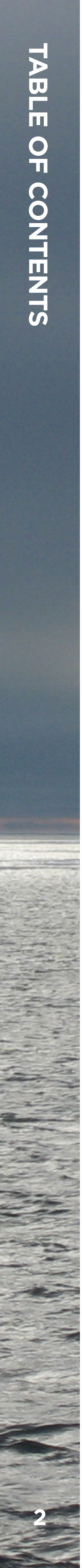
EcoChange 2018

UMEÅ UNIVERSITY

Linnæus University



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TRANSLATION: **CAROLINE LITTLEFIELD KARLSSON,** research assistant at Linnaeus University

COVER IMAGE: The common eider is one of the species that appears to suffer from thiamin deficiency. EcoChange researchers study how this problem starts at the base of the food web.

EcoChange.

EcoChange aims to increase awareness of the consequences of climate change in aquatic systems, and in the long term motivate authorities to introduce effective measures to address the effects of climate change.

THE STARTING POINT is that climate change affects the temperature, salinity and concentrations of dissolved organic carbon and nutrients in the Baltic Sea. This leads to a deterioration in food web efficiency, and thus an increased accumulation of contaminants in marine organisms.

FOOD WEB EFFICIENCY is a key concept within EcoChange, and is also an indicator of a healthy ecosystem. The food web efficiency can be altered by changes in, for example, species diversity, productivity, food web dynamics, population structure, amount of steps in the food web, evolutionary processes, and contaminants in the ecosystem.

THE BALTIC SEA consists of several basins, which have fundamental differences in hydrological conditions and food web structure. Specific studies in the different basins are important for projections of future conditions. The gradients in salinity, temperature and other variables are an important part of the EcoChange research. Umeå and Linnaeus Universities collaborate in field work, laboratory experiments and modelling.

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RESEACH WITH BREADTH AND DEPTH

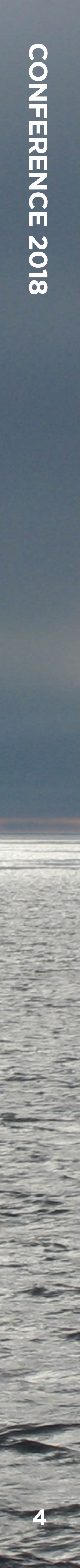
EcoChange is now in its ninth year. The research and collaboration between participating organizations and Swedish authorities has deepened and matured, and we have built a stable and long-term relationship.

Research funding has been used extensively to educate and promote young researchers. The first round of doctoral students have completed their studies, and many of them now work abroad, developing new international collaborations with prominent research groups. Others have gone on to marine environmental management, which promotes Swedish and international collaboration between academics and policy makers. We have recruited a second round of doctoral students who are now in the middle of their education.

Our holistic strategy offers answers to many of the questions surrounding marine environmental management

The research within EcoChange has been successful on many levels, and has led to an increased number of grants from various organizations, including FORMAS research council, the Swedish Research Council, and the EU. Researchers have also received awards for excellent needs-based research as well as various prestigious commissions.

As I read the 2018 collection of publications, I am struck by the great breadth and depth of EcoChange research. It ranges from biogeochemistry, ecology and environmental toxins to how best to monitor and manage the marine environment. Our holistic strategy, where the effects of climate change are investigated through experiments, modelling and field studies in different geographical areas of the sea, has answered many of the questions within marine environmental management. The government's investment in EcoChange has given us the opportunity to build stable and long-term research, with collaborations that extend well beyond the university and administrative boundaries. It lays the foundation for efficient, ecosystem-based marine environmental management.



SCIENTISTS WORRY ABOUT THE FUTURE OF THE BALTIC SEA

EcoChange researchers have delved deeper into the issues surrounding the climate and the sea. As a puzzle that forms piece by piece, so emerges an image of the future of the Baltic Sea. At the annual 2018 conference, scientists summarized the state of research within EcoChange.

There will be fewer fish and more environmental toxins in the future Baltic Sea, as evidenced by research into bacteria and phytoplankton. In the years since EcoChange began, ***food web efficiency*** has been forged as a central concept within the programme. It is expected to decline as an effect of climate change.

"It is important to investigate the effects of this decline on all parts of the marine ecosystem. We also study factors of large concern to people and society, such as concentrations of toxins in our food and fish production." says Agneta Andersson, professor in marine ecology at Umeå University and scientific coordinator of EcoChange.

> *"Within the projects carried out in EcoChange, many results show that climate change can negatively affect the Baltic Sea.*

Driven by organic carbon

Over the years, EcoChange researchers have focused on dissolved organic carbon (DOC) transported by rivers from land to sea. This carbon is expected to increase as a result of climate change.

Doctoral student Li Zhao at Umeå University studies the composition of organic carbon and how available the different forms are for bacteria. She investigates how bacteria adapt to changes in dissolved carbon composition – an important question for forecasting effects of the changing carbon inflow to the Baltic Sea.

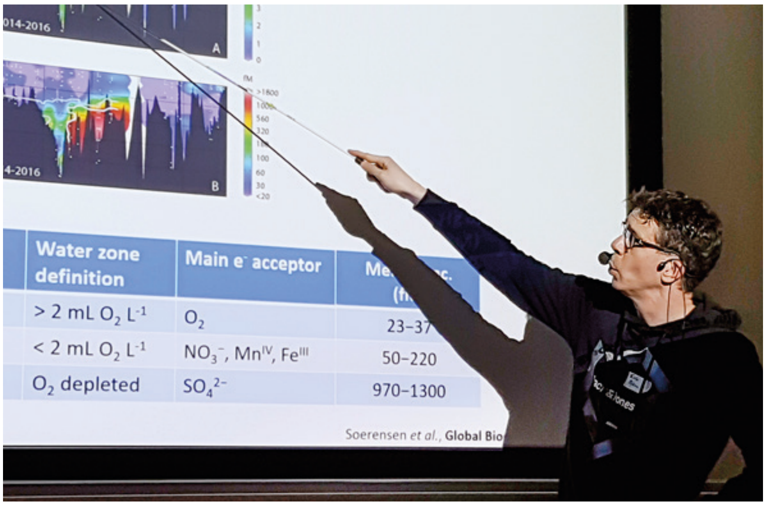
Increase of cyanobacteria blooms

Javier Alegria, doctoral student at Linnaeus University, focuses on picocyanobacteria, the smallest unicellular cyanobacteria. Cyanobacteria blooms are predicted to increase in the future. Javier investigates the seasonal variation of these blooms, how they react to changing nutrient conditions, and the differences in blooms between the coast and the open sea.

