COASTAL & MARINE

Coastal Climate Change

Adaptive management of beaches and coastal waters

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Editorial

Our coasts and seas are subject to manifold changes and increasing pressure during this century. Climate change is one of the most important challenges. Increasing water and air temperatures, sea level rise, and changes in wind pattern and storm likelihood are directly affecting coasts and seas. Our coasts and sea are indirectly affected by changes in river basins as well. Changing precipitation and runoff patterns together with increasing temperatures and changing agricultural uses will alter nutrient loads delivered to the sea. This will have an effect on eutrophication and coastal and marine water quality. Strong precipitation and flooding events have in several cases caused reduced bathing water quality and temporarily closed beaches. Climate change will most likely increase the likelihood of these events and therefore affect coastal bathing tourism. For the coastline itself, sealevel rise is of highest importance and ongoing erosion will increase the cost of maintaining beaches. Beaches are an important natural resource for tourism, which is the major source of income for most coastal regions. Further, we observe an ongoing increase in coastal tourism and the number of coastal residents. Higher temperatures, at least in the Baltic, will support this process and increase the pressure on the coast. We are currently observing a coastal squeeze, with ever-growing numbers of tourists using beaches that are being narrowed by increasing erosion. Climate change might increase income from tourism, but it will also raise the costs of maintaining and protecting infrastructure. This issue of Coastal & Marine addresses changes and pressures on our coasts and seas and outlines needs for adaptation as well as examples of possible adaptation measures.

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Adaptation in recreational beach management – Who will take responsibility?

Tourists expect clean, safe and preferably sandy beaches. But whose responsibility is it to provide and maintain them?

In Germany, for coastal protection the legal responsibility lies with public authorities such as the agencies for coastal protection of the federal states, or with environmental agencies when it comes to protected areas. Preservation of coastline often involves maintenance of coastal protection dunes and the beaches in front of them, which of course are a driving factor for tourism. However, legally such beach preservation can only be performed if the beach is required to protect the coastline.

For recreational beach management, the responsibility lies within the local community, and ranges from cleaning up beach wrack and litter to the provision of recreational facilities, restrooms, signage as well as parking spaces and other infrastructure. Most communities lease beach space or facilities to private tourism operators, who then provide gastronomic services, beach chairs, sport facilities and so on. These facilities are only provided and serviced during peak season and thus are rarely damaged by winter storm surges, which along with sea level rise are one of the major threads of climate change. A very important parameter for beach tourism which may be influenced by climate change is the bathing water quality. Here again the responsibility of monitoring lies with public authorities and not with private tourism operators.

So where is the niche for the tourism sector to take action?

Most tourism operators have a planning horizon of 1-5 years. Climate predictions cover a much longer period, and most changes or impacts will only be noticeable in a few decades. But instead of sitting back and waiting for the changes, a possible first step for the tourism sector on the trail to mid-term adaptation strategies is adapting to changing *weather events* rather than to long-term *climate predictions* and uncertainties. Examples with respect to beach management are the provision of sun shade or rain protection, free drinking water, and showers on the beach. As for bathing water quality, communication measures will be necessary to inform and educate guests about a possibly increased occurrence of harmful algal blooms or harmless jellyfish. If a beach is closed, alternative recreational options for the day should be prepared and the tourists must be informed.

Very few climate change adaption measures focusing on beach tourism have been realised at German beaches so far. One positive example is the Kiel Bay Climate Alliance (page 6) and the 'climate pavilion' they designed to inform tourists about coastal processes and changes. Other examples are sustainable infrastructure projects or sand nourishment projects, which are financed by local communities to provide wider beaches for their guests. However, most projects are not consciously driven by climate change but regardless address some of its threats. One of the main problems is the lack of awareness and information for tourism operators as well as tourists, which is why building networks and exchanging information is an advantageous way to initiate more adaption strategies. Tourism operators need to be encouraged and convinced that investing in climate change adaption now will give them a competitive advantage in the future.

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Flooded beach chairs, © Karl Erhard Vögele

Climate change - A push factor for the ecosystem approach in beach management?

Natural beaches provide biological productivity and diversity, serving as habitat for birds, invertebrates, and annual plant communities. Along with pollution or erosion, the intensive recreational use of beaches disturbs vulnerable processes in beach ecosystems. Future climate change may increase the pressure on beach ecosystems and aggravate the situation, as warmer temperatures extend the summer season and attract even more beach users to countries in Northern Europe and the Baltic Sea region.

Beach management today recognises beach cleaning as one of its most important tasks. During the summer season, 'beach wrack' consisting of washed-up debris such as uprooted eelgrass, macroalgae, animal remains, and terrestrial plants is the primary target for beach cleaning. Beach wrack is threatening from an economic point of view, since the foul smell of decomposing plant matter threatens tourism by rendering beaches undesirable for beachgoers. In the past, beach wrack accumulations in front of seaside resorts on the German Baltic coast have resulted in decreasing numbers of beach users and negative press reports. For this reason, spas and resorts spend up to 200,000 euros per year to remove stranded biological material with heavy machinery. It is commonly accepted that this method of removing beach wrack also removes sand and may advance beach erosion. It also degrades habitats which are essential for beach flora and fauna. From an ecological perspective, algae and seaweed should be left on the beach, as the natural debris is crucial for intact beach ecosystems.

Given the ecological functions of beach wrack, the implementation of recreational beach wrack management strategies that work *with* rather than *against* nature is a necessary step towards a more sustainable use of beaches. Leaving beach wrack on beaches will not prevent bathing tourism, as 'natural beaches' are not always covered by heaps of rotting plants. In fact, beach wrack monitoring along the German Baltic Sea revealed significant beach wrack accumulations on less than 10% of all summer days. If 'no cleaning zones' are not practical, technical or organisational adjustments of current management practices can support beach ecosystems functions. Limiting beach wrack removal in the stormy off-season, combined with banning the use of heavy machinery would

Beach wrack on a summer day at the German Baltic Sea, © Matthias Mossbauer


Beach cleaning with heavy machinery, © Karl Erhard Vögele

minimise the impact of beach cleaning on beach erosion. Another efficient option to meet the demand for clean beaches is a selective beach cleaning that removes only manmade litter. By removing only waste and leaving eelgrass and macroalgae, beach users would also get the chance to explore the coastline's natural ecosystem. Selectively cleaned beaches could be used for educational purposes to teach residents and visitors about coastal ecosystems and the value of wrack to coastal fauna and flora. Thus, natural beaches may even pluralise beach uses.

One reason for current beach management practice is the power wielded by local beach management practitioners. Intensive touristic use of beaches often provides essential income for coastal communities. Practitioners regard conservation activities as non-conducive to increasing income from beach tourism, and therefore do not plan to adopt conservation practices. The impacts of extreme beach cleaning on beach ecosystems are not visible for decision makers, and therefore are not taken into consideration. On the contrary, at beaches where the natural beach flora has disappeared, pure, 'clean' sand is a symbol of good beach quality. As a consequence, it seems that the thorough and frequent mechanical removal of stranded biomass will continue to be the dominant beach management strategy in the majority of coastal resorts in Germany.

However, the effects of climate change will continue to accrue in the future and these impacts will challenge future beach managers. Coastal decision makers are in a position to decide how to adapt their beach management to rising sea levels, enhanced sand losses, and a rising pressure from tourism on beaches. Favouring the ecosystem over cleanliness is an option worth considering.

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Natural beach, © Gerald Schernewski

The elusive future of our beaches – management approaches in Kiel Bay, Germany

Climate change and sea level rise will seriously affect beaches worldwide in the years to come. For coastal communities in Kiel Bay, two major problems concerning their beaches are manifest already: massive losses of beach sand during stormy winter season on the one hand, and excessive accumulation of beach wrack (organic matter from sea grass and macro-algae washed ashore) on the other. Both problems seriously affect the attractiveness of the beaches for regional tourism, thus hampering the economic stability of coastal communities.

