Ecology of the Baltic Sea and the Possible Impact of Climate Fluctuations

Baltijas jūras ekoloģija un klimata svārstību iespējamā ietekme

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Article is divided in two parts. First part focuses on general description of the Baltic Sea – describing the environment of the sea as well as characterizing the living organisms living in the sea. Second part of the article, in turn, deals with most relevant environmental problems and the impacts of possible climate change. This depiction provides the basic knowledge on the non-living and living compounds of the aquatic environment of the Baltic Sea. One can always learn more on the different issues related to the marine world.

Key words: Baltic Sea (ecology of), aquatic environment, living organisms, plankton, algea, bacterias, benthos, marine mammals, climate change impacts

1. The general description of the Baltic Sea

Environmental Characteristics

The Baltic Sea is an enclosed inland sea located at the Northeastern part of Europe with a narrow and shallow connection via Danish Straits to the North Sea. It consists of several sub-basins the largest of them being the Baltic Proper, Bothnian Sea and Bothnian Bay (called also the Gulf of Bothnia). The largest gulfs in the Baltic Sea are the Bothnian Bay, Gulf of Finland and Gulf of Riga (*see* Figure 1). The sub-basins are separated from each other by shallow sills or straits.

If the Baltic Sea is compared to its closest neighbor – the North Sea – then, for example, its volume is 21 631 km^3 and approximately half of the North Sea's volume. Also the average depth of the Baltic Sea is almost two times smaller than of the North Sea – 52 m and 94 m, respectively. In the terms of the World Ocean the Baltic Sea is really a shallow sea as its maximal depth does not reach even 0,5 km. The same is true for the width of the both seas – 300 km for the Baltic Sea and 580 km for the North Sea. Only regarding the length the Baltic Sea is similar to the North Sea both of them being stretched in north – south direction for about 1 000 km.

Fig. 1. **The map of the Baltic Sea with the largest gulfs**
(Source: http://www.zonu.com/images/0X0/2010-07-02-11806/
Region-del-Mar-Baltico-2008.png)

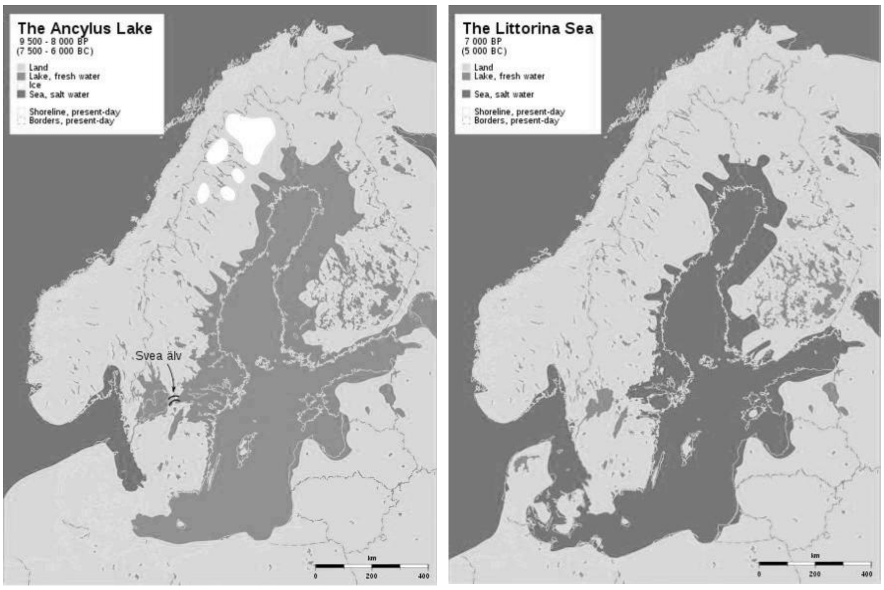


Fig. 2. **The examples of freshwater (The Ancylus Lake)
and marine (The Littorina Sea) stages in the history of the Baltic Sea**
(Source: http://my.opera.com/nielsol/blog/2009/08/19/short-history-of-baltic-sea-2)

Like everything on the Earth the Baltic Sea is unique in several ways. At first, in the terms of the geological time-scale it is a quite young sea, having its present shape only for six thousand years. Since the end of the Ice Age about 11 000 years ago it has switched several times from freshwater lake to saline water area. Due to the land uplift which occurred more intensively at the northern part of the Baltic Sea area approximately 7 000 years ago, the sea finally got the connection to the North Sea and gradually obtained its borders what are present today (*see* Figure 2). The land uplift still continues and the level of the sea is still changing – increasing each year by 6 mm in the southern part and respectively decreasing in northern areas.

The second unique feature of the Baltic Sea is the presence of gradients – gradually changing properties of the environment. Gradients are both in the north-south and west-east directions. Ecologically two most important gradients are those of water temperature and salinity (*see* Figure 3). The salinity – or grams of salt mixture per one kilogram of water, the value is per mille (‰) – has its highest values at the southwestern part of the Baltic Sea near the connection with the North Sea. Here it fluctuates between 25 and 30‰. In the World Ocean and also in the North Sea the salinity varies around 35‰. Gradually salinity decreases due to the decline of the North Sea effect and growing impact of inflowing rivers. Thus the Baltic Proper and certainly the Gulfs of Riga and Finland are already a brackish water basins – neither marine nor freshwater with a salinity around 5-7‰. In the most northern areas of Bothnian Bay the salinity is very low (1‰) and the water there is almost fresh. Water temperature follows similar southern-northern gradient although the changes are not so drastic. In general the winters are always more soft in the southern parts and spring starts earlier there while towards the north possibility of having ice in winter is higher and in summer warm water temperatures are present for shorter time.

