Baltic Ecosystem Adaptive Management

Research for sustainable management of the Baltic Sea

Baltic Ecosystem Adaptive Management, BEAM, is an interdisciplinary research program on ecosystem-based management of the Baltic Sea environment. The program gathers researchers from three Faculties and ten Departments to focus on five key areas and their interactions: ecosystem functioning, nutrient enrichment, hazardous substances, laws and management and climate change.

This is a mini-report about BEAM and the latest results from ten of the projects it supports.
1000 copies printed in November 2014. Please visit www.su.se/beam for more information and news.

Task force - a coordinating team
In order to enhance interaction and collaboration within BEAM a task force team was established and led by the Network coordinator Thorsten Blenckner. It consists of communicators and scientists from the key areas:
– Laws and management: Henrik Österblom, Stockholm Resilience Centre
– Hazardous substances: Johan Eriksson, Dept. of Ecology, Environment and Plant Sciences
– Ecosystem functioning and nutrient enrichment: Johan Gelting, Dept. of Ecology, Environment and Plant Sciences

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Baltic Ecosystem Adaptive Management, BEAM – Research for sustainable management of the Baltic Sea

Many years of environmental research have given us improved knowledge of how eutrophication, environmental toxins and climate change affect the sea. We are also starting to understand their interactions, including those with complex human social systems. By integrating knowledge from different disciplines, BEAM helps to create a better basis for sustainable management of the Baltic Sea.

Holistic approach needed for the Baltic Sea

The 85 million people living in the Baltic Sea catchment exert a strong pressure on the Baltic Sea ecosystem. The future of this unique sea largely depends on how we choose to take care of it. Baltic Ecosystem Adaptive Management, BEAM, is a strategic research program funded by the Swedish government, and part of Stockholm University's major research initiative on the Baltic Sea.

Aim

BEAM aims at developing a multi-discplinary scientific understanding of the Baltic Sea and its management and to provide strategic advice to practitioners and policy makers in order to make an ecosystem-based management operational.

BEAM aims to provide the knowledge needed for ecosystem-based management of the Baltic Sea environment.

– The Baltic Sea needs an environmental management based on the demands of its ecosystems. Since its environmental problems are interwoven they need to be treated together, not in isolation. Measures to mitigate eutrophication affect fish populations, while overfishing influences the levels of environmental toxins in fish and maybe even the severity of algal blooms, says Ragnar Elmgren, BEAM program coordinator and Professor at the Department of Ecology, Environment and Plant Sciences at Stockholm University.

Collaboration is key

Stockholm University is a leader in Baltic Sea research, particularly concerning ecosystems, organic environmental toxins, natural resource management and the use of ecological models for decision support. The University also has environmental lawyers, social scientist and other experts on ecosystem-based management.

– Coordinating existing projects and different disciplines in a single program, strengthens the research and provides a better basis for political decisions, directives and environmental goals, says Thorsten Blenckner, BEAM network coordinator and Associate Professor at Stockholm Resilience Centre.

Funding

The BEAM project started in 2010 and will be financed to the end of 2015. A positive evaluation in 2015 will make this strategic financing permanent. For the period 2010–2014, BEAM has received 41.9 Mkr in strategic funding from the Swedish government, 47 Mkr from external sponsors and approximately 50 Mkr from Stockholm University.

Words used in the titles of BEAM publications since 2010.

BEAM outcomes

BEAM programme results are published at an increasing rate – over 180 peer-reviewed publications until October 2014. Younger scientists are trained in ecosystem management issues on BEAM doctoral courses and through participation in program activities. BEAM participants are frequently asked to advise national and international government agencies and institutions. So far over 30 internal meetings and public events have been arranged, directly or partly, by BEAM researchers.

How has BEAM affected your area of interest?

Views from the board at Stockholm University

"The overarching aim of BEAM has been to open up for dialogue and collaboration among groups of researchers from different fields and perspectives.

BEAM was a prerequisite for the establishment of the Baltic Sea Centre – a centre that will work as a resource to gather current science and experts in inter-disciplinary projects with a societal relevance. This is a necessary approach in order to tackle the environmental problems in the Baltic Sea. "

Tina Elfwing
Stockholm University Baltic Sea Centre

"The societal focus of BEAM has resulted in more collaborations between social and natural scientists at Stockholm University - a great step forward.

To enable productive, cross-disciplinary meetings a common language is needed; a conceptual framework or model where the different disciplines can meet in the same world-picture. At the Stockholm Resilience Centre we work with facilitating these kind of cooperations and through BEAM this role within the University has been further strengthened."

Carl Folke
Stockholm Resilience Centre

"BEAM has enabled us to initiate projects that focus on aligning our research on environmental toxins more closely with management needs.

For example, we have been able to identify and explore applications of our model-ling tools that could be of use when managing marine ecosystems. We have been sharing these developments with the Swedish Environmental Protection Agency, and this has already strengthened the societal impact of our research."