The dinoflagellate *Alexandrium ostenfeldii*, an alien species that has come to the Baltic Sea by ballast water, can cause many problems. It produces a toxin that accumulates in the mussels who feed on it. Water seldom reaches toxic concentrations, but the mussels contain much higher concentrations, potentially toxic to humans. Elin Lindehoff, lecturer at Linnaeus University studies this dinoflagellate, and has shown that it will be promoted with climate change.

Fat-deficient zooplankton?

The food web is composed of many levels, and zooplankton connect the bottom of the food web to higher levels such as fish. Danny Lau, research assistant at Umeå University, leads a research group that studies unsaturated fatty acids in zooplankton. Zooplankton are unable to produce these unsaturated fatty acids themselves, and must satisfy their needs through food intake. Thus they are dependent on consuming food with sufficient concentrations of these unsaturated fatty acids. The research group investigates how the concentrations of unsaturated fatty acids will change as a result of climate change, and how this will affect higher



Erik Björn, Umeå University, shows how conditions in the Baltic Sea affect how methylmercury is taken up into the food web.

levels of the food web. Will fish contain less fat? Will fish production be affected? This area of research is new, and we await the answers.

Production under the ice

Sea ice coverage will definitely be affected by climate change. Jenny Ask and Elina Kari, researchers at Umeå University and Stockholm University, have shown how sea ice coverage strongly impacts marine life under the ice. The water becomes strongly stratified, a state that can continue even after the ice has melted. Jenny Ask has studied primary production in coastal areas and mountain lakes, and has shown that primary production occurs very early in the season, far before the ice cover disappears in the spring.

Adapting pike

Per Larsson's research group at Linnaeus University studies pike, a predator fish close to the top of the food web. Pike populations have decreased in coastal areas, primarily as an effect of the loss of wetlands adequate for pike reproduction. Wetland restoration is underway to improve these conditions. Kristofer Bergström, doctoral student in Per Larsson's group, has evaluated the restored wetlands, and found that these so-called pike factories do, in fact, increase pike production.

Mercury in the food web

Environmental chemists within EcoChange investigate how methylmercury is taken up and bioaccumulates in the food web. Erik Björn, associate professor at Umeå University, shows how changes in the balance between bacteria and phytoplankton also affect the uptake of methylmercury, which is the most toxic form of mercury. Bacteria methylate inorganic mercury to the toxic and more bioavailable organic form of mercury, methylmercury. Anne Sörensen, a researcher at Stockholm University, develops models that simulate mercury bioaccumulation in the food web.

"The most important process is the uptake from water to cyanobacteria and other phytoplankton. Species composition and size distribution of plankton impacts how much methylmercury that enters the food web" she says.

Concrete advice

The EcoChange program is closely connected to authorities, and researchers strive to synthesize results into concrete advice for the Baltic Sea management. From the start, marine management authorites took an active role in EcoChange, and this collaboration has developed over the years. Prepresentatives from various authorities have identified key questions to address, knowledge gaps, and which parts of the administration that have the greatest need for research support.

Results produced by EcoChange researchers must be broken down and quantified for authorities. How large is the problem of increasing dissolved carbon entering the Baltic? How much do increasing environmental toxins cost us? How can authorities use their knowledge of the filtering function of coastal areas in marine environmental management of the Baltic Sea?

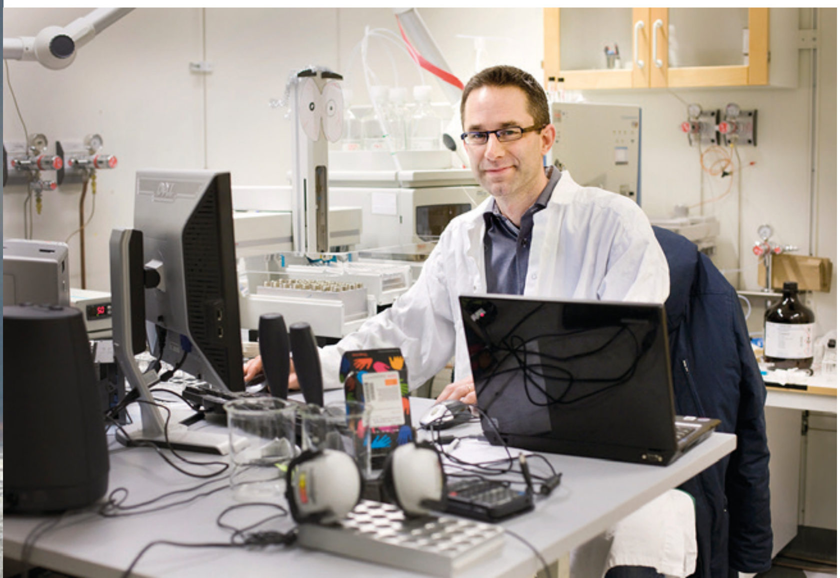
Scientists are worried

Agneta Andersson emphasizes the importance of good communication between research and marine environmental authorities.

"Within the projects carried out in EcoChange, many results show that climate change can negatively affect the Baltic Sea. This worries us. Marine environmental authories must have the opportunity to access our results and adapt both monitoring and planning strategies for the management of a changing Baltic Sea."

PHARMACEUTICAL RESIDUES WIDESPREAD IN THE BALTIC SEA

Pharmaceutical residues are widespread throughout the Baltic Sea – not even the open sea is free from these substances. In this pharmaceutical stew one can find traces of everything from blood pressure to epilepsy medications. Concentrations are closely tied to human population density in different areas.



Jerker Fick, researcher at Umeå University, investigates pharmaceutical residues in Baltic Sea water.

Björlenius, Berndt; Ripszám, Mátyás; Haglund, Peter; et al. 2018. *Pharmaceutical residues are widespread in Baltic Sea coastal and offshore waters: Screening for pharmaceuticals and modelling of environmental concentrations of carbamazepine.* Science of the Total Environment, Elsevier 2018, Vol. 633: 1496-1509.

