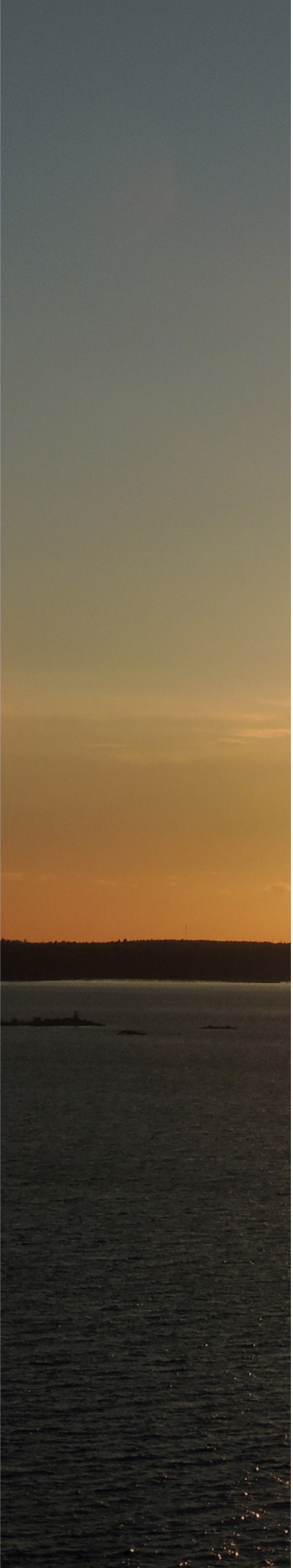
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OCTOBER 7, 2021

# Baltic Sea Day

## – Highlights frontier research on our unique sea

Less than a kilometre away from campus, the coastline meets the Baltic Sea. This, geologically considered, very young sea is one of the largest brackish water areas in the world, with hydrological properties that makes it home to a small but completely unique set of habitats and species; many of them has undergone an extremely rapid evolution.

Connecting nine countries along the entire coastline, the Baltic Sea also has a long history as a centre for trade and maritime affairs, which have been, and to date still is, key factor for economic growth in the region. Thus, this sea is a closely interconnected part of our society. But it is no news that the Baltic Sea faces a wide range of pressures and challenges, as a consequence of the life styles of this densely populated area.

At Stockholm University researchers have studied the Baltic Sea and its challenges in diverse disciplines and with different approaches, since the 1960's. The majority focus on scientific issues that are important for a better understanding and management of the Baltic Sea and its catchment area, and several research fields are considered world leading. During this day, we showcase the broad set of expertise at Stockholm University by having 19 of our colleagues explaining their recent research – ranging from source to sea.

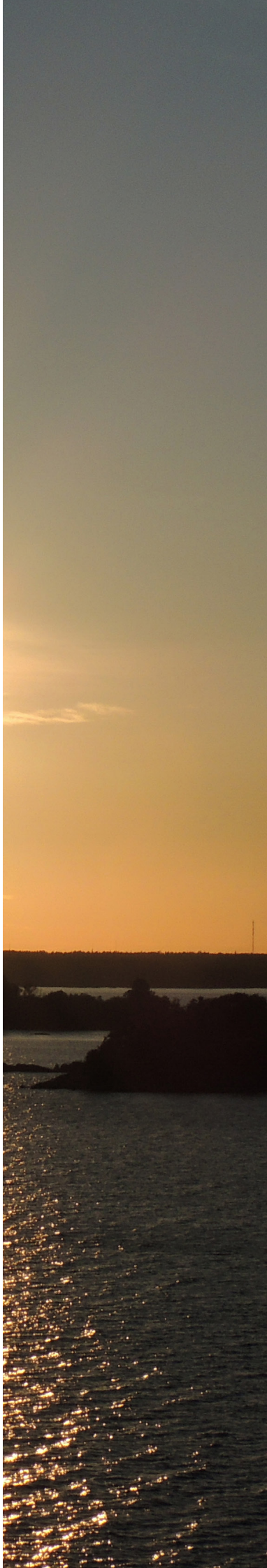
We want the Baltic Sea Days to inspire you who work with marine research at Stockholm University, to stay updated on research news and perhaps even find colleagues at other departments with expertise that can be useful to broaden or complement your own research.

*Warm welcome*

*/Baltic Sea Fellows & Stockholm University Baltic Sea Centre*

## Baltic Sea Fellows

As part of the governmental funding of strategic Baltic Sea research, a new interdisciplinary network of young Baltic Sea researchers has been established at Stockholm University for the period 2018-2022. This network, consisting of eleven researchers from seven departments at the university, perform cross-disciplinary projects concerning environmental challenges in the Baltic Sea.