Fig. 3. **The gradients of water temperature & salinity in the Baltic Sea –** salinity gets lower from dark to light; temperature gets colder from lighter to darker (Source: http://www.helcom.fi/)

The existence of seasons as it should be in the temperate climate and the enclosure determines the third characteristic feature of the Baltic Sea – the vertical gradients and layers. Although the Baltic Sea is not very deep still during warm seasons only the first 15-20 m of water column reach at least + 15 degrees Celsium. The rest of the water column stays at the temperature of 4-9 degrees depending from the sub-basin of the sea. It should be mentioned that the temperature drops quite drastically from e.g. +17 to +9 within the layer of some meters and this layer is called thermocline (*see* Figure 4). As the both water masses above and below the thermocline have different densities, they do not mix during the summer and the transport of any substances or particles through the thermocline is not intense. When the water cools again in autumn the temperatures become similar and the thermocline disappears. A vertical gradient exists also for water salinity – the inflowing freshwater mixes with the saline water and forms the upper layer with reduced salinity and density. This reduced salinity layer stretches deeper into water column – up to 80 m depth. There the salinity increases abruptly by 3-4 ‰ again in a quite thin layer which is called halocline. Halocline is a permanent layer and not occurring or disappearing seasonally. However, this phenomenon depends from the depth and in shallower sub-basins like Gulf of Riga the halocline does not occur at all. The absolute values of the salinity also are different regarding the sub-basin (*see* Figure 4). The halocline as well prevents the mixing of water masses. Occurrence of these layers is called stratification. An ecological significance of the stratification will be considered in Part II of this description.

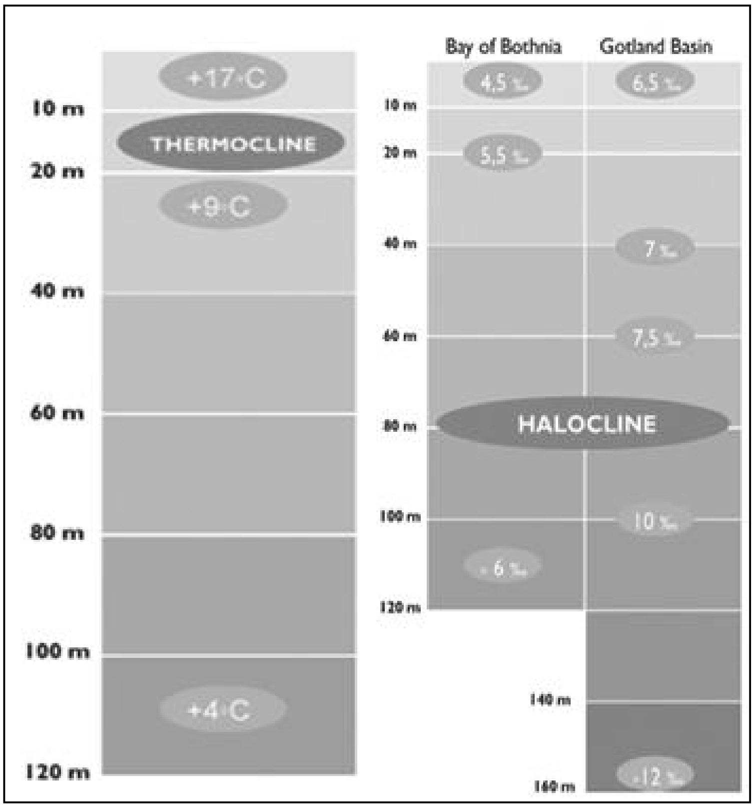


Fig. 4. **A stratification – the thermocline and halocline in the Baltic Sea**
(Source: http://www.balticseanow.info/)

Besides the dissolved mixture of salts determining the salinity there are several other substances dissolved in the seawater. Some of them are essential for development of living organisms and are called nutrients. The most relevant nutrients are nitrogen, phosphorous and silicate or N, P and Si. Dissolved forms of their inorganic salts are in the seawater in various concentrations depending from the season. The ways how the nutrients occur in the sea are several. Inflowing by rivers contributes the most to the nutrient pool of the Baltic Sea. Rivers collect the input from agricultural areas (mineral enrichment of the fields), from forests (leaching from the soil of cut areas), from wastewater treatment plants (the discharged water is not 100% clean) and from sparsely populated areas where are no wastewater treatment plants. The particles of various substances, including nutrients, are emitted in the air from industrial and agricultural processes and later are deposited back – also in the rivers. The atmospheric deposition is occurring directly in the seawater, too. Other direct ways of nutrients to the sea are leakage from the beaches and populated coastal areas, discharge from the wastewater treatment plants located on the coast. The nutrients are also stored in the seafloor sediments and in certain oxygen conditions are released back in the water column thus adding to the total pool. The life in the sea without nutrients is not possible but the consequences of excess nutrient amounts will be discussed in the Part II. Taking into account the relation of nutrients with the inflowing rivers and processes on the coast also the largest concentrations of nutrients are observed in coastal areas (*see* Figure 5) where the concentrations can be up to 10 times higher than in more off-shore areas of the sea.