In the project RADOST (Regional Adaptation Strategies for the German Baltic Sea Coast) a regional community network, the so-called Kiel Bay Climate Alliance (Klimabündnis Kieler Bucht, KBKB), has been established via cooperation between science and policy-making. One of the core issues of this network is to promote more effective beach management processes at the local level. In regional workshops experts from universities are engaging in dialogues with local practitioners and coastal authorities' representatives, addressing a number of key questions such as:

- What suitable measures are available to stabilize beach volumes locally without hampering adjacent coastal segments?
- Are near-shore artificial reefs suitable to dampen beach erosion (locally) while at the same time providing valuable submarine habitats?
- Are there best-practice examples for removing beach wrack and re-using it, e.g. by producing bio-energy?
- Is it possible to promote 'natural' i.e. un-groomed beaches to coastal tourists because of their high ecologic values?
- How can legal restrictions and bureaucratic obstacles in beach management be minimised?

During the RADOST-phase the KBKB project carried out a feasibility study on the effects of artificial submarine reefs built from rocks or concrete elements offshore from eroding beaches. In theory, such reefs could have a protective effect against ongoing erosion while at the same time an ecological improvement of near-shore habitats might be achieved. Currently, the chances for realisation of a pilot reef project at the coastal section of the Schönberg community northeast of Kiel are being discussed at the political level.

The major benefit of the Kiel Bay Climate Alliance project (funded by the Federal Ministry of the Environment from April 2013 to March 2016) is to intensify and to focus on a multi-lateral stakeholder dialogue, including the public, and to thus increase the chances for consensual and sustainable adaptation measures. Examples include increasing sand replenishment instead of implementing hard structures, tolerating the natural reshaping of beaches, and finding options for reusing beach wrack as biofuel.

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Natural beach development near Laboe, Kiel Bay. Spit growth has resulted in the formation of a wetland with rich wildlife – another way of keeping the coast attractive to tourists and locals. © Horst Sterr

Beach replenishment by moving nearshore sand to the beach, © Rainer Runge Schönberg

Beach wrack accumulation after stormy season. Large volumes of organic matter need to be removed for touristic beach use but could possibly serve as bio-fuel, © Sandra Enderwitz

Exploring a Multifunctional Artificial Reef for beach management at São Roque Beach, São Miguel Island (Azores)

Located in the middle of the North Atlantic Ocean, São Miguel Island is the largest of nine small volcanic islands in the Azores archipelago. São Roque is located to the east of Ponta Delgada, the most populated city on São Miguel. Major coastal engineering works, ending at the western limit of the São Roque pocket beach, were undertaken along the São Roque coastline to prevent the hinterland from flooding, increase buffer zones to protect existing houses and cultural heritage, and provide recreational amenities. With a statistically significant trend of rising sea level (2.5 ± 0.4 mm yr^{-1}) at a 99 % confidence level using Ponta Delgada tide gauges between 1978 and 2007, increasing wave height trends from westerly directions using 1998 to 2011 wind record, and projected increases in storm intensities associated with climate change, further damage is likely.

The São Roque reef is a natural existing shore-connected reef located between the São Roque pocket beach (to its west) and the Pópulo Milicias beach (to its east). A historic church is located atop a small cliff protected by a seawall that was constructed more than 50 years ago. The seawall was repaired in 2007, but is showing signs of undercutting at the base. In terms of its economic value, São Roque is the closest sandy beach within walking/cycling distance of Ponta Delgada, where tourists concentrate, while Pópulo Milicias is the most popular beach for bathers and surfers on the south coast. Current surfing conditions at São Roque reef are highly inconsistent due to the existing reef profile. However, the location has the potential to generate more consistently good quality surfing waves through slight bathymetric adjustment. An offshore submerged structure, or multifunctional artificial reef (MFAR), would not only provide additional coastal protection to the church and existing seawalls, but also enhance marine and recreational amenities such as surfing and beach widening. By slightly extending the reef further offshore with a smooth ramp, filling gaps and voids, and smoothing the existing profile, it is possible to enhance left-hand and right-hand surfing waves from W and SW storm waves in winter (see Figure 1).

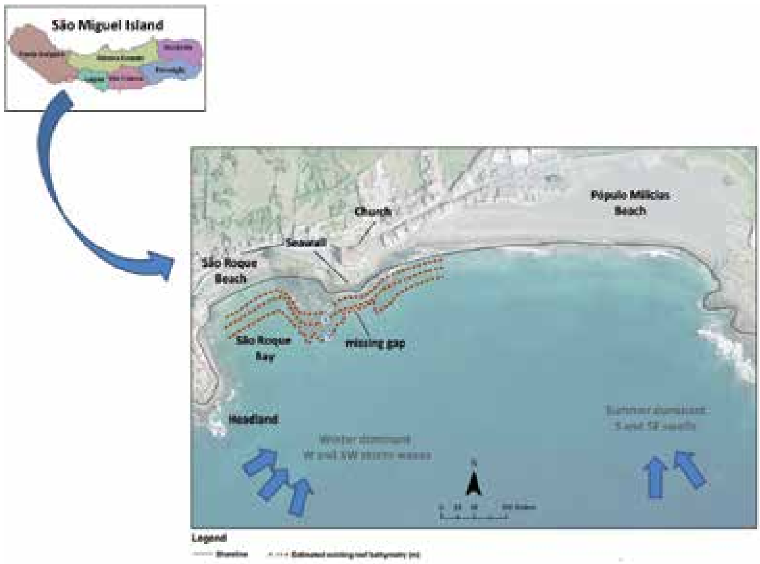

Figure 1: Estimated existing natural São Roque reef profile contours (aerial photograph from SRCTE, 2005)

With the existing reef profile being estimated from aerial imagery, the location meets preliminary MFAR design criteria. A small-scale reprofile design of the São Roque reef was proposed and a multidisciplinary feasibility study was subsequently undertaken. Based on preliminary qualitative and quantitative analyses using available and accessible data, São Roque MFAR shows potential in providing additional coastal protection to the historic church and existing seawalls, improving surfing amenity, widening the beach, and enhancing the marine ecosystem with minimal downdrift impacts. The seaward extent, orientation, and height of the installed reef can be adjusted according to future conditions, e.g. sea level and storm changes (intensity, frequency and track). Consequently, this soft-engineering measure could inform climate change adaptation planning and beach management strategies for the Azores and other similar small islands.

Kiat Ng, Michael Robert Phillips and Fernando Veloso-Gomes

CIBIO-Universidade dos Açores, University of Wales Trinity Saint David (Swansea Metropolitan) and Faculdade de Engenharia da Universidade do Porto

São Roque beach, © Kiat Ng

Surfing from São Roque to Pópulo, © Carlos Duarte

WATER MANAGEMENT

Can climate change be neglected in the definition of water management objectives?

In the last years the bad health of the marine ecosystems were brought strongly into focus by addressing the aims of 'a good environmental status' (European Marine Strategy Framework Directive) or a 'good ecological status' (EU Water Framework Directive). In the Baltic Sea these objectives are quite ambitious since at the moment only a few stations are in a good or moderate state, while it is bad in the central Baltic as well as in nearly all stations in the south-western part. The main reason for this problem is eutrophication. Fortunately the stakeholders have agreed that management actions are necessary, e.g. in 2007 the Baltic Sea Action Plan (BSAP) including a strong reduction of nutrient inputs was adopted, and further updated in 2013.

To separate the good and the bad statuses thresholds were defined using the lower parts of the trophic chain, e.g. the winter nutrient concentrations or summer chlorophyll a, which are most influenced by eutrophication. These thresholds were then used as a framing for ecosystem models to run backwards, calculating the allowable nutrient inputs to the Baltic Sea backward. By evaluating these models and whether the proposed nutrient input reductions were sufficient to achieve the good ecological status stakeholders can perform regular revision cycles, updating thresholds, water quality objectives, and allowable nutrient inputs depending on recent calculations and scientific results.

