Stockholms universitet

Baltic Sea Fellows

Strategic Research Area funding

Progress Report for the period 2017-2020 and for the year 2021

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Background – Strategic Research Area funding to marine research at Stockholm University (HavSU)

Baltic Sea research to provide relevant scientific information to support ecosystem-based management of the Baltic Sea.

In 2009, the Swedish government decided to stimulate excellent science clusters in Sweden by offering increased research funding to clearly specified research areas. Stockholm University (SU) applied for five Strategic Research Areas (SRA). Three of the applications were successful. One of the funded programs was "The Baltic Ecosystem Adaptive Management" (BEAM), coordinated by Prof. Ragnar Elmgren, running between 2010-2014. The program focused on an increased collaboration between strong marine research areas at various departments, with the overarching aim being that an interdisciplinary approach would develop and support ecosystem-based management of the Baltic Sea environment. Five key areas and their interactions were identified: ecosystem functioning, nutrient enrichment, hazardous substances, climate change, environmental laws and management of the sea.

In 2015, all funded programs were evaluated by an expert panel, consisting of internationally renowned scientists with vast experience in research management as well as innovation policy assessment. The BEAM program was evaluated positively, and proposed to receive continued funding. However, the evaluation panel highlighted that the program lacked a "clear mechanism to engage stakeholders [and] it is impossible to see how transfer of research results can be effective".

During this period the Baltic Sea Centre (BSC) was formed by merging SU Marine Research Centre (SMF) and the Baltic Nest Institute (BNI) thereby joining two major marine groups at SU providing research infrastructure and numerical modelling skills. Further, with both external and faculty funds the BSC has developed a strong communication-policy team, Baltic Eye, in order to ensure an effective transfer of scientific results and knowledge to societal actors and decision-makers. This communication-policy perspective is today also often the starting point for the scientific work of the Centre, where the societal need for knowledge is prioritized when deciding the research questions.

For the continued SRA funding to marine research at SU (HavSU) the Faculty tasked the BSC in 2016 with handling and coordinating these funds. A proposal for 2017-2020 was presented for a strategic group consisting of two section deans from the Faculty of Science and the Deputy Vice President for Human Science, nominated by the Faculty Dean. The proposal was approved and followed by discussions on practical implementations with the involved heads of departments, further modifying and elaborating the proposed funding scheme.

Executive Summary

Stockholm University has a leading role in the field of marine research, especially in the Baltic Sea. The interdisciplinary research program "The Baltic Sea Ecosystem Adaptive Management" (BEAM) , including six departments with a strong marine research profile, was initiated 2010 with Strategic Research Area funding from the Swedish government. The overarching aim of the program was, and still is, to support ecosystem-based management decisions in society.

The strategic funds (HavSU), coordinated by the Baltic Sea Centre (BSC) since 2016, lies within one of SU's profile areas: "Climate, Seas and Environment". Now, as from the very beginning in 2010 with the start of the BEAM program, a strong focus lies on further strengthening marine research environments and increase interdisciplinary collaboration between the various departments at SU. This report summarizes how the strategic funding has been used in the period 2017-2021, with a special focus on its current and future strategic values and related activities:

• **The research network Baltic Sea Fellows (BSF) has been created primarily by funding tenure track positions at six different departments.** Today, BSF consists of senior lecturers, assistant lecturers and postdoctoral fellows adressing research issues ranging from ecosystem functioning to regulatory ecotoxicology and environmental law.

• **The BSF were formed as a team by part time affiliations (20%) of all tenure track positions at the BSC, allowing for joint meetings and interdisciplinary dialogues.** These part time affiliations were funded by BSC, beyond HavSU funding.

• **Depending on scientific focus and interest, BSC has supported the BSF with marine infrastructure for field work, competences in numerical modelling, policy and communication advice.**

• **All Baltic Sea Fellows have demonstrated excellent scientific progress, shown both in number of publications and in received external funding**; some have already been promoted during the period. The tenure track positions are also nodes for a growing number of other research affiliates, such as PhD-students, postdoctoral positions and collaborating researchers within and outside the department.

• Despite, or precisely because of the high pressure on tenure track positions to merit academically and individually, **several interdisciplinary collaborations have been developed among the fellows by conducting common field campaigns on the R/V Electra and drafting joint research applications.**

• **Apart from participating in the department's teaching several of the fellows take part in the interdisciplinary course "Baltic Sea Ecosystem: Applications, Modelling and Management", developed by BSC and administrated by DEEP.**

• **BSF jointly arrange the annual Baltic Sea Day, a SU wide scientific seminar with some 150-200 participants.**

• Several fellows have also **contributed significantly to scientific communication, consultations and seminars with stakeholders and decision makers,** coordinated by BSC.

• **Addressing climate change issues is an increasingly important part of the daily research work of all fellows.** For the further development of the BSFs network new research opportunities are provided by the newly launched strategic collaboration between SU and University of Helsinki (UHel); Coastal Ecosystem and Climate Research (CoastClim). The focus is to strengthen the collaboration between marine ecosystem and climate change research within and between the universities, to evaluate links between coastal biodiversity, carbon cycling and climate feedbacks (www.coastclim.org).

• **BSC has received funding from the Swedish Research Council (VR) for atmospheric research equipment at Askö laboratory and onboard the research vessel R/V Electra.** The strategic funds of 2021 will partly fund a facility manager in the coming years, building up this atmospheric research facility together with ACES, as well as a tenure track position within atmospheric sciences that will work together with the marine scientists to explore this important research area.

• **CoastClim will provide an overall framework for the BSF to further develop their research through various collaborations, excellent infrastructure, and policy and communication support in both Finland and Sweden.**

Tina Elfwing

Christoph Humborg

Team overview: Skills and research areas covered

The Baltic Sea Fellows research group today consists of senior lecturers, assistant lecturers and postdoctoral fellows at six different departments. Their research range from the biogeochemical conditions and circulation processes of the Baltic Sea to long term ecosystem and food web changes and how human activities on land affect the sea. This also includes research on policy instruments and legislation that regulate management on marine protected areas, fisheries and pollution.

Anna Christiernsson
Department of Law

Agnes Karlsson
Department of Ecology, Environment and Plant Sciences

Camilla Lienart
Department of Ecology, Environment and Plant Sciences

Christian Stranne
Department of Geological Sciences

Elias Broman
Department of Ecology, Environment and Plant Sciences

Fernando Jaramillo
Department of Physical Geography

Francisco Jardim de Almada Nascimento
Department of Ecology, Environment and Plant Sciences

Inga Koszalka
Department of Meteorology

Matthew Salter
Department of Environmental Science

Marlene Ågerstrand
Department of Environmental Science

Wei-Li Hong
Department of Geological Sciences

Xiaole Sun
Stockholm University Baltic Sea Centre

"My Baltic Sea research mainly concerns the role of law in governing complex and dynamic ecosystems and achieving environmental targets and the interplay between law and ecology.