Michael McLachlan
Dept. of Applied Environmental Sciences

Elena Gorokhova
Dept. of Applied Environmental Sciences

"Thanks to BEAM, the ecological and ecotoxicological research at our department is now broader and more trans-disciplinary.

The programme has strengthened the links across environmental monitoring, basic and applied research. Our synthesis of environmental monitoring data with advanced molecular and physiological analyses as well as modelling can help us identify mechanisms and causes behind population changes in Baltic Sea organisms. This knowledge provides a basis for ecologically sound management strategies."

Lena Kautsky
Stockholm University Baltic Sea Centre
(member until 2011)

"BEAM has resulted in many worthwhile meetings among scientists from different disciplines and phases in their career.

Just the fact that our steering board has representatives from six different departments that work together toward the same goal – to promote cooperation and management related research – has almost never happened during my 40 year long experience of academic work. This BEAM spirit is then transmitted to the departments and thus to a wider scientific community."

Christoph Humborg
Baltic Nest Institute, Baltic Sea Centre

"BEAM has made it possible to integrate environmental contaminants and toxins in the decision support system NEST.

Scientists at the Baltic Nest Institute depend on high-quality data to parameterize Baltic wide fluxes of matter such as nutrient and contaminant fluxes in the catchment or nitrogen fixation by cyanobacterial blooms or organic contaminant transport and fate in the sea. The knowledge is used to continuously improve our models that provided the basis for the Baltic Sea Action Plan. Collaboration within BEAM has considerably contributed to societal use of scientific research."

Jonas Ebbesson
Dept. of Law

"Environmental law research at Stockholm University has a strong focus on international and transboundary dimensions.

There are also strong ties and collaborations with other academic disciplines. These elements are well reflected in our activities within BEAM, where we have examined international, EU and national law with a focus on eutrophication in the Baltic Sea. Through BEAM, the Stockholm Environmental Law and Policy Centre has been able to pursue research on the legal dimensions of ecosystem management."

Birgitta Bergman
Dept. Ecology, Environment and Plant Sciences
(member until 2013)

"The resources from BEAM have generated fundamentally important research findings about microbes and shown their vast importance for life within and around the Baltic Sea.

The BEAM programme has also strengthened the Baltic Sea research and contributed with a new, high-quality knowledge basis necessary for a future sustainable management of the unique resources characterizing the Baltic Sea."

Ragnar Elmgren
Dept. of Ecology Environment and Plant Sciences
(programme coordinator)

"BEAM builds a competence in research on ecosystem-based management that is unique to Sweden.

Examples include marine radioecology, marine remote sensing, two projects on cyanobacterial blooms, their metagenomics and production of neurotoxin, and their ecosystem effects, as well as the effects of climate change on Baltic Sea plankton, using our long-term ecological observations. All with the aim to improve environmental management of the Baltic Sea."

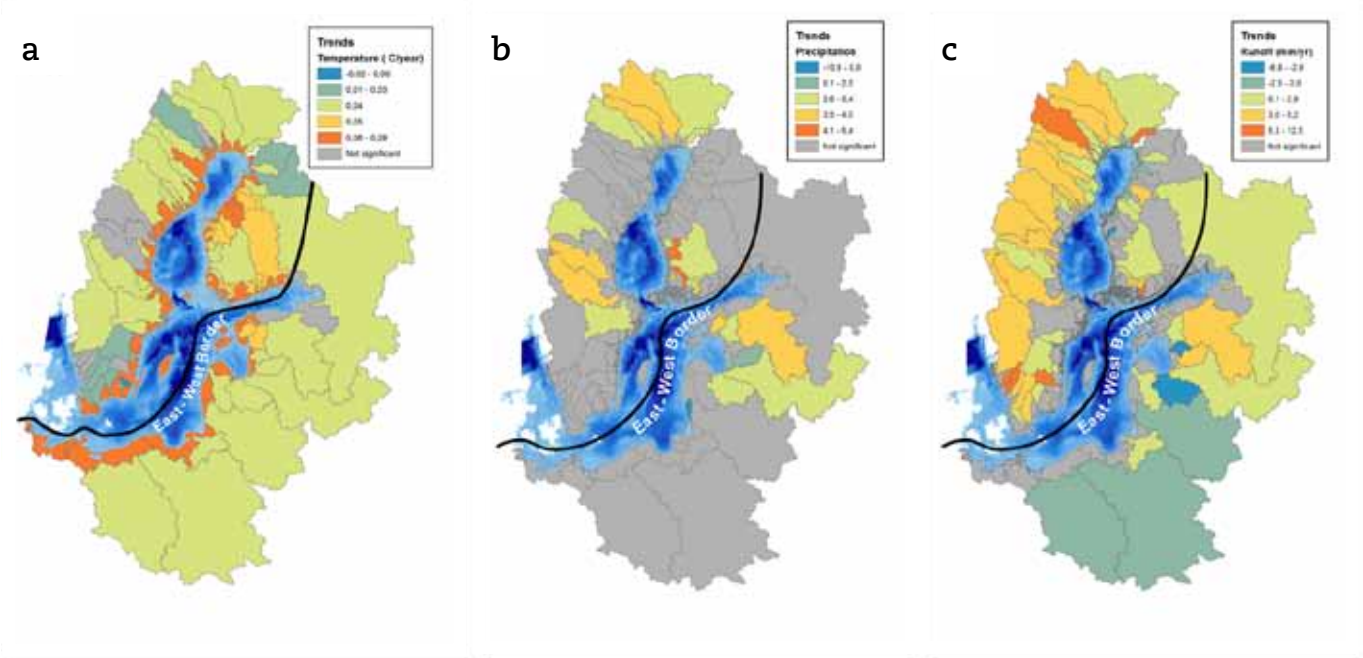
What controls nutrient flows into the Baltic Sea?