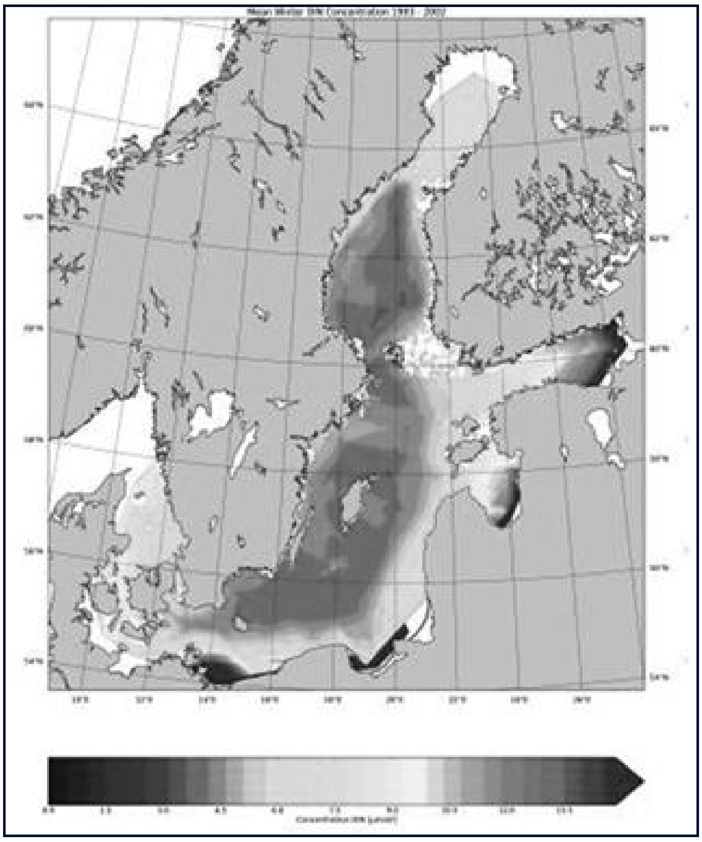


Fig. 5. **Spatial distribution of nitrogen concentrations in winter**
(Source: http://www.helcom.fi/)

Characteristics of the living organisms in the sea

Like we see and maybe know from the processes on the land if there are enough nutrients, temperature and light the production of plant biomass can be started. On land it starts in the spring and the same is true also for the Baltic Sea. The difference between the on-land and marine plants in the case of the Baltic Sea is the size. Plants, swimming in the water column, are algae of various species all together called phytoplankton. Phytoplankton is composed of microscopic organisms – in the Baltic Sea there are approximately 2 000 species of tiny algae. Algae belong to several taxonomic groups and most abundant are four of them – cyanobacteria or blue-green algae, diatoms, dinoflagellates and green algae. The shapes and forms of algae are very different – they live as lone cells, as colonies, as chains and as cenobies (*see* Figure 6).

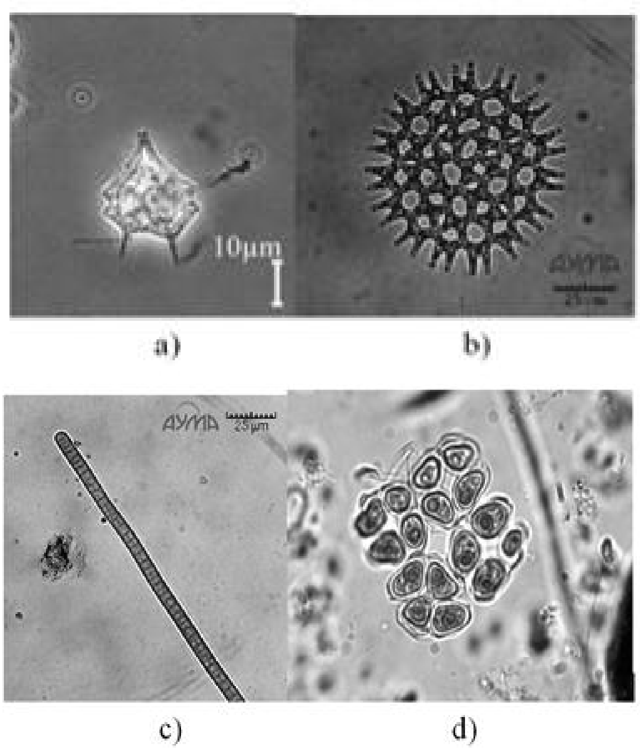
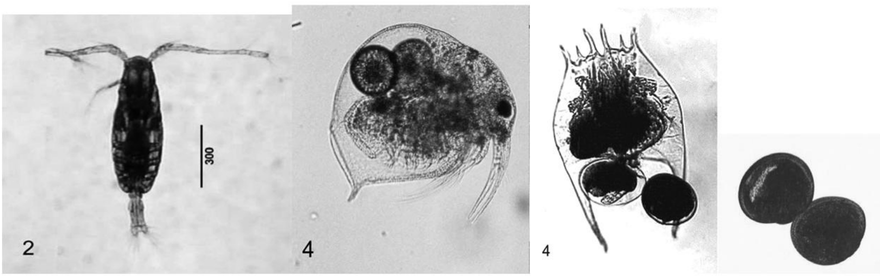


Fig. 6. **Variety of algal lifestyles – a) single cell; b) colony; c) chain; d) cenoby**
(Source: http://www.itameriportaali.fi; http://www.astro.temple.edu/)

So when the water temperature is sufficient – and in the Baltic Sea it means already about 5-8 degrees Celsium, the daylight is available for at least 10 hrs and there is plenty of nutrients in the water – algae start to grow intensively. This spring growth occurs from March to May according to temperature gradient in the sea, is called also "spring bloom" and consists mostly of diatoms. Diatoms are the algal group having the highest requirements for inorganic nutrients and their growth in spring is stopped by setup of thermocline, because algae cannot receive nutrient-rich water anymore. When the layer above thermocline is almost lacking inorganic nutrients other groups of algae – dinoflagellates and green algae – grow more intensely but never reaching the biomass levels of diatoms. Cyanobacteria appear later in summer when the water temperature is above 15 degrees Celsium and use the atmospheric nitrogen for their growth. In autumn when the thermocline is destroyed by dropping water temperature of the upper layer, diatoms have their autumn bloom although not so intense as in spring. Phytoplankton is a food source for other types of plankton and part of it sinks to the seafloor providing a food also for organisms living there.