My focus areas are fisheries and the legal protection of marine biological diversity, the ecosystem approach and seascape governance."

Anna Christiernsson
Associate Senior Lecturer
Department of Law
Joined in 2019

Anna is associate professor and assistant senior lecturer in environmental law at the Department of Law. She defended her PhD in environmental law at Luleå University of Technology in 2011 and have held a position at Uppsala University before joining Stockholm university in 2017, and becoming a Baltic Sea Fellow in 2019.

Her research interests revolve around the interplay between law, ecology, and governance where she has done substantial work on understanding fishing and protection of marine biological diversity in the Baltic Sea. "Law and seascapes in the Baltic Sea context" is Anna Christiernsson's ongoing research project on the subject. The purpose of the project is to bring new knowledge about how legislation should be designed to ensure that connections and ecological processes in the sea are taken into account in various forms of decisions that can affect the diversity of the sea. The research includes both assessments of how the law is (de lege lata) and how the law can be improved (de lege ferenda).

As a Baltic Sea Fellow, Anna collaborates broadly with other marine researchers on topics including the role of law in ensuring seascape linkages with a focus on planning instruments and MPAs, studying the network of marine protected areas in the Baltic Sea. She has also published on the efficiency of natural reserves as instruments to preserve and restore functional landscapes, the application of dispensation decisions (nature reserves, shore protection and dumping) on different governance levels and contributed to several policy briefs in the Baltic Eye series. Anna is just in the process of starting an additional PhD student on SRA funds.

"My research aims to advance our understanding of how individuals, populations, communities and ecosystems react and adapt to natural and anthropogenic stress such as eutrophication, over-fishing, contaminants, invasive species and climate change.

The long time-series of environmental monitoring in the Baltic Sea are especially important now as we are gathering new insights on how to manage the sea better, under a changing climate."

Agnes Karlsson
Associate Professor
Department of Ecology, Environment and Plant Sciences
Joined in 2018

Agnes received her PhD in Marine Ecology from Stockholm University in 2010 and is now associate professor and docent in Marine Ecotoxicology at the Department of Ecology, Environment and Plant Sciences. Her research combines traditionally separate disciplines in marine ecology such as food web ecology, biogeochemistry and contaminant science with particular interest in the effects of cyanobacterial blooms on the ecosystem. Studying these interactions during environmental change will help to improve ecosystem based management of the Baltic Sea.

She is currently the contract holder for the National Monitoring program for phytobenthos which started in 1993, a role that is closely associated with her research on long-term ecological research and co-analyses of monitoring data and archived biological samples which can be retrospectively analysed for biogeochemical tracers (stable isotopes).

As a Baltic Sea Fellow she recruited Baltic Sea Fellow Camilla Lienart as a PostDoc and collaborates closely with her on research where they have explored the use of stable isotopes in ecology, ecotoxicology and environmental monitoring.

Agnes has also collaborated with Baltic Sea Fellow Xiaole Sun on nutrient cycling among terrestrial, coastal and open sea systems.

In a recently initiated project, Agnes together with Baltic Fellow Christian Stranne and his PhD student Julia Muchowski link hydro- and bioacoustics methodology to better understand changes in fish communities during changing environmental conditions; together with Baltic Sea Fellow Inga Koszalka a forecasting system for cyanobacterial blooms (and their effects) is under development.

"An important research question for the Baltic Proper is to understand and mitigate the effect of climate changes and human activities on key species involved in ecosystem functioning.

One example is the blue mussel that I study, that play a key role in transferring and recycling nutrients and carbon from the water column to the sea floor."

Camilla Lienart
PostDoc
Department of Ecology, Environment and Plant Sciences
Joined in 2018

Camilla Lienart holds a PhD in Biogeochemistry and joined the Baltic Sea Fellows in 2018 from a previous position at the University of Bordeaux. She works at the boundary between biogeochemistry and marine ecology and collaborates closely with Baltic Sea Fellow Agnes Karlsson.

As a Baltic Sea Fellow, Camilla's research topic has been blue mussels and their role in transferring and recycling nutrients and organic matter particles from the water column to what mussels assimilate in their tissues - key mechanisms in coastal climate change processes that must be quantified in order to better understand the role of biology in carbon and nutrient cycles.

Camilla's research is focused on understanding the composition, dynamics and forcings of particulate organic matter in various marine coastal ecosystems. This includes tracing organic matter origin, dynamics and fate in coastal systems and especially its transfer to trophic networks. She aims to understand how natural or human induced long-term changes in organic matter quality affect food webs, and work with organic matter tracer tools like stable isotopes, CSIAA, fatty acids, mixing models and multivariate statistics.

"As a single researcher, it is often difficult to address the large overarching research questions. I'm interested in where and when our oceans can become hotspots for methane emissions to the atmosphere.

This is important because methane is a potent greenhouse gas, and increasing emissions could accelerate climate warming. This is, however, a complex task that requires broad interdisciplinary collaboration – the Baltic Sea Fellows provides a great foundation for such collaboration."

Christian Stranne
Assistant Professor of Marine geophysical mapping and modelling
Department of Geological Sciences
Joined in 2018

Christian Stranne received his PhD in Physical Oceanography from the University of Gothenburg in 2012, where he studied large-scale Arctic sea ice dynamics and coupled ocean-sea ice-atmosphere interactions.

He has since 2015 held positions at the Department of Geological Sciences, Stockholm University, and the University of New Hampshire, and became Assistant professor in Marine geophysical mapping and modelling at Stockholm university in 2018. As a Baltic Sea Fellow, Christian's main research interest has been around geophysical mapping with acoustic methods, and studies of large-scale climate warming-induced seafloor release of methane gas.

Together with other Baltic Sea Fellows, he has contributed to the development of hydro- and bioacoustics methodology.

Christian is also leading a research project aimed at developing a method for quantifying vertical mixing in the water column from wideband acoustic data. This project is a collaboration with turbulence experts at the Leibniz Institute for Baltic Sea Research in Warnemünde, Germany, and SMHI. He has also contributed to studies on predator-prey interactions in relation to the vertical distribution of oxygen in the water, and more recently, together with Baltic Sea fellow Agnes Karlson used acoustic methods to study Baltic fish communities.

"My research is focused on understanding how microbes adapt to climate change, their production and removal of greenhouse gases, biological cycling of nutrients, their interaction with other organisms, and how anthropogenic stressors such as eutrophication and industrial pollution influence microbial communities.

I use molecular data, typically large-scale sequencing of DNA and/or RNA in various projects, and the large variety of expertise among the Baltic Sea Fellows have made it possible to have a lot of fruitful collaborations."

Elias Broman
PostDoc
Department of Ecology, Environment and Plant Sciences
Joined in 2018

Elias Broman holds a PhD in ecology from Linnaeus University in Sweden, after which he was recruited as a PostDoc by Baltic Sea Fellow Francisco Nascimento in 2018.