Although the effects of climate change on the thresholds of a good status have yet not been considered, aside from human-induced eutrophication they will be the biggest impact factors on the ecosystem and strongly related to the water quality. Since both climate change and eutrophication have long influenced the Baltic ecosystem, it is hard to distinguish between the two influence factors. But the raising water temperatures in the last decades have had direct effects, for example the spring phytoplankton bloom in the central Baltic Sea starts earlier now. On the other hand, interannual weather variability directly influencing the ecosystem could be amplified even more due to climate change. Temperature and precipitation and the associated uncertainties are expected to increase and thereby provoke various direct and indirect effects on Baltic climate and ecology.

The most certain effect of climate change will be the increase of air temperature, which directly affects sea surface temperature. All climate models show a rise, with only the strength varying between the different carbondioxid scenarios (Figure 1). This temperature increase will directly influence the water quality, e.g. by improving the growing conditions of macrophytes which can currently be damaged or destroyed due to floating ice sheets. Alternatively, the higher temperature may boost bacterial processes like denitrification, so that more nitrogen could be taken out of the system, which would lead to a higher threshold for dissolved inorganic nitrogen. On the other hand, the fixation of atmospheric nitrogen (N_2) by Cyanobacteria also depends on the temperature, and could level out or exceed the positive effect of denitrification. This would increase the summer chlorophyll concentration and decrease secchi depth, both of which are often used as descriptors of water quality.

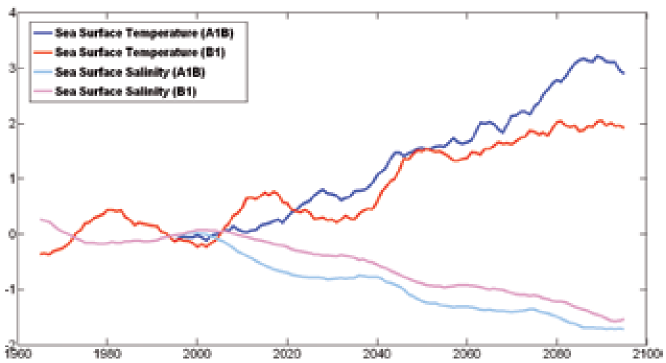

Figure 1: The Baltic Sea's surface temperature will increase in the 21st century up to 3 Kelvin (depending on the carbondioxid emission scenario) compared to the mean of 1960 to 2000, while the surface salinity decreases [adapted from Friedland et al. (2012)].

The solubility of oxygen is directly related to water temperature, resulting in increased anoxic zones and worse ecological rankings. Although strong efforts are being undertaken in the Baltic Sea to reduce anoxic zones, simulations showed that the BSAP nutrient input reductions of 2007 are almost enough to level out the temperature effect, but insufficient to reduce the anoxic areas during the 21st century. On the other hand in the BSAP simulations the chlorophyll concentrations during summer declined, so this objective could still be fulfilled.

Most climate change scenarios predict a strengthening of rainfall in central Europe, especially in northern Europe, leading to increased riverine runoff. Supposing that riverine nutrient concentrations do not change, the increased runoff alone would lead to higher amounts of nutrients entering the Baltic Sea. Vice versa following the attempt of maximum allowable loads such as those in the BSAP would lead to subsequent lower nutrient concentrations in rivers. Another unconsidered point is the effect of single heavy rainfall events, which are expected to occur more often. The effects on the ecosystem of flushing months worth of nutrient loads at once are still not well understood. It is especially unclear whether the nutrients stay near the river mouth and stimulate biological activity there, or are transported away too quickly for the ecosystem near the river mouth to metabolize them.

As another consequence of increased precipitation, surface salinity levels in the Baltic Sea are expected to decrease (Figure 1). Since current definitions of a water body include salinity, the borders between oligo-, meso- and polyhaline water bodies would shift and with them the distribution of salinity-depending species, e.g. most Baltic nitrogen-fixing bacteria depend on low salinities, which limits their growth in the Western Baltic Sea. With decreased salinity, algae blooms could also occur in German coastal waters where. The expected decrease in salinity could further result in the extinction of the Baltic cod, which eggs' survival depends on certain salinity levels. Without the top predator to control them, sprat and herring populations would expand, resulting in an increased grazing pressure on zooplankton and higher phytoplankton biomasses.

Climate change will affect the Baltic ecosystem and should be included in the definition of water quality objectives, but the uncertainties and shortcomings of the recent simulations have to be considered. Therefore within the framework of RADOST we have connected simulations on climate change with eutrophication scenarios. But – just like in the global climate models – regular revision cycles are necessary, not only to update water quality objectives and to evaluate if management actions and nutrient input reductions were sufficient to fulfill the objectives, but also to improve the used ecosystem model.

Blue-green algae in the harbour of Lubmin, © Gerald Schernewski

Parameter	climate change	climate change & BSAP
water temperature	↑↑	↑↑
ice coverage	↓↓	↓↓
water salinity	↓	↓
Chlorophyll concentration (summer)	↑	↓
water transparency (summer)	↓	↑
oxygen	↓	↔
denitrification	↑	↓↓
N-Fixation	↑	↓↓

Table 1: Summarised qualitative changes of important parameters in the Baltic Sea ecosystem until 2100 (↑↑ strong increase, ↑ weak increase, ↔ no significant change, ↓ weak decrease, ↓↓strong decrease) [adapted from Friedland et al. (2012)]

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Szczecin Lagoon, © Nardine Stybel

Tackling eutrophication in a changing climate – What can the Baltic and the Black Sea regions' experts learn from each other?

Despite lying in different corners of Europe, the Black Sea and the Baltic Sea have many features in common. Both of these semi-enclosed seas have brackish water and limited water exchange with the ocean. Both the Baltic and the Black Sea have densely populated catchment areas that are large in relation to their marine area. As a result, both marine regions suffer from excess nutrient input and eutrophication. Climate change exerts a further pressure on both of these regions, and has the tendency to exacerbate eutrophication symptoms.

In the Baltic Sea, climate change is expected to manifest as increased air and water temperature, diminished ice cover, altered precipitation patterns, rising sea levels, and an extended growing season during this century. The expected changes may *inter alia* increase bottom hypoxia, which enhances loading of phosphorus from the sediments and therefore accelerates eutrophication. Other projected symptoms may include increased cyanobacteria blooms. In the Black Sea, climate change is expected to result in increased salinity and enhanced eutrophication of coastal waters during the first half of this century.

Since 2011 expert knowledge has been transferred between the Black Sea and the Baltic Sea on monitoring and assessment of eutrophication with the view to enhance protection of both seas. This activity carried out as part of the project 'Environmental monitoring of the Black Sea with focus on nutrient pollution' (Baltic2Black). In the Baltic Sea, cooperative monitoring of eutrophication, using harmonised methods, has been carried out and indicator-based assessments of the Baltic Sea status been developed during the past decades. In the Black Sea there is an interest towards developing a regional nutrient load reduction scheme, similar to that in the HELCOM Baltic Sea Action Plan (BSAP). A starting point for constructing a commonly agreed-upon regional scheme is a common understanding of quantitative ecological targets, and a capacity for ecological modeling. The latter is used for modeling maximum nutrient loads that will allow ecological targets for eutrophication to be reached. In a warmer climate, reaching the ecological targets may imply that stricter measures are needed to reduce nutrient loads, especially if climate change is coupled to increasing riverine flow and inputs of nutrients as has been projected for the northern Baltic Sea.

A sea view opening from Istanbul, © Miia Mannerla

The overall goal is that both the Black Sea and the Baltic Sea will move towards a less eutrophied state and will ultimately reach a good status where man-made eutrophication does not cause adverse effects to the ecosystem or to humans. By working together, these two sea regions can also have a stronger voice in the EU, which tends to place more emphasis on truly oceanic environments, leaving these semi-enclosed brackish marine areas as peculiarities. The cooperation between these two regions has been an encouraging experience, and it will be particularly good to see that the expert networks established during the project will serve future research projects and help implement legislation related to the marine environment in the EU member states of both regions.