Now we address some of those eating phytoplankton and living in the water column. These are animals like in on-land ecosystems (cows and grass, for example) but again their largest deviation from the on-land parallels is size. Slightly larger than phytoplankton but still mostly microscopic beings are called zooplankton and in Baltic Sea they are about 200 species. Also for zooplankton abundant are three groups – two of them belonging to crustaceans and the third is called rotifers (*see* Figure 7). Representatives of crustaceans – copepods and cladocerans are the main constituents of zooplankton biomass and also a food source of plankton-eating fish. Zooplankton is present in the water all the year round, although the highest numbers of animals are in summer and early autumn when the water temperature is the most favourable for development. In zooplankton you can find also other organisms like jellyfish which are well-seen at the end of summer in the water and on the beach. Meroplankton is a special group of zooplankton consisting of planktonic larvae of benthic animals – those living on the seafloor. Bivalves, crustaceans and worms have the juveniles swimming and feeding in the water column and settling on the seafloor at a later stage.



a) b) c) d)

Fig. 7. **Zooplankton organisms – a) copepod *Acartia*, b) cladoceran *Bosmina*, c) rotifer *Brachionus*, d) larvae of Baltic clam**

(Source: http://www.io-warnemuende.de/)

Thus we gradually have turned from water column to the seafloor. The seafloor of the Baltic Sea consists of various types of sediments – mud, sand, gravel, rocks. All the types of sediments are habitats for benthos – plants and animals living on the seafloor. Different from plankton these organisms have longer life cycles and larger sizes. Most of the benthic animals are visible with naked eye when collected from the sediments. Animals or zoobenthos – worms, bivalves and crustaceans – use the sediments in several ways by living on the surface, digging in partly and totally (*see* Figure 8). Zoobenthos feeds on sunken algae or detritus, bacteria and other organic particles in the sediments. Benthic animals themselves are food source for benthic-feeding fish and seabirds like ducks which can dive for the food.

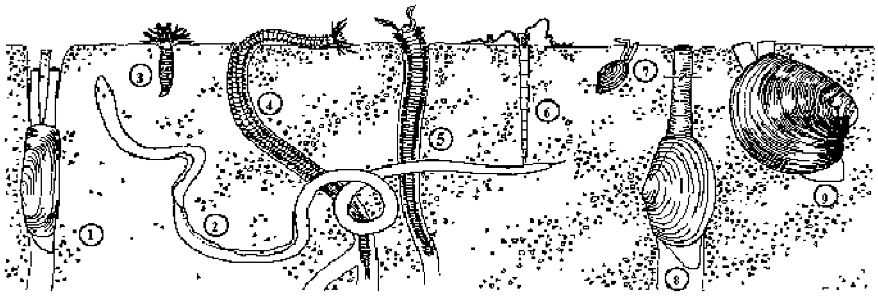


Fig. 8. **Zoobenthos in the sediments of the Baltic Sea**
(Source: http://www.dmu.dk/)

Plants growing on seafloor are also quite easily visible and all together are called phytobenthos. The suitable substrate type of seafloor or sediments fro growing are rocks and boulders. Availability of substrate therefore can be limiting the distribution of phytobenthos. Other limiting factor is light for photosynthesis and in this case if the substrate is suitable, phytobenthos can grow as deep as the light penetrates into the water in sufficient amount. Most popular species of phytobenthos in the Baltic Sea is brown algae *Fucus vesiculosus* or bladder wrack (*see* Figure 9). It is growing across almost the whole Baltic Sea and is regarded as a good indicator of environmental quality. Similar to the plants growing on land, also phytobenthos includes annual and longer living species. Excess of annual species is regarded as sign of declining environmental conditions with too high nutrient concentrations. We will consider this issue more in the Part II.

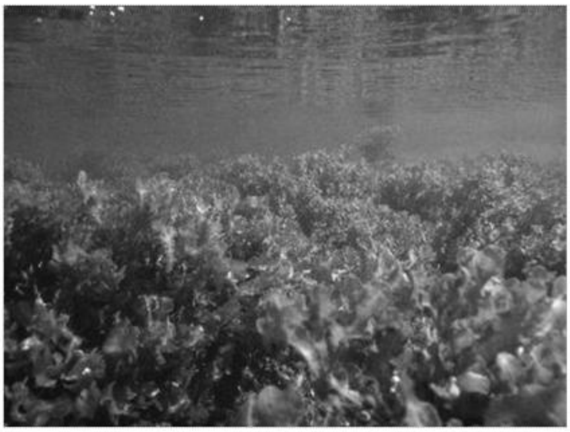


Fig. 9. **Bladder wrack in the Baltic Sea** (Source: http://www.helcom.fi/)

Grows of phytobenthos are the areas with a lot of different functions – it is a feeding place for zoobenthos, hiding opportunity for zooplankton, spawning site for Baltic herring, nursery area for several fish species and possibility to have a lunch for seabirds. Thus these locations are having high biological diversity and actually are the richest in the Baltic Sea.

Now we will discuss the largest creatures living in the Baltic Sea – fish, birds and mammals. Keeping in mind the food-web or "who eats whom", let's look at the fish at first being a food item both for waterfowl and mammals.

