



HERRING

An analysis of spawning ground management, ecological conditions and human impacts in Greifswald Bay, Vistula Lagoon and Hanö Bight.



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Source: Jeff Rotman/Photolibrary/Getty Images

PREFACE

*‘When you study herring,
there are no wrong answers’*

A.J. Geffen at ‘Linking herring’ Symposium, 2009

Fish are not just fish. Differences within marine fish species in terms of morphology, behaviour, life history, and certainly also genetic differentiation have been shown for an impressive number of species, including herring (*Clupea harengus*). Herring are renowned for their plasticity that challenges population definitions. The complexities inherent in the plasticity displayed by herring in terms of life-history strategies, like migration patterns and spawning time, challenge our scientific endeavors as the herring are never really just herring. Although we often consider herring as large schools with tons of similar fish, every single herring appears to be different. For instance; herring are quite unique among marine fish in having a wide range of discrete spawning seasons while using very specific spawning locations, as despite herring being a pelagic species, it has a close association with specific substrata and topographic features. The complex population structure of herring indicates that the high level of adaptability must be a basic trait. Adaptability and plasticity is observed throughout the different life-history stages and despite the obvious need to synthesize the available information for a better understanding, a single unifying explanation for all observed herring patterns is still elusive.

Thus herring are not just herring and though being highly adaptive, they are quite specific in terms of where they spawn. Maintaining the necessary available diverse spawning habitats while enabling the use of those habitats by other living organisms, including man, is not a trivial task. This book summarizes a recent collaborative research effort for integrating herring spawning areas into holistic coastal management and planning.

Lotte A. Worsøe Clausen
Chair of HAWG

– ICES Working Group on Herring Assessment for the Area South of 62°N

Copenhagen, December 2014



*Women involved in the processing of herring where it's cleaned, hung up on a skewer to dry and put in the oven to smoke. Bornholm, Denmark 1957.
Source: Stiegh Eldh*

INTRODUCTION

The Baltic Sea is one of the world's largest brackish inland seas which have undergone tremendous changes with its history of altering between being a lake and a brackish-water sea. The Baltic basin was formed only approximately 10 – 15 000 years ago by glacial erosion and the melting ice from the last ice ages. The current Baltic Sea is an almost enclosed basin and only connected to the world's oceans by the Danish straits and the Sound. It is currently characterised by a mixture of saltwater coming from the northeast Atlantic and fresh water coming from rivers, rainfall and infiltration. This salinity gradient from the south-west to the north-east strongly influences biodiversity and species distribution in the Baltic Sea. Despite the stress that organisms are exposed to, because of the brackish water, the Baltic Sea provides a great variety of valuable habitats. With nine countries bordering the Baltic Sea, the coastal areas are also very important for human activities that claim space for transport, fishing, and tourism as well as energy and supply activities.

Studying the herring (*Clupea harengus*) in the Baltic Sea gives a good insight into the challenges that arise when its functions as an important part of the marine ecosystem and a natural resource conflict with human activities and demands for space.

Herring plays a crucial role in the food chain of the marine ecosystem and has had an essential role as an important food source and commodity for several European countries throughout history. The origin of the Hanseatic League in the late 12th century was in large part due to the trade in herrings along the southern Baltic coast (Halliday, 2009). With the demand for the large scale preservation and transport of herrings, the trade in salt, foremost with Lüneburg, thrived. Likewise the demand for herring kegs and coopers became greater and it can be assumed that the herring trade brought with it commercial conditions that helped several other industries flourish (Denicke, 1905). Although not well documented there were probably periods in the southern Baltic Sea from the 13th century to the beginning of the 15th century when very large shoals migrated to the



Medieval herring fishing in Scania. Source: Olaus Magnus, History of the Nordic people. 1555.



Main cities and trading routes of the Hanseatic League in the Baltic.

coasts. There are legends that the herring was so abundant it was possible to scoop up the fish by hand. Skanör and Falsterbo in southern Sweden became an important centre for the herring trade, called Scania Market, as there was large-scale herring fishery in the area (Foot et al., 1996).

Herring periods when shoals of herring migrated and were found in vast numbers close to the coasts are well documented as far back as the 16th century and seemed to appear in cycles of 90 to 100 years. The well-known herring periods during the winters along the coast of Bohuslän in Sweden stretched from the 16th century to the early 20th century and spanned over a decade at a time (Corten, 1999). These



A fishing boat at the dock unloading herring catch. Simrishamn, Sweden 1980. Source: Stiegh Eldh

Women involved in the processing of herring where it's cleaned, dried and smoked. Bornholm, Denmark, 1957. Source: Stiegh Eldh

periods gave rise to large scale industries when directly or indirectly occupying a great number of people with preservation of herring and extraction of fish oil (Johansson, 2001). There are several explanations why these herring periods occurred. One suggestion is that it was due to weather phenomena when the North Atlantic Oscillation was in a negative phase and with easterly winds dominating in autumn. These easterly winds forced surface water out of Skagerrak and thereby strengthened the sub-surface Norwegian Trench Current that flows into the Skagerrak. The current could easily transport herring from the normal overwintering area near Egersund Bank towards the Skagerrak. As the herring periods in Bohuslän were more persistent than the easterly wind it has been suggested that the herring migration may be explained by “site-fidelity” of the older herring. Once a new migration route has been adopted by the population it is repeated in subsequent years even when the original environmental cause has disappeared (Corten, 1999).

The most recent herring period off the coast of Bohuslän ended at the beginning of the 20th century. The previous cycles over the last 500

years indicate that there should be a herring period occurring at the present time, although this is not something that seems to be happening. Studies have shown that the North European herring periods may have been caused by the autumn spawning North Sea herring wintering in the confines of the Bohuslän archipelago (Höglund, 1972; Jensen, 1963). As other exploited fish populations the North Sea herring is subjected to both changes caused by variations in the environment and fishery-induced changes. During the decades after the World War II new fishing technologies and larger fishing vessels were able to catch large amounts of herring further out at sea leading to the stock collapse in the 70s (Saville and Baily, 1980; Cushing, 1992; Anon, 1995). One suggestion is that these populations of North Sea herring have been too heavily fished especially during the 20th century and are therefore not able to grow into vast numbers as in previous centuries. The cause of the variations of herring abundance and migration routes are hard to predict and understand, although both fishery and changes in the environment has to be taken into consideration (Glantz, 2005).



*Icelandic pelagic trawler fishing
for herring in the North Sea.
Capacity 600 tonnes.
Source: © Vidar Sigurdsson*

Developments in fishing technology with higher operating costs have led to a general decline in the number of fishermen and fishing vessels despite a substantial increase in the catch. This also put pressure on small scale coastal fisheries that find it more and more difficult to survive.

Since then, due to declining fish populations and increased competition from larger more efficient trawlers, small scale fishing has significantly declined.

This illustrates the vulnerability of populations of marine species like herring and that the effect of overexploitation will in the long run rebound on fishermen and consumers. The recognition that marine resources are vulnerable and not endless has led to a willingness to exploit the sea in a more sustainable way. The growing influential role of the International Council for the Exploration of the Sea (ICES) as political advisers is one example of that direction. In the Baltic Sea the policy of sustainable marine management is pursued by political agreements and conventions like the European Marine Strategy Framework Directive (MSFD) the Water Framework Directive and the Baltic Marine Environment Protection Commission (HELCOM).

Although the size of many catches today is controlled by stock assessments and quotas to prevent overfishing it is a challenge to comprehend the actual status of fish populations since a range of different factors may affect the stock. In addition to catches there are weather phenomena, climate change, changes in ecosystems composition, eutrophication and pollution among other factors that may affect fish populations. Although herring is a pelagic species that migrates between vast areas of water, it is also dependent of shallow coastal areas for spawning.

This book compiles the findings of the HER-RING project which was conducted from 2012 until 2015 and part-financed by the EU South Baltic programme (European Regional Development Fund). As mentioned before, although herring is a pelagic fish, shallow coastal areas are vital for its survival. Herring depends on these areas for spawning, as well as for nursing its larvae and juvenile fish. Globally a large extent of the socio-economic development takes place and is targeted at the coastal zones. The South Baltic is no exception. Thus the Baltic coastal areas in Germany, Sweden and Poland among other countries are used for a wide range of human activities and interests. Quite often different interests collide and conflicts arise. For example it can be the demand and competition for space between various industrial companies or the demand for space and healthy environment by tourists and local inhabitants in conflict with industries disturbing the environment as well as contributing to job opportunities. Due to a variety of features, the South Baltic coastal areas are of high economic interest and especially since a few decades the demand for these spaces strongly increased. The various anthropogenic uses and activities may not only hinder and collide with other human activities, but more importantly might lead to a large array of potentially adverse impacts on the coastal and marine ecosystems. Additionally, natural changes like climate change, sea level rise or coastal modifications also influence the functioning of coastal ecosystems, and thereby the conditions that determine spawning success. Numerous stakeholders, policy makers and regulations on different administrative levels manage and govern the coastal areas of the South Baltic. But the important function of coastal spawning habitats is hardly valued and often inadequately included in existing management strategies and regulations. If included at all.

Therefore, the main objective of the HERRING project is to improve the consideration of including herring spawning grounds in coastal management. Herring as a resource recourse would be part of the economic development of coastal areas, and HERRING strongly emphasizes the importance of foster an integrated coastal management in the South Baltic Sea. Three case study areas in Germany, Poland and Sweden serve as the basis of the approach, which can be roughly distinguished in two parts.

- The analysis of the ecological parameters and conditions as well as the impacts of present and future human activities, spatial uses and natural changes
- The analysis and compilation of the multi-level institutions and management instruments that govern the use and protection of coastal herring spawning grounds.

The management of coastal spawning areas can function as an example to show the huge diversity of interest, demands and actors that need to be considered for the sustainable use of resources and ecosystems.



Rocky beach in the northern part of Hanö Bight. Source: Naomi Images

SPAWNING AREAS AND POPULATIONS

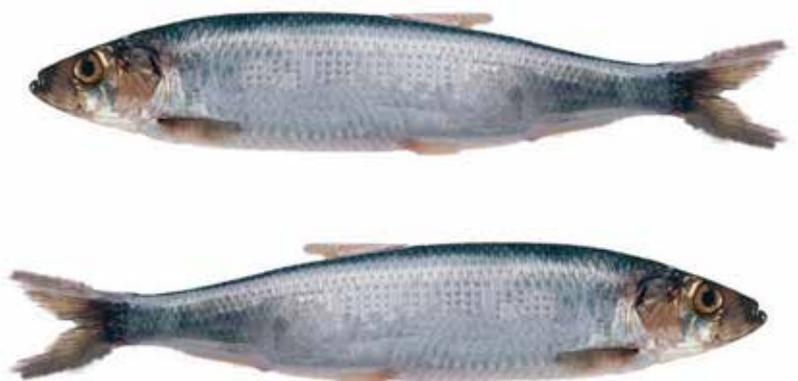
Atlantic herring, *Clupea harengus*, is a widely distributed species and its range covers also the entire Baltic Sea area, from the Gulf of Bothnia in the north to the southern and western Baltic.

Herring found in the central and northern part of the Baltic is sometimes referred to as a subspecies, *Clupea harengus membras*, since there are morphological differences. It is usually smaller, less fatty, having a longer head and fewer vertebrae compared to the herring in the Atlantic. These differences are believed to be adaptations caused by the stress the low salinity conditions in the northern Baltic impose on the herring. Although it has been found that the genetic differences are high at the individual level they are not significant between the northern and the south-western populations in the Baltic Sea (Ryman et al., 1984; Rajasalita et al., 2006). This may indicate that all herrings belong to a common Atlantic metapopulation and physical variations between subpopulations are a relatively recent adaptation to the local environment of for example low salinity. As the Baltic Sea is relatively young and not isolated any adaptations have not as yet led to genetic differentiation resulting in species separation (Ryman et al., 1984).

Herring is a pelagic fish that moves in large shoals between different bodies of water out at sea and along the coast. Studies shows there is also a migration vertically when herring moves to deeper waters during the day and more shallow water during the night. As zooplankton is the main prey of herring this migration may

indicate an adaptation to the light and prey distribution (Munk et al. 1989; Nilsson et al., 2003).

During spawning herring migrates to the shallower areas of the coast or shallow banks offshore. Spawning in the Baltic occurs mostly at depths from 0.5 m to 8 m (von Dorrien et al., 2013; Fey et al., 2014; Polte et al., 2014) although spawning in deeper waters has been observed (Lisivnenko, 1958, Aneer, 1979; Elmer, 1983). There are both spring and autumn spawning herring in the Baltic Sea although spawning that occurs during the autumn has decreased notably. It is mainly the temperature that triggers the herring to spawn. The spawning usually takes place a few centimetres above the substrate and gametes are released above, upon, and amongst the vegetation. Eggs adhere



Atlantic herring (*Clupea harengus*) Source: Malmgren Photo



Herring eggs attached to eelgrass (Zostera marina). Source Philip Kanstinger

to a substrate that usually consist of various aquatic plant, stones and boulders or sand and gravel (Aneer et al., 1983; Aneer, 1989; Rajasilta et al., 2006; Geffen, 2009; Ojaveer et al., 2011).

The eggs are about 1 to 1.4 mm in diameter and have an incubation period lasting from about 10 to 40 days depending on water temperature. The most favourable temperature for a viable hatch has been found to be between 7°C to 13°C. The larvae are 5-6 mm long and almost

transparent when hatching. Their yolk sacks are usually completely absorbed by the time they reach 10 mm in length (Horbowa and Fey, 2013). Herring larvae prey predominantly on small zooplankton and as they grow the diet is extended to also include larger copepods, various crustaceans, pelagic eggs and larvae.

As spawning takes place to a large extent in shallow coastal areas it is of importance that these areas are in good environmental condition to ensure a successful development of herring eggs and hatched larvae. In the HER-RING project each of the participant countries – Germany, Poland and Sweden – selected a case study area. The Greifswald Bay in Germany, Vistula Lagoon in Poland and the Hanö Bight in Sweden are regions known for being spawning grounds for herring.