# BIODIVERSITY AND ECOSYSTEM FUNCTIONING


Photo: Hans Kautsky/Azote

*With its harsh physical and oceanographic properties, the Baltic Sea is home to a unique assemblage of species, ecological functions and trophic interactions. In fact, some of these are only found in this area. The diversity on all these levels impact the resilience of the entire ecosystem, and there is still much left to understand about relationships between biodiversity and ecosystem functioning during environmental change. In this session, we will go into mechanisms that control seasonal changes in plankton communities and genetic variation as well as growth in herring, the effect of protective measures on fish communities in bays and what breeding strategies seals use to cope with the lowered ice coverage that follows from a changing climate.*

**09.10 – 10.40**

Speakers:

- **Monika Winder**
- **John Taylor**
- **Henrik Svedäng**
- **Johan Eklöf**
- **Anja Carlsson**

## BIODIVERSITY AND ECOSYSTEM FUNCTIONING

# Biotic interactions of Baltic Sea plankton communities identified by DNA metabarcoding and network analysis

*Monika Winder, Andreas Novotny, Baptiste Serandour & Kinlan Jan, Department of Ecology, Environment and Plant Sciences*

Plankton communities are characterized by diverse biotic interactions that drive seasonal population dynamics and guarantee ecosystem functions. Yet, the diversity of biotic interactions has seldom been described in natural plankton communities. Here we identify biotic interactions of dominant zooplankton species of the Baltic Sea community and ask how plankton interactions vary in relation to change in prey assemblage and seasonal environmental conditions. We used selective DNA metabarcoding of targeted consumer species and emphasized their trophic interactions over temporal and spatial scale, and integrate these findings in network models to quantify plankton interactions. Our data show that zooplankton exhibit differential feeding strategies that vary among species and location but also between seasons and depth strata. Detritivores and filter feeders play an important role and capitalize on filamentous cyanobacteria that likely reduce sedimentation to the seafloor. Moreover, small-sized zooplankton, consisting mainly of rotifers fill an important functional role in energy pathway from primary producers to fish and occupy important and unique niches at times when crustacean biomass is low. Overall, these feeding strategies are, however, not necessary linked to size-based structure of the communities, an approach that is often used in ecosystem modelling. Combined, this approach provides novel knowledge of energy pathways at the base of the food web, which is important to advice ecosystem management for sustainable fisheries and prevention of algal blooms.



*Monika Winder*

## BIODIVERSITY AND ECOSYSTEM FUNCTIONING

# Reevaluating the age-0 herring bioenergetics model

*John Taylor, Sture Hansson & Agnes Karlson, Department of Ecology, Environment and Plant Science*

Herring (*Clupea harengus Lineaus*) has been shown to influence the Baltic Sea zooplankton community through predation, with age-0 individuals contributing most to overall population consumption. Due to the importance of the age-0 class, a previously described herring bioenergetics model was tested against actual observed growth and further modified. A growth model, incorporating daily food consumption predicted by a functional response curve and ambient zooplankton densities, in combination with the cost functions of the age-0 bioenergetics model, failed to reproduce observed growth. By modifying the respiration function in the model and assuming that herring were inactive at night, the correct end mass and a more realistic growth trajectory was predicted, both when consumption was determined from the functional response and when consumption was a constant fraction of the maximum food consumption rate. With the bioenergetics model developed in this study, the estimated food consumption of an individual age-0 fish was re-evaluated. This model is unique in that diel variation in activity is considered as well as using in situ growth data and the functional response of food consumption to zooplankton abundance to tune the model. This example shows the importance for continued testing of a bioenergetics model as new data become available.




*John Taylor*

## BIODIVERSITY AND ECOSYSTEM FUNCTIONING

# Understanding population separation mechanisms in the herring complex on the Swedish east coast

*Henrik Svedäng, Stockholm University Baltic Sea Centre & Erik Isaksson, Department of Ecology, Environment and Plant Sciences*

The definition of populations is central to ecology and evolutionary biology. Although the concept has been established for more than a century, we still have a poor understanding of the mechanisms leading to population subdivision.

For marine fishes with free-floating early life stages, two mutual opposing ecological mechanisms for population subdivision have been suggested: natal homing of mature fish or physical forcing on the dispersal of early life stages; i.e. are fish populations behavioural entities or environmentally driven? Thus, population separation mechanisms are both an essential scientific issue and crucial for sustainable fishery management. For instance, the pace of colonisation will depend on the mode of population separating mechanism, and in the case of natal homing new behavioural patterns need to develop.

In this project, we will study population identification and separation mechanisms in marine fishes using the herring population complex in the Stockholm Archipelago. We will use a combination of herring larvae surveys to determine spawning activity in the area and otolith trace element analysis, and finally contrasting the results with population genomics analysis. The Stockholm Archipelago represents an excellent area to test hypotheses about population separating mechanisms: there are still many herring spawning aggregations with a varying degree of connectivity, and rich in environmentally-related contrasts that may be mirrored in otolith signals.



*Henrik Svedäng*

## BIODIVERSITY AND ECOSYSTEM FUNCTIONING

# Effects of seasonal fishery closures on shallow coastal fish and food webs

*Johan Eklöf et al, Department of Ecology, Environment and Plant Sciences*

Marine protected areas (MPAs) are a common and effective type of measure to reduce human impacts on deteriorating marine populations and habitats. Recently, many countries including Sweden have pledged to increase protection to 30% of national waters by 2030. However, implementation of MPAs that permanently ban fisheries has often generated infected conflicts, threatening MPA efficiency and undermining societal trust. A potential alternative that is often seen as less controversial are temporary MPAs, where species and/or habitats are protected from destructive activities during certain time periods like sensitive fish spawning seasons. However, knowledge about the effects of temporary MPAs, especially effects that go beyond target species in fisheries, is limited. Here, we assessed the influence of small seasonal fishery closures created in Stockholm archipelago, using field surveys in 12 closures and 12 paired reference sites. Experimental angling for pike (*Esox lucius*) – the main target species in recreational fisheries and the largest piscivorous fish in the area – generated 2-3 times higher catches per unit effort in closures than reference areas. This result may be caused by higher abundances in the seasonal closures, and/or fishery-induced behavioral changes (reduced catchability) in reference areas, both indicative of protection effects. Meanwhile, the more abundant perch (*Perca fluviatilus*), as well as pike prey species like roach (*Rutilus rutilus*) and three-spined stickleback (*Gasterosteus aculeatus*), for which we expect indirect protection effects, were unaffected by closures. Likewise, a hypothesized trophic cascade from perch to zooplankton via stickleback was supported by the data, but appeared unaffected by protection. In summary, our results suggest that small seasonal fishery closures may benefit abundance and/or behavior of pike; an important finding given the escalating decline of coastal pike populations. However, closure effects on other fish species and other trophic levels were either absent or too weak to be detected, suggesting that permanent no-take closures may be needed to generate ecosystem-level effects.