In order to manage nutrient input and maintain good water quality in the Baltic Sea we must have good knowledge on the characteristics of its different water contributing catchment areas. How much do their nitrogen and phosphorous trends vary? How large are the roles of climatic, societal and land cover properties on the nutrient inputs to the sea?

We have all heard that the load of nutrients such as phosphorous and nitrogen reaching the Baltic Sea has been increasing in recent decades and that this in turn has led to algal blooms and problems with eutrophication. An important indicator to keep track of in this regard may be the balance between nitrogen and phosphorous, namely the N:P ratio.

Steve Lyon, Department of Physical Geography and Quaternary Geology, Stockholm University, steve.lyon@su.se

Saaltink, R., et al. 2014, Societal, land cover and climatic controls on river nutrient flows into the Baltic Sea. *Journal of Hydrology: Regional Studies 1: 44.*

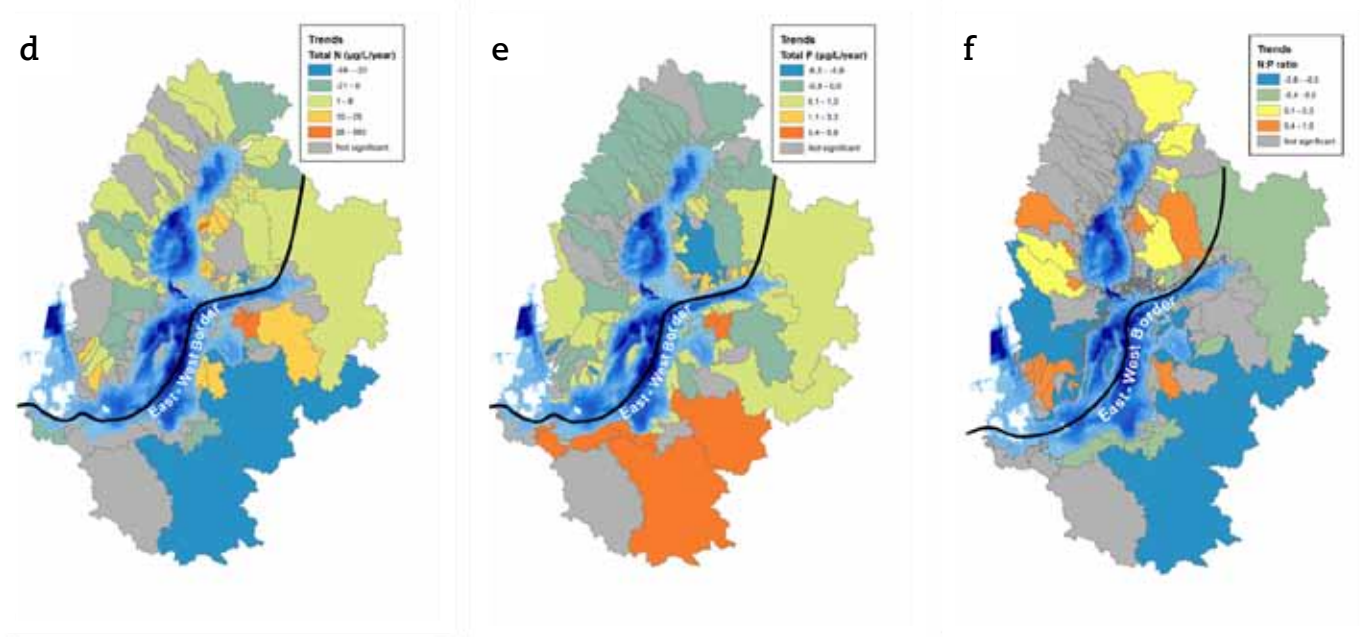


Annual trends in (a) temperature, (b) precipitation, and (c) stream flow between 1970-2000 over the Baltic Sea drainage basin.

– Since different algae species are either favoured or limited by these two nutrients, it is useful to monitor changes in the N:P ratios in the Baltic Sea water, says Dr. Ype van der Velde, BEAM associated hydrologist at Wageningen University in the Netherlands.

In a newly published study he and colleagues investigated the spatial distribution of nitrogen and phosphorous trends in relation to characteristics of the catchment areas from which the nutrients are transported to the sea. By combining observed catchment-scale nutrient concentrations and discharge data for the period 1970–2000 with climate and land cover data, the team looked at how societal, climatic and land cover properties controlled nutrient inflows.