Case study area Greifswald Bay (Greifswalder Bodden). Source: Thuenen-Institute of Baltic Sea Fisheries

Case study areas

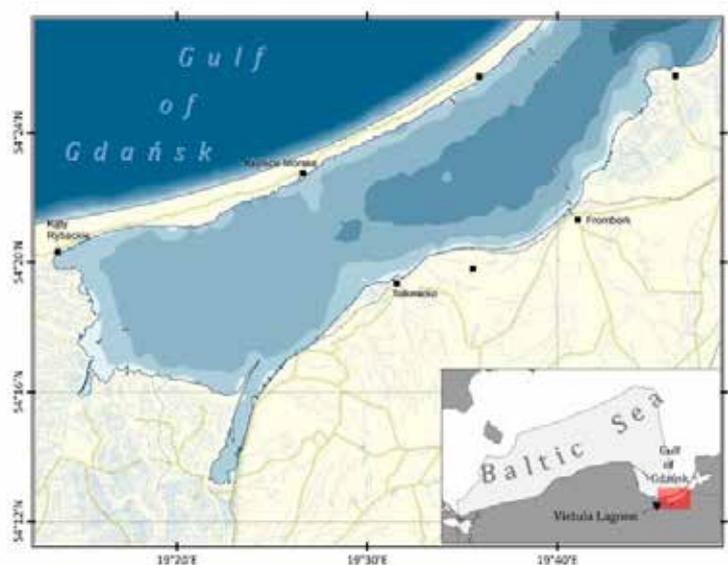
Greifswald Bay, the German coastal case study area, is a semi-enclosed inshore lagoon, which is considered the major spawning area of the western Baltic spring-spawning herring (WBSS). The bay covers approximately 514 km² and is bounded to the south and west by the coast of the federal state of Mecklen-



Shallow coast of Greifswald Bay. Source: Dr. Lars Tjepolt

burg-Western Pomerania and to the north by the island of Rügen.

The bay is characterised by a mean depth of 5.8m with a maximum depth of 13.6m. The bay is connected to the Baltic Sea through the narrow Strelasund in the west and a broader but shallower opening to the east. These topographic features and the marginal tidal amplitude in the inner Baltic Sea region (< 10 cm) account for the limited water exchange rate between the lagoon and the Baltic Sea. Thus, the exchange of the entire water body occurs approximately eight times a year (Stigge, 1989) and is mainly wind driven (Schnese, 1973).



Polish part of the Vistula Lagoon and case study area.

Practically the entire Polish coastal zone is considered to be an important herring spawning area, but the Pomeranian Bay the Gulf of Gdańsk, and the Vistula Lagoon are of particular significance. The case study area, the Vistula Lagoon, is fairly young in geological terms as it was formed just a few thousand years ago when it was separated from the coastal region of the Gdańsk Bay by the formation of the sandy Vistula Spit (Żmudziński and Szarejko 1955). The Vistula Lagoon, which is one of the largest coastal basins in the southern Baltic, is currently a very long, narrow, partially enclosed water body with water exchange between the sea and the lagoon only occurring through the Baltiysk, Strait located in the Russian part of the lagoon. The total surface area of the Vistula Lagoon is 828 km², of which 39.6 %, is located in Poland, while the other part belong to Russia. The total length of the Vistula Lagoon is approximately 91 km and the width ranges from 2 to 11 km.

The lagoon is very shallow and the bottom is almost totally flat, predominantly muddy (Żmudziński and Szarejko 1955). The mean depth in the Polish part of the Vistula Lagoon is 2.4 m. Since 1915, when the inflow of the Nogat River was cut off by a lock near Biała Góra, the Russian Pregola River has been the main source of water inflow into the lagoon. The most important Polish inflows are from the Pasłęka, Elbląg, Nogat, Bauda, and Szkar-pawa rivers (Chubarenko 2008). As an estuarine basin, the waters of the Vistula Lagoon are characterised by a specific hydrochemistry and many of their environmental factors fluctuate.

As the only connection with the Baltic Sea is located in the Russian part, various hydrological conditions and water quality parameters present a strong gradient along the lagoon main axis: impact of marine waters is much more pronounced in the Russian part while the Polish one is more influenced by the freshwater discharge from the rivers. The lagoon is very shallow and thus it is extremely vulnerable to resuspension of sediments driven by wind conditions. Moreover, a semi enclosed lagoon with a large drainage area has also a high internal potential to eutrophication.

The lagoon is a type of transition zone between terrestrial and marine waters in which the marine factors play the predominant role (Łomniewski 1958). River waters only have a distinctly greater impact during the spring flooding period (Uścińowicz and Zachowicz 1996). The impact of winds on the water surface is very important in determining water dynamics in the Vistula Lagoon. Generally, winds in the Vistula Lagoon range in speed from 1 to 4 m/s, and in spring and summer the prevailing wind directions are from the southwest, west, and northwest.

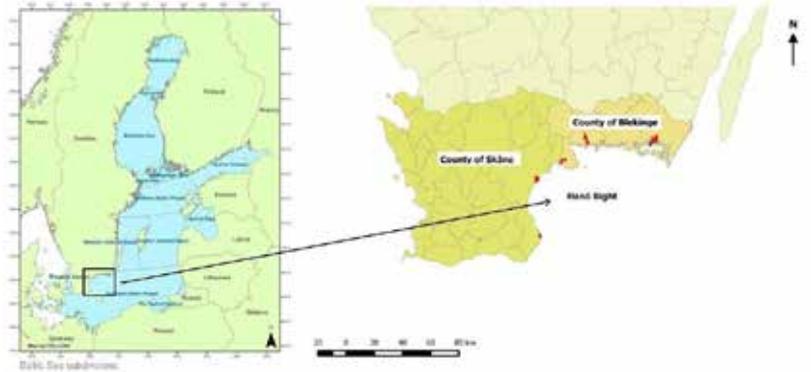
The Swedish Hanö Bight is the largest of the three case study areas and stretches from the southeast corner of Skåne to the east end of the Blekinge Archipelago and is a large open bay. The combined coastline stretches over 200 km and includes three municipalities in Skåne County and four municipalities In Blekinge County.

*Aerial view of the
Vistula Lagoon.
Source: Piotr
Domaradzki*



The marine area covering Hanö Bight and the Blekinge archipelago is about 5500 km² and there is a depth range from 0 m down to more than 60 m. The coastal marine area with depths from 0 m to 15 m, which would be most suitable for herring to spawn, covers about 1400 km². In general the Baltic Sea has a weak permanent current system. Because of the high amount of freshwater runoff, the current system is characterised by surface water with low salinity rotating in a counter clockwise direction. This creates a surface current running in a southerly direction in Hanö Bight (SMHI, Faktblad nr 52, 2011). In general the hydrodynamics of Hanö Bight are most likely more affected by wind, depending on its direction and speed. The environment along the coast of Hanö Bight is variable with the archipelago in the north creating sheltered areas between the islets and rocks and the more exposed and open coastline in the south.

Geological surveys show that the dominant seabed substrate close to shore is gravel and stone or rocks both in Skåne and Blekinge. Further out from the shore in Skåne, the seabed is dominated by sand and gravel as well as glacial clay with a surface layer of postglacial fine sand. In some part of southern and northern Skåne and in most of Blekinge, the deeper parts of the seabed are mostly covered by till with a surface layer of postglacial gravel and stone or rock as well as glacial clay with a surface layer of postglacial fine sand (SGU, 2012; Nordgren, 2012).



Case study area, Hanö Bight.



*View of southern Hanö Bight from Stensbuvud National Park.
Source: Lilitha Pongolini*

*View of the archipelago
in Blekinge.
Source: Robert Ekholm*



Herring populations

Being significant spawning grounds, these three case study areas are important for the recruitment of juvenile herrings to the spawning stock biomass. The size of herring stocks is also dependent on predation, competition for food source and landings from fisheries. Herrings are with other pelagic, economically important fish species not limited by national fishing zone boundaries. It is therefore important that international collaboration functions well in order to estimate the size of the fish stocks. This collaboration is conducted by the Baltic Fisheries Assessment Working Group (WGBFAS) of the International Council of the Exploration of the Sea (ICES). With collected fisheries-dependent data from landings and fisheries-independent data from scientific sampling and monitoring, WGBFAS makes estimations of specific fish stocks and gives scientific advices about sustainable management. Data are collected annually and is provided by all of the countries around the Baltic.

To be able to do stock assessments ICES has identified five separate stocks of herring in the Baltic Sea including the Danish Belts and The Sound. These five stocks, also described as management units, are the compromise between treating all populations that have been defined on biological basis and the practical limitations there is concerning reporting of catch (Payne et al. 2004). The stock distributions are described by geographical gridded areas called subdivisions (Payne et al. 2004).

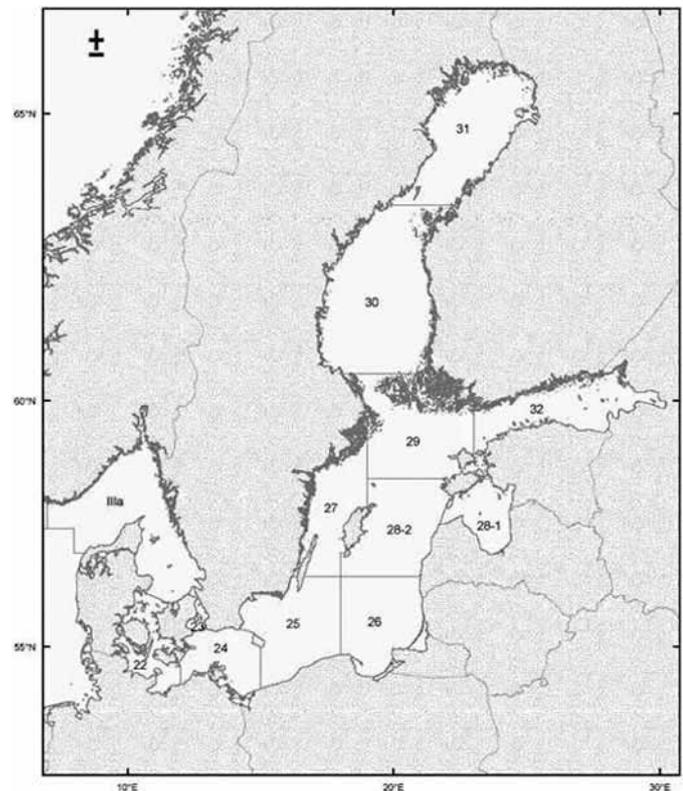
Herring stocks in the Gulf of Bothnia are divided in the Bothnian Bay in the north, covered by subdivision 31, and the Bothnian Sea in the south, covered by subdivision 30.

In the Baltic Proper also called the central Baltic there is a separation between a stock that includes subdivisions 25-29 and 32 and a stock in the Gulf of Riga belonging to the subdivision 28.1 (ICES, 8.4.7, Ecoregion stock, 2013). As the herring in the south-western Baltic Sea exchanges with herring populations from the Kattegat and Skagerrak it is treated separately from the central Baltic herring. These western Baltic spring spawners (WBSS) are therefore included in subdivision 22-24 (ICES, 6.4.8, Ecoregion stock, 2013).

The western Baltic spring spawning herring migrate annually between their feeding grounds in Kattegat and Skagerrak and their coastal spawning grounds, including the case study area Greifswalder Bodden in Germany that is part of subdivision 24. Spawning occurs in various areas of the shallow coastal waters of the western Baltic Sea (von Dorrien et al., 2013; Fey, et al. 2014; Polte et al., 2014). This herring stock is considered a meta-population composed of multiple spawning populations. One of the main components of the western Baltic spring spawning stock is the “Rügen herring” named after the shallow lagoons around the island of Rügen, including the Greifswalder Bodden, which are the main spawning areas of this group (Bekkevold et al, 2005; Clausen et al, 2007; Gaggiotti et al., 2009 Polte et al., 2014).

Similar to most spring spawners, the Rügen herring lays adhesive eggs on submerged substrates and vegetation in shallow littoral zones. The spawning activity takes place from March until May, and is triggered by water temperatures (Klinkhardt et al., 1996).

After the drastic decrease of the Spawning Stock Biomass (SSB) during the mid-1990s,



ICES subdivisions in the Baltic Sea.

Source: ICES

(http://geo.ices.dk/viewer.php?add_layers=ices_ref:ices_areas)

SSB levels have remained relatively stable, illustrated in the upper left graph in Figure 1. However, recruitment continued to decrease for reasons presently unknown (Figure 1, lower right graph).

Herring exploited in the case study areas of Vistula Lagoon and Hanö Bight belong to the Central Baltic Herring, subdivisions 25–29 and 32 (excluding Gulf of Riga). The stock contains both the fast growing southern Baltic populations as well as slow-growing northern Baltic populations. The stock comprises mainly spring-spawning herring and a small autumn-spawning population. In Vistula Lagoon only spring spawning occur and as the lagoon is shallow (5 m on average) and almost enclosed the spawning off herring becomes very effective resulting in extremely high abundances of fast-growing larvae (Fey, 2001). After spawning adult herring migrate to the deep basins to feed (Aro, 1989).

Pelagic stocks in the central Baltic are mainly taken by pelagic trawl fisheries, of which the majority take herring and sprat simultaneously. According to ICES WGBFAS Report this mixture of herring and sprat contributes to an uncertainty in the actual catch levels, particularly from 1992 and onwards. However regulations have been imposed on vessels operating

in the industrial sprat and herring fisheries forbidding the landing of unsorted catches, unless there is a proper sampling scheme to monitor species composition. This is thought to have led to a reduction of catch misreporting and a more secure landing assessment as discarding in this kind of fishery is negligible (ICES WGBFAS Report, 2013).