Elias research is centered on how microbes adapt to climate change, and he uses molecular tools such as metagenomics and RNA-seq to investigate microbe communities and their metabolic activity. In collaboration with Francisco Nascimento, Elias conducted the first large-scale-study of benthic metazoan diversity in the Baltic Sea. This system was used as a case with which to understand how pressures such as eutrophication and climate change act on benthic diversity at a regional scale. Furthermore, Elias showed for the first time using RNA-seq data combined with microscopic visualization that nematodes are alive in Baltic Sea dead zones, which was reported in several national newspapers.

Elias has collaborated extensively with other Baltic Sea Fellows, typically involving the expertise by different persons, coupling e.g. geochemistry with microbiology. This has made it possible to broaden the studies and combine different kinds of results over scientific disciplines.

His findings show for example how salinity, oxygen, and interactions with macrofauna drive meiofauna biodiversity, and suggest possible future trajectories of benthic diversity in coastal habitats under multiple pressures. In a Baltic Bridge a collaboration between Stockholm and Helsinki University, Elias developed e-RNA methods whereby sequencing it with the latest PCR-free high-sequencing-depth technology, he could detect expected ecological responses of nematode, foraminifera, ciliate, and bacteria communities to anthropogenic pressure such as organic enrichment, gaining new molecular insights from Baltic Sea samples.

In another joint cruise within the Baltic Bridge he showed how sediment methane oxidizing bacteria and their activity is related to water depth and acoustic data of bubbling methane from the seafloor, a combination of data which was possible thanks to the different expertise within the Baltic Sea Fellows framework. These findings led to a successful FORMAS grant application.

"The Baltic Sea is much more than the sea itself. In order to understand key processes in the Baltic Sea, we must study those occurring in its hydrological basins, which is much larger than the sea itself.

In my research I use a source-to-sea approach in combination with hydro-geodetic tools to understand changes in water resources in the basin and deepen our understanding of climate change effects on water resources."

Fernando Jaramillo
Assistant Professor
Department of Physical Geography
Joined in 2019

Fernando Jaramillo joined the Baltic Sea Fellows in 2019; he holds a Ph.D. in Physical Geography from Stockholm University with a focus on hydrology and freshwater resources, and is currently Assistant Professor and Docent at the same Department. Fernando is also Research Leader for Hydrosphere, Cryosphere and Climate at the Bolin Centre for climate research and Head of the Water Resources, Permafrost and Environmental Systems at the Department.

He studies the historical effects of both climate change and land and water use on freshwater availability and changes, from local to global scales. His main areas of research are hydroclimatic change via de Budyko framework, human water consumption, and application of space technologies to understand changes and impacts on water resources.

During his time as a Baltic Sea Fellow, he has developed a group on Hydrogeodesy, which is the study of hydrological processes by the understanding of changes in the Earths water and ground surfaces from space. He now combines data from space missions - Synthetic Aperture Radar, altimetry, and optical data - to unravel the hidden changes in wetlands and small lakes in the Baltic Sea basin and South America.

"How will climate change affect ecosystem diversity and function in the Baltic Sea, and are there limiting mechanisms to climate change in the ecosystems that we somehow can leverage?

These are the type of questions I am interested in exploring further in interdisciplinary collaboration projects involving biogeochemists, climate scientists, and marine ecologists."

Francisco Jardim de Almada Nascimento
Assistant Professor
Department of Ecology, Environment and Plant Sciences
Joined in 2018

Francisco Jardim de Almada Nascimento is Associate Professor at the Department of Ecology, Environment and Plant Sciences at Stockholm university. The overall focus of his research is to understand how ecosystems respond to anthropogenic and environmental disturbances both structurally and functionally.

Francisco recruited Elias Broman as his postdoctoral fellow and together with him and other collaborators, they conducted a series of field studies using the latest DNA and RNA (including mRNA) sequencing technology and microscopy to investigate two main questions. The first concerned the diversity of microscopic animals in sediments affected by oxygen depletion and a first screening of the biochemical mechanisms allowing them to live in such habitats.

Francisco and collegues found nematodes to be metabolically active in hypoxic, anoxic, and euxinic sediments, albeit in very low abundances and with differences in diversity dependent on geochemical conditions. This work provided new insights into how benthic animals adapt to extreme conditions, which are projected to become more frequent in the future.

Another focus of Francisco and his group has been to understand how climate change can impact benthic ecosystems. Projected climate changes in settling phytoplankton quality and quantity, related to increasing cyanobacterial blooms, are likely to change not only benthic biodiversity and community composition, but also how nitrogen is cycled in the Baltic Sea.

Additionally, together with the other Baltic Sea Fellows Xiaole Sun, Elias Broman and Christian Stranne, Francisco is also investigating the biological drivers of methane cycling in Baltic benthic ecosystems.

"Turbulent ocean currents like coastal upwelling and eddies are apparent in satellite images of ocean color as they stir and mix algal blooms in the Baltic Sea. Ocean circulation affects biogeochemical processes and the marine ecosystem, but we still do not fully understand how.

I envision gathering an interdisciplinary research team that will use available measurements and models to predict the development of algal blooms in the changing Baltic Sea climate and their impacts on coastal societies."

Inga Koszalka
Associate Professor
Department of Meteorology
Joined in 2019

Inga Koszalka is Associate Professor of Coastal Oceanography at the Department of Meteorology, Stockholm University (MISU). She holds a MsC in Physical Oceanography from the University of Gdansk in Poland and a PhD in Fluid Dynamics from the Politecnico di Torino in Italy and joined the Baltic Sea Fellows in 2019.

The focus of Inga's research is on ocean circulation in the Baltic Sea and in the Nordic Seas and its interactions with the atmosphere and the cryosphere, as well the coupling of physical and biogeochemical processes. These timely questions require holistic and novel approaches combining theory, observations, idealized and regional ocean models, Lagrangian (flow-following) analysis and advanced statistical methods.

Inga's current project as a Baltic Sea Fellow, DriftBloom, relies on utilizing observations collected by the R/V Electra and deployments of novel surface drifters to quantify ocean transport and wind drift in the Baltic Sea, and to evaluate and develop existing ocean forecast models to predict algal blooms. For the latter task that involves combined modelling of ocean circulation and marine ecosystem modeling and observations, Inga collaborates with the Baltic Sea Fellow Agnes Karlsson. The DriftBloom project is also a collaboration between the Bolin Centre for Climate Research and the Stockholm University Baltic Sea Centre.

"The crux of my role is bringing together a network of cutting-edge expertise in marine ecology, biogeochemistry, geophysics and atmospheric physics to quantify the full spectrum of habitat-specific greenhouse gas fluxes and aerosol production in the Baltic coastal zone."

Matthew Salter
Head of Atmospheric Facility
Department of Environmental Science
Joined in 2022

Matt is head of the atmospheric facility at Stockholm University and is based at the Department of Environmental Science and the Baltic Sea Centre. He defended his PhD in Marine Biogeochemistry at the University of Newcastle, UK in 2010 and has held positions at both Uppsala University and Stockholm University before taking on the role of head of atmospheric facility in 2022.