– Our work demonstrates that differences between the socio-economic structure and development in eastern and western regions of the Baltic Sea drainage basin have led to significant (and varying) changes in N:P ratio trends, says Dr. Ype van del Velde. This is primarily due to shifts in the diffuse and point sources accompanied by a change in land cover influencing the loads of nutrients. Looking north-to-south, climatic variations also become a key driver in addition to these patterns of lifestyle.



Annual trends in (d) total nitrogen, (e) total phosphorus, and (f) N:P ratio between 1970-2000 over the Baltic Sea drainage basin highlight the regional differences.

Targeted, adaptive management necessary

– Our results indicate that the reasons why nitrogen and phosphorous trends vary are not the same in the different catchments, says Dr. Steve Lyon, BEAM associated hydrologist at Stockholm University's Department of Physical Geography and Quaternary Geology. Thus improving water quality likely requires different actions in different areas. This necessitates targeted, adaptive management strategies.

The most effective way to reduce nitrogen is to continue to improve agricultural techniques and, specifically for N:P ratios, countries should still aim to develop better wastewater treatment plants and close heavy-polluting factories to reduce phosphorous loads.

– Overall, due to the importance of N:P ratio for algal bloom composition, an emphasis of management strategies more on P reduction rather than on N reduction may be warranted since the increasing trends in total phosphorous appear to be responsible for a declining trend in the N:P ratio from eastern catchments, Dr. Steve Lyon concludes.

Seafloor animals play a surprisingly large role in nutrient cycling

Biogeochemical processes in Baltic Sea sediments provide essential ecosystem services, such as reducing eutrophication by removing nutrients or converting them to food for marine organisms. New BEAM research shows that small animals in the sediment affect the cycling of the essential nutrient nitrogen much more than expected.

Field sampling in the Baltic Sea.

Stefano Bonaglia examines the experimental sediments at the Askö Laboratory.

Few species live in the bottom sediments of the Baltic Sea, but they can be very abundant where conditions are favourable. They are important for the decomposition of organic material and through their burrowing provide oxygen to organisms below the sediment surface.

Links to eutrophication

Stefano Bonaglia, doctoral student at the Department of Geological Sciences at Stockholm University and his co-authors have recently shown that both *Marenzelleria*, a polychaete that recently colonized the Baltic, and meiofauna, benthic invertebrates smaller than 1 millimetre, affect nitrogen cycling more than earlier suspected.

– Even though meiofauna is orders of magnitude more abundant than macrofauna and is also more diverse, its role in nitrogen cycling has not been well understood, says Stefano Bonaglia. We have shown that meiofaunal communities stimulate microbial denitrification, that is, the removal of nitrogen from the system. Thus, meiofauna provides an important ecosystem service that helps to counteract eutrophication.

In contrast, another experiment conducted by the team, showed that the invasive polychaetes *Marenzelleria* spp. did not stimulate denitrification as most infauna generally do.

– Instead, these polychaetes enhance the transformation of nitrate to ammonium, a process that retains nitrogen in the system, thus tending to stimulate eutrophication, Stefano Bonaglia explains.

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Bonaglia, S., et al. 2014, Meiofauna increases bacterial denitrification in marine sediments. *Nature Commun 5:5133.*

A new modeling tool simulates environmental toxins in the Baltic Sea

Pollution by organic contaminants and other hazardous chemical substances is one of the major stressors in the Baltic Sea. Now researchers in BEAM have developed a new modeling tool that can predict future distribution of organic chemicals in the Baltic Sea.

The well-recognized BALTSEM model (the BAltic sea Long-Term large Scale Eutrophication Model) is used to assess nutrient/carbon cycles and eutrophication in the Baltic Sea. This model has now been expanded to model also environmental transport and fate of organic contaminants – BALTSEM-POP. Organic contaminants are emitted within the Baltic Sea catchment, or transported there by air from outside. Fate, which means where the contaminants end up in the ecosystem, is influenced by a wide range of environmental factors, which are included in the BALTSEM-POP model.

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Undeman, E., et al. 2014,
A novel modeling tool with multi-stressor functionality for organic contaminant transport and fate in the Baltic Sea. *Sci. Total Environ. 407-408:382-391.*

– The novelty of the BALTSEM-POP model is that it dynamically calculates several key factors that can influence the amount and composition of contaminants ending up in the Baltic Sea, says Emma Undeman at the Baltic Nest Institute, Baltic Sea Centre and Department of Applied Environmental Science at Stockholm University.

This means that the model takes into account short- and long-term variation in important factors such as carbon cycling, water flows, wind speed, water and air temperature.

– It is important that the BALTSEM-POP model includes variation in these factors since they are affected by climate change and eutrophication. Moreover, this model can predict how contaminant concentrations will vary with the water depth for the entire Baltic Sea, says Emma Undeman.

The accuracy of the new model was evaluated by comparing simulated concentrations of the important environmental toxins polychlorinated biphenyls (PCBs), dioxins and furans (PCDD/Fs) and hexachlorobenzene (HCB) in water, suspended particulate organic matter and sediment with actual field observations.