Recent stock assessments in the central Baltic Sea indicate that the Spawning Stock Biomass (SSB) declined until 2001 and then increased again slightly and is currently above Maximum Sustainable Yield (MSY), as illustrated

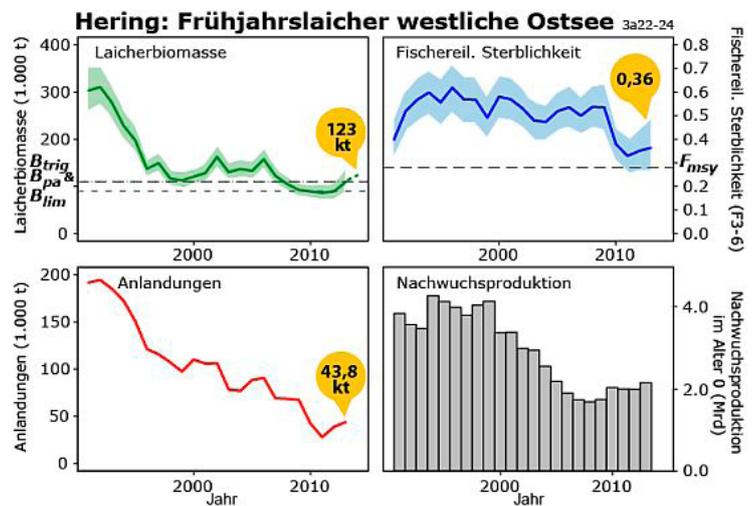


Figure 1 Development of the western Baltic spring spawning herring stock 1991–2013. Source: Thuenen-Institute/Fischbestände online 2013



A trawler in the Hanö Bight 1969. Source: Stiegh Eldh

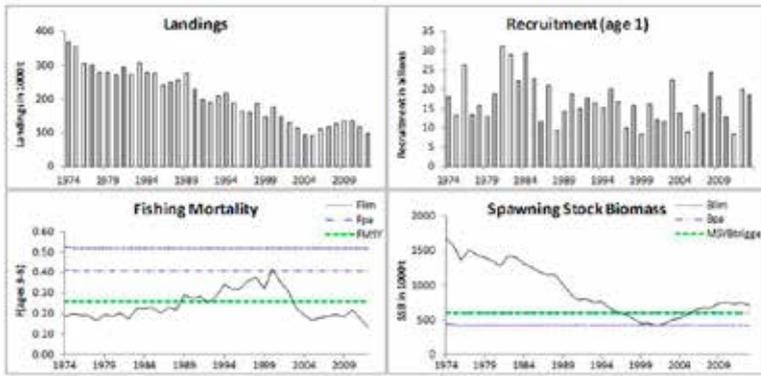


Figure 2 Herring in subdivision 25–29 and 32 (excluding Gulf of Riga herring). Summary of stock assessment (SSB and recruitment in 2012 predicted). Source: ICES, 8.4.7. 2013

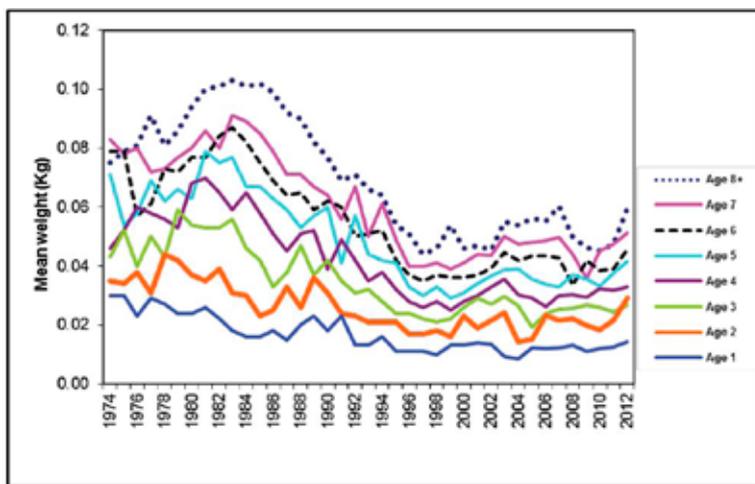


Figure 3 Herring in subdivisions 25 to 29 and 32, excluding the Gulf of Riga. Trends in the mean weight-at-age (kg) in the catch. Source: ICES, 8.4.7. 2013

in Figure 2, lower right graph. Mortality due to fishery (F) increased until 2000 and then decreased being below the Maximum Sustainable Yield of Mortality (FMSY) since 2003 (Figure 2, lower left graph). Recruitment of one-year-old herrings has generally been lower since the 1980s (Figure 2, upper right graph).

Herring biomass is dependent on the cod stock through predator-prey interactions, and through competition with sprat. The decline in the Spawning Stock Biomass (SSB) in the Central Baltic herring was partly caused by the decrease in mean weights-at-age during the 1970s to 1990s. The weights-at-age decline planed out after the 1990s and has since then been fluctuating without a clear trend (Figure 3).

Growth rate tends to change due to salinity variations, changes in zooplankton (prey) community, and competition with the Baltic sprat, i.e. a density-dependent effect (ICES WGB-FAS Report, 2013).

The central Baltic herring stock with a Spawning Stock Biomass of about 717 tonnes (ICES, 8.4.7, Ecoregion stock, 2013) is the most important stock in the Baltic Sea, followed by the western Baltic spring spawning herring with a Spawning Stock Biomass of 106.1 tonnes (Thunen.Institute of Baltic Sea Fisheries, 2013). To include spawning grounds in the management plan for herring may be of great importance for maintaining a viable herring stock. Increasing and evaluating the knowledge of the environmental and anthropogenic factors that affect herring at its different life stages is therefore of great importance.



Blekinge archipelago
Source: Henrik Nilsson

Eelgrass meadow
Source: Michael Palmgren





THE ECOLOGICAL ENVIRONMENT

The marine ecological environment with its biological and abiotic parameters affects the herring and its spawning in various ways. It is assumed that there is a certain homing behaviour expressed in the spawning migrations of the Baltic herring. If well-established spawning grounds should deteriorate ecologically, leading to low spawning success, adult herring would not spontaneously change to more favourable spawning grounds. As a result, regional spawning sites may have an important ecological function in supporting the resilience of a herring population.

German case study area - Greifswald Bay

Environmental monitoring programme

The environmental monitoring programme in Greifswald Bay (GWB) in its current form started in 1990 although there is data collected since the 1970s as well. There are several authorities responsible for environmental monitoring and measurements in the area. For example the state of pollution of marine environment, chemical and physical parameters, phytoplankton and macrophytic species composition and abundance is monitored by Lfa-Fischerei MV, the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) and the State Office for the Environment, Nature Protection and Geology (LUNG M-V). In addition the Thünen

Institute of Baltic Fisheries conducts extensive surveys of the different stages of Rügen herring larvae.



Sample sites for environmental monitoring in Greifswald Bay (LUNG M-V).

Herring response to ecological parameters

Water temperature

Temperature is considered to be one of the most influential factors of marine fish development. Water temperature controls growth rates, numerous biochemical reactions, and the duration of the hatching period (Laurence and Howell, 1981; Blaxter, 1956; Hufnagl and Peck, 2011). As a result, water temperature also

impacts hatching success, larvae size and larval growth. Studies have shown the optimum temperature for successful hatching of the western Baltic spring spawning herring to be between 5°-17°C, with decreased hatching success at water temperatures of 2.9°C and 21.7°C. At higher temperatures hatched larvae showed a smaller size (5.5 mm standard length), whereas at lower temperatures size of larvae was 7.5 mm (Peck *et al.*,2012)..

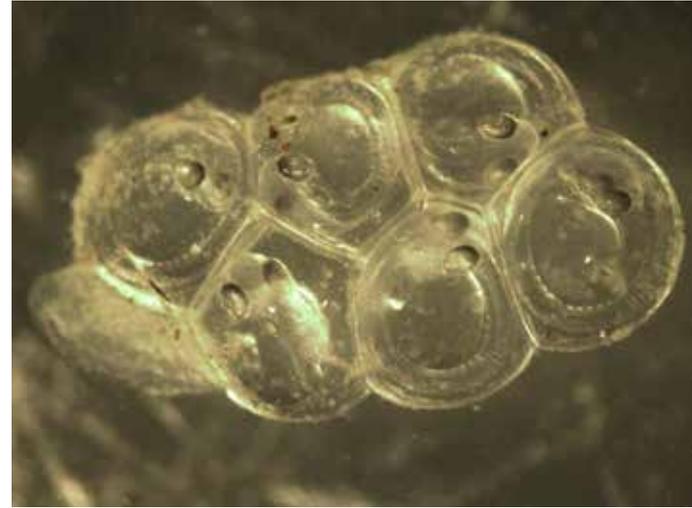
Furthermore, incubation temperature has a significant influence on the rate of yolk utilisation (Klinkhardt, 1996). Freshly hatched larvae of Baltic Sea herring exhaust their yolk in 4.5 days at a temperature of 8°C (Blaxter and Hempel, 1963) , while Ruegen herring exhaust their yolk in 6.5 days (Rannak, 1958). Another important aspect for successful larval development is salinity (Alderdice and Velsen, 1971). Pacific herring larvae incubated under limiting salinity and temperature conditions showed anatomical and behavioural anomalies at temperatures below 5°C and salinities below 7.8 PSU. Larvae hatched with missing or rudimentary lower jaws and showed no feeding behaviour (Alderdice and Velsen, 1971). Therefore salinity and temperature are equally important for normal anatomical and behavioural development (Rosenthal, 1967).

Water temperature not only directly impacts reproductive success, but also indirectly affects the developmental success of herring eggs. Moreover, oxygen solubility and therefore oxygen supply is related to water temperature.

Salinity

The GWB is a mesohaline ecosystem (Schiewer and Schernewski, 2002). Low salinity is mainly caused by the influx of fresh water from the River Peene. This fresh water plume is related to river outfall. The Strealsund connects the GWB water body with the more saline water body of the Darßer Schwelle. This water enters the GWB by strong north-westerly winds, driving salinity fluctuations.

Next to water temperature and oxygen supply, salinity is a central abiotic parameter for the ontogenetic development of fish (Klinkhardt, 1986) and plays a major role in osmoregulation and buoyancy (Laurence and Howell, 1981; Laurence, 1977; Holliday and Blaxter, 1960).



Close-up of herring eggs and embryo.
Source: Dorothee Moll

Generally the Baltic herring, as with the herring of the Atlantic and Pacific, spawn within a wide range of salinity (Holliday and Blaxter, 1960; Aneer, 1989).

The effect of changes in salinity on herring spawn has been investigated in order to identify the critical levels of salinity. Herring eggs fertilised at a salinity of 0.08 PSU showed a mortality rate of 95% after four days, with a final mortality rate of 100% (Klinkhardt, 1984). Eggs incubated at a salinity of 3.51 PSU also suffered high mortality, with only 5% of fertilised eggs developing successfully. The critical salinity value for the normal development of herring eggs is 4 PSU. At this salinity 50 % of the embryos develop in a normal way. Additionally, eggs fertilised at a normal local salinity (9.5 PSU) incubated in water with a lower salinity of 3.7 PSU still suffered high mortality (Klinkhardt, 1984).

Oxygen supply

Wind induced hydrodynamics usually result in adequate oxygen supply in the GWB (Schoknecht, 1973). Local and temporal oxygen deficiency can occur at the bottom in coastal waters and are caused by stratification (LUNG, 2008 a). An oxygen content of > 6 mg/l is considered a good oxygen concentration (LUNG, 2008 b).

The oxygen uptake of herring larvae is related to temperature and increases with increasing temperatures (Almarar, 1984).

Oxygen becomes available to the embryo through the embryonic membrane. Depending on duration and intensity, oxygen deficiency can lead to developmental damages or egg mortality (Klinkhardt, 1996). One reason for egg mortality caused by oxygen deficiency is the agglutination of spawn, wherein multiple layers of eggs prevent deeper layers from obtaining oxygen, often causing egg mortality in those deeper layers (Blaxter, 1956; Klinkhardt, 1996). In a study on Atlantic herring eggs, larval size at hatching was reduced considerably when dissolved oxygen levels were kept below 50% of saturation throughout the incubation period (Braum, 1973). Herring eggs were able to tolerate a decreased oxygen supply, but egg development slowed, and some embryos showed malformations such as distortion of the eyes that were small and underdeveloped (Braum, 1985). The tolerance of Baltic herring eggs to chronically reduced oxygen supply is relatively high, down to about 20% to 25% saturation for a single egg under conditions of relative good water exchange (Aneer, 1987).

pH value

In the GWB the mean pH is about 8. Investigations on the effect of lower pH values (from pH 8 to pH 7) on early life stages of Atlantic herring revealed no significant relationship on fertilisation, embryonic development and malformations. Furthermore, there was no effect on total larvae length or yolk sac area of newly hatched larvae. However, the relative RNA

content in yolk sac larvae was significantly lower, indicating a decrease in protein biosynthesis (Franke and Clemmesen, 2011). Egg production may also be impaired by lower pH values. Cyprinid egg development decreased at pH levels between 4.5 and 6.0 compared to a higher pH of 6.8 (Craig and Baksi, 1977).

Hydrodynamics

Hydrodynamics have an impact on reproductive success. Strong currents may damage the sensitive egg membranes or even rip out submerged aquatic vegetation in the shallow littoral zone as a consequence of storms. There are reports of storm-induced wave actions causing up to 40 % losses of Pacific herring spawn (Haegele and Schweigert, 1985).

In 2012 the Thünen Institute of Baltic Sea Fisheries, in collaboration with the University of Rostock, examined the importance of hydrodynamic effects on herring egg mortality. Within the GWB an important spawning site (Gahlkower Haken) was sampled with a mini Van Veen grab sampler at six fixed locations prior to and immediately after a storm lasting several days. Additionally, fixed transects at defined depth strata were sampled weekly throughout the spawning season. Egg density and macrophyte coverage were quantified for both of these approaches. A beach section of 571 m located to the lee of the transects was also sampled for macrophyte litter with attached herring spawn after the storm. The egg

*Eelgrass (Zostera sp.)
effected by waves.
Source: Timo
Kleinrueschkamp*

biomass was found to be significantly higher in areas shallower than 2 m, especially compared to waters deeper than 3 m. The observed reduction of macrophyte spawning substrate from the spawning site after the storm was 26%. The number of herring eggs found on the macrophyte litter washed ashore on the beach was substantial.