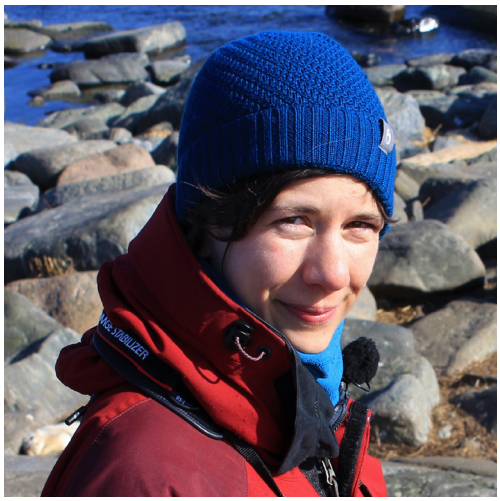
*Johan Eklöf*

## BIODIVERSITY AND ECOSYSTEM FUNCTIONING

# Grey seal pupping in the Baltic

*Anja Carlsson & Markus Ahola, Environmental research and Monitoring, Swedish Museum of Natural History*

Grey seals (*Halichoerus grypus*) in the Baltic Sea have recovered from a population of only a few thousand in the 1970s to a population of around 60 000 today. They are unique among the pinnipeds in that they breed on free floating pack ice, land-fast ice and on land. However, the extent to which they breed on land along the Swedish coast is unknown. Land breeding will likely become more important for the continued survival of this species in the future as the extent and quality of the sea ice decreases as a result of climate change. Identifying land breeding sites and ensuring that they continue to be available for grey seals and protected is therefore important. Here we present results from the first comprehensive aerial inventory of on land pupping sites of grey seals. Compared with a smaller survey conducted in 2001 several new land pupping locations have been identified.



*Anja Carlsson*

# REMOTE SENSING TECHNIQUES FOR WATER RESOURCE ASSESSMENTS


Photo: Danksten/Mostphotos

*The climatic and human-driven changes occurring across the Baltic Sea basin have impacted freshwater entering the Baltic Sea and the amount of water-borne elements transported by it. The draining of wetlands, river regulation, agriculture expansion and forestry management over the past 200 years are some human activities driving these changes. Besides in-situ monitoring, hydrologic and biogeochemical modelling and remote sensing products and techniques can help understand the magnitude and relevance of these changes. In this section, we will focus on specific studies using these technologies to elucidate changes in water resources and the drivers of water inputs into the Baltic Sea. Furthermore, such technologies can help restore and conserve important aquatic, terrestrial and marine ecosystems and the management of pollutant and nutrient loads into the Baltic Sea.*

**11.00 – 12.10**

Speakers:

- **Farzad Vahidi Mayamey**
- **Noemi Marsico**
- **Mehri Tabarmayeh**
- **Saeid Aminjafari**

## REMOTE SENSING TECHNIQUES FOR WATER RESOURCE ASSESSMENTS

# Improving water extent monitoring of Swedish wetlands with open-source satellite data and Google Earth Engine

*Farzad Vahidi Mayamey, Saeid Aminjafari & Fernando Jaramillo, Department of Physical Geography*

Wetlands are strategic ecosystems that provide a variety of services to humans and the environment. As climatic and anthropogenic drivers have affected wetlands in recent years, there is a need to monitor this valuable ecosystem better. In Sweden, there are 68 sites recognized as wetlands with international importance with Baltic coastal wetlands accounting for roughly a fourth of them. In this condition, water delineation is vital to understand wetlands' water availability changes and strengthen their resilience to the effects of human activities and climate change. Recent advances in remote sensing have improved the monitoring of wetlands; however, mapping their water extent is still challenging. Water below vegetation is difficult to recognize, and its changes remain hidden. Here, we used different polarizations of SAR and optical data of 10 m ESA Sentinel-1&2 satellites. We processed this data in the cloud computing platform of Google Earth Engine (GEE) and took advantage of machine learning clustering methods to detect the increased backscatter due to the double-bounce of the radar signal on flooded vegetation. We also analyzed the interferometric coherence increase as a sign for inundated vegetation. Furthermore, we used the thresholding method in the SAR images to extract open water extent. Finally, we compared the results to high-resolution optical images and field data. Our workflow found areas with water below vegetation not recognized by optical methods, improving the water extent delineation in Swedish wetlands. Hence, we recommend combining polarimetric features of Radar data, optical data, and interferometry to fully account for wetland and water extent, improving the quantification of the world's surface waters.