His research centers around the interaction between the surface ocean and the atmosphere and, more specifically, the emission of matter from the oceans, in the form of sea spray aerosols, and how these aerosols can impact climate and transport pollutants.

A major focus of his work is establishing an air-sea interaction laboratory at the Askö laboratory along with a network of researchers with the aim of improving understanding in the connections between processes in the atmosphere and the marine biosphere. It is only through the formation of interdisciplinary networks like this that the grand environmental challenges we face, such as the global biodiversity and climate crises, can be solved.

"My research focuses on understanding the science-policy interactions in risk assessment and management of chemicals. I am especially interested in how risk assessors evaluate and use data in decision-making processes and the role of experts in the assessment and management of hazardous chemicals.

A better understanding of our policy processes and the role of science in decision-making can lead to more sustainable chemicals management of the Baltic Sea."

Marlene Ågerstrand
Assistant Professor
Department of Environmental Science
Joined in 2019

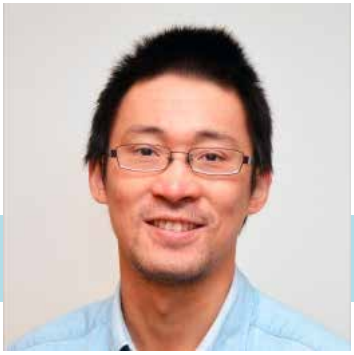
Marlene Ågerstrand is an Assistant Professor at the Department of Environmental Science at Stockholm University. She holds a PhD in Risk Assessment of Chemicals from the Royal Institute of Technology and joined the Baltic Sea Fellows in 2019.

Her research focuses on understanding the science-policy interactions in risk assessment and management of chemicals, and together with colleagues at Stockholm University and Karolinska Institutet, she has developed the web tool SciRAP which provides methods for the evaluation of toxicity and ecotoxicity studies for use in hazard and risk assessment of chemicals. Further, she has scrutinized chemical assessments performed under major regulations in the EU.

Marlene has a close collaboration with Dr Emma Undeman at the Baltic Sea Centre. Together they evaluate the functioning of the Water Framework Directive, with regards to how chemicals are handled to reach the goal of a non-toxic environment. She also works closely with the Baltic Sea Centre's policy officers to provide timely input on the current policy processes.

"I'm a geologist in the core and geochemist in the soul. I apply numerical models to quantitatively describe the geochemical observations in pore fluids, sediments and authigenic minerals.

The Baltic Sea is a interesting research area and the network of Baltic Sea Fellows provides a great foundation for collaboration."



Wei-Li Hong
Assistant Professor of Geochemistry
Department of Geological Sciences
Joined in 2019

Wei-Li Hong is Assistant professor of Geochemistry at the Department of Geological Sciences and joined the Baltic Sea Fellows in 2020. Wei-Li has a combined background in geochemistry and marine geology, and he applies numerical models to quantitatively describe the geochemical observations in pore fluids, sediments and authigenic minerals.

In 2021, Wei-Li recieved funding for the period 2022-2027 from Swedish Foundations' starting grant fellow-Ragnar Söderbergs stiftelse, to deepen the understanding of silicate alteration in marine sediments. On land, chemical weathering and reverse weathering involving silicate minerals are likely the most important processes controlling the long-term CO_2 concentration in the atmosphere and thereby, green house forcing. It is much less understood whether similar processes occur in marine environments and what the scale of such processes is, which this project will begin to examine as it commences during spring 2022.

Wei-Li closely collaborates with Baltic Sea Fellows Christian Stranne and Xiaole Sun on a number of topics regarding the silicate alteration in sediments and gas hydrate dynamics along continental margins.

"My specialty is isotope geochemistry and I am especially interested in understanding how the (bio)geochemical cycles of elements have evolved over time and how they respond to climate change and anthropogenic perturbation, with an emphasis on the sources and sinks to/from marine systems.

In the Baltic Sea, we have already obtained interesting observations of carbon and nutrient cycling through the Baltic Sea Fellows network."

Xiaole Sun
PostDoc
Stockholm University Baltic Sea Centre
Joined in 2019

Xiaole Sun received her PhD in Geochemistry at SU in 2012 and was a postdoctoral fellow at the Baltic Sea Centre before joining the Baltic Sea Fellows as a PostDoc.

Xiaole has collaborated with Baltic Sea Fellows Francisco Nascimento, Elias Broman, Wei-Li Hong to investigate the carbon cycle in the Baltic Sea catchment as well as deep sea sediments.

Together with Christoph Humborg, Francisco Nascimento Elias Broman, Xiaole found that high variability in the spatiotemporal distribution of greenhouse gas challenges the global budget of greenhouse gas emissions across vegetated coastal ecosystems.

In a project with Christoph Humborg and Agnes Karlsson, as well as researchers from University of Helsinki studying carbon and nutrient fluxes in benthic fauna, they found that shallow coastal zones may provide cross-habitat nutrient subsidies for benthic communities offshore when macrophyte matter can drift to deeper sediments. Using a triple-isotope approach and Bayesian mixing models the study found interesting links suggesting that in shallow habitats, production from *Fucus vesiculosus* is the primary energy source for *Macoma balthica*.

In a project with Baltic Sea Fellow Wei-Li Hong and a PhD student, Xiaole is currently looking into silicate alterations in deep sea sediments via combinations of stable isotopes, mineralogical analysis and reactive transport models. Silicate alteration may play a more important role in marine carbon burial than we previously thought.

The building of a network

2017-2020 – framing a Baltic Sea Fellows identity

In the area of marine research, Stockholm University conducts independent basic research and impartial applied research of highest quality. A strategic research program implies an identification of long-term aims or social interests and the means of achieving them which may find its expression in SU's long term-vision "Knowledge and education for a sustainable world". However, the strategic research program creates a subtle balance between basic and applied research. Basic research does not necessarily result in a solution to a practical or societal issue such as ecosystem-based management of the Baltic Sea, whereas a predefined research direction with a more applied character defines exactly these necessary scientific or regulatory approaches and tools to achieve a healthy ecosystem in the Baltic Sea. However, major societal challenges such as climate change and biodiversity loss make comprehensive knowledge about the global oceans and their marginal and shelf seas politically and socially indispensable and both basic and applied research are needed to achieve this knowledge.

When creating the scientific network "Baltic Sea Fellows", BSF, we took the applied character of the BEAM project as a starting point for framing, together with the heads of departments, two assistant professor positions in i) the role of law in governing ecosystems and achieving environmental targets and ii) regulatory ecotoxicology and risk assessments of chemicals. These two positions could be linked to the Baltic Eye Policy team within the BSC as leverage to conduct their research and get across their policy advice. The second group consists of one associate professor, five assistant professors and three PostDocs that cover a broad range of disciplines including oceanography, hydrology, marine geology/geophysics and marine ecology. Their research could be characterized as more basic and curiosity driven and was supported especially by the BSC's infrastructure facilities as major leverage for their research. The entire team met regularly at the BSC. Common activities such as running the Baltic Sea Days, an annual SU-wide seminar event, shaped the identity of being a Baltic Sea Fellow as a bridging function between on the one hand the various SU departments conducting marine research and on the other hand the BSC. The provided policy, communication, modelling and infrastructure facilities offered by the BSC were much appreciated amongst the Baltic Sea Fellows as an important platform for their scientific and academic careers.