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Small island Torra lövö in the Baltic Sea , © Miia Mannerla

Beach in Wolin, Poland, © Dominika Szponder

New management instruments for bathing water quality

High bathing water quality is of outstanding importance all over the world, but especially in bathing tourism centres. In 2012, more than 95 % of European beaches achieved the minimum quality standards requested by the EU directives, including good hygienic water quality. Yet, bathing water quality can be affected by factors such as insufficient sewage treatment, diffuse runoff from agricultural land caused by heavy rainfall, or by animal faeces near or at the coast. Climate change might also have an effect, as changes in water temperature and salinity will lead to a changing water environment and ecosystem composition.

In order to guarantee high water quality standards, the EU Bathing Water Directive 2006/7/EC requires the measurement of several water quality indicators including *E.coli* bacteria and intestinal *Enterococci* during the bathing season. Since these microorganisms are passively transported with water currents, the application of 3-D numerical models can be used to simulate their distribution in the water body and hence act as an addition to water quality measurements. Model studies conducted in the Polish Oder river mouth showed that in this area wind plays only a minor role for the distribution of *E.coli* bacteria, assuming a constant mortality rate, since the river flow dominates the transport distances and directions. The results also indicated that a full sewage treatment will very likely increase the general bathing water quality in the entire area. However, a case study analysis in the Pomeranian Bight found wind direction and speed to be the main drivers for microorganism transport in the water, assuming both constant mortality and no other dominant flow. These analyses allowed deriving supra-regional first action recommendations aimed at safeguarding the health of bathers in the event of a contamination without first running a model study. These suggestions are particularly important for the clarification of sampling points and ranges in case of accidental contamination.

Besides faecal pollution, other microorganisms not registered in the EU Bathing Water Directive can also impact bathing water quality. Human pathogenic *Vibrio* bacteria, a natural component of the water, occur repeatedly and unpredictably in Baltic Sea waters of Sweden and Germany, and were also found in the North Sea and the Mediterranean Sea. According to the German Robert Koch-Institute, they present a potential risk for tourists with predisposing factors for *Vibrio* infections, such as pre-existing diseases like diabetes mellitus, liver or heart diseases, or a generally poor immune system. With respect to climate change, the results of an epidemiological study of Baker-Austin et al. in 2013 showed that the expected increases in temperature will favour *Vibrio* occurrence and infections in coastal areas of the mid and southern Baltic Sea. In a model study based on water measurements taken from the Governmental Institute of Public Health and Social Affairs of Mecklenburg-Western Pomerania, possible reasons behind their recurrence in a Baltic Sea bay were studied. The modelling included variable and water temperature dependent division rates of *Vibrio* bacteria derived from laboratory experiments, which allowed simulating bacterial growth and die-off. The model results indicated that the bay's environmental factors had already increased *Vibrio* reproduction in early summer, and helped the authorities to identify future monitoring sites and parameters.

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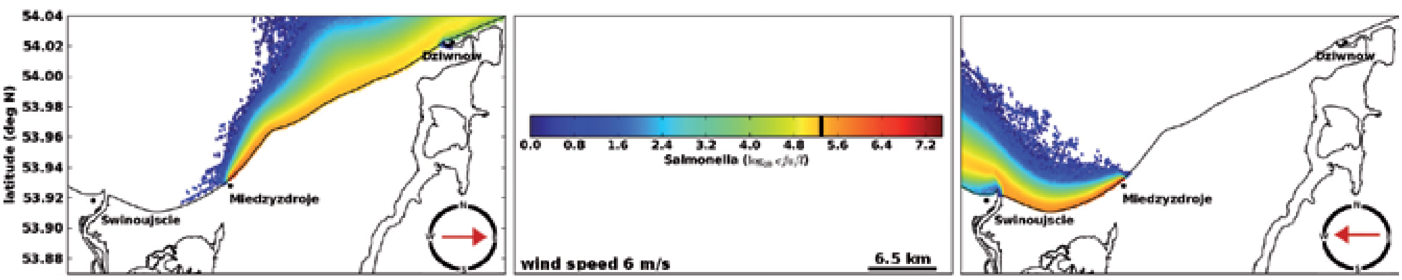

Figure 1: Scenario risk maps of Salmonella density according to east (right panel) and (left panel) west wind with speed of 6m/s. Shown are concentrations integrated over the entire water column. The black line indicates the Salmonella threshold for an infection according to Briese and Heinemeyer (1989) and Havemeister (1989). © Bianca Schippmann

Beach in Lubmin, © Claire Hivert

Warmer bathing water can change the nutrient balance

Temperature regulates the speed of almost all chemical and biological processes on earth. This is also true for the processes regulating nutrient concentrations in water. The most important nutrients in aquatic systems are nitrogen and phosphorus. Limited access to nitrogen and phosphorus is often the main limitation of algal growth (Figure 1). Increased nutrient concentrations therefore lead to more phytoplankton, which has a number of negative effects, such as more turbid water, hypoxia, and loss of underwater vegetation and fish. This is commonly called eutrophication and is one of the most severe environmental problems we will have to face over the coming decades. In a long-term study of 12 Danish coastal monitoring stations we found that increased temperatures lead to increased phosphorus concentrations and decreased nitrogen concentrations.

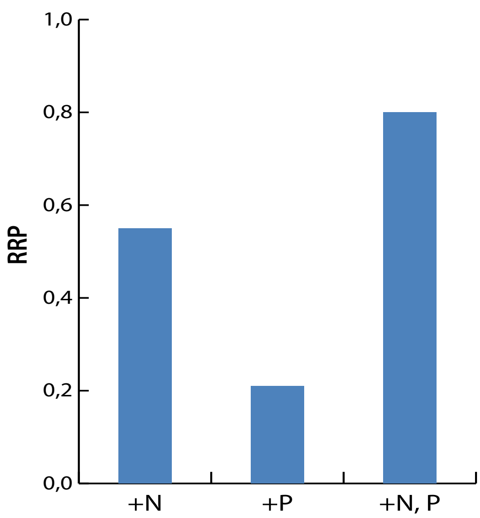

Figure 1: Logarithm to the relative response in primary production (RPP) after addition of either nitrogen (+N) or phosphorus (+P) or both (+N, P) in marine environments. 0 is corresponding to no response, 0.2 to a 22 % increase, 0.5 to a 65 % increase, and 1 to a 170 % increase. Based on 149, 141 and 197 studies, respectively, and summarised in Elser et al 2007.

BOX 1

Any child can tell us what rust is: it's those reddish-orange flakes that iron (Fe) turns into after exposure to air and water for a period of time. Chemically, the iron is oxidized (loses an electron) through a redox-reaction with the oxygen in the air, causing the iron to donate electrons to oxygen and turn into Fe(II) and Fe(III). Only in its most oxidized state, Fe(III), will it precipitate and bind to phosphate in the sediment. During anoxic conditions in water, Fe(III) will be reduced (receive electrons) and turn back into Fe(II), causing the iron-phosphorus complex to dissolve, releasing phosphorus from the sediment into the water. Since warmer water can dissolve less oxygen than cold water, and the use of oxygen in respiration increases with temperature, rising temperatures will only increase the risk of anoxic conditions and therefore the release of phosphorus from the sediment.

Nitrogen and phosphorus have different pathways in nutrient cycling. Phosphorus is always in a dissolved or solid state and hence moves with currents, either dissolved in water or bound to or incorporated in particles. In contrast, nitrogen also has a gaseous state (N_2). When microorganisms in aquatic ecosystems use the oxygen bound in nitrate (NO_3^-) to breathe and therefore convert the nitrogen into N_2 in a process called denitrification, the nitrogen in N_2 is lost from the ecosystem. Nitrogen and phosphorus are both removed from the ecosystem through burial in the sediment and transport out of the ecosystem in flowing water. The latter will in most cases start with the uptake of nitrogen or phosphorus in a plant, which is then eaten or degraded and ends up as small organic particles called detritus.