*Farzad Vahidi Mayamey*

## REMOTE SENSING TECHNIQUES FOR WATER RESOURCE ASSESSMENTS

# Remote sensing application to evaluate the relationship between discharge and water quality on the Swedish Baltic Coast

*Noemi Marsico, Fernando Jaramillo, Department of Physical Geography & Susanne Kratzer, Department of Ecology, Environment and Plant Sciences*



*Noemi Marsico*

The coastal areas of the Baltic Sea are under severe anthropogenic stress due to intense agriculture and other damaging human activity. Monitoring and assessing the main contributors of freshwater inputs is fundamental to safeguard marine ecosystems and guarantee continued access to marine resources. Suspended particulate matter (SPM) is one of the main optical constituents in coastal waters and a key indicator of coastal water quality from Space. SPM concentration reduces the penetration of solar irradiance within the water column and limits the photosynthetically available radiation. As a result, SPM may affect the development of phytoplankton biomass in the water body. Studying the concentration of chlorophyll-a as a proxy of phytoplankton biomass is optimal to evaluate the effects of SPM inputs in terms of water quality. This research studies the concentration and distribution of SPM and Chl-a caused by inputs from the unregulated Öre river (north of Sweden). We aim to identify the plume of SPM and Chl-a from the Öre River and on the Baltic Sea (Bothnian Sea). We extracted monthly averaged data for particulate backscattering coefficient (bbp) and Chl-a from the sensors MODIS, onboard the NASA's Aqua satellite, and OLCI, onboard the ESA's Sentinel-3. In the MODIS analysis, we compare data for high and low discharges events, 2018 and 2020 during May. We found a low correlation between river discharge and concentration in the water body, indicating a low influence of the Öre river on SPM and Chl-a at 30, 60, and 90 km from the coast. For the second analysis, daily OLCI Level 2 data were collected from ESA's Copernicus data archive for a more refined analysis of the Öre estuary. The results showed a strong correlation between discharge and SPM and Chl-a concentration and extent area of dispersion in May 2018. Furthermore, episodes of high runoff, occurring at the start of the month, coincided with high SPM plumes and an increase in Chl-a, which may be explained by increasing nutrient supply during high runoff. The difference between MODIS and OLCI results can be explained by the different products acquired. Level 3 MODIS products were monthly averaged values (4 km resolution), which gave a much broader understanding of SPM and Chl-a concentration and dispersion. This poses a problem in coastal waters, as a coastal pixel is likely to include mixed land-water pixels, thus influencing the data quality and analysis. OLCI data level 2 provided instead information at 300 m spatial resolution and daily temporal resolution. OLCI thus allowed the study of the Öre Estuary on a much shorter time and spatial scale.

Overall, the research showed that the Öre River originates a plume of SPM and Chl-a that extends offshore into the Baltic Sea (Bothnian Sea) waters, especially in the sea area close to the coast. Thus, the study improves the scientific research on the Bothnian Sea by providing a better understanding of the linkage between freshwater inputs and water quality.

## REMOTE SENSING TECHNIQUES FOR WATER RESOURCE ASSESSMENTS

# Predicting groundwater levels in Gotland island, Sweden, with time series modeling

*Mehri Tabarmayeh, Department of Physical Geography*

Southern Sweden has experienced over recent years a critical decrease in groundwater levels during summer. This decrease also applies to the island of Gotland, suffering from water scarcity in the summer due to the water demand required by seasonal tourism and agriculture. Hence, the importance of groundwater resources in this area requires forecasting and predicting groundwater levels and their fluctuations to preserve and sustainably manage this virtual resource. We here use the time series modeling approach to predict future groundwater levels in Gotland. We applied a seasonal Autoregressive Integrated Average (SAIMA) technique called the Box-Jenkins multiplicative seasonal model to predict groundwater levels in central Gotland, based on groundwater level data available during 1968-2019 from the Geological Survey of Sweden (SGU) were used to perform the model. Various types of SARIMA model by changing hyperparameter were applied on groundwater level data and then the Akaike information criterion, the residual autocorrelation function (ACF), and PACF (Partial autocorrelation function) options were used to compare the performance of each model. Results indicated that the appropriate model fitted on groundwater level data is SARIMA (0,1,1) *(1,1,0)12 model. Based on this model, the forecasting behavior of the groundwater table up to the year 2025 showed that it continuously falls with a significant trend over time.



*Mehri Tabarmayeh*

## REMOTE SENSING TECHNIQUES FOR WATER RESOURCE ASSESSMENTS

# Water Level Changes in Small Lakes in Sweden Using High-Coherence Pixel Interferometry

*Saeid Aminjafari & Fernando Jaramillo, Department of Physical Geography and Bolin Centre for Climate Research*

Lakes cover nine percent of Sweden; however, the water level is only monitored in 36 lakes due to economic and logistic constraints. Space technologies can fill this gap; however, we need to overcome the limitations of space-borne methods regarding scale and resolution. We exploit Interferometric Synthetic Aperture Radar (InSAR) to monitor water level changes in small lakes. While previous InSAR studies determining water level retrieve spatially relative water level changes between two locations, the novelty of this study measures absolute water level change in 30 small lakes not covered by altimetric sensors but monitored by the Swedish Meteorological and Hydrological Institute. We take advantage of the 6-day revisit time of the Sentinel-1 satellites and generate 40 short temporal-baseline interferograms for each lake from March to December 2019. We accumulated the phase change of all the pixels inside the lakes' surface area that exhibit a steady, coherent behavior in all interferograms. We find correlation coefficients between our water-level method estimates and in-situ observations ranging from 0.31 to 0.93. Based on geomorphological and vegetation similarity among lakes, we extended the methodology to ungauged lakes and selected the potential pixels that replicate water level changes. Moreover, the phase change of candidate pixels was compared with precipitation patterns in the lakes' basin area for validation purposes. This study shows that pixel-specific InSAR can monitor absolute water level change in lakes not covered by other conventional water level gauges and satellite altimetry.