The BALTSEM-POP model predicted concentrations of most of these organic contaminants in water and sediment with high accuracy, while contaminant concentrations in particulate organic matter was more difficult to predict.

– The generally good performance of the new model shows that it can be an important tool for predicting future contaminant concentrations in different matrices in the Baltic Sea in response to variations in input of contaminants and nutrients and climatic conditions, says Emma Undeman.

Regulation to decrease eutrophication

Marine environmental issues, not least those related to eutrophication, are held important in the Baltic Sea region, and has thus been subject to legal agreements and regulation on international and national level.

The international law that governs the situation is based on a so-called ecosystem approach. By studying the laws on nutrient emissions in four Baltic Sea countries, environmental lawyers can conclude that ecosystem-based management is not sufficiently implemented in binding regulation or realized in legal decision-making on the national level.

Environmental Law Researchers in Sweden, Denmark, Poland and Estonia have examined their respective legal systems, with emphasis on the regulations on agriculture and wastewater discharges into the Baltic Sea. The results show similarities between the studied systems, for example regarding best practice rules for storage and spreading of manure in agriculture. Regarding regulation of sewage treatment plants, most of the countries have permit-requirements, in which there are some possibilities for an ecosystem adaptive management approach.

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Download the country studies:
bit.ly/nutrientreductions

– A general observation in our study is that there is considerable room and potential for ecosystem approach in the national legal systems, says Annika Nilsson, leader of the BEAM project and lecturer at Uppsala University. Unfortunately we also observed that the available space for ecosystem adaptations is not utilized. Regulation is often not clearly related to the relevant ecosystem status and functions, and only rarely is it adapted to suit management of an ecosystem subject to environmental change, or flexible in response to such change.

Towards an adaptive legal framework

Central for implementation of ecosystem approach into legal regulation is to clarify and strengthen the meaning and legal authority of management plans and action programs, and to clearly prescribe legal responsibilities in environmental management. In other words, it must be clear who has to do what and when, and what happens if they do not. This will help implement and control ecosystem-based management.

– As environmental law researchers we can easily see the challenges and shortcomings but it is important that we take on the responsibility of managing the potential and to move forward in trying to develop ways to implement an ecosystem approach all the way into legal decision-making, says Annika Nilsson.

The conference 'Towards an ecosystem-based legal framework for the Baltic Sea' was held at Stockholm University on October 7th, 2014.

A conference on the subject of this project was jointly organized by BEAM and Stockholm Environmental Law and Policy Centre, with special participation by the Swedish Agency for Marine and Water Management. It gathered over 80 scientists, experts and representatives from authorities and interest organisations.

Watch all presentations and panel discussions on su.se/beam.

How will the future Baltic Sea foodweb change?

In the past decades, the combination of intensive exploitation of marine resources and climate change has caused large reorganizations of many of the world's marine ecosystems. The Baltic ecosystem is one of the most affected. Researchers in BEAM and ECOSUPPORT have modeled how multiple forces drive the dynamics of the Baltic food web and its response to environmental change.

In a recent study, responses of the central Baltic Sea food web to the combined effects of fishing, nutrient loads and climate were tested for the past (1974–2006) and projected into the future (2010–2098).

– We developed a new food web model using extensive monitoring data across trophic levels. Our model described past food web dynamics quite well, and was then used for future projections, says Susa Niiranen who completed her PhD within the ECOSUPPORT project, in collaboration with BEAM.

Management actions will have impact

The results show that regional drivers, such as fishing, can have large effects on the future Baltic Sea, but climate-induced changes in hydrodynamic conditions still set the boundaries for food web structure and function.

– Regional management is likely to play a major role in determining the future of the Baltic Sea ecosystem, says Susa Niiranen.

Different scenarios and time scales

In a worst-case scenario with intensive cod fishing and high nutrient loads, a strongly eutrophicated and sprat-dominated Baltic Sea ecosystem is predicted. On the other hand, in a best-case scenario, prudent cod fishing in combination with low nutrient loads resulted in a cod-dominated ecosystem with eutrophication levels close to present.

The processes shaping the foodweb had different time scales. The Baltic Sea ecosystem responded quickly to changes in cod fishing (less than 10 years), while responses to nutrient reductions took as long as 30–40 years.

Sudden ecosystem surprises

In the various scenarios, several climate and species biomass variables reached values outside the ranges measured in the past, indicating that the ecosystem conditions are moving out of the event space of the past.

– This means that if we pass unseen threshold values in species response to changing drivers, sudden ecosystem surprises may result. Thus we need to apply a precautionary management that is quick and flexible in its actions, says Thorsten Blenckner, project supervisor and Associate Professor at Stockholm Resilience Centre.