If temperature increases, we expect both import and export processes to speed up, and the decomposition of organic material in the soil and sediment will increase, along with the release of nutrients. Due to increasing decomposition in the sediment and lower oxygen saturation concentrations in warmer water, we also expect increased phosphorus release from the sediment (Box 1). On the other hand, we also expect increased denitrification to remove more nitrogen. Other studies on both lakes and oceans also indicate that phosphorus concentrations increase and nitrogen concentrations decrease with increasing temperatures.

We tested a dataset with 22 years of monitoring data from 12 Danish stations and our results confirm that this hypothesis is also valid for coastal areas. We used a multiple linear regression model called partial least squared regression to find and model developments at the 12 stations including climate, nutrient loading, and water physics. At all stations we found a positive relationship between temperature and phosphorus concentrations, and a negative relationship between nitrogen and temperature. The exact relationship is uncertain, but we found effects varying between a 1 and 10 % increase in phosphorus concentration per degree Celsius and a decrease in nitrogen concentrations from 1 to 4 % per degree Celsius (Table 1).

A changing climate might change the parameters of nutrient cycling and hence affect eutrophication in aquatic ecosystems. For nitrogen, higher temperature seems to have a negative effect, presumably due to higher nitrogen removal, whereas for phosphorus the situation is reversed due to increased release from sediments. In addition, the effects of higher runoff must be considered. These effects are uncertain, but if the concentrations of nutrients in freshwater are maintained at the same level as today, the effects are expected to be 3 to 17 % and 5 to 35 % higher inputs to marine waters for phosphorus and nitrogen respectively within 70 years from now (Table 1). However, if nutrient inputs to the nutrient reservoirs in soil increase slightly, the nutrient concentrations in runoff might increase even more. In conclusion, higher temperatures should decrease or maintain nitrogen concentrations in the Danish coastal areas, whereas phosphorus levels should increase. This might affect which eutrophication abatement strategies are optimal and most cost effective in the future.

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Scenario	Impact	Effect
SRES A2	Temperature	Increase (3-5°C)
	Winter precipitation	Increase (>40 %)
	Summer precipitation	Decrease (3-15 %)
	Sea level	Increase (0.5 -1.5 m)

Rivers

Climate change	Impact	Effect	Main cause
Increased runoff	Nitrogen concentration	Increase (7-35 %)	Subsurface and surface runoff
	Phosphorus concentration	Increase (3-17 %)	Surface runoff

Estuaries

Climate change	Impact	Effect	Main cause
Increased temperature	Nitrogen concentration	Decrease (3-20 %)	Increased denitrification
	Phosphorus concentration	Increase (5-50 %)	Decreased redox potential in sediment Increased mineralisation

Table 1: Summary of a scenario that shows the potential changes in Danish marine systems the next 70 years. We used the climate predictions from the Danish meteorological institute (DMI) based on the IPCC SRES A2 climate scenario and assumed a linear relationship between temperature and nutrient cycling which can only be expected for moderate temperature increases. (From BaltAdapt impact assessment report www.baltadapt.eu)

Lessons learned from long-term nitrate monitoring and a pilot project to reduce eutrophication

The coastal waters of the Baltic Sea still suffer from large nutrient inputs originating from inland rivers. While the amount of phosphorus has significantly declined during the last 20 years, nitrogen loads remain at a high level. Intensive agriculture has been identified as the main source of diffuse nitrate pollution. In northeastern Germany, artificial drainage plays an important role in leaching nitrate, as it shortens the retention time of soil water and changes hydrological and biochemical processes.

For more than 10 years, the soil physics group of Rostock University has recorded runoff and solute concentrations in an artificially drained agricultural catchment, representative of the coastal hinterland of northeastern Germany, with a high temporal resolution (daily to several days). The study area is located near the city of Rostock (Mecklenburg-Western Pomerania) and is the catchment of the Zarnow, a small tributary of the river Warnow, which drains into the Baltic Sea. Runoff and solute concentrations are measured at three monitoring points: outlet of a tile drainage collector, a ditch, and the Zarnow itself. Figure 1 shows the development of nitrate concentrations at the three monitoring points, as well as the relationships between nitrate concentrations and runoff over the period 2003-2013. These data give us a precise picture about long-term trends of nitrate leaching and insights into hydrological and biogeochemical processes. Generally, nitrate concentrations are much higher in winter than in summer (Figure 1a). The magnitude of nitrate concentrations is mainly driven by runoff (Figure 1b), but various other environmental factors like quantity, intensity and duration of rainfall, temperature, soil moisture, and snowmelt are important as well. There is a slight tendency of decreasing nitrate concentrations over the course of the monitoring period at all three monitoring points, but these reductions are marginal.

Based on our long-term monitoring, we are convinced that 'good agricultural practice' is not enough to achieve the good ecological status for coastal waters claimed by the EU water framework directive. Given the fact that the highest nitrate concentrations/loads occur during high flow rates, waterborne reduction measures are needed that focus on periods with high runoff. In 2011, we established a 'controlled drainage' unit (Figure 2) aiming at regulating the runoff at the tile drain outlets. This would hold soil water in the field longer, where nitrate could be reduced through denitrification. Furthermore, this reduces the amount of peak runoff, resulting in reduced nitrate loads. After solving some technical problems, runoff and solute data are recorded and compared with a reference 'non-controlled drainage' station to evaluate the system. Preliminary results indicate that 'controlled drainage' has the potential to reduce nitrate pollution, but further investigations are necessary for a final assessment.

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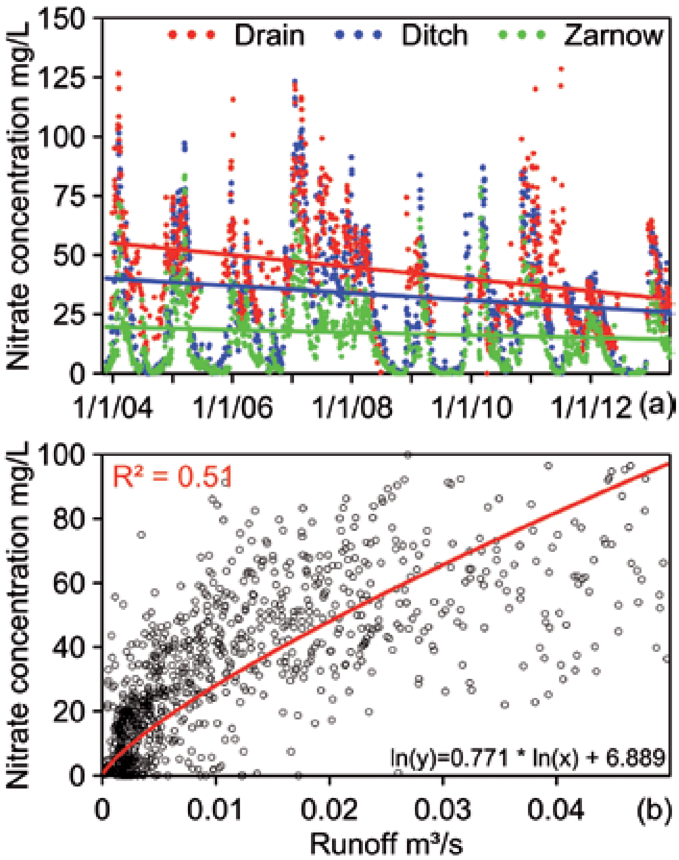

Figure 1: Temporal evolution of nitrate concentrations (a); relationship between runoff and nitrate concentrations at the ditch (b)

Figure 2: 'Controlled drainage' unit, © Tilo Hartwig

Water flow within a dense reed belt, © Svenja Karstens

Coastal reed belts: Sources or sinks for phosphorus?

Coastal reed belts are important zones for the retention of excess nutrients given their ability to absorb nitrogen and phosphorus. As a result many wetlands have been rehabilitated or constructed. However, so far research has focused on lakes, while coastal areas have been mostly neglected.