Pharmaceutical residues are found in every sea in the world. This trend appears to be increasing in the marine environment, which partly may be due to the fact that scientists have been actively looking for these substances. Various areas have been investigated, but not previously in the Baltic Sea. A research group within Eco-Change has sampled both the coastal areas and the open sea throughout the Baltic Sea, Kattegatt and Skagerrak. They looked for the presence of 93 different pharmaceutical substances in the samples. They found 39.

Population matters

There is a clear correlation between the human population size of an area and the amount of pharmaceutical residues found in the seawater – this is also true for the Baltic Sea. Concentrations are highest near the coast, and even higher near large cities. The Baltic Sea shows a gradient from north to south. The total number of pharmaceuticals found in the water increased from the Bothnian Bay to the Bothnian Sea, and was highest in the Baltic Proper. Concentrations are far below the levels that could affect humans, but are still at levels that previous studies have shown to affect other organisms.

A mix of everyday medications

Among the substances found in the largest amounts were, for example, medications for blood pressure, heart disease, fungal infections, allergies, and pain relief. In these results, one substance stood out in particular: the epilepsy drug carbamazepine. Although a few samples from the northernmost Bothnian Bay lacked carbamazepine, it was present in all other samples.

Large amounts of carbamazepine

The geographical spread of samples combined with modelling work enabled researchers to describe visually how much of this substance each country contributed to the Baltic Sea. Poland has by far the largest amount of carbamazepine, which is explained both by the large population and the extensive use of this drug there. Sweden comes in second place, followed by Finland.

It takes over three years for carbamazepine to decompose once it has entered the Baltic waters. This makes the substance an appropriate indicator of the environmental status of drug residues. The total amount of carbamazepine in the Baltic Sea is estimated at 55 tonnes.

SMALL, UNIQUE PIKE POPULATIONS

There are over 27,000 fish species on earth, and the variation among different species is enormous. Not everyone is aware, however, that large variations also can occur within species.

In practice, this means that different populations of the same species can show variation in genetics as well as in appearance and behavior. Understanding which factors affect population structure and intraspecific diversity is important not only from a management standpoint, but it also helps to understand how species are affected by environmental changes.

Pike in focus

Oscar Nordahl received his PhD from Linnaeus University for his thesis work on coastal Baltic Sea pike. This species, which was initially considered to show little genetic variation, turns out to show a variety of genetically distinct subpopulations, even on fine spatial scale. This type of population structure has been studied in some Baltic Sea species, but not previously in a freshwater-adapted species such as pike. Because climate changes are expected to lead to decreased salinity in the Baltic Sea, knowledge about this freshwater species in brackish water will be vital for the future.

Swimming home to spawn

So, how can variations occur when there are no obvious physical boundaries?

An important factor for this to occur in coastal pike is their homing behavior. This means that they return to the same area to spawn. They have this behavior in common with a variety of fish species; the best-known example is salmon. Some coastal pike find their way into the waterways of suitable wetlands where they spawn in the spring. As soon as the spawning is over, the pike migrate back to the coast. Other pike stay on the coast and spawn there. During the remainder of the year, pike from the various subpopulations live together in the coastal area.

Divergent behavior and morphology

The pike in different subpopulations not only prove to be genetically distinct, but there are also differences in morphology and behavior. For example, the number of vertebrae and egg size differ, which in turn can affect the reproduction, growth and survival of the fish. The pike can have local adaptations to their spawning areas, which means that they have the most reproductive success if they spawn in their home environment. Such adaptations can further reduce gene flow among neighboring subpopulations.

Sun-basking pike

Pike, like most fish, are ectothermic animals with a body temperature that closely matches that of ambient water. Even small changes in water temperature can have large impact on individuals and populations and fish are known to seek out areas with beneficial water temperatures. However, Oscar has shown that fish in fact can raise their body temperature to be higher than the surrounding water by sunbasking close to the surface. This has been considered impossible for fish due to the strong cooling effect in water. The temperature gain proved to be associated with an increased growth rate.

More effective measures

The pike is one of Sweden's most common predatory fish. As a predator at the top of the food chain, it has an important ecological role in the Baltic archipelago environment. However, pike populations have declined dramatically, and despite extensive conservation efforts, populations are still weak. Knowledge of population structures and local adaptations is crucial to being able to work effectively with measures, such as fisheries management, habitat restoration and connectivity among and within habitats. ●

Oscar Nordahl

Doctoral Thesis

Nordahl, Oscar. Intra-specific diversity of pike (Esox lucius) in the Baltic Sea and new insights on thermoregulation in fish. Linnaeus University 2018.

ADAPTABLE PIKE

Coastal dwelling pike are affected by changes in salinity, but appear to have an inherent ability to adapt. Different conditions during spawning engenders variation in populations, which can be crucial for the survival of coastal pike in the Baltic Sea.

Fifty percent of the pikes in the coastal area seek freshwater to spawn. Studies show that pike are highly adaptable to local conditions.

What happens when salinity changes in the Baltic Sea, and the salinity gradient shifts southward? Will species living in one area disappear or move to other areas? …or can they live in changing environmental conditions? These issues are important for management of the future Baltic Sea, and are perhaps even more vital when concerning fish. Fish, in addition to being an important part of the ecosystem, are often sensitive to salinity concentrations. Salinity is one of the most important factors constraining the distribution of fish populations.

Environmental variation leads to genetic variation

A stable environment generally leads to higher specialization among organisms, while changing conditions lead to greater genetic variation. This variation can be the key to survival in changing habitats. It is therefore crucial to consider the genetic variation that exists within populations in the management of species.

Homing behavior

Pike have a natural inclination to swim back to the area where they hatch when they spawn. This means that populations that spawn in nearby waters can still be genetically distinct. It also gives rise to fish adapting to their local environments. For example, there may be differences in growth rate, body length and number of vertebrae. Not previously known was the question if they can differ even in terms of salinity tolerance, or if they have an inherent ability to cope with different salinity levels.

Local adaptation

In the Kalmar region in the southern Baltic Sea, a group of researchers studied coastal pike populations. Their research clearly shows that there is not one pike population but many local populations. Fifty percent of the pikes live in the coastal area's brackish water, while about half of them seek freshwater to spawn. Of the pikes spawning in freshwater, some experience stable freshwater conditions, while others spawned in locations where salinity fluctuates.