Susa Niiranen,
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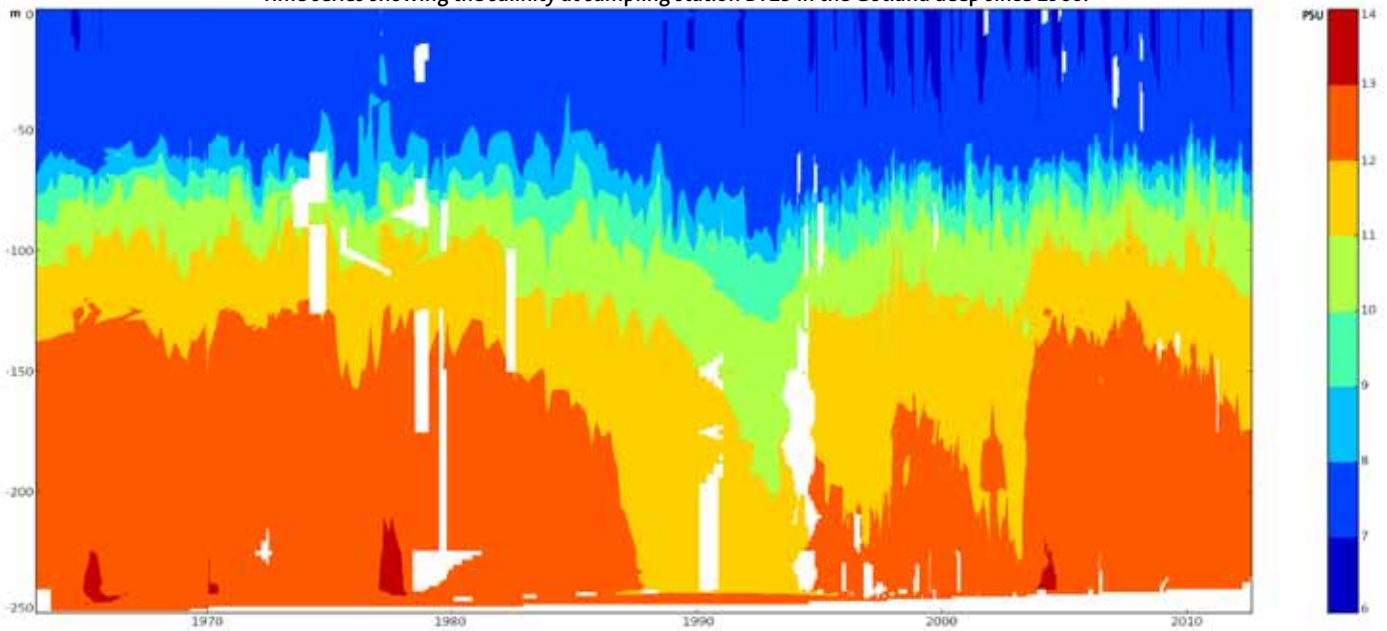
Niiranen, S. et al. 2013, Combined effects of global climate change and regional ecosystem drivers on an exploited marine food web. *Glob Chang Biol 19:3327.*

New model to identify future inflows to the Baltic Sea

Strong inflows of sea water through the Danish straits play a major role in the environmental conditions of the Baltic Sea. Oceanographers within BEAM has developed a new model, an algorithm, which successfully identifies these large saltwater intrusions by correlating them with atmospheric pressure conditions.

Time series showing the salinity at sampling station BY15 in the Gotland deep since 1960.



The Baltic Sea is relatively sensitive to environmental changes and stressors. The new algorithm is based on air-pressure changes over Europe and has shown that inflows occur when pressure fields develops in a particular way during a 40 day period. The algorithm manages to identify almost all the major inflows that occurred between 1961–2010.

– Now we can discern how atmospheric pressure conditions are driving the larger inflows of saline sea water, says Markus Meier oceanographer at SMHI and Adjunct Professor at Stockholm University. In addition, we have investigated the few occasions with favourable conditions that have not led to a reported inflow.

In these cases, the inflows seem to have been hindered by other oceanographic factors such as unusually high freshwater supply or high water levels.

Projections improve management

The number of occasions with the 'right' air pressure for a larger saltwater inflow has decreased in recent decades. This is the reason that the oxygen situation in the deep Baltic Sea basins has not improved despite the fact that nutrient loads have actually decreased. But the scientists have now tested the new algorithm in a number of existing climate scenario models, and it seems that the events with favourable conditions will increase slightly in the future.

– Knowledge of why the inflows occur at a particular time is of great importance for the management of the Baltic Sea. If we become better at projecting the future of the Baltic Sea climate and environmental conditions, we can more easily make the right management decisions, says Markus Meier.

Markus Meier, SMHI and Department of Meteorology, Stockholm University, markus.meier@su.se

Schimanke, S., et al. 2014, An algorithm based on sea level pressure fluctuations to identify major Baltic inflow events. *Tellus A 66, 23452.*

Can ecosystem-based management improve Baltic fisheries?

Fish stock assessments for the Baltic Sea use single-species fisheries models for short-term tactical setting of total allowable catches. However, to evaluate the impact of alternative management strategies on the state and dynamics of exploited fish populations, strategic modelling approaches are essential tools.

Thorsten Blenckner,
Stockholm Resilience Centre, Stockholm University, thorsten.blenckner@su.se.