An analysis of the hatching success of Pacific herring eggs on living brown algae (*Fucus* spp.) washed ashore after a storm resulted in a proportion of viable hatched larvae of 32% (Hourston and Rosenthal, 1976).

Solar radiation

In general, solar radiation can have detrimental effects on early life stages of fish. UV-A and UV-B radiation damages molecules such as DNA, RNA and proteins, and causes oxidative stress to cells and tissues. Even low UV-levels are able to induce photo-enhanced toxicity by photo-activation of contaminants in the water column caused by human pollution and eutrophication (Zagarese and Williamson, 2001). Furthermore, UV radiation can lead to skin lesions in fish, which may also initiate outbreaks of infectious diseases (Nowak, 1999).

Anchovies exposed to DNA-altering doses of radiation had a survival rate of 50%, with survivors exhibiting radiation-induced lesions in the brain and eyes and retarded growth and development (Hunter *et al.*, 1979). In addition, UV-B radiation can suppress phagocyte functioning and therefore compromise the immune system of fish (Salo *et al.*, 1998).

Eggs developing in the air-water interface may minimise UV damage by using sunscreen defences (Epel *et al.*, 1999). There are a few investigations of the impact of UV radiation on pelagic eggs. There is evidence that UV radiation influenced the mortality of cod eggs in surface water (Béland *et al.* 1999), but there is a lack of literature on the effect of UV radiation on herring eggs.

Interactions between the physical environment, spawning beds and herring biology

Temperature, salinity and seabed substrate

Herring spawns on submerged aquatic vegetation (Polte *et al.*, 2013). The density, diversity, and distribution of vegetation depends on several abiotic factors including water temperature, salinity, and turbidity, and on habitat characteristics like sediment composition.

The GWB is a brackish water ecosystem including marine and limnic species. In brackish ecosystems there is a great diversity of vegetation. Limnic pondweed and marine eelgrass are one of the main spawning substrates of Rügen herring. This was observed during an initial spawning area monitoring by the Thünen Institute of Baltic Sea Fisheries.



Eelgrass meadow (Zostera marina) in Greifswald Bay, an important spawning substrate for Rügen herring. Source: Thomas Förster

Besides salinity and substrate composition, light availability is the limiting factor for growth and distribution (Blümel *et al.*, 2002) of aquatic plants. Increased turbidity leads to light limitation for submerged aquatic vegetation. Light penetration potential leads to vertical zoning of the phytal zone, because different species of macrophytes need different intensities of light (Johansson and Snoeijs, 2002).

In Greifswald Bay eelgrass appears to live near its growth limits in the estuary and is distributed from 2.2 m down to a depth of 3.4 m near the island Vilm, whereas pondweed can be found at depths above 2 m (Munkes, 2005). Both macrophytes species can be found in sandy areas.

An increase of water temperature can change species composition by invasion of non-indigenous species. The ecological impact of non-indigenous species might have an impact on the reproduction success of herring as a result of competitive and predatory effects on native species and the increasing virulence of non-native parasites and pathogens (Rahel and Olden, 2008).

Furthermore, water temperature is an influential factor triggering herring migration into their spawning areas and spawning activity (Klinkhardt, 1996).

Sub-zero conditions have a great impact on the growth of vegetation. On the one hand, ice coverage limits light penetration in the water body. This causes decreased light availability for bottom-dwelling macrophytes. On the other hand, ice drifts can impact submerged vegetation through mechanical stress (Rambow, 1994). The duration of ice coverage affects the initiation of growth of macrophytes in the spring (Geisel, 1986).

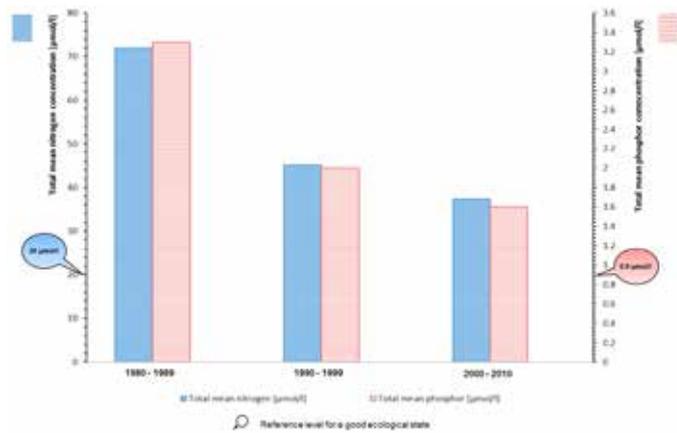
Nutrients, eutrophication and ecosystem impact

The catchment area of the GWB is (without water surface) about 665 km², with important inputs from the Rivers Ryck (231 km²), Ziese (115 km²) and Peene (5,110 km²) (Schlungbaum and Baudler, 2001).

Nitrogen and phosphorus concentrations have been continuously monitored since 1979 and 1978 respectively, however there is only one station in the GWB. Total mean nitrogen and phosphorus concentrations are marked by strong decreases over time until the early 1990s, with a weaker yet still decreasing trend since then.

According to Water Framework Directive assessments, the total mean concentrations of nitrogen and phosphorus in the GWB have exceeded the reference levels (nitrogen: 20 µmol/l, phosphorus: 0.9 µmol/l) (LAWA, 2007; BLMP, 2007) for achieving a good ecological status of coastal waters for the last 30 years (Robakowski, 2012).

The sea bottom of the GWB is characterised by sandy sediments in the coastal areas and mud-



Total mean nitrogen and phosphorus concentrations at one station in the GWB from 1979-2010. Source: Robakowski, 2012

Period	1978-1979	1980-1989	1990-1999	2000-2010
Total mean nitrogen concentration [µmol/l]	28.9*	72,1	45,1	37,4
Total mean nitrogen concentration fluctuation range of annual mean value (min. and max.) [µmol/l]	27.7 – 30.0	39.7 – 96.8	34.1 – 58.7	31.5 – 52.2
Total mean phosphorus concentration [µmol/l]	2.5**	3,3	2	1,6
Total mean phosphorus concentration fluctuation range of annual mean value (min. and max.) [µmol/l]	2.4 – 2.6	2.0 – 5.3	1.2 – 3.2	1.2 – 2.0

*Measurements started in 1979, only 2 measurements.

**Measurements started in 1978, in two years only 11 measurements.

dy sediments in the central area. As a result of the excessive nutrient inflow in the past years, a considerable amount of phosphorus has accumulated in muddy sediments. These sediments have a high potential to resuspend nutrients in shallow water through hydrodynamics.

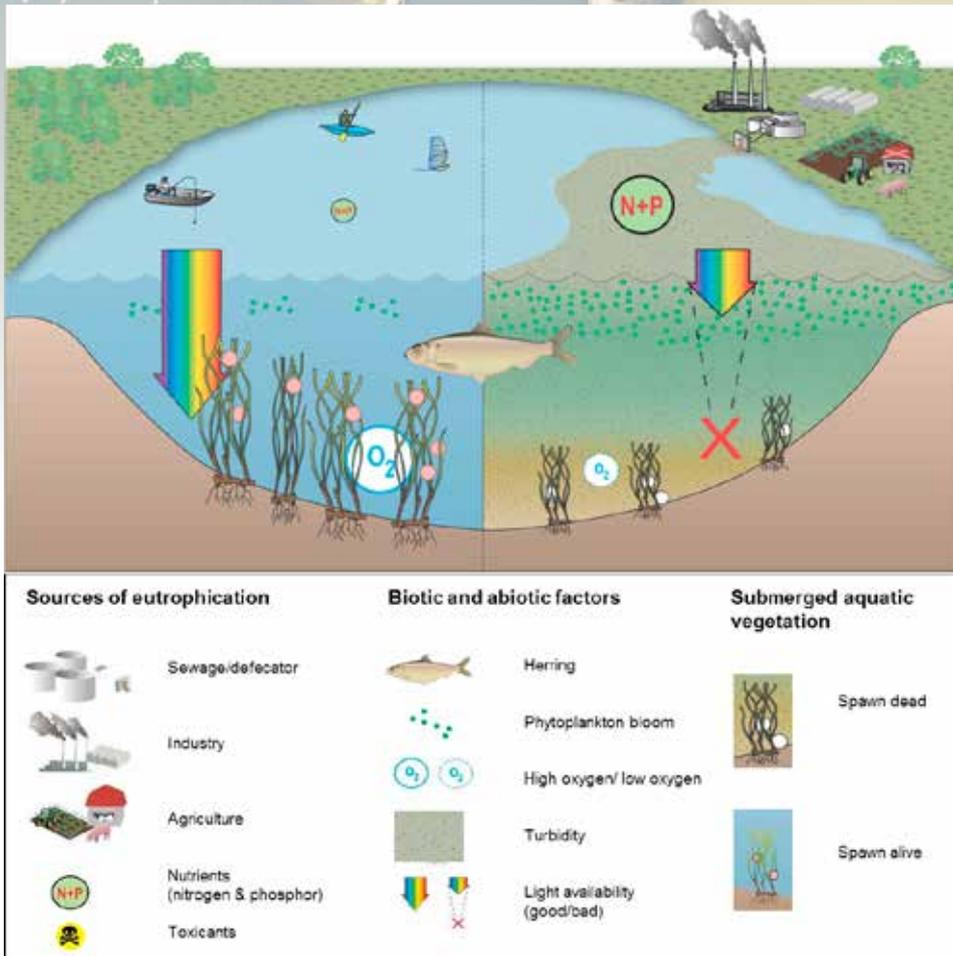
Although external phosphorus inflow decreased in the last years, these internal reservoirs have the potential to slow down any improvement (Bachor, 2005).

Coastal waters possess a high filtering and buffering capacity for the open Baltic Sea, and thus lagoons are naturally eutrophic systems. But the increased anthropogenic utilisation of coastal waters in the last few centuries has overloaded the natural potential of these ecosystems (Schütz, 2004).

HELCOM (2005) describes eutrophication as a condition of high nutrient concentrations stimulating algae growth leading to an imbalance in the aquatic ecosystem.



*The river Ryck with its outflow into the Greifswald Bay.
Source: Dr. Lars Tiepolt*



*The impact of eutrophication on the spawning habitat of herring.
Source: Dorothee Moll; symbols courtesy of ian.umces.edu/symbols/*

The water quality assessment of Mecklenburg-Western Pomerania (2003–2006) classified the GWB as a eutrophic ecosystem (LUNG, 2008 b). High nutrient loads in river inflow originate from agricultural labour in neighbouring regions. The most important

inflow to the Pomeranian coastal waters is the River Oder with a mean drainage volume of 540 m³/s, this river being one of the most polluted rivers in Europe (LUNG, 2008 a, 2008 b). The Peenestrom takes approximately 15 % of Oder drainage and enters the GWB periphery

with a direct outlet to the Baltic Sea. The river Ryck enters directly into the GWB and along with the river Ziese is the main source of the Lagoon.

The water quality assessment noticed pesticide input from the Rivers Ryck. Ryck and Ziese are both highly eutrophicated (LUNG, 2008 b). From the mid 70s to the early 90s, the cooling water for the nuclear power station in Lubmin was taken from the Peenestrom, appropriating approximately 30 % of the Peenestrom drainage (Hübel et al., 1995). Nevertheless, even the inflow from small rivers and streams running through intensively used agricultural lands shows disproportionately high nutrient loads (LUNG, 2008 a). The nitrogen and phosphorus loads of municipal sewage plants (e.g. Stralsund, Greifswald and Anklam) are small in comparison to the nutrient inflow from agriculture. Figure 5 shows the impact of eutrophication compared to a good trophic state and the complex relationships between the input of nutrients and their influence on an ecosystem.

Annual nitrogen and phosphorus inflow into coastal waters are generally dominated by river discharge, which varies depending on meteorological and hydrological conditions. The highest nitrogen inflow rates were registered in drainage-rich months (Feb. 2004, Feb- Apr 2005 and Feb- Apr 2006), which coincides with the herring spawning period (LUNG, 2008 b).

Nitrogen and phosphorus are essential nutrients for growth of microalgae (phytoplankton). If one nutrient is not available in an adequate concentration, phytoplankton growth is limited (Cloern, 2001; Munkes, 2005). High nutrient loads result in massive phytoplankton growths.

Since phytoplankton is the food source of zooplankton, high primary production leads to high zooplankton abundance. Phytoplankton can cause increased water turbidity and consequently decrease light availability for submerged aquatic vegetation.

Vegetative cover in the GWB has dropped from 90% (Seifert, 1938) in previous years to 10%-15% today (Munkes, 2005; Messner and Von Oertzen, 1990, 1991). In the 1980s the worst situation was found in the eastern inner



*Bloom of cyanobacteria in the harbour of Lubmin.
Source: Gerald Schernewski*

part of the bay, due to the higher anthropogenic loads of nutrients and reduced exchange rates with the Baltic Sea. While a recovery of a 25% increase in vegetative coverage is reported for the area (Schiewer and Schernewski, 2002), this information is unreliable and not supported by data.

Demersal eggs of herring are mainly attached to macrophytes. Increased turbidity results in a reduction of aquatic submerged vegetation in deeper waters. On the other hand, shallow zones are more severely exposed to storms, where the high wind velocity damages eggs and uproots macrophytes, thus reducing the available herring spawning substrate. Microbial breakdown of strong phytoplankton blooms can lead to a decreased oxygen supply, which also impacts herring spawn. Sedimentation creates deposits on vegetation, leading to the decomposition of organic matter. These fine precipitates on the egg surface can impede or prevent metabolism and gas exchange, as was observed in 1982 and 1983 in the GWB (Klinkhardt, 1996). The decomposition of precipitates by bacteria further consumes oxygen and can lead to anoxic conditions.

Eutrophication allows for an increase of epiphytes, fast-growing filamentous green and brown algae. Epiphytes are characterised by

filamentous algae covering leaves of flowering plants, which can thereby overgrow herring eggs, again decreasing the oxygen supply.