Phosphorus is a key nutrient for plant growth, but when it exceeds a natural level, eutrophication of the water body results, creating algae blooms and oxygen shortages. Therefore the capacity of coastal wetlands to act as a buffer is of paramount importance. Interactions between wetland plants, sediments, and water are complex, and the processes of phosphorus mobilization and immobilization not yet fully understood. Still, release of phosphorus from sediments is often linked to oxygen-deprived (anoxic or anaerobic) conditions and high temperatures. Seasonality, given its changing ecological conditions, is therefore a crucial aspect.

During the course of a year, coastal wetlands dominated by *Phragmites australis* (common reed) can shift from being a nutrient sink to a source. During growth in spring and early summer, large amounts of phosphorus are incorporated in plant biomass. In autumn, the majority of nutrients is transported back into the rhizomes and stored below ground during winter. The decomposition of leaves starts in early autumn and once decomposed, detached leaves and fragments of culms provide a nutrient source. In times of geomorphic instability triggered by human activity or extreme weather events associated with climate change, large reed-clusters with attached sediments can be abruptly eroded and washed out into the adjacent coastal waters. If sheltered from turbidity, dead biomass and partially decomposed litter will eventually settle on the sediment surface between the reed culms and contribute to the formation of organic mud. Hence reed stocks not exposed to wind, currents, or ice will function as nutrient sinks.

In contrast to most other plant species, in reeds air conducting channels (aerenchyma) allow the transport of oxygen from the upper parts of the plant into the root zone. The resulting aeration of the sediment in the vicinity of the roots (rhizosphere) can lead to the formation of oxidised forms of iron and manganese. These oxidised ferric or manganese oxides constitute very effective adsorption surfaces for phosphate. Consequently, phosphate availability in the pore water may be reduced under such conditions.

Research on phosphorus dynamics is scientifically and economically relevant, since phosphorus is a plant nutrient which cannot be replaced by any other nutrient, and phosphorus deposits for fertiliser production will be exhausted in the near-future. On the other hand, many surface waters suffer from the adverse environmental effects of excessive phosphorus inputs (eutrophication). Spatially and temporally resolved data on nutrient flows in different coastal ecosystems will be collected within the BMBF-funded project *BACOSA* (Baltic Coastal System Analysis and Status Evaluation). The project is run jointly by the universities of Rostock, Greifswald and Kiel, and embedded within the *Science Campus Phosphorus Research Rostock* (www.sciencecampus-rostock.de).

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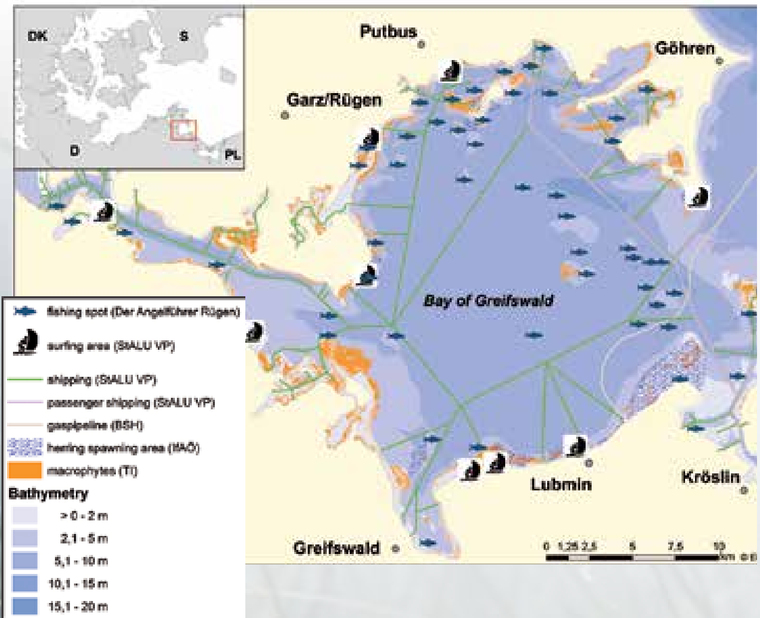
Dense reed belt along the Darß-Zingster-Bodden, © Svenja Karstens

HERRING

Sustainable management of the natural resource HERRING

Coastal areas of the Southern Baltic Sea region are central spawning and nursery areas of the herring. Important spawning grounds are found in the German Greifswald Bay, the Polish Vistula Lagoon and the Swedish coastal waters of Blekinge and Skåne. Even though the ICES advice and stricter adherence of the approved total allowable catches have resulted in a more sustainable fisheries management, the two most important herring stocks of the Central Baltic and the Western Baltic Spring Spawning stock have declined substantially. Next to fisheries management measures, coastal spawning and nursery grounds play a vital role in the recovery of the herring stocks. Spawning success and epitaxial growth of fish larvae depends on the quality of coastal habitats (availability of macrophytes as spawning substrate, temperature, water and food quality, etc.) In future, spatial conflicts, climate change impacts and anthropogenic water quality deterioration will put additional pressure on coastal spawning and nursery areas. Until now, monitoring of the quality and importance of coastal spawning areas in the riparian member states has not been holistically taken into account for overall Baltic Sea fisheries management. Moreover, fragmented and partly conflicting competencies often impede sustainable coastal management.



Map of the German case study region Greifswald Bay (© EUCC-D, Data sources: StALU VP: State Agency for Agriculture and Environment Vorpommern, BSH: Federal Maritime and Hydrographic Agency, IfAÖ: Institute of Applied Ecology, TI: Thünen Institute for Baltic Sea Fisheries)

The international project HERRING seeks to improve the sustainable and holistic management of herring fish in the South Baltic region, a major ecosystem resource, and with it both the reproductive capacity of the species and the success of future sustainable herring fisheries.

The project will address questions such as:

- What are the main stressors for coastal habitats and what are the drivers in terms of present and future anthropogenic impacts?
- What are the strengths and weaknesses of present marine ecosystem management with respect to the development of sound management strategies for spawning and nursery areas?
- Which stakeholders, institutions and authorities should work together at regional, national and international level to develop sustainable solutions for preserving those important habitats?
- What are the necessary tools and mechanisms to improve coastal management?

HERRING also aims at building competence and increasing awareness within coastal management structures. The project strives for the inclusion of the habitat condition and the monitoring of coastal spawning grounds into overall Baltic Sea (herring) fisheries and coastal management.

The course of the project is made up by three main steps. In a first step direct and indirect stressors that influence the ecosystem and contribute negatively to the herring spawning areas have been analysed. This information has been visualised in GIS maps showing the current state of spatial uses and possible future changes. In a second step the outcomes are to be discussed with regional stakeholders to identify critical influences as well as best practices for an improved coastal zone management. In 2014, experiences of regional round tables will be discussed on an international and cross-border level. As a final step, management recommendations for integrating regional and supraregional spawn area management systems in the Southern Baltic Sea area into an integrated coastal zone management system are to be developed. Those recommendations will be given to local stakeholders, and regional and pan-baltic authorities.

More information about the project can be found online under www.baltic-herring.eu.

Herring

Part-financed by the European Union (European Regional Development Fund)

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Eelgrass, © Wolf Wichmann

Coastal Case Study: Greifswald Bay, Germany

The German case study area of Greifswald Bay (GWB) is a semi-enclosed inner coastal water, formed by the mainland of Mecklenburg-Western Pomerania and the island of Rügen. GWB covers an area of approximately 514 km^2 and is characterised by a mean depth of 5.8 m with a maximum depth of 13.6 m.

GWB is considered the main spawning area of western Baltic spring spawning herring (WBSS), which is also an important target species of the commercial fisheries in this region. In recent years, catches and spawning stock biomass of WBSS herring have declined. Moreover, despite a sufficient number of spawners, recruitment has declined considerably within the last decade, while reasons for this alarming decrease remain unknown. At the same time, human use and spatial demands (for example nutrient and pollutant loads, dredging of fairways, and beach nourishment) in GWB are increasing. Consequently, anthropogenic impacts are changing the physical and biological environment, affecting the success of egg development and spawning habitat.