*Saeid Aminjafari*

# EUTROPHICATION MANAGEMENT


Photo: Mattias Murphy

*The effects of eutrophication from anthropogenic activities is one of the core environmental challenges in the Baltic Sea. Successful measures to reduce the input from land have been implemented historically but the large amounts of nutrients accumulated in the sea makes recovery take time. Being one of the fastest warming sea regions, this process might be further delayed. We need to understand how this situation affects and is affected by ongoing climate change, not least in policy processes and management strategies concerning water quality goals. In this session we present quantification attempts to address legacy stores of nutrients, how the coastal water quality conditions are affected by land-sea and hydroclimatic interactions. We will also see how constructed wetlands can be assessed as nature-based mitigation solutions and take a look at a new framework for forecasting algal blooms.*

**13.00-14.30**

Speakers:

- **Benoit Dessirier**
- **Julián García**
- **Guillaume Vigouroux**
- **Samaneh Seifollahi-Aghmiuni**
- **Inga Koszalka**

## EUTROPHICATION MANAGEMENT

# Dynamics of Nitrogen legacies in agricultural landscapes

*Benoit Dessirier, Stockholm University Baltic Sea Centre*

Early efforts to mitigate eutrophication in the Baltic Sea have successfully targeted point sources of nutrient pollution for example by developing wastewater collection and treatment infrastructure, which typically leads to a rapid reduction of river nutrient loads. The remainder and, now often major part, of the loads comes from diffuse sources such as excess fertilizer and manure leaching from fields and pastures. Nutrient loads often show a slow, delayed response to measures targeting diffuse sources, sometimes over up to several decades. This is understood as the consequence of continued release of nutrient stores accumulated in the landscape under past agricultural practices, commonly denoted as "legacies". While the principle underpinning legacy effects is simple, the estimation of the magnitude of legacy nutrient stores and their dynamics at the scale of a watershed or a region is not an easy task, owing both to the spatial complexity of diffuse sources and to the variability of climate and in particular precipitation and drainage. Field measurements of soil nitrogen or concentrations in groundwater give valuable indications, especially if time series are available, but most of the work to understand the dynamics of legacies is left to models that try to reconstruct the history of legacy stores based on records and detailed estimations of land use alterations, agricultural nutrient surpluses and practices, as well as climate over the past 100 to 200 years. We present examples of ongoing attempts to quantify Nitrogen legacy stores in agricultural watersheds in Sweden (Mälaren region and Scania) and Denmark. Such local historical studies are a required stepping stone to later realistically predict responses to current and future agricultural policies in terms of nutrient loads to the sea.



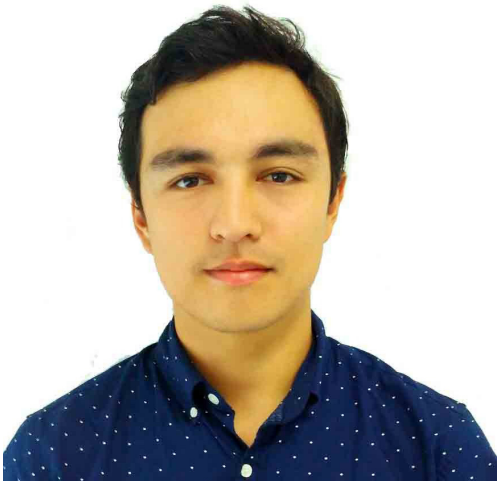
*Benoit Dessirier*

## EUTROPHICATION MANAGEMENT

# Assessing the retaining nutrient effectiveness of constructed wetlands as Nature-based Solutions in Sweden

*Julián García, Fernando Jaramillo, Department of Physical Geography & Sofia Wikström, Stockholm University Baltic Sea Centre*

Eutrophication in the Baltic Sea drainage basin has been one of the major environmental issues during the last century, partly due to extensive land-use change, loss of natural retention systems, and poor management. European legislation such as the Water Framework Directive attempts to guide the achievement of good ecological status from freshwater to the sea and suggests wetlands as ecosystems that can potentially contribute to achieving this goal. Constructed wetlands are considered remarkable Nature-based Solutions for improving water quality by diminishing nutrient loads. However, despite their implementation in Sweden, the national objectives to support wetlands thriving and halt eutrophication have not been achieved. Here, we design a set of criteria framed under the Nature-based Solutions and based on spatial analyses (wetlands' location and hydrologic connections) to assess the potential of constructed wetlands. We propose five spatial criteria on 541 constructed wetlands for nutrient retention in southern Sweden to qualitatively assess the potential. Our results showed that >56% of the wetlands have low to moderate potential as Nature-based Solutions, with the state of Skåne as the best performer. Furthermore, the potential of constructed wetlands as Nature-based Solutions has remained steady over time for most criteria; however, the agriculture area in the upstream watershed of the constructed wetlands has decreased in time. In combination with other assessment methods such as Water District Authorities eutrophication map or nutrient transport modelling, these qualitative criteria can support decision-making processes and help fulfil the national and European eutrophication goals.