The list of Baltic Sea fish has about 170 names in it and even more – 90 of those are regarded as threatened. Still, part of these threatened species is just very seldom guests from the North Sea or Atlantic Ocean. Regarding the salinity values in the sea, the fish species composition is a mixture of truly marine, brackish-water and freshwater species. It is interesting that despite the high number of species, in the Baltic Proper there are just three dominant species of North Atlantic origin – cod, Baltic herring and sprat. Being the most commercially important species, they are the best investigated ones in the Baltic Sea. Abundance and breeding success of cod is related with the salinity and oxygen concentrations under the halocline – here the cod is spawning and eggs need a certain water density to develop in the water layer. Different from the North Sea where cod is a benthic-feeding fish, in the Baltic it feeds in the water column on zooplankton (juveniles) and other fish, mostly sprat (adult). Baltic herring and sprat are also strictly plankton feeding species and copepods are the group they like to have in their diet. Regarding other interests of industrial fisheries, three species of flatfish are the benthic – eating fish being targeted. The juveniles of flatfish grow up in shallow areas and feed on zooplankton, while the older stages are feeding on bivalves and other benthic animals in deeper areas. Close to 30 species of freshwater fish occur in the coastal areas – pike, perch, pikeperch and roach are among the most abundant ones. Due to the better feeding possibilities freshwater fish in the brackish water are bigger than their siblings in lakes and rivers. Several species of the Baltic Sea fish are the migratory ones – being born in the river they live in the sea (salmonids) and vice versa – born in the marine conditions spend their life in freshwater (eels). So traveling occupies an important part of their lives and is determined by "home effect" – need to return for spawning to the sites where they had hatched.

The number of bird species is approximately 4 times lower than of fish – about 30 bird species are nesting at the coastal areas of the Sea and about 20 species have the Baltic Sea as an overwintering or resting during migration area. Abundance of overwintering birds in numerous areas of the Baltic Sea is high and reaches the level of area of European significance for the respective population. Density of nesting birds has a decreasing gradient from the south to north related to the mildness and length of winter. However, there are several species – eiders, terns, gulls – that have spread in their distribution in the northern direction during the last 100 years and most probably due to more milder climate in the Baltic Sea area in this period. Bird and human interactions are quite complex but here I will just mention that human activities in the Baltic Sea area have stimulated the increase of some species previously close to extinction. Ban of several pollutants and stronger protection measures have resulted into upward trend for e.g., white-tailed eagles, cormorants and barnacle geese. Distribution of birds in the sea is related to the depth and available food there. For example, in the deeper areas exceeding 50 m depths mostly gulls are utilizing the by-catch and waste from the fishing trawlers, but in the depth of 10-25 m ducks and goldeneyes are diving for benthic animals.

The largest animals in the Baltic Sea eating fish are marine mammals – seals and cetaceans. Three seal species inhabit the Baltic Sea – the grey seal, the ringed seal and the spotted seal. All of them are protected species in the European scale, however Finland and Sweden issue certain amount of hunting licences on seals. The grey seal is the largest one and also having the highest abundance in the sea – more than 23 000 animals. They are migrating intensively in search of food or for some other business and can cover several hundreds of kilometers in few days. The ringed seal is an endemic (i.e., found and living only here) species of the Baltic Sea and concentrated in the northern part of the sea. It is almost by 1/3 smaller than the grey seal and not migrating for so long distances. The breeding success of the ringed seal depends on existence of ice very much. Ice is a nursery ground for cubs where they can hide in holes and caves their mothers have made or found for them.

Due to decline in ice presence during mild winters of late 1980s – 1990s the amount of the ringed seals dropped quite significantly – from 15 000 to 6 500 currently. The spotted seal is staying at the southern areas of the Baltic Sea and also not performing extensive migrations. By size it is in between of the other two species and population is estimated as 6 000 animals. Seals are feeding on fish and it is known than adult grey seal needs 10 kg of fish per day. The diet requirements is unfortunately the reason of conflict between seals and fishermen (from fishermens' perspective, certainly).

A lone cetacean species or small whale occurs in the Baltic Sea and it is harbour porpoise. Abundant 80 years ago (10-15 thousands of animals) and often sighted in many parts of the Baltic Sea, it is now rarely observed (about 600-800 animals). The drastic decrease of dolphin's abundance occurred after World War II and reasons are still unclear why. Lack of food resources, intensive fishing and traffic, pollution and natural increased migration to the North Sea are mentioned as possible causes. The porpoise is feeding on benthic fish and benthic animals and has been using the Baltic Sea as a feeding area during warmer part of the year. In winter it stays in the North Sea. In recent times the animals are believed to stay in the southern Baltic Sea as most of the sightings are recorded there and does not travel to Gulfs of Riga and Finland anymore.

Now we have got the impression what are the features of the Baltic Sea and who lives there. Based on the obtained knowledge we will try to embrace the most relevant problems for the environment of the Baltic Sea and how could the possible climate change influence the environmental quality of the Sea.

2. The most relevant environmental problems and the climate change impacts

The catchment area of the Baltic Sea is inhabited by 90 million people. 9 countries around the Sea with some of them having extensive agriculture and some – highly developed industries, certainly is a pressure for the marine environment. Therefore already 40 years ago the Baltic Sea countries understand that the common sea should be protected and that protection measures should be coordinated and carried out as mutual cooperation. Thus in 1974, Helsinki, the Convention on protection of the Baltic Sea environment was created and signed. The executive body of the Convention is known as Helsinki Commission or HELCOM and it consists of country representatives. HELCOM has worked actively since then by identifying the most urgent environmental problems and finding the solutions by joint practical actions and elaboration of recommendations. Currently identified main fields of environmental problems are eutrophication, hazardous substances, loss of biological diversity and maritime activities. Below each of those is shortly explained.