By examining the ability of these populations to handle different salinity levels, the researchers were able to demonstrate an inherent ability of the pike to adapt to different conditions. The adaptation seems to take place at a very local level, so that pike that spawn in a stream differ genetically from the pike that spawn in a nearby stream along the coast. When the freshwater juveniles are about a month old, they migrate back to the coastal waters The adaptation thus occurs despite the fact that the fish live together in the same area for the rest of the time.

Coping with change

The pike in Kalmar Sound seem to have a sufficiently wide genetic variation regarding salinity tolerance to be able to withstand future changes in salinity, provided that that this variation may remain in the future and form the basis for decisions on the management of the coastal area and its population of coastal pike. ●

Sunde, Johanna; Carl, Tamario; Tibblin, Petter; et al. 2018. *Variation in salinity tolerance between and within anadromous subpopulations of pike (Esox lucius).* Scientific Reports, Nature Publishing Group 2018, Vol. 8.

TO THE BOTTOM WITH THIAMIN DEFICIENCY

Changes in the phytoplankton community can affect fish and birds, and may explain why vitamin deficiency occurs among top predators.

Several top predators in the aquatic food chain have shown signs of vitamin deficiency, more specifically, lack of thiamin, B_1 . Salmon have had problems with reproduction, and mortality among the common eider is very high. The question is why this thiamin deficiency arises. To get to the bottom of the problem, a research group within EcoChange has examined the part of the food web where everything begins: phytoplankton and zooplankton.

Produced by phytoplankton

Thiamin is an essential vitamin for virtually all living organisms. It is needed for basic metabolism, and thiamin deficiency leads to a variety of symptoms. Behavioral changes, weakened immune system and serious reproductive effects are among them.

In the aquatic environment, thiamin is primarily produced by phytoplankton and bacteria. This means that all animals must receive the compound via ingestion. The body cannot store any large quantities either, but must receive a continuous supply of it via food. Also, not all species of phytoplankton can produce thiamin. The species composition of phytoplankton is therefore important for the availability of thiamin.

Inhibited thiamin uptake

Filamentous cyanobacteria bloom annually in the Baltic Sea, and have been found to contain relatively large amounts of thiamin. Nevertheless, the presence of cyanobacteria appears to inhibit the uptake of thiamin by the zooplankton. Cyanobacteria provide relatively poor food for zooplankton, as they do not contain the correct fatty acids, in some cases produce toxins and the filaments are difficult for zooplankton to ingest. They also have an inhibitory effect on zooplankton reproduction, which can also affect the amount of thiamin reaching higher levels in the food web. Thus even though cyanobacteria contain high concentrations of thiamin, it is not certain that this thiamin can be transported further up into the food web.

Important species composition

The species composition of phytoplankton is a factor that is of great importance for how much thiamin zooplankton can get. Zooplankton grazing on phytoplankton can to a certain extent select which phytoplankton it eats, and can thus influence the species composition of the phytoplankton community.

The conclusion of the study is that the amount of thiamin in higher trophic levels, such as top predators, could be closely related to the composition of the phytoplankton community, and is adversely affected by the increasing amount of cyanobacteria in the ecosystem.

Filamentous cyanobacteria can contain large amounts of thiamin. Despite this, it seems that the presence of this cyanobacteria inhibits the transfer of this vitamin to zooplankton.

Fridolfsson, Emil; Lindehoff, Elin; Legrand, Catherine; Samuel Hylander. 2018. *Thiamin (vitamin B1) content in phytoplankton and zooplankton in the presence of filamentous cyanobacteria.* Limnology and Oceanography, John Wiley & Sons 2018, Vol. 63, (6) : 2423-2435.

DECREASED EFFICIENCY IN A COMPLEX FOOD WEB

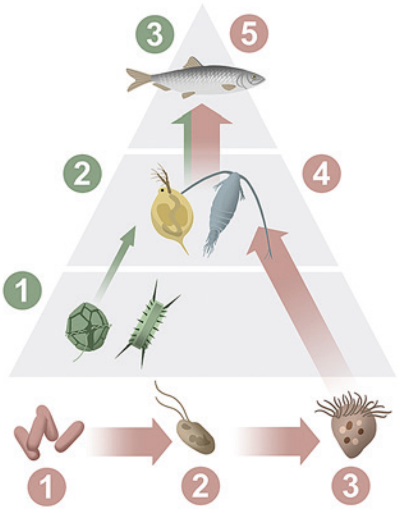
It is now clear that more dissolved organic carbon in the seawater leads to a less efficient food web. But what controls this, and what roles do each part of the food web play?

At the bottom of the food web we find phytoplankton and bacteria, basal producers. The balance between these two actors can be decisive for how efficient the food web will be, i.e. how much energy from the basal production reaches top consumers. Zooplankton feeds on phytoplankton, while bacteria are too small to be directly consumed by zooplankton. Instead, they are eaten by protozoa, which are then consumed by zooplankton. Thus, another step has been added to the food web, and it grows more complicated.

Decreased efficiency

Bacteria are to some extent dependent on phytoplankton production to gain access to organic nutrients, while phytoplankton can use inorganic nutrients. In aquatic systems that are affected by terrestrial carbon, bacteria can be decoupled from their dependence on phytoplankton by using dissolved organic carbon originated on land. When the bacteria account for a larger part of the basal production, the food web becomes less efficient, since the energy is channeled through several steps. Additionally, bacteria are of poorer quality than phytoplankton for many consumers.

Degerman, Rickard; Lefébure, Robert; Byström, Pär; et al. 2018. *Food web interactions determine energy transfer efficiency and top consumer responses to inputs of dissolved organic carbon.* Hydrobiologia, Vol. 805, (1) : 131-146.



The increased influx of organic carbon will result in several steps in the food web, making the food web more complex.

The marine food web is a highly complex system, and the balance between plankton and bacteria at the base can be controlled both from below, for example by nutrient supply, and from the top by top consumers. There are very few studies that include all levels from bacteria and phytoplankton to fish.

Surprising response

A group of EcoChanges researchers have conducted experiments to investigate what actually controls food web efficiency. By using mesocosms, they were able to study both basal production and top consumer production in different combinations of added DOC, and with and without fish as top consumers.