During the spawning season from March through May herring migrates into the coastal waters to attach its eggs to submerged macrophytes in the shallow littoral zone. It is assumed that there is natal homing in population of WBSS herring, highlighting the importance of individual and small-scale spawning sites for the overall population.

This combined with the fact that the importance of individual sites for the recruitment success varies between years implies that a precautionary approach to coastal spawning ground management is needed. Although total mean nitrogen and phosphate concentrations decreased in previous decades, eutrophication levels are still above suggested thresholds. In addition, at the same time aquatic submerged vegetation has declined dramatically from 90 % to 15 %.

Linking the ecological function of herring spawning sites to existing coastal and fishery management regulations has been one of the main tasks within the HERRING project. During a stakeholder workshop a priority setting revealed 'eutrophication' as one of the main problems impacting GWB. However, stakeholders' interests are quite distinct when it comes to protection and usage of spawning sites. Future spawning ground management should aim to preserve or improve the ecological status quo, and to include the ecological function of submerged aquatic vegetation in existing environmental and management regulations. To achieve effective management, relevant stakeholders need to be involved in the process.

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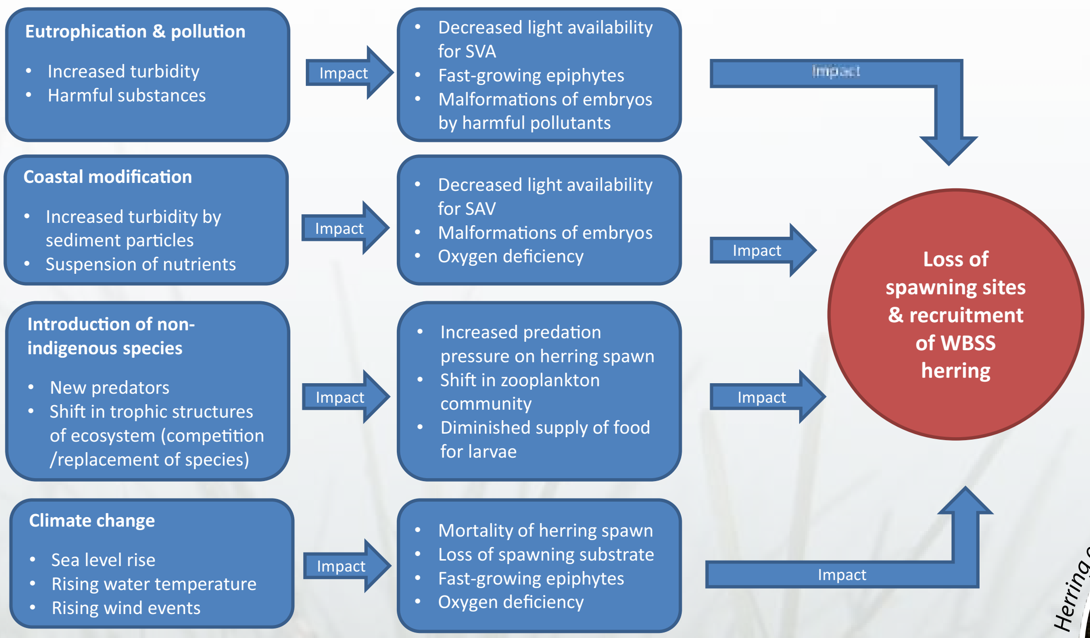


Overview of multiple impacts of anthropogenic stressors on herring spawning habitat. Source: TI-OF


Herring eggs on eelgrass, © Philipp Kanstinger

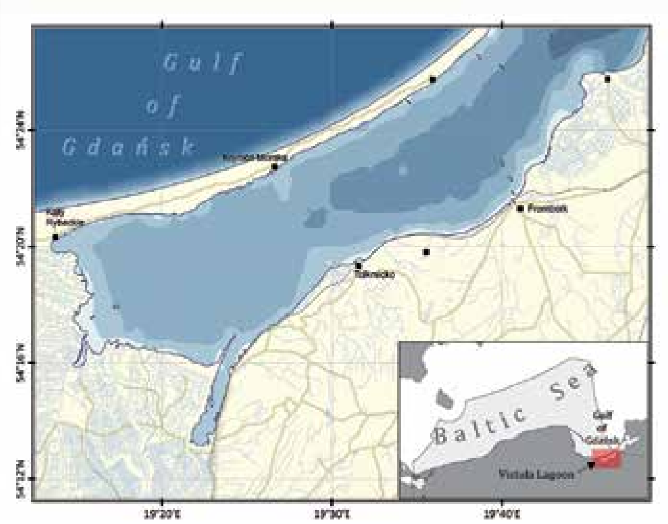
Vistula Lagoon , © Dariusz Fey

Coastal Case Study: Vistula Lagoon, Poland

While the entire Polish coastal zone is an important herring spawning area, Vistula Lagoon is an especially important site. Although the highest intensity fishing took place from 1983-1990 with 3,000-4,000 t annually, systematic and significant increases in landings from a low level of 500 t in 2008 to over 2,000 t in 2012 have been observed in the last few years. The lagoon is a partially-enclosed, shallow body of water at most 5 m deep. Water exchange between the sea and the lagoon occurs only through the Pilawa Strait located in the Russian part of the basin. Water temperatures, which are high in comparison to more open coastal waters, not only provide suitable spawning conditions but also support increased growth rates of herring larvae hatched in this area. Moreover, high productivity, which includes zooplankton, provides excellent feeding conditions for adult herring as well as larvae and juveniles. Interestingly, the intensity of spring herring spawning in the lagoon is high despite the unfavorable bottom structure, which is mostly sandy and muddy with a very limited area covered by plants with submersed leaves.

It is a widely-held opinion that herring spawning grounds in the Vistula Lagoon do not require any special protection. Consequently, only pikeperch and bream protected areas have been designated in it. Even though it seems there is little need to implement special protection for herring spawning grounds at present, such a cavalier approach could lead to overlooking potential risks to both effective spawning and egg and larva survival in the future. So, what precisely are the possible direct threats? *Damage to spawning grounds, pollutants levels that increase egg and larval mortality, and eutrophication that results in low oxygen levels and changes in bottom structure from sandy to muddy*.

Most of the human activities that could be responsible for such changes in the Vistula Lagoon area are currently practiced at either very low levels of intensity, for example fisheries, tourism, passenger and cargo transport, dredging, industry, urbanisation, or are non-existent in this region, such as mining and energy extraction. Tourism is most likely to increase in intensity, especially if the plan for building a channel through the Vistula Spit is executed. Still, increased tourism will probably not be intense enough to pose significant threats to the environment or herring spawning grounds.



Polish part of the Vistula Lagoon (© Lena Szymanek)

However, the most significant of all human activities impacting the lagoon is agriculture. Although nutrient concentrations have decreased in the lagoon considerably in recent years, especially with regard to phosphorus, the risk posed by increased intensity in agriculture on the drainage area cannot be ignored. This is especially true if the high internal potential for eutrophication and contamination of the lagoon is considered; the shallow depth of the lagoon facilitates bottom sediment resuspension, and restricted water exchange with the Gulf of Gdansk severely limits the ability of lagoon waters to self-purify.

Despite the low intensity of human activities impacting the Vistula Lagoon at present time, it is important to provide effective administrative supervision for the region. The challenges of doing so and possible improvements in this field are currently being analysed in the project HERRING.

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Vistula Lagoon , © Dariusz Fey

Blekinge Archipelago, © Lilitha Pongolini

Coastal Case Study: Blekinge Archipelago and east coast of Skåne, Sweden

The Hanö Bight stretches from the south east corner of Skåne to the east end of the Blekinge Archipelago. The area covers 680,000 ha and has a combined coastline length of over 200 km, not including the islands. Natura 2000 sites cover around 4 % of the area. The deepest point reaches 60 m, and the salinity ranges from 7.5 PSU to 13 PSU in the deeper parts. It is characterised by two different shore types: In Skåne, the majority of the coast is covered by sandy beaches and wetlands, while the coast of Blekinge is formed by an extensive archipelago with several small islands and skerries.