Eutrophication – it is a process, starting when the nutrient concentrations are exceeding the levels necessary for regular ecosystem functioning. In the Baltic Sea nutrient concentrations started to increase rapidly in 1960s when agricultural practices enlarged the use of mineral enrichment, the number of population grew but waste water treatment was not on so high level as it is now. Eutrophication so far is the best investigated environmental problem of the Baltic Sea. Increased nutrient concentrations are triggering increased growth of phytoplankton and short-living species of phytobenthos, called filamentous algae. The large amounts of organic matter in the water decrease the transparency and thus limit the light availability for long-living phytobenthic species. In this case the depth distribution of e.g. bladder wrack decreases. After the bloom phytoplankton settles to the seafloor where it is used by zoobenthic animals as a food but also utilized by bacteria which are transforming the organic matter back to inorganic components. This transformation process requires oxygen and if there is plenty of settled material, bacteria can utilize the whole oxygen near the bottom. The stratification brings additional pressure – the water cannot be mixed to have additional oxygen in it. Therefore several areas in the deeper parts of the Baltic Sea are constantly lacking oxygen and certainly nobody alive is there (*see* Figure 10). A term "dead zones" is used to describe these areas. Stratification is permanent and the only way of aerating these deep areas would be with the massive inflows of oxygen rich water from the North Sea. However, this phenomenon is becoming less and less frequent due to the changes in atmospheric circulation – the last large-scale consecutive inflows occurred in 1997 and 2003 while till 1980s were observed once a year.

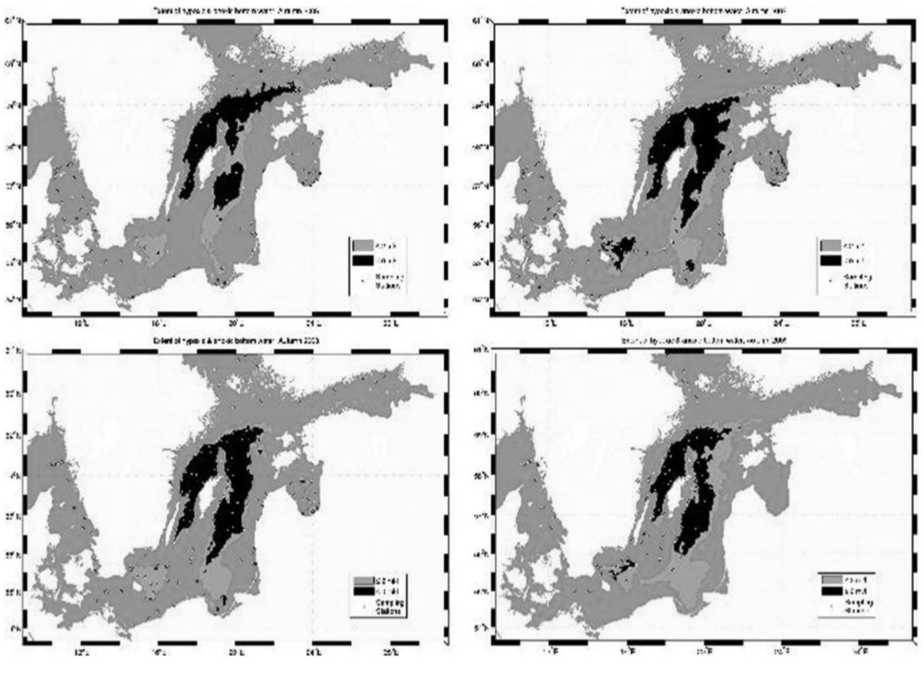


Fig. 10. **The bottom zones without oxygen (black) in the Baltic Proper, during the year 2010**
(Source: http://www.smhi.se/)

So eutrophication involves several changes in the plant and animal communities of the sea – species composition is changing towards more tolerant and short-living ones, the number of species is often reduced and in the worst cases the communities disappear at all. Almost every summer the Baltic Sea faces the problem of massive blooms of potentially toxic cyanobacteria. Their toxins are produced in certain conditions depending on age of algae, their density and water temperature, therefore they are not mandatory toxic. This group of algae need some concentrations of phosphorus salts in the water and high water temperatures – excellent if around 20 degrees. The phosphorus is re-circulated in the water column therefore no external supply is needed. Cyanobacteria are able to fix atmospheric nitrogen and thus can grow in really nutrient-poor conditions. The lethal toxic effects so far have been observed on animals but the massive blooms are the reason for closing the beaches and ban of swimming just in the middle of holiday season.

HELCOM has been initiating and coordinating various actions combating eutrophication since its foundation. The most recent overarching activity is the acceptance and implementation of the Baltic Sea Action Plan or BSAP (2007). The BSAP addresses the Baltic Sea health in several aspects, in case of eutrophication the focus is on reducing the basin-based and country-based nutrient loads. Every country has a commitment to reduce a particular amount of nitrogen and phosphorus loads to the Baltic Sea through better management of agriculture, wastewater treatment, transboundary pollution and shipping.

Hazardous substances – two types of hazardous substances can be identified. One group includes naturally occurring elements and compounds but in too high concentrations. The best known representatives of this group are trace metals. The second group consists of human created substances, mostly of organic nature, i.e., organic pollutants. Effects of the older ones like DDTs (dichlorodiphenyltrichloroethane) are investigated and unfortunately, also experienced – the numbers of grey seals and white-tailed eagles dropped drastically during 1970s and 1980s in the Baltic. Still, new organic compounds are appearing in the production continuously. The largest problem is the lack of knowledge how these substances impact the ecosystem health as they are accumulating in the food –webs and always being as a mixture of various pollutants.

HELCOM has called for a range of actions to reduce the impact of hazardous substances. The use of DDTs has stopped in the area and there is evidence on concentrations declining in the surface water of the Baltic Proper (*see* Figure 11). A list of priority hazardous substances has been created – the countries are recommended to monitor the distribution of these and apply usage restrictions for them. And certainly, the preventive and reduction measures should be coordinated between the countries around the Baltic Sea.