In general, the addition of DOC resulted in lower food efficiency, as expected. What was more surprising were the differences in response to the different levels of the food web. For example, phytoplankton was favored by added DOC when the topmost level in the food web was zooplankton, while they were disadvantaged when the same addition was made with fish as the topmost level.

It could also be stated that food web efficiency was controlled both from the top and the bottom. When fish were included in the experiments, it could have an effect on production throughout the food web, all the way down to plant plankton and bacteria. However, the decrease in food web efficiency was not primarily the result of changes in the top consumers' production, but rather a result of changes at the bottom of the food web.

Complex system

The marine food web with all its steps and parts is complicated, and it can therefore be difficult to know how changes will affect its many different parts. This study contributes to the understanding of complexity, and shows clearly that even in relatively simple experiments, the path of energy through the food web is complex and difficult to predict.

BASAL ENERGY SOURCES ARE CHANGING

Carbon from land is eaten by benthic fauna in lakes and seas. In this way, carbon from land enters the aquatic food web. Through isotope studies, researchers have been able to follow carbon from its arrival in coastal waters to its path up the food chain.

We know that climate change leads to an increased influx of terrestrial carbon, that is, carbon originating from land and often brown in color. Exactly how this influx will affect our coastal food webs is still unclear, but thanks to this study, some pieces of the puzzle have fallen into place. Rivers transport terrestrial carbon to the sea, and earlier studies have shown that brown water reduces light penetration in the water and that bacteria production is favored over algae production. But where does the terrestrial carbon go once it has entered the coastal waters?

By labelling the terrestrial carbon with deuterium, heavy hydrogen, the researchers were able to trace its path through different parts of the food web. They showed that some of this carbon was transported up the food web to higher trophic levels, such as fish. The path into the food web seems to go through benthic fauna which probably eat the terrestrial carbon directly when particles fall to the bottom. Some animal groups eat more of the terrestrial carbon, while others mainly feed on bottom-living algae, i.e. marine carbon.

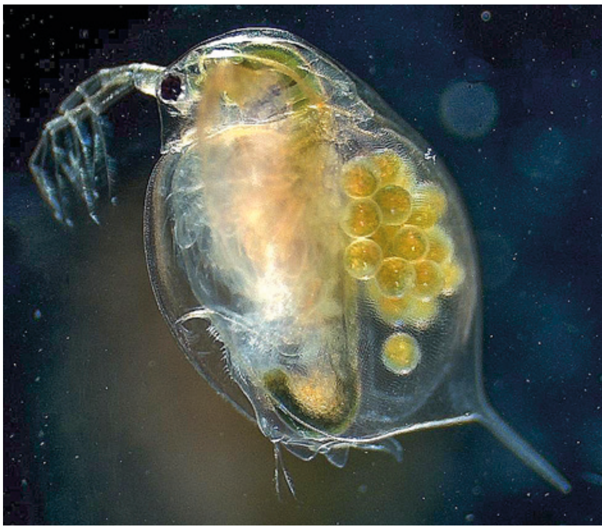
Zooplankton feed on marine carbon

Bacteria in the water column, which are often favored by terrestrial carbon, could conceivably contribute to carbon entering the food web by being eaten by small zooplankton. However, this study indicates that this is not the case to any great extent. Zooplankton does not contain much terrestrial carbon, but instead appears to feed on carbon produced in the marine environment.

Perch feed on terrestrial carbon

The researchers also studied sticklebacks and perch, and saw great differences between the two species. The sticklebacks were not very dependent on the terrestrial carbon, while perch seemed to heavily depend on it. The results therefore show that perch to a large extent eat benthic fauna.

Zooplankton do not appear to use terrestrial carbon to any great extent.



Variation during summer

The degree to which different organisms depend on terrestrial carbon varies during the summer. Benthic fauna use this carbon throughout the summer, with a slight dip in early June. Values were highest near the estuary, and lower further out in the sea. The values were also higher in deep areas, which indicates that the dependence on terrestrial carbon from these organisms is higher where there is a shortage of marine produced carbon. Zooplankton, on the other hand, showed a very low dependence on the terrestrial carbon during most of the summer, but with a slightly higher value in May. The study emphasizes that climate change will change the basic energy sources in coastal ecosystems. ●

Bartels, Pia; Ask, Jenny; Andersson, Agneta; et al. 2018. *Allochthonous Organic Matter Supports Benthic but Not Pelagic Food Webs in Shallow Coastal Ecosystems. Ecosystems* (New York. Print), Springer 2018, Vol. 21, (7): 1459-1470

SENSITIVE BACTERIOPLANKTON COMMUNITIES IN THE BALTIC SEA

Bacterial communities are sensitive to environmental disturbances, and will change in the Baltic Sea of the future. The question is – what are the consequences for the ecosystem? EcoChange researchers have synthesized current research and experiments surrounding the sensitivity of bacterioplankton to environmental disturbances in the Baltic Sea.

Bacteria are found everywhere in the sea, and play an important role in the ecosystem. They can, among other things, break down organic material, and make carbon dioxide and minerals available again to other organisms in the food web. In this way, they are the main players in the flow of energy and matter in the ecosystem.

Change or resist?

Climate change will lead to an increase in temperature and a decrease in salinity in the Baltic Sea. Will this affect the composition of bacterial communities, and will bacterial communities be able to adapt to these changes? And above all, will any changes in the composition affect bacterial function in the ecosystem? EcoChange researchers have compiled the state of research on how sensitive bacterial communities in the Baltic Sea are to environmental disturbances.
Bacterial communities can react in three ways when exposed to environmental changes. They can be sensitive, and change their community composition when exposed to disturbances; they can be resistant to the disturbances, and they can change but have the ability to return to their former state. How bacterial communities react is crucial to how the ecosystem will be affected by environmental disturbances.

Salinity has large-scale control

Many studies show the ability of bacteria to react differently to changes in the environment, such as temperature, salinity and nutrients. Given the important function of the bacteria, changes in the bacterial communities can also affect other parts of the food web. On a large scale, salinity controls how the bacterial communities are composed. In the Baltic Sea, there is a salinity gradient from north to south, which greatly affects bacteria that are present in the various sea basins.