In the absence of suitable abundances of grazing invertebrates, epiphytes can also displace submerged vegetation by shading their tissues from sunlight (Sand-Jensen, 1977, 1990). Filamentous green and brown algae detach from the bottom and float on the surface in thick algal mats, which are constantly subject to partial decomposition, limiting the oxygen supply for herring eggs (Aneer, 1987, 1985).

Species introduction and ecosystem impacts

The increase in shipping worldwide is potentially the main cause of the introduction of non-indigenous species. Empty sea-going vessels often store ballast water for stabilisation. This water contains organisms, such as phytoplankton, zooplankton, jellyfish larvae, and other species which are transported from one ecosystem to another. Another example of species introduction is ship hull fouling (Gollasch, 2002), where organisms colonise the ship's outer surface. If environmental conditions are suitable, these non-indigenous species are able to become established and change the way the natural ecosystem functions (Rahel and Olden, 2008; Gollasch, 2006).

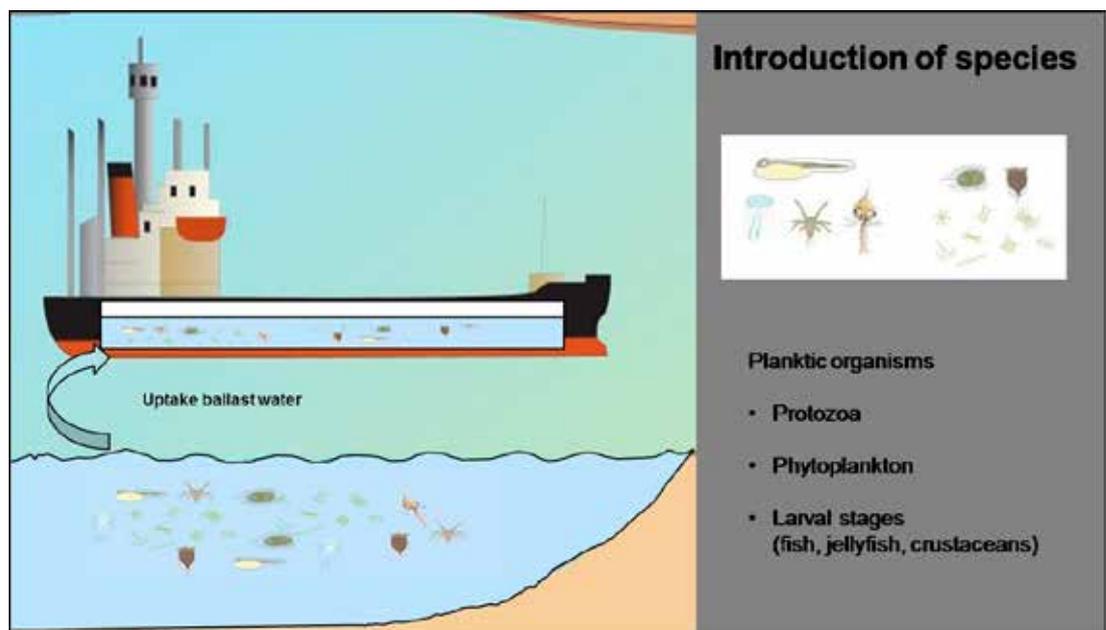
The introduction and establishment of alien species generally changes ecosystems. Non-in-

digenous species may lead to an increased predation on herring spawn or larvae. Furthermore, they may lead to competition for food and/or displacement of native species.

Non-indigenous species may directly interfere with the trophic regimes and habitat structures and have an indirect impact on changes in the entire community. There are various new species found in the present GWB ecosystem, with the following two cases providing such examples.

The estuarine mud crab (*Rhithropanopeus harrisi*, Gould 1841) is native to the Atlantic coast of North America and was introduced into the Baltic Sea by ballast water. These crabs tolerate a wide range of salinity values, which enables them to invade different aquatic ecosystems (Nehring, 2000). The estuarine mud crab was discovered for the first time in 1993 in the GWB (Zettler, 2002). It is presumed that this crab feeds on herring eggs, but there are currently no investigations on the potential predation pressure.

Another non-indigenous species is the euryhaline round goby (*Neogobius melanostomus*, Pallas 1811), which is native to the coastal regions of the Caspian Sea (Sapota, 2004). In 1999 this species was discovered on the coasts of the German island of Ruegen. The life history of this non-native species is the key for its successful invasion, as it spawns up to six times per



Introduction of non-indigenous species into an ecosystem via shipping and ballast water.
Source: Dorothee Moll; symbols courtesy of ian.umces.edu/symbols/

year from April until September (Skora et al., 1995). Although the diet of this fish is mainly composed of bivalves and gastropods (H. Winkler, pers. commun.), it might potentially prey on herring spawn during phases of high spatial overlap.

Climate change and ecosystem impact

It is well-known that climate change will lead to increased global temperatures and a higher frequency of extreme weather.

Climate change is an anthropogenic factor that has a high impact on the natural ecosystem through higher water temperatures, changes in salinity, sea level rise, and more frequent storms, to name but a few examples. A rising sea level also causes problems for coastal lagoons, because the naturally sheltered character of these ecosystems could be endangered (Schernewski *et al.*, 2011). Increased storms cause sediment mobilisation, which due to increased turbidity and multiple storms can uproot submerged aquatic vegetation. Furthermore, storms lead to resuspension of accumulated harmful substances and nutrients in the water column. In combination with an increase in temperature, these stressors would pose a serious threat to the way the natural ecosystem functions.

It has been shown that changing water temperatures may result in a shift of spawning periods and spring plankton blooms, and this might affect fish recruitment by predator-prey mismatch (Cochrane *et al.*, 2009; Hays *et al.*, 2005; Winder and Schindler, 2004).

It has also been reported that climate change might affect the condition of the adult herring. Investigations of first-time spawners of Norwegian spring-spawning herring suggested that herring were skipping reproductive seasons due to their small size compared to older spawners and therefore may often need an extra year to regain the energy stores needed to migrate and spawn (Engelhard and Heino, 2006). These aspects could lead to a decreased reproductive success of the herring.

Considering the complexity of these interactions and their ecosystem effects, it is important to conserve the present environmental status before investing in expensive restoration efforts. Some examples of important first steps

include minimising nutrient discharge or implementing sustainable management of urban coastal development. Furthermore, it is important to promote research on multiple impact factors in order to understand ecological cascades and to evaluate the ecological response to an increasingly large suite of anthropogenic stressors.

Polish case study area – Vistula Lagoon

Environmental monitoring programme

The Regional Inspectorate of Environmental Protection in Olsztyn (Branch in Elbląg) is responsible for the monitoring of Lagoon environmental conditions within the National Monitoring Programme (RIEP 2011). Samples are collected six times a year starting from April until October at nine monitoring stations located in the Polish part of the Lagoon.



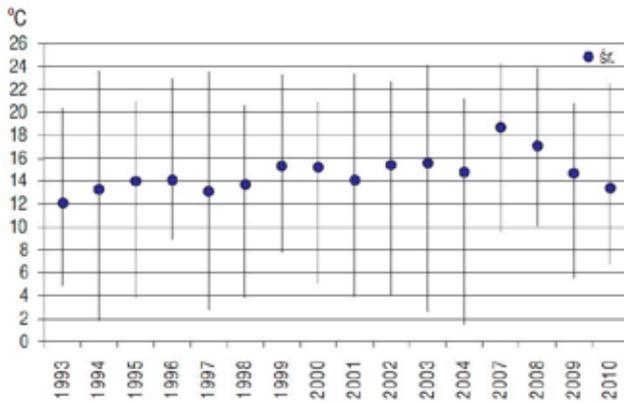
Location of sampling stations of the National Monitoring Programme in Vistula Lagoon. Source: RIEP 2011

Present ecological situation

Water temperature

The average, recorded water temperature of the Polish part of the Lagoon oscillated around 13°-15°C. Higher values observed between 2007 and 2008 were a consequence of the delayed beginning of the sampling season (RIEP 2011).

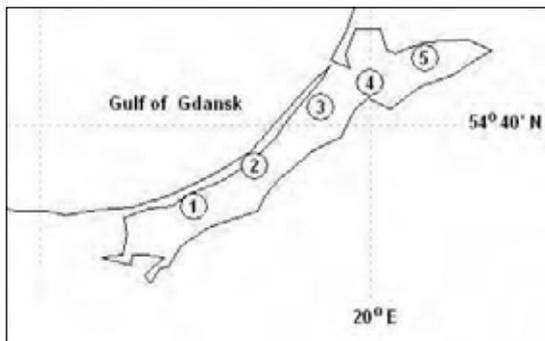
The sea surface temperature (SST) of the Vistula Lagoon is increasing which is consistent with regional climate changes and is expected



Sea surface temperature 1993-2010 (minimum, maximum, and average values are presented) Source: RIEP 2011

to continue into the future (e.g. Meier H.E.M. 2006 and Siegel et al. 2006).

As stated in LAGOONS (2012), satellite data of ocean colour scanner MODIS (on Aqua and Terra satellites) with a spatial resolution of 1×1 km have been widely used for climatological investigations. SST, derived from MODIS data for the period 2003-2011, was used for the analysis of thermal regime changes in Vistula Lagoon and identifying of potential trends. The area of investigation includes a transect consisting of 5 points through the central part of the Lagoon. A positive linear trend of SST with an



Locations of points of satellite monitoring in the Vistula Lagoon. Source: LAGOONS 2012.

Measurement point	Average ±σ	Trend		Increase, °C/period
		°C/day	°C/year	
P. 1	12.97±6.69	0.00029	0.02	0.14
P. 2	13.04±6.60	0.00021	0.01	0.10
P. 3	12.73±6.82	0.00014	0.01	0.07
P. 4	12.59±6.81	0.00026	0.01	0.13
P. 5	12.75±6.87	0.00013	0.007	0.06
Average	12.82	0.00021	0.011	0.10
±σ	0.18	7.09E-05	0.010	0.084

* N – number of measurements

Average surface temperature, its linear trends and increase in the Vistula Lagoon based on MODIS data from 2003 to 2011. Source: LAGOONS 2012

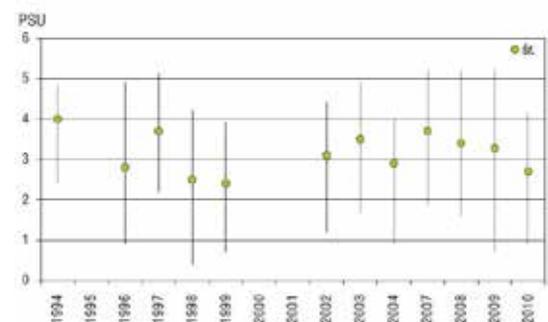
increase of 0.01° to 0.02 °C per year occurred in the Lagoon.

The transect satellite data also shows that the SST has increased by 0.06°–0.14°C during the period of investigation. A minimum increase of SST occurred at point 5 which was located in the north-eastern part of the Lagoon (ship-canal, Pregola River mouth). The positive trend of the SST in the Lagoon is weaker than the trend which is observed in the south-eastern part of the Baltic Sea and means an increase of 0.2°–0.3°C/period..

Annual water temperature dynamics (from –0.2°C up to 25–26°C) are the result of solar heating. The maximum water temperature usually occurs at the end of July or beginning of August, one week after the maximum air temperature, and about two weeks after the maximum solar radiation. Spatial and vertical variations of water temperature are less pronounced in comparison with temporal changes (daily variations during the summer are ca. 1°–1.5°C on average, with a maximum of 3°–4°C) (Chubarenko and Margoński 2008).

Salinity

The long-term average measured at the monitoring stations (1994–2010 period) equalled 3.2 PSU in the Polish part of the Lagoon (RIEP 2011).



Salinity during the 1994-2010 period (minimum, maximum, and average values are presented). Source: RIEP 2011

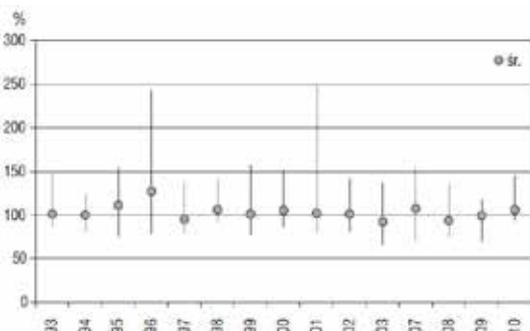
With respect to salinity the Vistula Lagoon is considered a transitional area. The hydrological regimes of the Vistula Lagoon have changed dramatically since the beginning of 20th century. Before 1915, the Nogat River only brought up to 2200 m³s⁻¹ of water to the Vistula Lagoon during the spring freshet. Marine water

intrusions were very seldom and not intensive. In 1916 the discharge of the Nogat River was regulated and today it equals 25 m³/sec on average. After the Lagoon became preponderantly marine water, salinity has increased to today's values (Lasarenko, Majewski, 1971).

As described by Chubarenko and Margoński (2008), seasonal salinity changes are caused by variations in balance between marine and river drain influences. The minimum salinity in the Lagoon (0.5–4.5 PSU) is in the late spring after the maximum river runoff occurs (March and April). Then, from May till August, salinity increases to 3.5–6.5 PSU, the river runoff is very low and the marine influence prevails. In the autumn, steady desalination starts, and finally, in the winter, the ratio between the fresh and salt water influxes stabilises during ice coverage and the Lagoon comes to equilibrium between the salting and refreshing processes (Chubarenko I., et al., 2004). During the winter a significant amount of salt comes from the ice formed in the water column which then mixes totally possibly causing an increase in the Lagoon water salinity by 10–25 percent (Chubarenko et al., 2005b).

Oxygen

The long-term average (1993–2010) oxygen saturation of the surface waters oscillated or even exceeded 100% (RIEP 2011). However, it is possible that during the summer phytoplankton blooms, hypoxia or anoxia might be observed locally, especially during the night and in calm conditions.