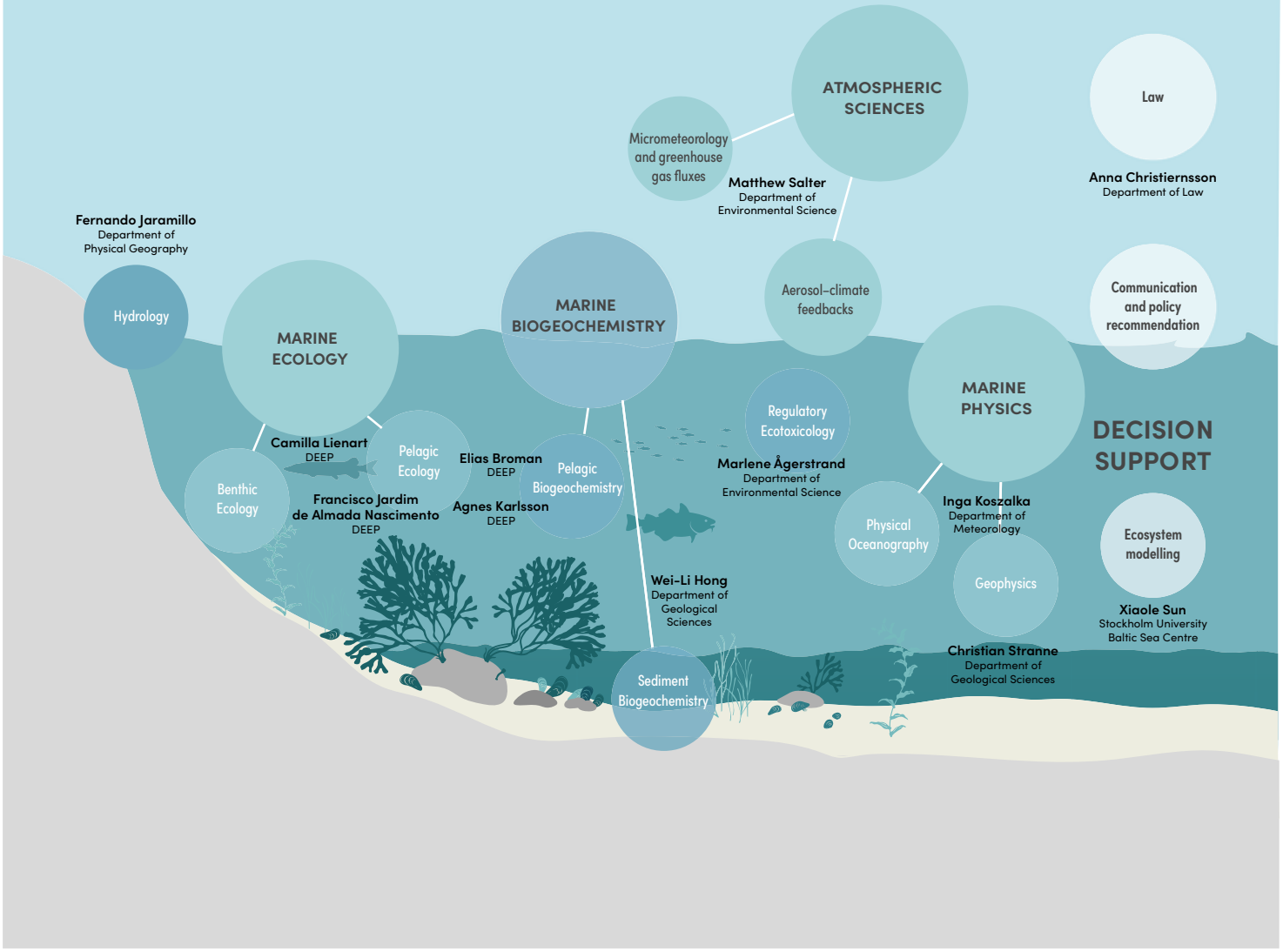
2021 – connecting marine and atmospheric science

Today, Stockholm University has internationally prominent research in atmospheric science. As part of the further strengthening of this research, great efforts have been made in recent years to develop the research infrastructure to achieve the goals of long-term, accessible, quality-controlled observations of atmospheric processes.

The Baltic Sea Centre received a major VR infrastructure grant to build up the Baltic Sea Observatory for Coastal Ecosystems and Climate Change (CoastClim), within the strategic collaboration "Baltic Bridge" between Stockholm University and University of Helsinki. This is a new investment in research infrastructure at the field station Askö and onboard R/V Electra that connects marine biodiversity and climate research. HavSU funds for the year 2021 were therefore invested to a newly established Atmospheric Facility with the Department of Environmental Science (ACES) as the host institution. The facility deals also with the Swedish part of the European research programme ACTRIS (Aerosol, Clouds, Trace gases Research Infrastructure). CoastClim and ACTRIS are part of the national research infrastructure that offers Swedish and international researchers improved opportunities to understand connections between processes in the atmosphere, biosphere and hydrosphere and how these interact with the Earth's climate. This requires new types of integrated measurement of greenhouse gases, aerosols,

clouds and trace gases in the same places where gas exchange and related relevant environmental processes at land and sea are measured. A facility manager (Matthew Salter) has been recently hired to build, plan and coordinate the daily CoastClim work at Askö/R/V Electra and the atmospheric science laboratory at ACES. He will also manage interactions with users and actively participate in research development as a link to connect atmospheric scientists with marine scientists. Further, the 2021 HavSU funds will be used to attract a new assistant professor in atmospheric sciences as a new Baltic Sea Fellow when the observatory is up and running.

The figure shows the distribution of Baltic Sea Fellows across disciplines mapped over a Baltic Sea system model. By bringing together young researchers in several disciplines, interdisciplinary environmental research on Baltic Sea has been strengthened broadly at Stockholm University.



Baltic Sea Fellows in Numbers

Funding

Early on, it has been decided from the BSC lead that the teacher positions within the Baltic Sea Fellows network, i.e., all associate and assistant professor positions, should be supported by own BSC funds for part-time positions (20%) of these Fellows at the BSC. This investment in the network was motivated to achieve an active involvement of the BSF in the daily work of the BSC. Thereby, the fellows took an important bridging function between on the one hand the various SU departments conducting marine research and on the other hand the BSC. These part-time salary costs summed up to 7,45 MSeK between 2017-2020. The total SRA funds (HavSU) for this period were 42,25 MSek. This total amount was partly spend for i) coordination, modelling and infrastructure support (R/V Electra cruises, sampling devices etc.); in total 9,85 MSek and ii) salaries for the BSF (32,40 MSek).