Möllman, C., et al. 2013, Implementing ecosystem-based fisheries management: from single-species to integrated ecosystem assessment and advice for Baltic Sea fish stocks. *ICES J. Mar. Sci. 71:1187*.

Exploited populations do not exist in isolation, and their response to a fishing pressure emerges from the feedbacks caused by its interactions with other species in the food web, as well as from direct and indirect effects of abiotic pressures.

Ecosystem approach is needed but not applied

The theory behind ecosystem-based management and ecosystem-based fisheries management is now well developed. However, in practice fisheries manage-

ment is still largely based on single-species assessments, and ignores the wider ecosystem context and impact.

– We need to focus on the whole ecosystem and use an ecosystem-based management, says Thorsten Blenckner, BEAM network coordinator and co-author of a published paper on the topic.

Useful tool developed to help the implementation

According to Thorsten Blenckner the reason why ecosystem-based management is not used more in practice is that the lack of a coherent strategy prevents or slows down the implementation of ecosystem-based fisheries management.

– But now we can offer such a strategy by integrating fish stock data and ecosystem assessments into a combined, interdisciplinary framework to quantitatively analyse information on relevant natural and socioeconomic factors, in relation to specified management objectives, he explains.

As in all modelling, the accuracy of the outcome depends on the quality of the data used. The researchers identified a lack of data as well as limited accessibility to data on particularly zooplankton and phytoplankton. Reduced funding poses a serious threat to the continuation of important monitoring and the maintenance of crucial long-term time-series.

– As a basis for the strategy, a standard set of indicators for the ecosystem assessment needs to be developed, and the risks posed by human activities and natural processes to these indicators need to be identified. With these additions, the strategy for an ecosystem-based fisheries management in the Baltic Sea should be readily implemented and operational, Thorsten Blenckner concludes.

Nutrient trading to reduce eutrophication of the Baltic Sea

The Baltic Sea ecosystem continues to be harmed because existing environmental legal instruments are not effectively implemented. Dr. Katak Malla, a legal researcher at the Department of Law at Stockholm University, suggests that nutrient trading could help.

His research within BEAM analysed the potential of nutrient trading by taking into account the existing International Emission Trading Scheme (IETS), the European Union Emission Trading Scheme (EUETS) and the white certificate economic instrument (e.g. Sweden's CEASAR of "tradable nitrogen certificates").

– The legal aspects of a trading scheme were examined in terms of jurisdiction, transparency, monitoring, verification and effective compliance, when dealing with eutrophication, nitrogen and agricultural discharges of the Baltic Sea, Dr. Katak Malla explains.

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Department of Law,
Stockholm University,
katak.malla@juridicum.su.se

Malla, K. 2014, Legal Prerequisites for a Nutrient Trading Scheme to Control Eutrophication in the Baltic Sea. *Journal for European Environmental & Planning Law 11:272.*

Possibilities within existing laws

Should the Helcom parties reach consensus on a trading scheme, the existing Helcom legal frameworks can be enhanced and upgraded, according to the research. The Helcom parties can either individually adopt national nutrient trading schemes within their territorial borders, or create a joint scheme covering the territories of two or more states.

– The Kyoto protocol-based IETS and EUETS could be useful guides for collective scheme among states. Whether the CEASAR-based Swedish scheme could be applicable was also examined with specific conditions of the three countries: Sweden, Poland and Russia, especially in terms of their domestic emission-reduction schemes. The main obstacle identified is how the Russian legal mechanisms could be aligned with the proposed scheme, says Dr. Katak Malla.

Joint direction needed

The existing joint river commissions within the Baltic Sea basin could be given added responsibility for nutrient control in a manner integrated with the relevant EU directives, including estuaries and marine waters.

– Compatibility between a nutrient trading scheme and the relevant EU directives will be necessary, especially for making the scheme complementary to these directives, Dr. Katak Malla concludes.

Watch the filmed presentation 'Legal prerequisites for a nutrient trading scheme to control eutrophication in the Baltic Sea' on su.se/beam.

Herring eggs laid on the filamentous algae, *Ceramium tenuicorne*, one of the species that produce brominated phenols.

Brominated substances toxic to marine wildlife

Many substances produced by man can be harmful for human health and the environment. But naturally produced chemicals can also have such effects. Natural products, such as brominated phenols, are widespread in the Baltic Sea. New research suggests that they can be toxic to marine wildlife, for example by interfering with their energy production.

Brominated substances are produced by humans for use as flame-retardants, but algae and cyanobacteria produce similar substances. One group of such naturally produced brominated substances are hydroxylated polybrominated diphenyl ethers, OH-PBDEs.

– We now have evidence from in vitro experiments that OH-PBDEs have toxic effects, says Lillemor Asplund, leader of the BEAM research on the topic and Associate Professor at the Department of Materials and Environmental

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Blue mussels that filter large amounts of water contain high concentrations of brominated phenols during the summer months.

Chemistry. This should be taken seriously, since the production of these compounds are likely to increase with eutrophication.