Within each sea basin however, other factors appear to control composition. For example, it may be a matter of the degree of oxygen deficiency. The bacteria are also linked to phytoplankton, and the composition of the bacterial communities is locally linked to the dynamics of the phytoplankton community.

A need for long-term studies

Bacterial communities in the Baltic Sea seem to be sensitive to disturbances, which means that communities change as a result of various environmental impacts. So far, however, very few studies have been conducted over periods of time lasting longer than a few weeks, which means that one does not actually know whether communities can return to their original composition. There is a seasonal variation in the composition of bacterial communities, with clear spring and autumn communities. Much of this variation is explained by differences in temperature.

Unknown consequences

Researchers also question whether the expected major changes in the composition of the bacterial communities will have any consequences as regards the function of the ecosystem itself. This issue has not yet been specifically investigated. Studies are needed on how changes in bacterial communities affect, for example, the carbon cycle, as an important part of decisions regarding measures for the marine environment in a changed climate. ●

Lindh, Markus V.; Pinhassi, Jarone. 2018. *Sensitivity of Bacterioplankton to Environmental Disturbance: A Review of Baltic Sea Field Studies and Experiments.* Frontiers in Marine Science, Frontiers Media SA 2018, Vol. 5.

BACTERIA INDICATE DISTURBANCE IN THE MARINE ENVIRONMENT

Studying bacterial community composition gives EcoChange researchers a fast, simple and effective look at disturbances in the marine environment. Researchers have investigated how bacterial communities change when exposed to combinations of increased organic matter and environmental toxins.

As a result of climate change, the amount of organic material flowing into the seas will increase, especially in the northern regions of the Baltic Sea. This leads to major changes in the basic levels of the food web, which then affects the entire food web. The clearest effect is that bacteria will benefit from the influx, while phytoplankton will be disadvantaged.

These changes can have effects not only on the food web itself, but also on how environmental toxins are absorbed and disseminated in the food web. EcoChange researchers investigated how bacterial communities change and how this may affect the uptake of environmental toxins.

Controlled experiments

To study the changes under carefully controlled conditions, so-called mesocosms were used. To mimic the inflow of organic matter, soil was added. A mixture of organic pollutants occurring in the Baltic Sea was added, and bacterial production and the composition of the bacterial community could be studied by the addition of different combinations of soil and environmental toxins.

Soil and pollutants led to changes

It is already known that bacteria can react differently to organic pollutants. Some are inhibited in their growth, many are not affected at all, and some can even benefit from the toxins. Bacteria that benefit likely can use the organic environmental toxins as food.

The results of the experiments clearly showed that the combination of increased amounts of organic material and environmental pollutants can change the composition and function of bacterial communities. In general, the bacteria were favored by the organic material and disadvantaged by the environmental pollutants. When the environmental pollutants were combined with organic material, the inhibitory effect of the environmental pollutants became even greater.

In mesocosms, experiments are done under carefully controlled conditions.

Uncommon types were eliminated

The diversity of the bacterial community increased with increasing amount of organic matter, and decreased with the amount of environmental pollutants. It was primarily the less common types of bacteria that were eliminated by the environmental pollutants, while the more common types were less affected, possibly because more common bacteria have the ability to adapt to changes in the environment.

Indicating disturbance

The study shows that bacterial communities are affected, both in terms of composition and function, when they are exposed to environmental disturbances in the form of environmental pollutants. The researchers therefore suggest that analyses of bacterial communities should be included in the environmental monitoring as an indicator of disturbances in the marine environment. It could work quickly and efficiently, and relatively cheaply. ●

Rodríguez, Juanjo; Gallampois, Christine; Timonen, Sari; et al. 2018. *Effects of Organic Pollutants on Bacterial Communities Under Future Climate Change Scenarios.* Frontiers in Microbiology, Frontiers Media S.A. 2018, Vol. 9.

BACTERIAL RESPIRATION CONTRIBUTES TO HYPOXIA

Hypoxia is a growing problem in the coastal areas of the Baltic Sea. Implementing effective measures requires good knowledge of what regulates oxygen consumption in these areas.

Kevin Vikström

Kevin Vikström of Umeå University, in his doctoral dissertation, explains why action taken does not always have the intended effect. Bacterial respiration is important in this context. "We breathe, all animals breathe, even bacteria breathe. In breathing, oxygen is consumed, and this oxygen, together with carbon compounds, is converted into energy. The energy is not only used for growth, but also for life-sustaining functions. Breathing maintains a certain level even when no growth occurs, which means that oxygen is consumed even when growth is at a standstill.

Carbon from rivers

The carbon compounds used by marine bacteria for their respiration come partly from phytoplankton but also largely from the organic material transported via the rivers to the sea. The river-carried carbon is particularly important in the northernmost parts of the Baltic Sea. In early spring, the amount of organic matter in the coastal zone increases, and the bacteria that live on this material thrive. Bacteria use this carbon for growth, metabolism and respiration. Already today, the amount of organic material is higher in the Gulf of Bothnia than in other parts of the Baltic Sea. Climate change will increase the flow of river water, packed with carbon compounds. In a few hundred years, the Baltic Sea will receive twice as much carbon compared to today. The dissolved carbon can be utilized by bacteria, thereby disfavoring primary producing phytoplankton.

Bacteria: important oxygen consumers

Kevin Vikström studies bacterial maintenance respiration in the Baltic Sea. Bacteria are so small that you can hardly see them in a microscope, but there can be millions of them in a single milliliter of seawater. They are important as biodegraders, and account for 50-80 percent of all oxygen consumption in the seas. More than half of the oxygen is spent on bacterial maintenance, which is partly decoupled from growth. Thus, the daily energy needs of bacteria play an important role.

Understanding bacterial maintenance respiration increases our knowledge of oxygen dynamics, and how oxygen deficiencies occur in the oceans. The thesis shows that oxygen consumption does not necessarily decrease even though the growth of bacteria decreases. Instead, bacteria switch to maintenance resperation, and oxygen consumption remains largely the same as it was before, despite measures to regulate the growth of microorganisms.