The SRA-funding for 2021 was allocated to connecting SU's marine and atmospheric research by the recruitment of an additional Fellow; the head of the atmospheric facility hosted at ACES, which will be funded 50% by SRA-funds. This Fellow, Matthew Salter, will start his position in autumn 2022 and will be responsible for the build-up of the atmospheric equipment at Askö; CoastClim Observatory, funded by the Swedish Research Council. Remaining SRA-funds from 2021 are allocated for supporting a tenure track position at ACES within the area of atmospheric research, when the CoastClim observatory is up and running.

Publications, external grants and attracted PostDoc and PhD positions

During the period 2018-2022 the Fellows have received external grants of 92,3 MSek, and from these funds additional 11 PhD-students and 10 PostDocs have been recruited to SU and connected to the BSF network. The funding is from various sources spanning from national research councils as VR, FORMAS, international sources such as EU but also from private foundations as the Ragnar Söderbergs or the Finnish Nottbeck foundation.

11

PhD students

10

PostDocs

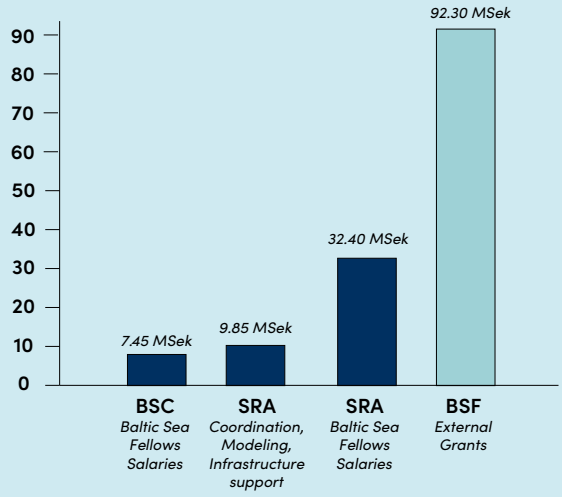
92,3

Million SEK
External Grants

200+

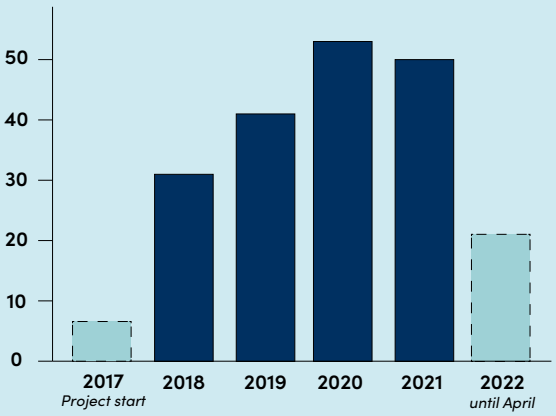
Publications

FELLOWS FUNDING



The figure shows the total funding of the Baltic Sea Fellows. By April 2022, the Baltic Sea Fellows have been successful with their applications and granted more than 90 MSek in external grants, effectively doubling the combined investments made with BSC and SRA funding.

FELLOWS PUBLICATIONS



The figure shows the total number of publications per year 2018-2022 (April). During the first two years, the scientific output in terms of number of peer-reviewed articles about doubled and in 2020 the average output was roughly five published papers per Fellow.

Accomplishments of the Strategic Research Area Funding

The objectives of the strategic research funding have been continuously elaborated from the original BEAM proposal by taking in new infrastructure, modelling and policy/communication opportunities as provided by the BSC and more recently by addressing the strategic partnership between SU and UHel towards a joined Centre for Coastal Ecosystem and Climate Research (CoastClim).

The original objective of the BEAM project, i.e., the increased collaboration between strong marine research areas within SU to support ecosystem-based management of the Baltic Sea, is still the core and high on the agenda of all Baltic Sea Fellows. A committed engagement with stakeholders and the effective transfer of research results as requested by the BEAM review panel was achieved by the active involvement of the BSC policy/communication team. Further, the new R/V Electra provided a completely new research platform for Stockholm University and acted as a catalyst for research cooperation between the BSF and is widely used as an education platform for these young scientists. Lastly, the recently developed CoastClim framework linking marine ecosystem and climate change research by bringing in SU's and UHel's climate research centers to the table, i.e., the Bolin Centre (SU) and Institute for Atmospheric and Earth System Research (INAR; UHel), forms a much broader and timely research objective for their future research.

In the following we present successful examples how the strategic objectives have been implemented by manifold collaborations among the BSF facilitated by the **BSC support in infrastructure**. Further increased **interdisciplinary collaborations** has been fostered by **regular group meetings contributed by BSC staff to accelerate new scientific insights on the Baltic Sea environment** and a **transfer of knowledge to the policy area.**

The value of available infrastructure to make research and education possible

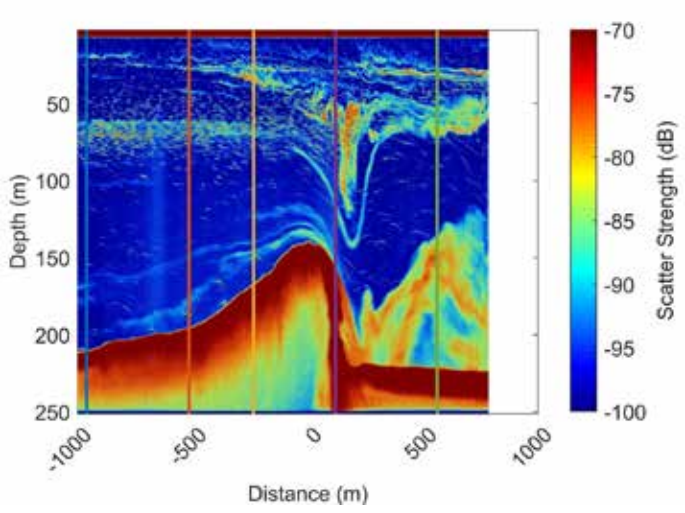
Stockholm University has two important infrastructure resources that are available for marine research and education; a marine field station at Askö, founded in 1961 with many long time series of abiotic and ecosystem variables, and the research vessel, R/V Electra, built in 2016. Compared to other universities with strong marine research, both the field station at Askö and R/V Electra are small and thereby relatively inexpensive to operate. Thus, the needs for logistic, administrative and financial support to run them are lower. Although small, R/V Electra is equally equipped with scientific instrumentation as other larger research vessels in Sweden and elsewhere in the Baltic Sea. The smaller size comes with other advantages, such as being able to operate also in shallower waters compared to larger vessels making her an ideal research vessel for the Archipelago Sea surrounding Sweden and Finland.

Making infrastructure resources available for the Baltic Sea Fellows was considered strategically important both regarding their possibility to merit academically and develop

their research, but also as platforms for collaborations between Baltic Sea Fellows. Parts of the strategic funds were set aside for field work and cruises, and many of the BSF intensively used either the field station at Askö and/or the new research vessel R/V Electra. Especially the latter research platform functioned as a catalyst to foster interdisciplinary research on a national and international level and joint cruises into the Baltic Sea led to collaborative research results, interdisciplinary research applications to various funders and new teaching opportunities for these Baltic Sea Fellows.