*Julián García*

## EUTROPHICATION MANAGEMENT

# Investigating land-sea and hydroclimatic linkages for coastal eutrophication management in the Baltic Sea

*Guillaume Vigouroux, Department of Physical Geography*

Eutrophication threatens coastal ecosystems worldwide, including in the Baltic Sea, where coastal waters are influenced by hydroclimatic, land and coastal drivers and feedbacks, but also by eutrophied open sea conditions. This presentation synthesizes my thesis work aiming to further deepen our understanding of how these drivers simultaneously affect coastal water quality, which is necessary for implementing management strategies and measures to reduce coastal eutrophication. This has been tackled through water quality models applied to specific coastal areas, and analysis of water quality variable and driver trends for the past 30 years over the Swedish coast, and of the scientific literature on Baltic coastal eutrophication.



*Guillaume Vigouroux*

Throughout this work, we have found that (i) effects of open sea water quality improvements propagate to substantial areas of the coastal waters while those of land-based nutrient reductions are more localised. Both local land- and regional sea-based reductions are therefore needed to reduce coastal algae, nitrogen and phosphorus concentrations. This is emphasised further by data analysis, where trends in coastal summer chlorophyll a (Chl-a), a proxy for algal biomass and eutrophication, are well correlated to trends in riverine nitrogen load and in open sea Summer Chl-a. (ii) Remediation of coastal eutrophication is further found to be easier under drier and colder hydroclimatic conditions and more complicated to achieve under wetter and warmer ones. Moreover, trends in sea-ice are well correlated with trends in Summer Chl-a. These results show that coastal waters are a melting pot of drivers and conditions from the land, the coast itself, and the open sea, as well as from climate. (iii) The complexity of the coastal system in term of its drivers, coastal functions and management is mostly well-represented in the scientific literature, but feedbacks between eutrophication drivers and impacts in the coupled land-coast-sea continuum and measures for their management are often understudied.

In conclusion, increasingly important shares of legacy nutrient inputs from land, but also from sediments and the open sea, create time lags between remediation at the source and observed coastal load reductions. This calls for more research on coastal remediation measures, such as wetlands and mussel farming, which are understudied even though they may be effective also against legacy sources. Finally, management of coastal eutrophication requires consideration of local coastal conditions, influenced by multiple drivers, feedbacks, and interactions with larger-scale regional conditions.

## EUTROPHICATION MANAGEMENT

# Systems thinking approach for integrated understanding of land-sea interactions in the Baltic region

*Samaneh Seifollahi-Aghmiuni, Zahra Kalantari & Georgia Destouni, Department of Physical Geography & Bolin Centre for Climate Research*

Eutrophication in the Baltic Sea is largely driven by nutrient enrichment from human activities in hydrological catchments draining to the sea. In addition to current point nutrient sources, the retention and accumulation of excess nutrient in the soil, slow-moving subsurface flows, and sediments over time form diffuse legacy sources on land that contribute also slowly and continuously to nutrient loading into and eutrophication of the Baltic Sea. In addition, regional climate change and associated shifts in inland hydrological and coastal-sea conditions affect the land-sea interactions and pose additional risks to the health of the Baltic Sea, which in turn feed back to inland societal and ecosystem conditions.



*Samaneh Seifollahi-Aghmiuni*

To support effective land-sea integration in coastal regions, this research considers coastal regions as coupled land-sea systems where human activities, physical and environmental processes, and their associated consequences on land and at sea interact. The Norrström drainage basin, its surrounding coastal areas, and the associated marine basin of the Baltic Sea are used as the study region and a systems thinking approach is followed by engaging relevant stakeholders to explore opportunities for water quality improvement and sustainable development in this coastal region. As such, dynamic interactions in the complex land-sea system of the coastal study region are analyzed in fuzzy scenarios to test and assess possible shifts in coastal water quality conditions under climate and socio-economic changes. Such shifts can only be resulted from synergistic strategies and measures across the whole Baltic Sea region, involving mitigation of the potential dominant contribution of nutrient/pollutant legacy sources to the water bodies in the study area. These analyses can provide a basis to prioritize key land-sea interactions involved in coastal and marine water quality challenges and effectively address them in developing synergistic regional management and development plans.

*Acknowledgement*

*The research was funded by the European Union's Horizon 2020 research and innovation program under grant agreement N° 77378261 (COASTAL project.).*

## EUTROPHICATION MANAGEMENT

# The surface drift and algae blooms in a changing Baltic Sea climate

*Inga Koszalka, Department of Meteorology & Agnes Karlson, Department of Ecology, Environment and Plant Sciences*

Algae blooms, specifically cyanobacterial blooms, are frequent in the Baltic Sea and pose major environmental problems for the marine ecosystem and coastal societies. Surface accumulations of algae downgrade esthetic values of the sea but can also limit access to oxygen and be toxic to humans and marine life. They affect marine services including drinking water resources, marine operations, tourism and fishing. Monitoring of algae blooms based on satellite-borne and in-situ data have been ongoing for years. Reliable forecasts are still lacking however due to the complexity of physical and biological processes involved in algae growth and too sparse data to constrain complex marine ecosystem models. As the algal blooms are expected to intensify under the observed long-term warming of surface waters, developing relevant forecasting models is a priority.