Oxygen saturation of the surface waters (minimum, maximum, and average values are presented).
Source: RIEP 2011

Ice cover

Usually, the Vistula Lagoon is covered by ice for several months (LAGOONS 2012). During very cold winters, a permanent ice cov-

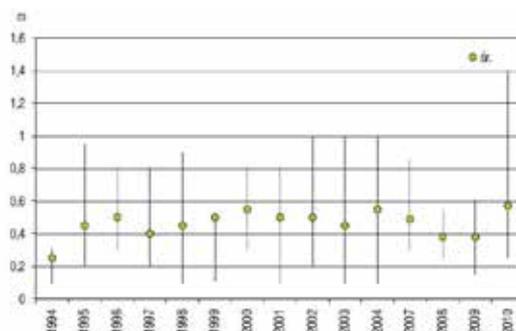
er remains from December to March. In warm winters, the ice cover lasts during a short period only, or no permanent ice cover is observed at all. Due to recent climate changes this period is getting shorter and is not stable in time. Ice periods enable active self-cleaning of the Lagoon's waters. At that time there is no wind influence on the Lagoon's waters and all air pollution is accumulated by the ice. When covered by ice, the Lagoon's water is refreshed by marine water inflow, as well as by fresh water inflow from rivers. At the same time, the sedimentation process, undisturbed by wind mixing, allows for chemicals present in the water column to be absorbed. All these processes may lead to "self-cleaning" of the Lagoon's waters. However, if the ice period is shorter and split up in time the self-cleaning process is not so efficient. This means great changes in the way the ecosystem functions (Chubarenko, 2008).

The thickness of the ice cover may vary from 30 cm during mild winters to as much as 60 cm during severe ones.

Turbidity

Water transparency is very low although the average Secchi depth is 0.4–0.6 m in the Polish and Russian parts, it very often falls to 0.3–0.4 m during the vegetation period. On cloudless days, the maximum value of photosynthetic active radiation (PAR) penetrating into the water is 2,500–2,600 $\mu\text{mol m}^{-2} \text{s}^{-1}$. Half of this is lost in the top 0.25 m, and about 1% of it reaches to a depth of 1.5 m (Chubarenko and Margoński 2008).

Annual average values of Secchi depth measured in 1994–2010 in the Polish part of the Lagoon usually oscillated between 0.40 to 0.60 m and the highest values were observed at the outer edge of the Szarpawa River mouth in October (RIEP 2011).



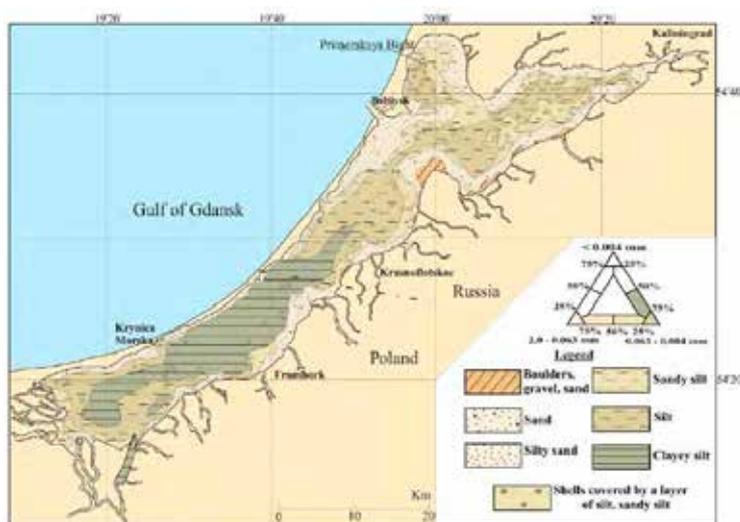
Secchi depth (minimum, maximum, and average values are presented). Source: RIEP 2011

Hydrodynamics

As described by Chubarenko and Margoński (2008), waves and currents develop immediately when the wind starts to blow. The average values of advective currents are $0.1\text{--}0.2\text{ m s}^{-1}$, with a maximum of about 0.5 m s^{-1} . The existence of near-bottom compensative currents against the wind direction, and the influence of the Coriolis Effect on intermediate and slow currents ($\leq 0.2\text{ m s}^{-1}$) make it necessary to consider the current pattern in the Vistula Lagoon as fully three dimensional (Chubarenko I. and Chubarenko B. 2002).

Wave height observed in the lagoon for winds of 10 m s^{-1} is 0.8 m , 0.95 m for winds of 15 m s^{-1} , and 1.1 m for winds of 20 m s^{-1} (Lazarenko and Majewski 1971).

Several mechanisms are responsible for vertical mixing. Surface cooling leads to night convection, which destroys vertical stratification on a nightly basis. For winds of $3\text{--}9\text{ m s}^{-1}$, Langmuir circulations develop and usually penetrate down to the bottom due to weak stratification. Wind wave mixing becomes significant when winds exceed $6\text{--}7\text{ m s}^{-1}$. Waves cause a resuspension of bottom sediment, which is redistributed over the Lagoon by currents. Vertical mixing under ice coverage is caused by salt release upon water freezing.



Joint scheme of distribution of the surface (0–5 cm) sediment types in the Vistula Lagoon during the whole of the 1990s developed according to Shepherd's classification. The Polish part of the Lagoon was compiled from Zachowicz & Uscinowicz, 1996. Source: LAGOONS 2012

Bottom sediments

The muddy sediments cover most of the deep part of the Lagoon bottom, with a depth of more than $2\text{--}2.5\text{ m}$, while sandy sediments are mostly found along the dynamically active shallow coastal zone (to a depth of $1.5\text{--}2\text{ m}$). The largest quantity of coarse sand is found in the vicinity ($1\text{--}1.5\text{ km}$) of the Lagoon inlet, where it actually forms a reversed bar (depth $1.5\text{--}2\text{ m}$) inside the Lagoon area (Chechko and Blazhchishin 2002, Chubarenko and Margoński 2008).

LAGOONS report (2012) summarised changes in the bottom sediment type spatial coverage: the comparison (Chechko, 2008) of a bottom sediment scheme developed first by Chechko and Blazhchishin (2002) with the one published 35 years ago (Wypych, Nieczaj, 1975) allows an estimation of the ratio of areas covered by different types of sediments in 1960s and 1990s.

The most valuable changes occurred in the redistribution of areas, covered by clayey silt, i.e. the finest sediments. As before, this type of sediment dominates in the south-western part of the Lagoon, however, its area had been considerably reduced from 29% to 20%. Areas covered by sandy silt, are generally reduced from 23% to 17%. Areas covered by sand have increased from 21% to 29%.

Comparison of the two schemes showed that the re-deposition of sediments, i.e. sorting and redistribution of material within the basin in accordance with its hydrodynamic state, is characteristic of contemporary sediment accumulation in the Vistula Lagoon (Chubarenko et al, 2005a). Coarse fractions are located in the energetically most active areas of the Lagoon proper – in shallows and in the coastal zone – while a fine material accumulates in deeper, calmer areas.

Basic changes in the spatial distribution of the bottom sediments in the Vistula Lagoon are caused by regulation of the Vistula River drain which started in late years of 19th century, that resulted in the change of evolution of the Vistula Lagoon as a single whole system and, in particular, in its natural regime of sedimentation.

Nutrient conditions and eutrophication

This paragraph is prepared based on the work of Chubarenko and Margoński (2008)) with emphasis on those factors which might influence the herring spawning grounds conditions.

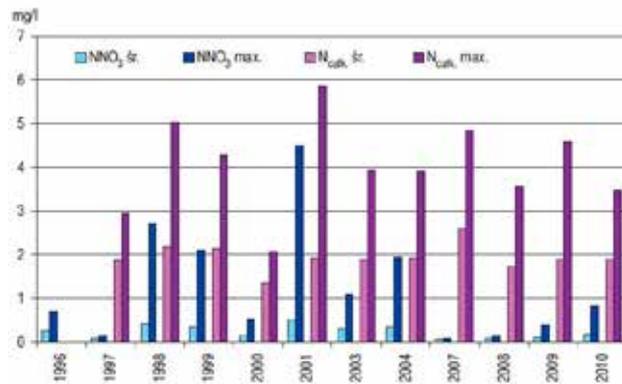
The horizontal distribution of water quality parameters in the Vistula Lagoon is strongly influenced by hydrological and meteorological factors, one of the most important of which is the exchange of water masses between the Gulf of Gdansk and the Lagoon. As a consequence, the area close to the Baltiysk Strait is “washed-out”, and the concentrations of nutrients in this area are lower in comparison to those in remote parts of the Lagoon.

Eutrophication processes are not only influenced by riverine loads but also by nutrient exchange between the water and sediments: significant sources of nitrogen and phosphorus are accumulated and released from silty bottom sediments (Kwiatkowski 1996). As a consequence of water mixing, the redistribution of labile inorganic nutrients from the upper layer of bottom sediments to the water column is almost continuous (Ezhova et al. 1999). Thus, a high internal potential for eutrophication occurs. Kwiatkowski (1996) estimated that as much as 138,600 tons of nitrogen and 55,800 tons of phosphorus have accumulated in the 10 cm sediment layer. Approximately 22% of the nitrogen and 35% of the phosphorus loads are exported to the Gulf of Gdansk.

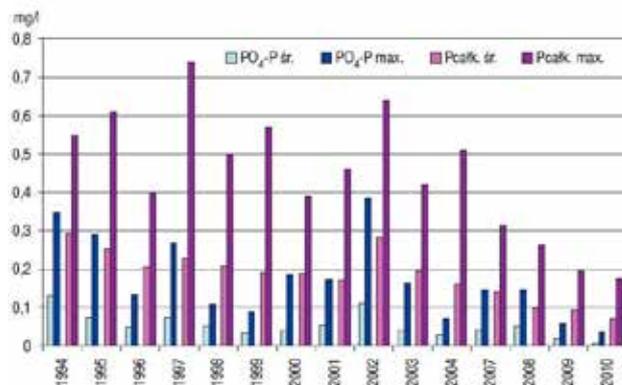
Light and nutrient availability are among the most important factors controlling primary production. Light limitation is caused mostly by the amount of suspended matter in the water column. Large amounts of suspended solids result from frequent resuspension of bottom sediments, which is typical of shallow water bodies exposed to winds, such as the Vistula Lagoon.

The Vistula Lagoon is mostly a light and nitrogen limited water body. Phytoplankton growth limitation estimated with modelling tools confirmed that phosphorus limitation occurs only during early spring. Throughout the rest of the vegetative season, nitrogen is the main limiting factor (Ezhova et al. 1999; Kwiatkowski et al. 1997).

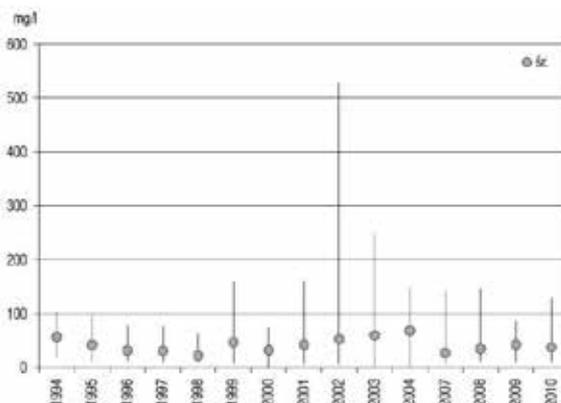
The analysis of recent monitoring data collected in the Polish part of the Lagoon (RIEP 2011) leads to the conclusion that total nitrogen concentrations remain at stable, high levels, whereas a systematic decrease in phosphorus concentrations might be observed. Chlorophyll *a* concentrations are high and the long-term average equals 42 mg l⁻¹.



Nitrogen ($N\text{-NO}_3$ and N_{tot}) concentrations during the 1993–2010 period. Source: RIEP 2011



Phosphorus ($P\text{-PO}_4$ and P_{tot}) concentrations during the 1994–2010 period. Source: RIEP 2011

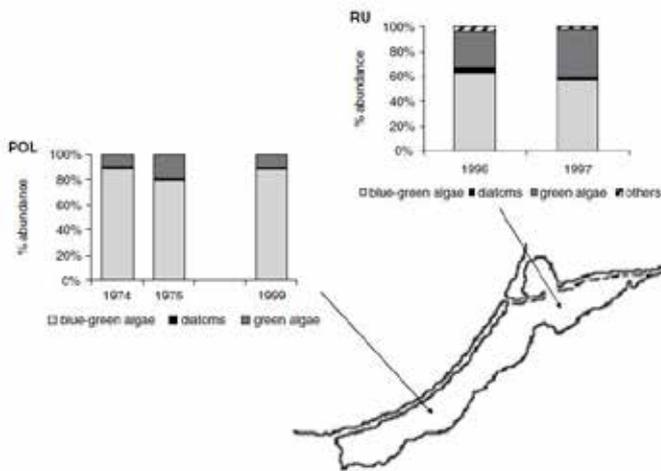


Chlorophyll *a* concentrations during the 1994–2010 period. Source: RIEP 2011

Phytoplankton

Taxonomic composition of phytoplankton and long-term changes in composition and abundance are relatively well described. Trends as well as similarities and differences between Polish and Russian parts of the Lagoon are presented here based on Chubarenko and Margoński (2008).

Three phytoplankton groups dominate in terms of abundance in the Polish part of the Vistula Lagoon i.e. Cyanobacteria, green algae, and diatoms.



Proportion of main phytoplankton groups in Vistula Lagoon: POL - Polish part, RUS - Russian part. Source: Chubarenko and Margoński, 2008

Cyanobacteria comprise over 80% of the total abundance. The highest biovolume of Cyanobacteria is usually observed in August, when the mass occurrence of filamentous species from *Anabaena* genus and *Aphanizomenon flos-aquae* was noted. Blooms of these species were observed from June to September in the central and north-eastern regions of the Polish part of Vistula Lagoon (Szarejko-Lukaszewicz 1957; Plinski and Simm, 1978, Chubarenko and Margoński 2008). Green algae comprised from 10% to 15% of the total phytoplankton abundance in the 1970s and 1990s (Plinski and Simm 1978, Chubarenko and Margoński 2008) whereas the share of diatoms in the phytoplankton abundance is lower than 2%.