Cutting edge oceanographic and geophysical instrumentation onboard R/V Electra: physical mixing in the Baltic Sea – Christian Stranne and Xiaole Sun

The near-bottom water of the deeper basins in the Baltic Sea are often anoxic which leads to a release of large amounts of nutrients such as phosphate from the sediments. By means of complex and not fully understood vertical transport mechanisms, this phosphate reaches the surface water in winter where it reinforces the already problematic eutrophication of the Baltic Sea. There is a large discrepancy between quantifications of mixing made from direct observations and those made from budget arguments. In other words, there exists mixing in the Baltic Sea that has not yet been identified through direct measurements. The identification and quantification of this "missing mixing" is a major open question in Baltic Sea research, and one that has been addressed by the international cruise consisting of researchers from the Leibniz Institute for Baltic Sea Research (Germany), the University of New Hampshire (USA), SMHI and Stockholm University led by Baltic Sea Fellow Christian Stranne. Two cruises onboard R/V Electra in 2019 and 2020 focused on the influence of gentle and steep slopes in the Baltic Sea bottom topography on vertical mixing. This was achieved through a combination of traditional methods (including shipboard multibeam seafloor mapping, CTD, ADCP and microstructure profiler, as well as moored ADCP and CT-logger chains) with new acoustic techniques for observing ocean stratification and turbulent microstructure using state-of-the-art broadband echo sounder technology provided by R/V Electra. The fist research expedition took place in the Southern Quark outside of Grisslehamn and the results surpassed all expectations – they measured some of the highest mixing rates ever observed in the Baltic Sea, and the acoustic data captured the detailed structure of hydraulic controlled overflow over a steep sill, with turbulent patches associated with a hydraulic jump (see figure below). The combined data set has already provided important insights regarding vertical mixing in this area, and the mechanisms behind it. A first scientific peer-reviewed article will soon be published based on these data, led by PhD student Julia Muchowski. In February/March 2020 the



The figure shows an echogram from a broadband echosounder with a transect over a sill in the Southern Quark area. The sharp deep red boundary is the sea floor and coloured vertical lines are locations of direct sensor measurements with a free-falling microstructure profiler.
A number of different features can be identified in the water column, most of which are associated with stratification and/or turbulence (e.g. the v-shaped feature, a so-called stagnation wedge associated with a hydraulic jump).

group repeated the 2019 experiment, but this time with one additional mooring and, more importantly, with the addition of a WEGAS (Water Equilibration Gas Analysis) system that continuously collected greenhouse gas data during the filed campaign. The WEGAS was run by Baltic Sea Fellow Xiaole Sun and made real-time measurements of the concentrations of carbon dioxide and methane in the water and air just above the water, so that ocean-atmosphere fluxes can be estimated. These data will be the basis for the next two publications within this project.

Floating platforms and continuous greenhouse gas measurements: how to estimate greenhouse gas dynamics in the coastal ecosystems - Franscisco Nascimento, Elias Broman and Xiaole Sun

The study "High spatiotemporal variability of gereenhouse gases across vegetated coastal ecosystems" was conducted by Baltic Sea Fellows Franscisco Nascimento, Elias Broman and Xiaole Sun, in close cooperation with marine researchers from the collaboration Baltic Bridge between SU and UHel. The researchers made continuous measurements of carbon dioxide and methane concentrations and emissions from contrasting coastal habitats outside Askö Laboratory in Trosa using the WEGAS system that was installed on a floating houseboat moored near the coast. Based on their extensive data from continous measurements over more than 60 days in 2020, the team proposes sampling intensities that help resolve the scale and drivers of this variability and reduce uncertainties of emission estimates by up to 70 per cent. The researchers discuss that failing to include spatially and temporally resolved measurements in future studies will result in a continued systematic bias of emission estimates from heterogeneous coastal environments subject to global change. The improved understanding of methane emissions will inform efforts addressing climate change with the net potential of vegetated coastal ecosystems to act as carbon sinks. Over an annual cycle, methane emissions offset one third of the estimated carbon sink attributed to atmospheric carbon dioxide uptake in coastal habitats. Accounting for methane alongside carbon dioxide sea-air fluxes becomes indispensable to correctly quantify the potential of vegetated coastal ecosystems as net atmospheric carbon sinks and develop informed climate mitigation strategies.

Education using echo-sounding to study fish stocks and behavior - Christan Stranne, Agnes Karlson and Inga Koszalka

R/V Electra was also widely used in several masters programs of SU.

One example is the course "Baltic Sea Ecosystem: Applications, Modeling and Management", hosted by DEEP, that provides students in environmental or marine science a complete overview about all aspects of 'ecosystem management'. The students actively participate in all parts of the process starting with sampling and data assimilation, ecosystem modeling and future predictions, and ending with drawing conclusions and recommending management measures, having direct dialogue with different authorities and stakeholders during the end of the course. Several Baltic Sea Fellows teach on the course and Christan Stranne and Agnes Karlson show the students onboard R/V Electra how to combine geophysical echo-sounding data to study fish stocks and behavior and the idea is to develop this part into a full-fledged course module in bioacoustics, a cooperation between DEEP and IGV. Further, how the scientific data relate to legal aspects were addressed by the Anna Christiernsson in the course module dealing with management policy decisions. Since 2019 Inga Koszalka developed the masters course "Physical Oceanography" by including a fieldwork module with R/V Electra and a data analysis lab at Askö. This is the first time the Department of Meteorology (SU) has established a field course on Askö/R/V Electra and now SU students have the opportunity to learn the techniques of observational oceanography.

Collaboration to accelerate new insights on the Baltic Sea environment

Collaboration between scientists of different backgrounds can open up new scientific fields which can greatly improve our understanding of key processes within the Baltic Sea ecosystem. Joint meetings and discussions at the BSC, facilitated by their part time positions at the Centre, enabled the Fellows to plan and implement collaborative studies towards this deeper understanding. Below are a few examples of these collaborative efforts presented, and several others are on its way to be realized in the coming years.

Greenhouse gases emissions during the 2018 heat wave - Francisco Nascimento, Elias Broman, Xiaole Sun and Christian Stranne

R/V Electra's smaller size makes her useful for measurements in coastal areas, and also more flexible for event driven samplings. One example is the summer heat wave in 2018 which led to the highest recorded water temperatures since 1926 – up to 21 °C – in coastal bottom waters of the Baltic Sea, with implications for the greenhouse gas dynamics in these shallow coastal systems. The Baltic Sea Fellows Francisco Nascimento, Elias Broman, Xiaole Sun and Christian Stranne participated in an "ad hoc" cruise covering the coastal archipelagos of Sweden and Finland and also the open and deeper parts of the Northern Baltic Proper. This field study represents a unique combination of the Fellows' skills in molecular biology, geochemistry, geophysics and chemical and physical oceanography. The Fellows used data from real-time measurements of surface water methane and carbon dioxide concentrations, acoustic detection of methane seeps in the bottom water, and sediment DNA plus RNA sequencing to investigate the formation and oxidation of methane in coastal environments. The overall results from this cruise are published in several peer-reviewed publications and suggest that the heat wave triggered greenhouse gas fluxes, especially in the shallow coastal zones, that are comparable with maximum emission rates found in other hot spots, such as boreal and arctic lakes and wetlands.