Biological diversity or biodiversity is affected as a rule in negative aspect both by eutrophication and hazardous substances. In addition to these factors reducing the biodiversity, fishing, oil spills and transportation, invasive species should be mentioned. Why is biodiversity important? Richer it is, more easy for the ecosystem is to stand the pressures and influences – ecosystem is more flexible and adapts faster and without particular losses to the changed conditions. Although often understood so, the biodiversity is not just a list of species. The keywords here are “functional groups” and “habitats”. Functional group ensures happening of certain process or function in the ecosystem, e.g., predators ensure predation. The functional group may have several species or – often for the Baltic Sea – just one species in it. Number of cod (only top predator) declined considerably in 1990s due to heavy fishing and decreasing salinity worsening the spawning and hatching conditions (*see* Figure 12). Across the food-web it expressed as increasing number of sprat and partly Baltic herring, decreasing abundance of certain copepod species because of predation pressure from fish, growth of phytoplankton and strengthening of eutrophication effect in some areas as the phytoplankton was not grazed so much anymore.

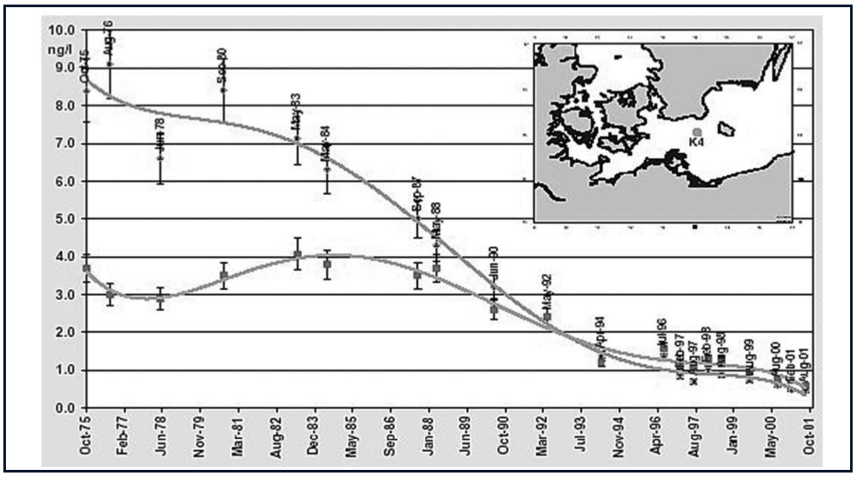


Fig. 11. **Time trends of DDTs in the surface water of the Baltic Sea, Arkona basin, 1976-2011**
(Source: http://www.helcom.fi/)

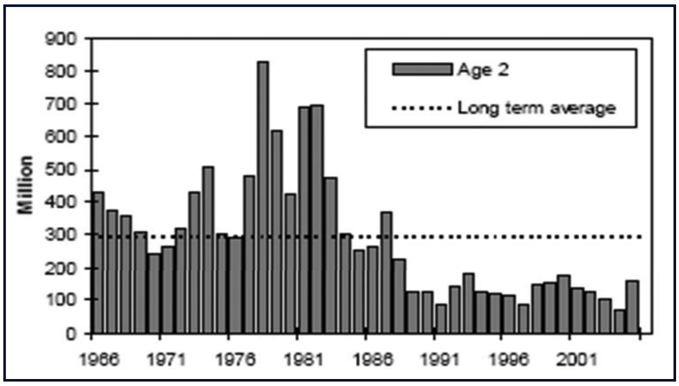


Fig. 12. **Recruitment success of cod in the Eastern Baltic Sea**

In general, the biodiversity of the Baltic Sea is quite low due to the salinity gradient and presence of brackish water. Brackish water is evolutionary quite young environment and therefore the number of species having adapted to it still is low. It also give an opportunity for other species from other areas to compete (and in many cases – successfully) for the place in the ecosystem. So we tackle now the issue of invasive species. The invasive or non-native species occur in the sea mainly due to shipping – in ballast water or attached to the hull. Other important route for invasive species is the channel connections of catchment areas of Baltic and Black Seas. As the shipping intensity is continuously increasing, so does also the appearance of the invasive species (*see* Figure 13).

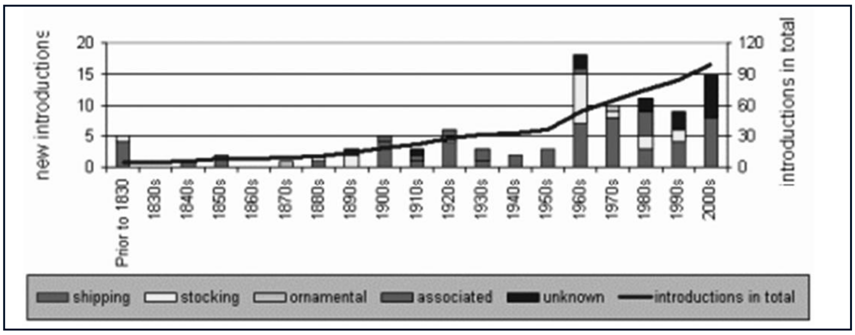


Fig. 13. **Dynamics of introduction rate of non-native species into the Baltic Sea** (Source: http://www.helcom.fi/)

The main concern in the appearance of the invasive species is the possibility of outcompeting of local species thus changing the food-web and ecosystem functioning. Indeed, if the species establish itself in the sea it is impossible to get rid of it. As a rule the incoming species are always ecologically very tolerant and with high ability of adaptation. Fortunately, currently only the competition of local and invasive species has been observed (e.g., for benthos polychaetes), no local species has been extinct yet. Rate of distribution is quite high for the marine areas – it takes about 5-10 years for animals and 10-15 years for plants to "travel around" the sea (*see* Figure 14).