As in the Polish part of the Lagoon, Cyanobacteria also dominate in the Russian part. The percentage of Cyanobacteria with respect to total phytoplankton abundance is very similar in both parts of the Lagoon. At present, Cya-

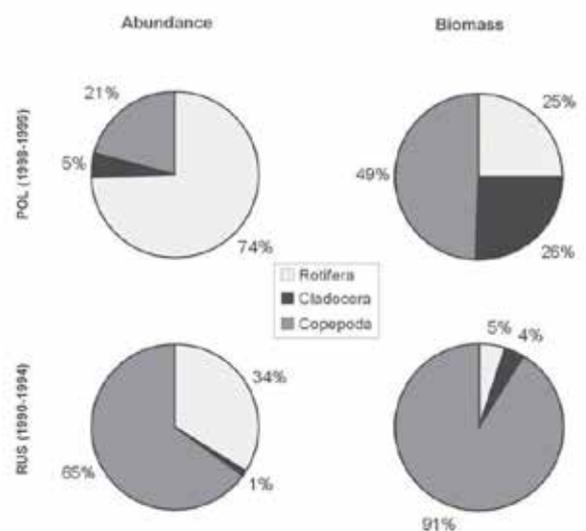
nobacteria blooms are observed annually in the Russian part of the Lagoon, while such blooms were noted only sporadically in the 1970s (Krylova and Naumenko 1992).

Significant differences in the phytoplankton composition between the Polish and Russian parts of the Lagoon could be observed in the share of dinoflagellates and cryptophytes during the late 1990s. In the Polish part, under conditions of lower salinity, cryptophytes were more abundant, while in the Russian part, with higher salinity, dinoflagellates were more frequent (Chubarenko and Margoński 2008).

Zooplankton

Research on zooplankton community structure, abundance, biomass, and seasonal as well as long-term changes has a long history in both parts of the Vistula Lagoon. This summary was prepared based on Chubarenko and Margoński (2008).

Significant changes in the zooplankton community occurred after 1915 when the Nogat River was cut off by flood-gates. This caused a dramatic decrease in the freshwater discharge into the Lagoon. Until this time, the Lagoon had been inhabited mainly by freshwater species (Wiktor and Wiktor 1959). As a consequence of the construction and the subsequent increase in water salinity, the zooplankton consisted of freshwater euryhaline and brackish water species (Rozanska 1967, 1972).



Proportion of main zooplankton groups in the Vistula Lagoon: POL - Polish part, RUS - Russian part. Source: Chubarenko and Margoński, 2008

Differences in zooplankton abundance biomass, and species composition between the Russian and Polish parts of the Lagoon are influenced primarily by different salinity regimes i.e. rotifers play a much more important role in the Polish part whereas the Russian part is dominated by copepods.

The composition of dominating species in the Polish and the Russian parts of the Lagoon is similar. The highest species diversity of zooplankton was observed close to the Pregola River estuary (84 species) and in the south-western area of the Polish part, while the lowest diversity was close to the Baltiysk Strait (Adamkiewicz-Chojnacka and Majerski 1980; Krylova 1985; Naumenko 1999; Tsybaleva et al. 2000). As regards abundance and species diversity, the dominating group of zooplankton was Rotifera (Adamkiewicz-Chojnacka and Radwan 1989) and as they were represented primarily by weakly euryhaline, freshwater species, their abundance and biomass decreased as salinity increased (Rozanska 1963; Adamkiewicz-Chojnacka and Lesniak 1985).

The seasonal dynamics of zooplankton abundance and biomass are similar in the two parts of the Lagoon (Adamkiewicz-Chojnacka and Rozanska 1990), and are characterised by two peaks that are usually coincident in the spring (April–May) and the summer (August). This is typical of eutrophic waters (Naumenko 2004).

The zooplankton of Vistula Lagoon is vulnerable to the salinity gradient. Moreover, as it is subject to the trophic pressure of juvenile Baltic herring, the naturalisation of the additional predator can negatively affect zooplankton structure as well as initiate significant changes in the trophic chain (Naumenko and Polunina 2000b).

Macrophytes

Macrophytes are playing an important role as habitat builders and therefore any changes (positive or negative) in their spatial extent and structure are extremely important for the whole Lagoon ecosystem.

The structure of communities and the spatial distribution of the higher aquatic plants in the Vistula Lagoon are similar to that of the Curonian Lagoon. The Vistula Lagoon is distin-

guishable from the Curonian Lagoon by the additional common reed and common club-rush communities that occupy a major part of the Lagoon coast along the Vistula Spit (BERNET 2000).

According to Plinski et al. (1978), the total area covered by plants was 2,197.4 ha, which constitutes 6.86% of the total area of the Polish part of the Lagoon. Approximately 40% of the plant cover there were aggregations of *Phragmites communis* and an association of *Scirpo-Phragmitetum* with *Phragmites communis*, which comprised 93% of the overall plant biomass in the Lagoon. The same authors compiled a list of recorded species with their abundance and distribution characteristics. Later studies (Plinski 1995) showed that significant changes have occurred, i.e. a decrease in the area covered by vegetation and especially a drastic decrease in the surface covered by narrow-leafed cattail and plants with submerged and floating leaves. Apparently, in some areas, submerged plants and plants growing further away from the coastline were disappearing, probably due to increased turbidity limiting photosynthesis and changes in the structure of bottom sediments. Those changes, however, did not affect homogenous reed aggregations, which remained nearly unchanged.



White water-lily (*Nymphaea alba*) in Elblag, Vistula Lagoon. The coontail (*Ceratophyllum* sp.) can be seen under the water surface. Source: Iwona Psuty



Yellow water-lily (Nubar lutea) in Elblag, Vistula Lagoon. Source: Iwona Psuty

Invasive species

Among the most important invasive species in the Vistula Lagoon are the round goby (*Neogobius melanostomus*) and the common rangia (*Rangia cuneata*).

The round goby is a non-indigenous species that was observed for the first time in the Lagoon in 1997 (Borowski 1999). Its numbers increased over the subsequent four to five years to a significant level, and this species has become a stable part of fyke net catches. In the case of the round goby, catch statistics indicate the timing of its increase; however, they do not reflect the actual abundance. Currently, some wholesalers buy it from fishers, while others do not. Observations of fyke net catches indicate that shortly after their invasion, the abundance of round goby increased rapidly, but that it had stabilised by 2002.



Round goby (*Neogobius melanostomus*) a new fish component (from 1997) in the Vistula Lagoon.
Source: Iwona Psuty

The appearance in 2010 of the common rangia, a new alien bivalve species in the Vistula Lagoon (Ezhova 2012, Rudinskaya and Gusev 2012), could have a fundamental impact on the ecosystem of this basin not only in terms of the characteristics of the filter-feeding organisms described above, but also because it is a potential source of food for benthivorous fish and it provides habitats for other organisms. Since environmental conditions such as low salinity, high turbidity, and substrates of mud, sand, and vegetation are the most favourable habitats for this species (Traver 1972), the Vistula Lagoon seems to offer an appropriate environment. In the Russian part of the Lagoon, *R. cuneata* has colonised and inhabited a large area adjacent to the Kaliningrad sea channel at a maximum abundance of 4,040 ind./m² (Rudinskaya and Gusev 2012). Possibly, the improved water

transparency that is notable in this region is a result of the filtration activity of the common rangia. Warzocha and Drgas (2013) discussed the current status and potential consequences of the *Rangia cuneata* invasion to the Polish part of the Vistula Lagoon. Although the common rangia has also been observed in the Polish part of the Lagoon, the large number of empty shells of both juvenile (2-4 mm) and older (2-3.5 cm) specimens could indicate the limiting effect of environmental conditions such as disadvantageous oxygen content that is likely linked to the impact of eutrophication. Another factor that could increase mortality is harsh winters. Additionally, the prospective reproductive success of this species in the Polish part of the Lagoon is lower since salinity is less variable than it is in the vicinity of the Strait of Baltiysk, where this parameter fluctuates significantly. According to Cain (1975), water temperatures above 15°C are probably the main factor influencing gametogenesis, while salinity is responsible for spawning and recruitment success; however, not just salinity itself induces spawning, changes in it are also a factor. The range of this fluctuation is approximately 5 ppt (Cain (1975)). It is too soon yet to say definitively whether the *R. cuneata* population in the Vistula is, in fact, a stable one. If, however, this species becomes a permanent element of the benthos, it could play a substantial role in counteracting the effects of eutrophication. Higher temperatures and shorter ice cover periods stemming from climate change could be advantageous for the population development of this species.

The invasive species common rangia (Rangia cuneata) with another introduces species attached i.e. the zebra mussel (Dreissena polymorpha). Common rangia appeared in Vistula Lagoon in 2010, probably transported with ballast water of ships.
Source:
Katarzyna Horbowa



Fish assemblages and seasonal movements

Some forty fish species have been recorded in the Vistula Lagoon, of which only eel, pikeperch, bream, and herring have been constant target species in Polish Lagoon fisheries. Other species, such as perch, roach, trout, ziege, and burbot are landed as commercially important bycatch, while the remaining species are often caught as bycatch but are discarded. (Borowski and Dąbrowski 1998, Psuty-Lipska 2005).

As stated by Chubarenko and Margoński (2008), fish assemblages in the Polish part of the Vistula Lagoon exhibit seasonal changes in both abundance and occurrence. From December to February during the spawning season of cold-water species, high concentrations of burbot and anadromous species heading for rivers, such as trout or river lamprey, are typical. Pike spawning concentrations occur from February to March, followed by those of herring from Baltic coastal regions, as well as perch and ruffe. Pikeperch usually follow these species, spawning in April, while ziege, smelt, and common bream spawn at the end of April and the beginning of May. Roach, silver bream, and rudd spawn in May. The spawning season ends in July with tench and Crucian carp. After spawning, adult individuals of species such as pikeperch, bream, and smelt leave the Polish waters of the Vistula Lagoon in search of the best feeding conditions, which are in the deeper Russian waters of the Lagoon or even in the coastal areas of the Baltic Sea (Filuk 1955, Filuk 1957).

Young of the year (YOY) individuals of most species are typical of the littoral habitat of the Vistula Lagoon. The pelagic area is used mainly by YOY herring and smelt, and by both juvenile and adult sabre fish. The species occupying the different niches in the Vistula Lagoon habitats depends on prevailing environmental factors, including temperature, which influences spawning time and larval growth rates (Fey 2001, Margoński et al. 2006, Grzyb 2007). The availability of zooplankton prey also plays an important role. All these factors combine to shape the prey-predator relationships in fish assemblages. A great number of Vistula Lagoon fish species have been identified as opportunistic feeders, which means they are not selective in their search for energy. Ziege can prey upon pelagic fish larvae even though it is known to be

zooplanktivorous (Terlecki 1987a). Perch and ruffe will consume any kind of food available on bottom surfaces as well in pelagic areas (Filuk and Żmudziński 1966). When herring are spawning, all other fish exploit them as a source of energy. Pikeperch, burbot, and large perch feed on adult herring, perch, roach, and ruffe, while smaller pikeperch and ruffe have been known to eat herring eggs. Extensive research has been conducted on the feeding patterns of some life stages of selected fish species and groups (Filuk and Żmudziński 1966, Żelepień and Wilkońska 1999), but no comprehensive model has yet been devised, with the exception of an attempt by Horbowy (1998).

Fish spawning area

Larval fish distribution analysis conducted recently within project IGUM (based on data from 2010-2012) resulted in the maps in **figure 1** which shows the main spawning areas of the most important fish species for Vistula Lagoon fisheries. No data of this kind are available for herring.

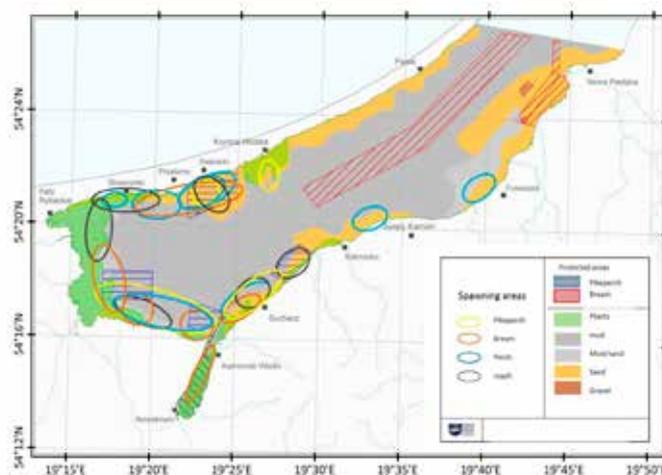


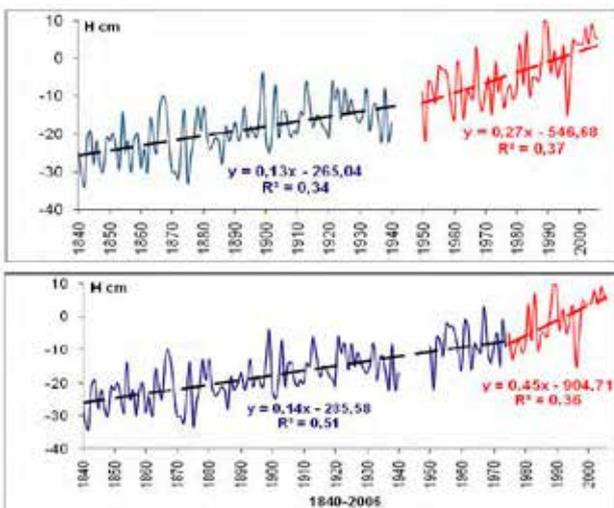
Figure 1 Main fish spawning grounds in the Vistula Lagoon. Source: Dariusz Fey

Future consequences of ecological changes

Temperature increase and sea level increase

Due to the expected climate change, it would appear that the sea surface temperature (SST) positive trend will continue in the future, a result of the increase in the maximum temperatures of water and air (LAGOONS 2012). As a result, sea level increase may be expected. Observations, summarised by LAGOONS (2012),

clearly show a constant increase of average annual levels in the Russian sector of the Vistula Lagoon, at a rate of 1.7 mm/year (Baltiysk, 1840-2006) and 1.9 mm/year (Kaliningrad, 1901-2006) (Navrotskaya and Chubarenko 2012a). A speed up of the increase in the water level was noticed in the second part of 20th century by up to 2.2–4.5 mm/year, especially after 1975. The highest rate of the level increase was observed after 1993, with more than 10 mm/year. These changes correspond to a long-term level increase of the Global Ocean, with a rate of 1.7-1.8 mm/year in the previous century, and a speed up to 3.1 mm/year at the end of that century and the beginning of the next one (Climate Change 2007; Malinin et al. 2010). An increase in the water level may potentially influence the quality and spatial extent of spawning grounds.