In 2001 the Swedish Board of Fisheries carried out an investigation of herring spawning sites in Skåne and the archipelago of Blekinge by interviewing fishermen in the area about their visual observations of spawning sites. It showed that, according to the observations made by the fishermen, herring spawn in scattered places along the east coast of Skåne as well as in the archipelago of Blekinge. Based on this survey the World Maritime University in Malmö (WMU) in cooperation with the County administrative Board of Skåne carried out samplings in the same area to find out if herring roe still could be found. The sampling results confirmed abundance of herring roe in two of the areas that were, by visual observations, said to be spawning areas. Due to the lack of repeated surveys conclusions can however not be drawn from these result and additional studies are needed.

After observations of decreased abundance of fish along the coast, brown smelly coastal water and an increased frequency of wounds on fish, the County Administrative Board of Skåne together with Region Skåne appealed to the Swedish government. The Swedish Agency for Marine and Water Management conducted an investigation of plausible causes to these symptoms. Three public hearings in Gothenburg, Åhus and Simrishamn were held in order to get input from the public about observations from the area. They gathered approximately 80 people each from various different sectors and organisations such as fisheries, local and regional authorities, politicians and scientist. Based on these hearings in-depth analyses were made on a number of topics which had been suggested as possible contributing factors to the degrading state of the Hanö bay. In October 2013 the Swedish Agency for Marine and Water Management presented their findings in a final report. They had looked particularly at four different fields; hazardous substances, water quality, fish and fisheries, and ecosystem services. None of these areas alone could be the cause of the observed problems. Hazardous substances come from different sources and are monitored through a so called recipient control, and no particular substance could be confirmed to have caused the observed problems. High levels of organic material in the largest river in the area, the Helge river, may have had an impact on the coastal waters around the river mouth and may also explain what was observed as brownified coastal water. Lower fish abundance in coastal areas could not be confirmed by the investigation, but it was shown that cod landed in the area were thin and showed signs of weak reproductive capability. Ultimately, according to monitoring data of the ecosystem in the south Baltic Sea some negative trends were observed, such as decreased abundance of benthic organisms. However this is valid for the entire south Baltic Sea, not just Hanö bay.

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Blekinge Archipelago, © Lilitha Pongolini

REGIONAL PROJECTS INVOLVED

RADOST (2009 – 2014)
Regional Adaptation Strategies for the German Baltic Sea Coast

Climate change is confronting the German Baltic Sea coast with the challenge to develop suitable adaption strategies. RADOST aims at developing these strategies in cooperation with science, economy, administration and the public. The project is equally about minimising damage to business, society and nature as well as about making use of the development opportunities provided by the change. It further strives for the permanent establishment of stakeholder networks and communication structures in the region and beyond. Regional implementation projects in cooperation with partners will demonstrate exemplary adaptation measures, compromising amongst others the following topics: Innovative coastal protection, adaptation measures for tourism and ports, aquaculture, optimisation of ship hulls, combination of coastal protection and use of geothermal energy. RADOST is one of seven projects funded by the German Ministry of Education and Research within the ministry´s initiative KLIMZUG ("Regions adapt to climate change"), which supports selected regions in Germany in the development of innovative approaches to climate adaptation. A central goal is the creation of long-term, sustainable cooperative networks for regional stakeholders. **www.klimzug-radost.de**

HERRING (2012 – 2014)
Joint cross-border actions for the sustainable management of a natural resource

Using herring as an example, the project aims at an improved management of the region's coastal areas by pointing out their important ecosystem function as natural spawning areas. As South Baltic coastal waters provide spawning and nursery habitats for several Baltic herring populations, four regional case study areas have been selected: Greifswalder Bodden (DE), Vistual Lagoon (PL), and the coastal waters of Blekinge and Skåne (SE). The coastal case study activities compile knowledge on the ecological parameters and conditions, the impact of present and future human activities and spatial uses and on the multi-level institutions and management instruments governing the use and protection of coastal herring spawning grounds. By consolidating natural science results, policy and planning levels, HERRING will develop strategy options and joint recommendations for an improved management of coastal areas as spawning habitats. The project consortium is made up by EUCC - The Coastal Union Germany as coordinator, the Thünen Institute of Baltic Sea Fisheries (DE), the National Marine Fisheries Research Institute (PL), the World Maritime University (SE) and eight associated partners. **www.baltic-herring.eu**

Part-financed by the European Union (European Regional Development Fund)

Baltadapt (2010-2013)
Baltic Sea Region Climate Change Adaptation Strategy

Adaptation strategies are needed to cope with the inevitable consequences of climate change. The EU Strategy for the Baltic Sea Region (EUSBSR) recognizes this necessity and calls for the development of a macro-regional climate change adaptation strategy for the Baltic Sea Region. Focussing on the marine and coastal environment, the project Baltadapt has developed a transnational strategy and an action plan as the operational basis for implementation. By involving decision makers on the transnational, national and regional level into the elaboration of the strategy as the basis for a subsequent political endorsement, the project facilitated a knowledge-brokerage process between research and policy, thus contributing to improved institutional capacity. Furthermore, Baltadapt developed the 'Baltic Window', a Baltic Sea Region information portal connected to the European Climate-ADAPT platform as a new sub-section. **www.baltadapt.eu**

Part-financed by the European Union (European Regional Development Fund)

Baltic2Black (2011-2013)
Environmental monitoring of the Black Sea with focus on nutrient pollution

Both the Black and Baltic Sea, as semi-enclosed water bodies share numerous challenges that are serious threats for the marine environment, for example eutrophication and nutrients input. The Baltic2Black project, a collaboration between the Secretariats of the Black Sea Commission (BSC) and the Baltic Marine Environment Protection Commission (HELCOM), assessed the monitoring of eutrophication and pollution of the Black Sea and transferred solutions, methods and best practices from the Baltic to the Black Sea. A series of workshops set in the Black Sea region were implemented to arrange knowledge transfer between Baltic and Black Sea experts regarding this case, but also to establish longer-term scientific cooperation and plan further projects on shared problems. Results of the project can be found at: **http://meeting.helcom.fi/web/projects**

BACOSA (2013 – 2016)

Populations of aquatic plants in the inner coastal waters of the Baltic Sea provide important ecosystem services: they filter nutrients from terrestrial sources and regulate the transport of sediments; they offer food and shelter for fish. The highly complex systems are strongly influenced by anthropogenic use. Nutrient input and climate change can have huge consequences on the stability and functionality of these shallow coastal water ecosystems. The BACOSA-Project (Baltic Coastal System Analysis and Status Evaluation) aims at analysing the quality and quantity of the functions of aquatic plants and intends to identify and evaluate ecosystem services provided by coastal ecosystems of the Baltic Sea. Thus, the project offers a basis for refining and adjusting environmental monitoring programs, as required e.g. for the EU Water Framework Directive (WFD) or the EU Marine Strategy Framework Directive (MSFD). **www.oekologie.uni-rostock.de/forschung/bacosa**

EUCC - The Coastal Union Germany (EUCC-D)

EUCC-D was established as a non-governmental association in 2002, forming the German branch of the Coastal & Marine Union (EUCC), the largest European coastal and marine organisation. The main objective of EUCC-D is to strengthen German activities within the field of Integrated Coastal Zone Management (ICZM) by bridging the gap between coastal science and practice. EUCC-D provides relevant information, consults and educates coastal practitioners, hosts workshops and conferences and runs demonstration projects in the field of coastal and marine management. We develop information systems, create tools (e.g. databases, learning modules) for international networks and disseminate coastal and marine information via our German Küsten Newsletter or in shared media with our international colleagues. EUCC-D offers memberships for professional and private individuals, and other non-profit organisations. The German membership also includes membership with EUCC International. Please visit **www.eucc-d.de/membership.html** for more details.