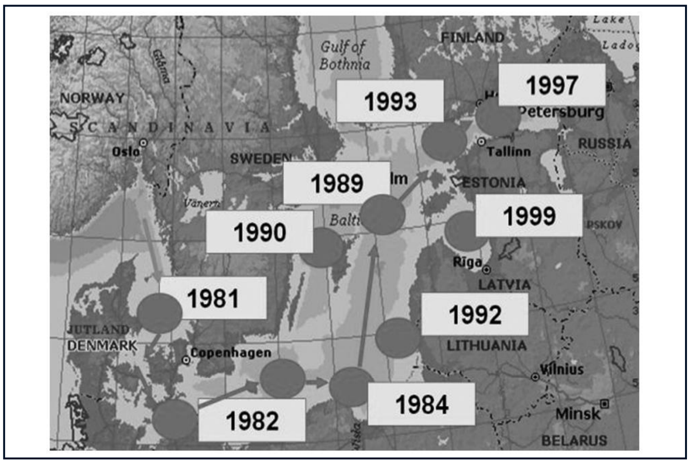


Fig. 14. **Distribution history of non-native phytoplankton species *Prorocentrum minimum* in the Baltic Sea** (Source: http://www.helcom.fi/)

Oil spills and oil transportation having a risk of oil spill pose another threat to the biodiversity mostly by destroying the habitats as the long-term effect and causing death of organisms as the short-term impact. Oil pollution disturbs or inhibits growth and respiration of coastal benthic systems. The scale of damage definitely depends on the volume of spilled oil but also small-scale still frequent events can result in chronic contamination and destruction of benthic communities.

In the range of HELCOM's response to the mentioned threats are designation of protected areas which have high biodiversity values, development of maritime spatial planning – to balance the needs of all users of the sea and the ecosystem, cooperation on measures between countries as neither invasive species nor oil spills follow the borderlines of the countries and increase of general public knowledge to ensure that people around the Baltic Sea are aware of the values and fragility of the sea.

Climate change has two components at least – the natural and human-induced changes and the problem is to disentangle them. Therefore the possible changes in the Baltic Sea are described but without indications of reason. The water temperature increase in the sea is indicated both by globally and regionally provided climate change scenarios. It could lead to the disappearance of ice cover, earlier development of phyto- and zooplankton communities and shift of macrozoobenthos breeding time. During springs the composition of dominant phytoplankton species will be determined by nutrient concentrations and water stability. If the nutrient concentrations will increase and water stratification sets early then a current dominance of diatoms will be replaced by dinoflagellates (*Peridiniella catenata*). If the wind activity will be strong causing higher water turbulence then diatoms could held their dominant position as the turbulence helps the species to remain in the water column. Also spring zooplankton development will start earlier. In case of dinoflagellate dominance as a food source higher proportion of rotifers is possible. Also in summer the wind strength will have essential significance besides the temperature increase and water stratification. If the wind activity will be stronger the increased abundance of cyanobacteria will not be observed. However, with the growth of phosphate concentrations and water temperature an increase of total phytoplankton biomass is possible exactly as a result of successful cyanobacterial development. Zooplankton community can have a higher share of freshwater species as the salinity is foreseen to decrease. Still, the changes in the food web would affect mostly the lower levels since the total zooplankton abundance is more likely to increase and food source for fish will not be modified substantially. Increase of primary production in combination with prolonged low oxygen concentration will classically lead to decline of macrozoobenthic communities in the deeper areas. Consequently the self-purification possibility of the sea varies and the food base for benthic fish is reduced. At the same time importance of coastal areas will raise for thriving functioning of the sea since long unfavorable conditions are not expected there. Course of future for phytobenthic communities will rely on the level of nutrient concentrations at the coastal areas. Short-term living algae will be more present if nutrient concentrations grow. Increased wind activity will diminish water transparency and thus also limit prosperous development of long-living algal species.

The productivity of the Baltic herring will increase at higher mean water temperature in spring. Dynamics of the Baltic cod stock will relay on fishing mortality by positive or negative modifications of salinity fluctuation. The abundance of sprat will vary in the cycle of 7-11 years not so directly related to climate change. Still the calculations of fishing mortality indicate that illegal fishing constitutes a significant part of the total catch. Illegal fishing causes high fishing mortality and reduces the total allowed catch. Therefore a successful fisheries management requires the reduction of fishing mortality via exclusion of illegal fishing almost independently of the climate.

The climate change can improve or worsen the productivity of year classes but in the situation of intensive fishing will not solve the level of stocks.

So still in the Baltic Sea the key factor remains the human being and his activities – how positive or negative they are. The course of climate change mainly will just strengthen or hide the impacts of the anthropogenic measures. We have to be reasonable in our attitude towards our common sea.

Baltijas jūras ekoloģija un klimata svārstību iespējamā ietekme

Kopsavilkums

Raksts ir sadalīts divās daļās. Pirmā daļa sniedz vispārēju Baltijas jūras raksturojumu, aprakstot jūras ekovidi, kā arī tajā dzīvojošos dzīvos organismus. Otrā daļa savukārt skar būtiskākās vides problēmas un iespējamo klimata pārmaiņu iespaidu. Tādējādi raksts sniedz pamatzināšanas par Baltijas jūras ūdens baseina nedzīvo un dzīvo vidi.

Atslēgas vārdi: Baltijas jūras ekoloģija, dzīvie organismi, planktons, aļģes, jūras dibena flora un fauna, jūras zīdītāji, klimata pārmaiņu iespaids

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