Environmental management strategies

The largest source of carbon used for respiration is phytoplankton. A common measure to counteract oxygen deficiency is to regulate the growth of phytoplankton by reducing the influx of nutrients. With this measure, respiration, and therefore oxygen consumption, decreases as the amount of carbon decreases. But the addition of carbon from the rivers counteracts this, raising the basic level of oxygen consumption in the coastal ecosystem. From an environmental management perspective, we must deal with the problem of oxygen deficiency in a way that is adapted to local conditions. In coastal ecosystems, the basic level of the ecosystem in terms of oxygen consumption should be taken into account when deciding on growth-regulating measures.

Thesis:
Importance of bacterial maintenance respiration and baseline respiration for development of coastal hypoxia. Umeå: Umeå University 2018.

KNOWLEDGE-HUNGRY WATER MANAGEMENT AUTHORITIES

Researchers and environmental management authorities must collaborate closely to achieve a good marine environment and a sustainable use of our seas. EcoChange offers the adminstrators of our water the basis for making decisions on environmental monitoring and measures.

Knowledge is a perishable commodity that must be continuously reviewed and used in the right context. It becomes even more important as the climate changes and we must reevaluate assessments and weigh different interests in new ways. Within the sea and water management work, we address many challenges. A changed climate, synergistic effects of various environmental problems and the lack of data on the marine environment are at the forefront.

The problems are complicated, and the results are not obvious. Research must be synthesised and broken down on a fine geographical scale, as conditions differ greatly in distinct marine areas. When ecosystems differ year by year, the environmental problems and the effect of measures taken will differ too. We are constantly in need of future prospects, different scenarios, knowledge of response at ecosystem level, illumination of synergy effects, deeper knowledge of the effect of various measures, and of other unknowns we don't yet have the knowledge to ask about today.

Difficult equation

In ecosystem-based management, we look for ways to preserve biodiversity and use natural resources in a sustainable way. We want to use ecosystems for blue growth in the form of tourism, protein production and raw material extraction. Right now, we load the seas with fertilizers, plastics and environmental pollutants. We want to protect ever larger areas as much as possible from these environmental problems. The pressure on the coasts is increasing, and the equation is increasingly difficult to solve.
We need cooperation at all levels. But perhaps more important is the need for knowledge. With more knowledge on how the ecosystem and individual species are affected by the changing climate and multiple impacts, we must find a system that takes into account the entire ecosystem and provides the best possible conditions for long-term management and blue growth.

Intercalibration in the Bothnian Sea between Umeå Marine Research Center (KBV181) and Finland's Environmental Center (R / V Aranda). Comparability between different samples is important in order to be able to draw firm conclusions about the state of the environment.

Evaluating measures

When environmental management needs more knowledge about complex and changing causal relationships, research programs like EcoChange are especially important. In our work with the Water and Marine Environment Directives, we identify the most cost-effective measures to achieve good status in our marine environments. But in order to succeed, Swedish environmental marine monitoring must be developed. We need to know the natural variations, be able to show trends and evaluate the measures taken.

Close contact is crucial

Connecting the research world with the authorities that have the tools and the power to make decisions is essential. The results from EcoChange provide the basis for evaluating which measures are most effective, and gives insight into which environmental monitoring is needed. In a changing world, we see the need for even closer contact and established forums where sea and water management can record their continued need for research efforts. ●

Irene Bohman

FROM RESEARCH TO IMPLEMENTATION – ECOCHANGE OPENS AN IMPORTANT DIALOGUE

Åke Bengtsson has followed EcoChange closely since its inception. In addition to being a board member, he is involved with emerging results and how they should be implemented. As director of water conservation, strategist and community planner, he knows how important it is that measures are based on scientific knowledge.

Crooked spines started it all

His own research efforts have been greatly influential in the field of environmental toxin release from the cellulose industry. And it all began in the 1980's with the discovery of vertebral deformities of fourhorn sculpins.

”We found these fish outside pulp factories, and I was tasked with mapping and describing the problem. As a young researcher, it was tough to enter such a minefield, where big money was at stake and the results were constantly questioned by industry representatives. But when I look back on that time, it was incredibly useful and educational, and the results have actually led the cellulose industry to use more environmentally friendly methods. It probably cost the industry billions, but Sweden was the first to bleach paper without chlorine, and thus gained great competitive advantages. Today, that kind of chlorine bleaching is eradicated.”

The difficulties in putting research into practice

Since then, Åke has worked in the public sector, and understands the need for scientifically-proven knowledge in his work. He knows the importance of coupling research and administration, which is crucial for scientific results to be implemented in society. But getting results translated into practical action is no easy task.

“When confronted with revolutionary knowledge, the question naturally arises: How important are these results for the whole? As a rule, there are many factors in play, and then politics enters as well. We are always confronted with the problem that it takes time for new knowledge to have an impact, both as a result of a lack of knowledge transfer and a certain degree of skepticism towards the new. ”

Chlorine bleaching in the pulp industry is an example of where research has been translated into practical action. Sweden was the first to bleach paper without chlorine, and today that type of chlorine bleaching is gone from the processes.

Important knowledge on river carbon

Some of the results produced within EcoChange have a direct bearing on the planning and monitoring of the marine environment. Åke highlights the results about the importance of river carbon for the nutrient status of our coastal areas as important to get out to the administration.

”The results obtained thus far are extremely interesting from management and action perspectives, and can affect decisions about the extent to which you should try to remove phosphorus in different seas in the future. Maybe we should work on removing carbon instead of phosphorus, at least in the Bothnian Sea? But more evidence is needed in general. Are the results valid for shallow bays in the Bothnian Sea or the entire Baltic Sea? And what is the actual source of this carbon? How much is caused by human activity?“

The pessimistic optimist

In his career, Åke has "experimented" on all scales, from small aquariums to the sea. Over the years he has seen huge improvements in decreasing the spread of environmental toxins and the state of the marine environment. He has an optimistic basic belief that everything can be solved, but he has become more pessimistic with time.
"Blue growth, as it is discussed today, I am skeptical of. What conditions do we need to achieve growth based on finite, hard-pressed resources? Very little concrete action has arisen from these wide-scale discussions."

Regarding the environmental status, Åke asks whether the Baltic Sea has already been lost, and if the Bothnian Sea isn't already on its way there. It takes power to make improvements. "The Swedish people must take responsibility for our old sins. The glass is already full, so even though we are now filling less than before, it is already spilling over. Not until we empty the glass can we bring about change."