Our interdisciplinary collaboration takes up the tantalizing task of building a framework tailored for forecasting of algae blooms in the Baltic Sea. The framework will rely on numerical simulations of Lagrangian (drifting) trajectories and a Lagrangian ecosystem model which will be tuned based on available data. The first step toward this goal consists of collecting observations of the surface drift in the Baltic Sea relevant to the dispersion of algae accumulations. To this end, we deployed 6 innovative CARTHE Smart surface drifter platforms close to the slope of the Landsort Deep in August 2021. These drifters were designed to sample sea currents closer to the surface compared to other standard drift and dispersion measurements, and their floating parts are biodegradable. We will present data from this experiment and show how these can be used to evaluate numerical simulations of algae drift. The drifter project is a collaboration between the Bolin Centre for Climate Research (RA3 Spring 2021 Call) and the Stockholm University Baltic Sea Centre (Baltic Sea Fellows Program).



*Inga Koszalka*

# MULTIPLE STRESSORS AND ASSESSMENT TOOLS



Photo: Magnus Fyhr/Mostphotos

*The Baltic Sea is a good example of the challenges in managing a shared waterbody, where several nations and many different interests coincide. National and international agreements and regulations have so far only solved a few environmental problems. To assess the different drivers impacting the sea, a social-ecological perspective is needed, but how can this be done practically? In this session, we get introduced to a new teaching method that illustrate the complex environmental management challenges as a game and we take a look at the new Baltic Health Index framework for assessing marine health. We also go deeper into examples of anthropogenic effects such as ecological disturbance from bottom trawling activities, how plastic debris enters the Baltic Sea's food web via algae habitats and how contaminant exposure drives isotopic variation in biota.*

**14.50 – 16.15**

Speakers:

- **Clare Bradshaw**
- **Gastón Alurralde**
- **Hoi Shing Lo**
- **Torsten Blenckner**
- **Navid Ghajarnia**

## MULTIPLE STRESSORS AND ASSESSMENT TOOLS

# Suspension of sediment and release of nutrients by trawling on Baltic seabeds

*Clare Bradshaw, Department of Ecology, Environment and Plant Sciences*

Bottom trawling is a fishing method that disturbs the seafloor through direct contact of the gear with the seabed and through hydrodynamic drag entraining sediment. Although there is extensive data from other seas, the physical and biogeochemical impacts of bottom trawling in the Baltic Sea are not well understood. We measured the suspension of sediment and associated substances following the passage of a trawler, as well as quantifying sediment disturbance on the seafloor. For every kilometre of trawl track, 500 t sediment was displaced on the seafloor and at least 10 t suspended into the water column up to 10-15 m above the seabed. The sediment cloud contained particulate nutrients and remained in the water for at least 4 days, spreading more than 1 km from the track. A short pulse of dissolved substances was released from the sediment porewater immediately after the trawling event. In a complementary field experiment, we also found changes in fluxes of nutrients and oxygen across the sediment-water interface up to 2 weeks after disturbance.



*Clare Bradshaw*

In areas with intense commercial trawling, frequent seabed disturbance of this type will not allow sedimentary processes to re-equilibrate between trawling events, but will maintain the seabed in a state of flux. This has the potential to affect nutrient cycling on large scales. Semi-permanent turbidity in the bottom water may also result, with negative impacts on marine life. The EU Marine Strategy Framework Directive specifies that “seafloor integrity” (e.g. physical, chemical and biological characteristics and ecosystem processes) should be safeguarded to ensure that the structure and functions of benthic ecosystems are not adversely affected. The role of bottom trawling needs to be considered in this context, as well as when planning marine protected areas.

## MULTIPLE STRESSORS AND ASSESSMENT TOOLS

# Reproductive disorders and contaminant exposure drive isotopic variability in *Monoporeia affinis*

*Gastón Alurralde et al, Department of Environmental Science*

Stable isotope (SI) signatures for carbon (δ13C) and nitrogen (δ15N) are commonly used in trophic ecology, including dietary niche analysis. However, one of the main assumptions involved in the data interpretation is that the physiological condition of the animals has a relatively low effect on the fractionation values. Here, we assessed the variability of SI signatures and the associated Layman niche metrics of the sentinel amphipod *Monoporeia affinis* collected in uncontaminated (Askö) and contaminated (Bråviken) sites in a coastal Baltic Sea area. Moreover, the health status was assayed in the gravid *M. affinis* females using embryo aberration analysis, classifying the females as healthy or unhealthy based on the frequency of their embryo malformations. We found that amphipods in poor health status had higher isotopic variability, resulting in niche metrics distortions. The unhealthy females from both sites showed an apparent niche expansion, with the breadth and shape of the ellipses in the δ-space significantly different among the sites. Furthermore, unhealthy Bråviken females had a higher δ13C and δ15N variability compared to those from Askö, together with a much steeper slope for the relationship between the isotopes, indicating a response conditioned by the contaminant exposure. Thus, dietary niche estimates can be affected by the physiological condition of the animals. Moreover, analysis of SI signatures can support the in situ assessment of the biological effects of contaminants.