Inhibited larvae development ...

OH-PBDEs were acutely toxic to adult and larval zebrafish. Zebrafish embryos stopped developing when exposed to OH-PBDE, even at low concentrations.

... and disturbed energy production

OH-PBDEs also affects energy production by mitochondria, crucial organelles found in the cells of all higher organisms. The mitochondria convert metabolic degradation products (from for example carbohydrates) to energy (adenosine triphosphate, ATP) in the cell.

– This process is called oxidative phosphorylation and the OH-PBDEs disrupt it, says Anna-Karin Dahlberg, doctoral student in the project. This in turn leads to a shortage of available energy and in the long run weight loss.

Substances widespread

Brominated phenols are believed to increase with eutrophication, since cyanobacteria and many filamentous red and brown algae that produce them are favoured by nutrient-rich conditions. In turn, blue mussels and small crustaceans can accumulate high concentrations of OH-PBDEs, and they can also be found in fish such as herring and perch.

Species with health problems

Recent research has shown that many Baltic Sea species, such as mussels, herring, guillemots and seals have become leaner. Poor hatchability of herring eggs laid on filamentous algae has also been reported. Today we know that these algae contain OH-PBDEs, the same substances shown in laboratory experiments to inhibit the development of zebrafish larvae. Eider ducks need to eat up to two kilograms of blue mussels per day - mussels that may contain high concentrations of OH-PBDEs.

– We find these results worrying, but need more knowledge to make a robust assessment of the impacts of brominated phenols on Baltic Sea wildlife, says Lillemor Asplund.

The murky side of efficient fishing

Bottom trawling is under debate because of its effects on the marine environment. Yet, trawling is on the increase almost all over the world, even in deep waters, where ecosystems are particularly sensitive. Ecotoxicologists in BEAM have studied the effects of sediment resuspension by bottom trawls.

Even this small shrimp trawler has gear that weighs half a ton and that sweeps a 25 metres wide track on the seafloor.

Field equipment to measure uptake of pollutants by different organisms.

Lab experiment to test effects of toxic sediment on blue mussels.

Sediment dispersal in the world's oceans can harm marine plants and animals. Fish that spawn on the seafloor can be disturbed, and some fish eggs and larvae find it difficult to survive in muddy waters. A new study compares the environmental effects of sediment dispersal by dredging and bottom trawling.

– Our results show that trawling suspends up to 90 times more sediment particles than dredging in the Baltic Proper, says Ingrid Tjensvoll, lead author of the study. We also found that trawling is the main cause of sediment resuspension below 70 metres water depth. Yet, regulations differ greatly for the two activities; dredging is strictly regulated by permissions and monitoring, whereas trawling is regulated purely from the point of view of fish quotas.

Toxins dispersed

Bottom trawling can also release contaminants that have been trapped in the sediments. In an experiment with sediment-clouds from trawling in a polluted Norwegian fjord, exposed blue mussels accumulated toxin concentrations that exceeded the maximum levels approved for human consumption within a month.

– We need to take both the effects of increased sediment resuspension and the release of harmful pollutants through bottom trawling into account when managing Baltic fisheries and ecosystems, says Ingrid Tjensvoll. This applies particularly to trawling in deep waters, where organisms are not adapted to high sediment resuspension. Rules are needed for how, when and where trawling can be performed based on all ecosystem impacts, not only fish stocks.

Ingrid Tjensvoll and Clare Bradshaw, Department of Environment, Ecology and Plant Sciences, Stockholm University, Ingrid.tjensvoll@su.se

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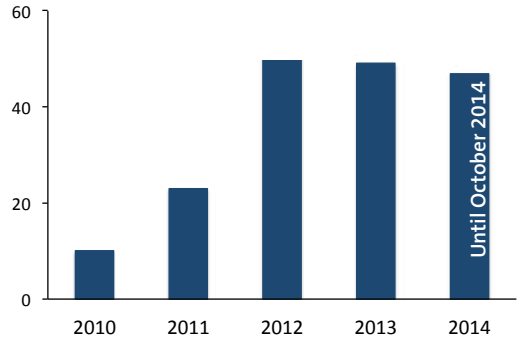

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BEAM programme results are published at an increasing rate in peer-reviewed scientific journals, including in high-impact journals such as Science, Trends in Ecology and Evolution, Nature Geoscience and PNAS. Over 130 articles were published by the end of 2013. Please visit www.su.se/beam for 2010-2013 publication lists.

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The aim of Baltic Ecosystem Adaptive Management, BEAM, is to develop a multidisciplinary scientific understanding of the Baltic Sea environment and its management and to provide strategic advice to practitioners and policy makers in order to make ecosystem-based management a reality. BEAM gathers scientists who are experts on ecosystems, organic environmental toxins, natural resource management, environmental law and the use of ecological models for decision support.

BEAM is a strategic research programme funded by the Swedish government and is part of the major research initiative on the Baltic Sea at Stockholm University. The Stockholm University Baltic Sea Centre hosts the programme and distributes the funds after decisions made by the interdisciplinary steering board.

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