Beneficial meetings

Åke is a frequent participant in EcoChange meetings and conferences. He sees them as the most effective way of communicating research results to the administration. At the meetings, researchers are given the opportunity to present their work, and environmental managers are given the opportunity to discuss how these results can be applied. But the meetings need to be followed up in order to influence the management of our seas.

"Maybe the researchers would dare stick their necks out little more, and come up with more concrete suggestions for changes? And maybe we administrators could push for more when it comes to discussing the application of the results? There are many good examples of where this has worked well, and where a proper dialogue has started. This is an important part of EcoChange's operations, where there is also a great potential for development. I hope for many exciting EcoChanges meetings between research and management in the future."

Åke Bengtsson is a pessimistic optimist who has had many roles in water management. Among other things, he has been involved in how research results should be put into practice.

Is the Baltic Sea already a lost sea, and is the Bothnian Sea heading in the same direction? This picture was taken at Ulvön in the Bothnian Sea.

WE WELCOME:

CLARA PEREZ MARTINEZ

I began my doctoral studies in Kalmar last year, with Jarone Pinhassi as the main supervisor. My research is focused on marine microbial ecology, diversity and function. I am interested in how bacterial communities respond to climate change. I also study how bacteria affect their environment, with a particular focus on the cycle of organic and inorganic nutrients.

My analyzes are based on the very latest methods in microbial ecology, such as metagenomics and metatranscriptomics. At the moment I am researching vitamin B and its role and dynamics in the Baltic Sea. I use data from LMO, Linnaeus Microbial Observatory time series.

I am happy to be part of EcoChange, and to participate in the annual conferences. I also look forward to developing collaborations within the research program.

KRISTOFER BERGSTRÖM

I have been a PhD student at Linnaeus University in Kalmar since 2018 with Per Larsson and Petter Tibblin as supervisor. I previously worked as a technician at Linnaeus University focusing on marine sampling and was involved in EcoChange from its very beginning.

My doctoral studies are based on the fact that the Baltic coastal ecosystem is dominated by fish species of freshwater origin and that several of these species are limited in terms of salinity and distribution. In a future scenario in which salinity decreases as a result of climate change, these species may increase in distribution and dominance - an invasion that has its distribution from lakes and streams. Therefore, with in-depth research on anadromy and local adaptations of fish species in the Baltic Sea, I want to increase understanding of these processes.

The aim is also that these studies will contribute to predicting how species and populations will be able to handle future environmental changes in the Baltic coastal ecosystem, and what consequences it will have in terms of population dynamics and the species composition of the fish community.

ANDRIY REBRYK

I am a PhD student at Umeå University, with Peter Haglund, Mats Tysklind and Christine Gallampois as supervisors. I started my studies in analytical chemistry in Ukraine, and then came to Sweden to continue these studies.

My project will focus on unconditional analysis to find and identify new biomagnifying organic pollutants in top Baltic consumers. It will include the development of general methods for extraction and purification of biological samples, unconditional analysis and identification of bioaccumulative organic pollutants in top consumers in the Baltic ecosystem. I attended the EcoChange conference in November 2018, and appreciated the friendly atmosphere and the fact that so many experienced researchers shared their knowledge.

KAROLINA ERIKSSON

I am a biotechnologist and doctoral student at Umeå University, with Agneta Andersson (EMG) and Johanna Thelaus (FOI) as supervisors. Infectious diseases are receiving more and more attention, both because of antibiotic resistance and climate change. Bacteria and climate change have long caught my attention. An intriguing theory is that there is an evolutionary link between the ecosystem where the bacteria live and the evolution of their pathogenic properties. The focus of the project is on identifying ecological drivers that lead to the emergence of disease-causing bacteria in aquatic environments.

I am originally from Umeå and am very pleased that this project is included by Umeå University's Business Research School with FOI as a partner and at the same time is part of EcoChange, enabling broad collaboration for the project.

DARYA KUPRYIANCHYK
RECEIVES UMEÅ MUNICIPALITY'S SCIENTIFIC PRIZE

Darya Kupryianchyk at the Department of Chemistry, Umeå University, has in 2018 received the Umeå municipality's Scientific Prize to young researchers in the environmental field. Her work focused on the processes that control the release of environmental toxins from sea sediments. The research is of great importance for the challenges we face with regard to contaminated sediments in the Baltic Sea. Darya Kupryianchyk has also actively disseminated her results to county administrative boards and water authorities, to provide the opportunity to translate the results into practical environmental work.

JARONE PINHASSI
ELECTED TO THE CRAFOORD PRIZE COMMITTEE

Jarone Pinhassi at Linnaeus University, has been elected to the Crafoord Prize Committee. The Crafoord Prize is intended to promote international research in a variety of subject areas, and is a collaboration between the Royal Swedish Academy of Sciences and the Crafoord Foundation. The Royal Academy of Sciences appoints award winners according to the same model as the Nobel Prize winners. The Crafoord Prize is awarded each year by His Majesty the King.

AGNETA ANDERSSON
INVITED SPEAKER AT ROYAL VISIT

At the beginning of the year, a climate seminar was held at Umeå University, which was attended by, among others, His Majesty the King. John Anderson, holder of H. M. King Carl XVI Gustaf's professorship in environmental science 2017-2018 was keynote speaker, and Agneta Andersson was one of four additional speakers during the seminar. Agneta Andersson presented EcoChange and the research conducted within the program.

EcoChange.

EcoChange increases knowledge about the consequences of climate change in marine systems. The starting point is that climate change affects the temperature, salinity and concentration of dissolved organic carbon (DOC) and nutrients in the Baltic Sea. This leads to a deterioration in food web efficiency, and thus an increased accumulation of environmental toxins in marine organisms. Food web efficiency is a key concept within the research program, and high efficiency is a good indicator of a healthy ecosystem.

EcoChange is a part of the government's strategic research initiative on marine environmental research., and is based on a close collaboration between Umeå University and the Linnaeus University, as well as Sweden's Agricultural University and the Swedish Museum of Natural History. Umeå University hosts the program. About sixty researchers are currently working on projects linked to EcoChange. Collaboration takes place with other researchers and research groups around the world.

This report describes the activities within the research program during the year 2018. More information about EcoChange can be found at www.umu.se/en/ecochange/

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