*Gastón Alurralde*

## MULTIPLE STRESSORS AND ASSESSMENT TOOLS

# Plastic litter in macrophyte system: environmental fate and ecological implications

*Hoi Shing Lo, Department of Environmental Science*

Plastic pollution is ubiquitous in coastal ecosystems, including the Baltic Sea, and macrophyte beds with high conservation and economic values are at the forefront of the plastic littering. Recently, high sedimentation and fragmentation rates of plastic were reported from the macrophyte beds. We hypothesized that the microorganisms is the key component mediating the interactions between the plastics and biota as well as microplastic retention in the system. Using macroalga *Fucus vesiculosus*, we will test this hypothesis in the macrophyte habitat as an entrance point for microplastic in the food web in the Baltic Sea and evaluate the effects of microplastic exposure on the macrophyte templet functions, including energy transfer efficiency. To assess the ecosystem health risks posed by plastic litter, the project will also examine effects of microplastic and their leachates on plant physiology, growth, and metabolite production. This project will provide an understanding of the pathways, fate and effects of plastic debris in a macrophyte system as well as an approach to evaluate environmental impacts of persistent solid waste in the Baltic Sea.



*Hoi Shing Lo*

## MULTIPLE STRESSORS AND ASSESSMENT TOOLS

# Challenges to assess ocean health – examples from the Baltic Health Index

*Torsten Blenckner, Stockholm Resilience Centre*

Open oceans and coastal areas resources play an essential role in human well-being and are under high pressure with multiple and cumulative drivers affecting these ecosystem functioning, and the services they provide across scales. Under these circumstances assessment tools are required that include a social-ecological dimension with linked human and biophysical components that equally considers ecological, economic, and social objectives. Here, the Baltic Health Index (BHI) as the first transboundary application of the Ocean Health Index framework in a region with comprehensive international policies and monitoring frameworks will be presented. The BHI captures priorities and characteristics of the Baltic Sea by modifying certain goals and incorporating data with a high temporal and spatial resolution, using local reference points from already established international targets (including good environmental status for some conservation objectives), and developing detailed resilience information. The development of BHI incorporated the intensive spatial and temporal monitoring data that are collected by long-term national monitoring programmes operating the Baltic Sea. The BHI provides a good starting point to understand the Baltic Sea as a complex social-ecological system, and, importantly, can be repeated, built-upon, and fine-tuned since all analyses and decisions are coded and available online. The BHI assessment results will be discussed in the context of applying the index to advance EBM and in which way novel conditions may influence the recovery pathway and management objectives.



*Torsten Blenckner*

## MULTIPLE STRESSORS AND ASSESSMENT TOOLS

# Developing an Educational Negotiation Game for the Baltic Sea's Environmental Problems

*Navid Ghajarnia, Samaneh Seifollahi-Aghmiuni, Hanna Kreplin & Zahra Kalantari, Department of Physical Geography*

The Baltic Sea and its surrounding coastal regions are in poor environmental conditions. Extensive agriculture and shipping activities for tourism and fishing have increased the nutrient load and worsen the eutrophication of the Baltic Sea. Algae blooms reduce the level of oxygen in the water and overfishing contributes to these problems by changing the species composition and decreasing the overall marine ecosystem's biodiversity. These processes threaten the ecological condition of the Baltic Sea and decrease the recreational value of the coasts.



*Navid Ghajarnia*

Different actors are involved in these complex water quality and associated environmental problems, either by contributing to the problems or being affected by their consequences. National and international agreements and environmental regulations put in place for decades still have not managed to sufficiently solve the environmental problems of the Baltic Sea. With a shared understanding of these problems, possible solutions should be based on collaborations between various actors and possibly provide benefits for them while managing the problems. In addition, to establish actor collaboration for implementing potential solutions, relevant actors should agree upon those specific solutions.

In order to better understand the challenging situation of the Baltic Sea, we have developed a negotiation game named the Cross-Sectoral Negotiation Game for the Baltic Sea (CS-Baltic). This game aims to enhance the players' negotiation skills on how to leverage complexity to build win-win agreements and identify solutions for the above-mentioned problems within the Baltic region. It also aims to educate the players that a desirable environmental condition in the Baltic Sea region, can only be established through a real cooperation between all involved actors. Players will represent five sectors of: (1) Agriculture, (2) Fisheries, (3) Environmental Organizations, (4) Industry, and (5) government who are the main stockholders involved in the Baltic Sea environmental problems. They will negotiate on a specific solution or a combination of several solutions that will improve the environmental condition of the Baltic Sea. The goal of each player is to achieve the best possible condition in the region not only for themselves but also for other players, through compromising and collaboration.



Photo: Ulrika Brenner

## Baltic Sea Day 2021

At Stockholm University researchers have studied the Baltic Sea and its challenges in diverse disciplines and with different approaches, since the 1960's. The majority focus on scientific issues that are important for a better understanding and management of the Baltic Sea and its catchment area, and several research fields are considered world leading. During this day, we showcase the broad set of expertise at Stockholm University by having 19 of our colleagues explaining their recent research – ranging from source to sea.

## Baltic Sea Centre

Stockholm University's Baltic Sea Centre connects science and society. Our focus lies on the four main environmental challenges for the Baltic Sea: less eutrophication, sustainable fishing, reducing pollution from environmental contaminants and preserving biodiversity.

The Baltic Sea Centre consists of a unique combination of researchers, communicators and policy analysists who work to improve knowledge about the Baltic Sea and provide scientific support in policy decisions. At Stockholm University, marine research and education have been conducted for over six decades. One of our missions is to support and promote this well renowned science.

A focus of our international scientific work is to provide a unique decision support system that is used by the Baltic Sea countries to improve marine management. It thus has a key role in Helcom's Baltic Sea Action Plan.

**Science and communication with focus on the sea**

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