Linkages between large scale circulation and algal blooms - Inga Koszalka and Agnes Karlson

Another example of a fruitful research cooperation is between the Fellows Inga Koszalka and Agnes Karlsson within the DriftBloomClim project financed by the Bolin Centre for Climate Research. Here, the Fellows collaborate closely with scientists from SMHI and the BSC. The overall aim is to elaborate new theoretical and numerical models validated by new observational and analysis techniques for simulation of future phytoplankton blooms in the Baltic Sea. The Baltic Sea is one of the best-surveyed and studied seas on earth. Yet the Baltic Sea circulation and its role in the complex climate system is neither fully quantified nor understood, despite important implications for coastal societies of the Baltic Sea region. The team studies circulation in the Baltic Sea from short- to climate time scales, as well as processes at the sea-air interface. The Fellows investigate coupling between physical and biogeochemical processes and consequences for the marine ecosystem. Specific questions to consider are salinity dynamics, methane transport and exchange processes, wind-driven and turbulent currents and their impacts on marine productivity and algae blooms, which in turn affect water quality and contribute to eutrophication and oxygen deficiency in the bottom layers.

Collaborations to accelerate transfer of knowledge to the policy area

The evaluation by the expert panel of the initial BEAM project (2015) highlighted that "without a clear mechanism to engage stakeholders it is impossible to see how transfer of research results can be effective". The panel also stated in their report that the capacity to transfer knowledge is greatly improved by the Baltic Eye work at the BSC. At the time of this evaluation the buildup of the Baltic Eye had started, with external funding, with the aim to form a structure where communicators and policy analysts work together with researcher to provide decision makers and other relevant actors in society with scientific knowledge in a policy relevant context. This Baltic Eye work is, since 2019, financed by university funds.

During the period of 2017-2021 all Fellows have been participating in different outreach activities in cooperation with the BSC and the Baltic Eye team and in the following a few examples are given.

Chemical pollution – Marlene Ågerstrand

The Baltic Sea Fellow Marlene Ågerstrand was part of the two-year dialogue with the Swedish Commission for the Seas (Miljömålsberedningens havsuppdrag) appointed by the Swedish government in 2018. Together with BSC staff, Marlene supported the parliamentary Commission with scientific advice during numerous meetings. The Commission office had the opportunity to meet researchers and learn and ask questions about relevant marine research. The support to the Commission continued by commenting reports and presentations to the parliamentarians in the Commission. Once the Commission report (Havet och människan, SOU 2020:83) was published and sent out for consultation, Marlene was one of the researchers giving further detailed comments and recommendations.

Further, Marlene had key role in the proposal for creating an international panel for chemical pollution, IPCP, where a network of scientists supports policy makers and policy development within this area. The initiative was supported by the Swedish Minister for Environment.

Finally, Marlene has also, together with colleagues from ACES and the BSC, contributed significantly to the development of the EU Commission chemicals strategy by answering consultations, analysing policy development and disseminated knowledge in various fora.

Environmental law – Anna Christiernsson

Anna Christiernsson has been active in transferring scientific knowledge into policy processes. More specifically, Anna had a central role in a number of answers from SU to governmental consultations (remisser), for instance the report from the Commission on shoreline protection (strandskyddsutredningen), the Commission's report on marine issues (Havet och människan, SOU 2020:83), and numerous consultations regarding fisheries. By joining forces between natural scientists and environmental law scientists, answers to these consultations were of high societal relevance.

The importance of time series – Agnes Karlson

The long-term collection of data in different environmental monitoring programs is of vital importance for interpreting changes in the natural environment. This important work is however often threatened by severe cuts in economic allocations. The Baltic Sea Fellow Agnes Karlson participated in producing a Policy Brief explaining and clarifying the need of these long time series, also in the context of understanding climate change effects. Agnes also participated in different fora to present and discuss this issue, as for example in a "Baltic Breakfast", a series of short breakfast seminars in the city center of Stockholm with frequent participation of policy and decision makers, journalists and everyone interested in environmental issues of the Baltic Sea.

Photo: N Wijkmark/Azote Library

Next steps

The Baltic Sea Fellows' research is mainly related to "classical" and still highly relevant environmental problems such as pollution, overfishing, eutrophication and coastal exploitation, whereas climate change is intertwined in all these issues and has become a more important research field to address for all fellows in the recent years.

In other words, the management of the Baltic Sea and the climate crises are intimately linked and can no longer be viewed through separate lenses. Coastal seas and ecosystems are highly productive and dynamic in terms of ocean-atmospheric carbon fluxes, and they have been proposed as potential powerhouses of mitigation and part of the ocean-based solutions to combat climate change. This calls for interdisciplinary collaboration within natural science but also between natural and social scientists, as successfully developed in the Baltic Sea Fellows network.

The CoastClim observatory will provide the BSF an international framework for their research activities. A Finnish sister CoastClim Observatory is based at Tvärminne Zoological Station under the main responsibility of University of Helsinki. Both observatories will be further developed by 4 partner institutions from SU and UHel under the general framework of the strategic partnership "Baltic Bridge", and with the support of the SU & UHel leadership as a spearhead project.

The partnership has been established to bring together both marine and atmospheric research. The additional partners are the Bolin Centre for Climate Research at SU and the Institute for Atmospheric and Earth System Research at UHel and today some 50 scientists including many fellows are already deeply involved (https://www.coastclim.org/people/). In the coming years, a full-fledged Swedish-Finnish CoastClim Centre (https://www.coastclim.org/) will be established, supported by VR, The Finnish Academy and many private foundations, dedicated to attract the critical mass of scientists and scientific infrastructure facilities needed to be competitive for attracting major national and international research grants.

We hope that the Baltic Sea Fellows network, covering the whole range from basic marine research to applied legal aspects and decision support, may thrive and grow in this international setting.

As a continuation of the governmental funding of strategic Baltic Sea research, an interdisciplinary network of young Baltic Sea researchers was formed at Stockholm University 2018.

By bringing together young researchers in several disciplines, environmental research on Baltic Sea has been strengthened broadly at Stockholm University. The research group today consists of senior lecturers, assistant lecturers and postdoctoral fellows at six different departments. Their research range from the biogeochemical conditions and circulation processes of the Baltic Sea to long term ecosystem and food web changes and how human activities on land affect the sea. This also includes research on policy instruments and legislation that regulate management on marine protected areas, fisheries and pollution.