Mean annual sea level changes (and its trends) measured at Baltiysk: blue solid line – sea level changes in the period 1840–1940 (1.3 mm/year) and 1840–1974 (1.4 mm/year); red solid line – sea level changes in the period 1950–2006 (2.7 mm/year) and 1975–2006 (4.5 mm/year). Source: Chubarenko et al. 2012

Temperature increase and ice-cover period

Natalia Krasovskaya (2002) in her paper describing herring spawning in the Vistula Lagoon during the period 1950–2000, stated that the most important factor influencing the spawning timing was the time of the break-up of the ice and the clearing of the Lagoon, which was a consequence of the severity of the preceding winter. Furthermore, water warming processes and water salinity were also important. Even considering the high inter-annual variability of spawning timing within a wide range of environmental conditions, the distinct

shift towards an earlier time of spawning at lower temperatures was observed in spite of the positive trend of the mean water temperature in the spring. Furthermore, the earlier beginning of spawning resulted in a longer reproduction period. The same author noted a clear trend towards more frequent mild winters and the early occurrence of spring, especially during the last decade of her study. Such climate changes effectively advanced reproductive processes of herring through both physiological and environmental conditions as higher temperatures accelerated gonad growth and the achievement of a higher stage of maturity.

Considering these observations, any future changes in meteorological and hydrological conditions as a consequence of the expected climate scenarios will have a pronounced impact on the timing, duration and intensity of herring spawning in the Lagoon and further, on the level of recruitment success.

Projected future warming in the Baltic Sea Basin (BACC 2008) generally exceeds the global mean warming in Global Climate Model (GCM) simulations. Looking at the annual mean from a compilation of 20 GCM simulations, shows that regional warming over the Baltic Sea Basin would be 0.9°C higher than global mean warming, or some 50% higher in relative terms. Consistent with GCM studies, all available downscaling (regional) studies also indicate increases in temperature during all seasons for every sub-region of the Baltic Sea Basin. Combined results show a projected warming of the mean annual temperature by some 3°C to 5°C for the total basin.

Projected changes in precipitation from downscaling studies (presented by BACC 2008) show that seasonally, winters become wetter in most of the Baltic Sea Basin and summers become drier in southern areas for many scenarios. Hydrological studies show a decrease in mean annual river flow in the southernmost catchments. Seasonally, summer river flows would tend to decrease, while winter flows would tend to increase by as much as 50%.

Based on different KLIMAT models results, the predicted changes in ice-cover extension for the period 2011–2030 were rather inconsistent, depending on the type of model and selected

*Ice covering Vistula Lagoon.
Source: Anetta Ameryk*



emission scenario. In spite of those differences, the general conclusions are similar:

- Ice-cover conditions will be different for Baltic Sea sub-regions – milder winters will be observed in the western and southern parts of the Baltic Sea.
- The most pronounced changes are going to be recorded in the southern part of the Baltic Sea and several winters without ice-cover are expected in the Vistula Lagoon.
- The frequency of mild winters will increase but the appearance of really severe winters cannot be ignored.

The increased frequency of milder winters with shorter ice-cover period or even entirely without ice-cover will extend the herring reproductive period. In consequence, considering the fact that higher water temperature and no-ice conditions may significantly influence the functioning of the whole Lagoon, the longer herring spawning period will increase the probability of matching the best first feeding conditions for herring larvae. This, on average, should result in higher survival of the herring year-classes.

Swedish case study area – Hanö Bight

Environmental monitoring programme

A regional environmental monitoring programme called The Water Protection Association of Hanö Bight of Blekinge was established in 1990 in Blekinge County. The following year, 1991, a similar regional monitoring programme was established in Skåne County called Water Protection Association of Western Hanö Bight. These two water protection associations combined their monitoring programmes with the aim of monitoring the physical and biological environment of the whole Hanö Bight (Hanöbukstens kontrollprogram, 2010).

The voluntary members of these associations include industries, companies, associations as well as municipalities, county councils and county administrative boards. The aim is to monitor the environmental status of the Hanö Bight and assess the impact of the urban and industrial activities in the region. At several locations along the coast different measurements are performed, including physical and chemical measurements (i.e. temperature, salinity, nutrients among other), qualitative and quantitative studies of algal communities, epifauna (i.e.

abundance, and species composition of animals living on top of the seabed) and infauna (i.e. abundance and species composition of animals living in the seabed sediments). There are also measurements of metals and toxic pollutants in sediments as well as studies made on the physiology of viviparous blenny (*Zoarces viviparus*) in order to detect industrial emission (Palmkvist et al. 2013).

About 50 stations in the Hanö Bight are included in the monitoring programme of the Water Protection Associations of Hanö Bight County of Blekinge and Water Protection Association of Western Hanö Bight. The regularity with which the different stations are sampled varies in terms of annual and monthly measurements. There are also some variations regarding which stations and number of stations that are used in the monitoring programmes. The three most geographically extensive surveys include the monitoring of physical and chemical properties of the water (hydrography), benthic fauna, and the properties of the sediment.

In the outer part of the Hanö Bight there is a monitoring station called Hanöbukten that is part of the Swedish Meteorological and Hydrological Institute (SMHI) offshore programme, having made regular physical and chemical



Stations surveyed in the environmental monitoring programme in Hanö Bight. Source: Water Protection Associations of Hanö Bight County of Blekinge and Water Protection Association of Western Hanö Bight

Station	Depth (m)	Winter	Temperature range (°C)	Summer	Temperature range (°C)
Hanöbukten	0	January	2.43-6.39	August	13.21-20.85
VH1	1	January	1.29-6.51	July	11.33-19.93
K7	1	January	0.54-6.37	July	9.14-22.0

Table 1 Variation in surface temperature. Total temperature range from 1999 to 2010 for monitoring stations Hanöbukten, VH1 and K7. Source: SMHI, Marine environmental database

Station	Depth (m)	Winter	Salinity range (PSU)	Summer	Salinity range (PSU)
Hanöbukten	0	January	6.86-8.17	August	6.76-7.68
VH1	1	January	6.61-8.94	July	6.74-7.80
K7	1	January	3.90-7.81	July	5.97-7.44

Table 2 Variation in salinity in surface waters. Total salinity range from 1999 to 2010 at the monitoring stations Hanöbukten, VH1 and K7. Source: SMHI, Marine environmental database

Figure 7 The temperature in January from 1965 to 2011 at 0 m and 20 m depth, and temperature in July from 1971 to 2011 at 0 m and 20 m depth at station Hanöbukten. Source: SMHI, Marine environmental database

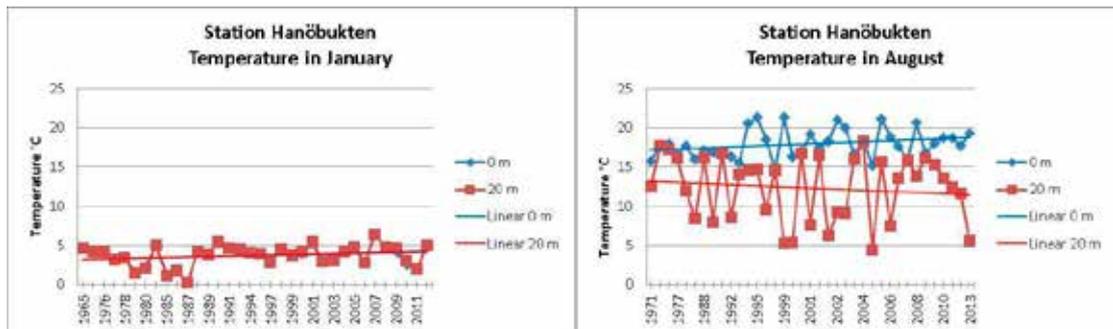


Figure 8 The temperature in January from 1999 to 2009 at 1 m and 10 m depth, and temperature in July from 1998 to 2010 at 1 m and 10 m depth at station VH1. Source: SMHI, Marine environmental database

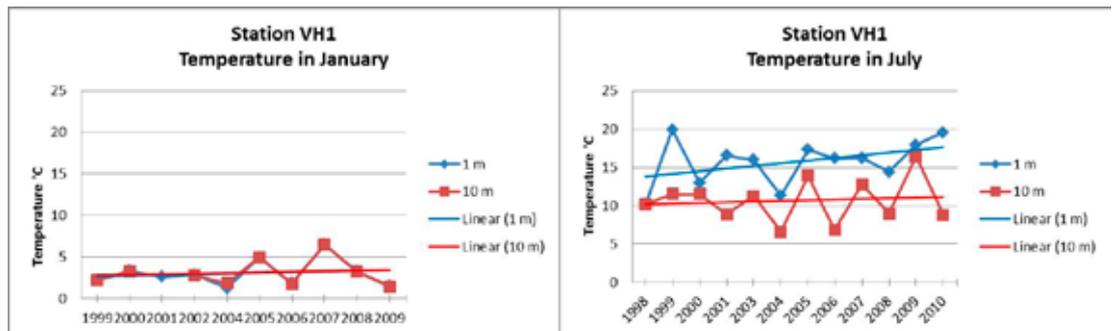
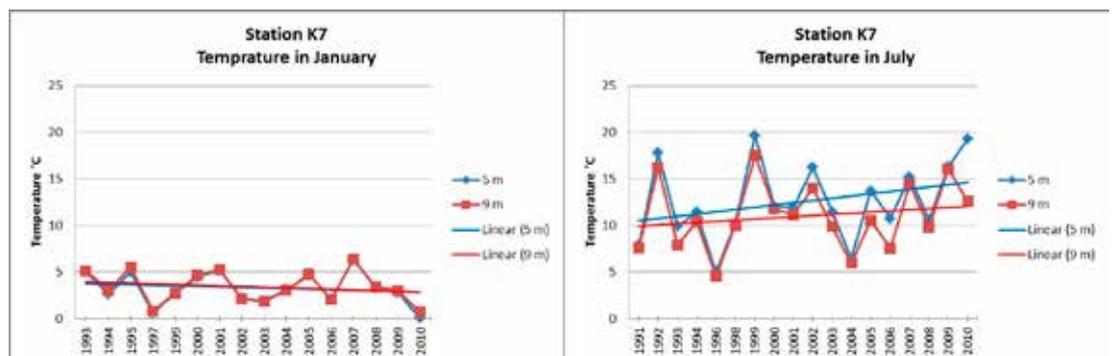


Figure 9 The temperature in January from 1993 to 2010 at 5 m and 9 m depth, and temperature in July from 1991 to 2010 at 5 m and 9 m depth at station K7. Source: SMHI, Marine environmental database



measurements since the 1960s. Among those that have been carrying out the marine surveys through the years are the University of Kalmar, SMHI and consulting firms specialising in aquatic and marine surveys. The results of the different physical and chemical measurements as well as biological measurements are reported to SMHI, one of the Swedish data hosts for the marine environment (SMHI, Marine environmental database).

Present ecological situation

Temperature and salinity

At the stations where hydrographic parameters are sampled, temperature and salinity are sampled once at different depths in specific months and years. Although sampling is not consistent regarding time and depth. The stations Hanöbukten VH1 and K7 are selected due to the possibility of being able to compare temperature and salinity depending on year, month and to an extent also depth. The selected stations differ regarding location and oceanographic influence. Station Hanöbukten is located in the outer part of Hanö Bight with a maximum depth of 80 m. Station VH1 is situated closer to the coast with a maximum depth of 14 m and K7 is located in a sheltered area close to the coast with a maximum depth of 9 m. **Table 1 and 2** illustrate the temperature and salinity range in the surface water between seasons, years and stations Hanöbukten, VH1 and K7.

The surface temperature at the stations in Hanö Bight follows a natural annual and seasonal variation. In general the annual temperature variations are similar throughout the whole Hanö Bight where the winter temperatures have a lower variation due to cooler water surface and the more homogenous water column. The summers display larger variations, possibly due to the more frequent temperature variations at the sampling occasions. The temperature of the surface water may rise quickly due to the effective heating of the sun in summer or sink due to occasional mixing of the water column.

The salinity in the surface water along the coast of the Hanö Bight also follows seasonal and annual variations. The salinity during the winter

displays higher variations and may be explained by the higher occurrence of precipitation and inflow of freshwater as well as higher frequencies of upwelling. Notable is the general lower salinity levels and higher salinity variations at station K7, that is situated by the coast in the vicinity of river outlets.

The variation of temperature at the four monitoring stations (Hanöbukten, VH1 and K7) are shown in the graphs, **figure 7 to 10**, for the months of January and July at two depths, 0 m and 20 m.

The temperature variation between years and depths is greater during the month of July and August at all stations. In summer the thermocline is formed dividing the colder deeper water from the warmer surface water that is heated up by the sun. In January there is no apparent increasing or decreasing temperature trend, but there is a slight upward trend in the temperature of the shallow water in July and August. Although there is only one measurement of temperature at each depth in each sampled month and no statistical significance has been calculated.

The variation of salinity at the four monitoring stations (Hanöbukten, VH1 and K7) are shown in the graphs, **figure 11-13**, below for the months of January and July at two depths.

The salinity has a greater variation between years in the month of January whereas in July and August the variation is less distinct. As previously mentioned it may be caused of the higher precipitation and supply of fresh water during winter. There is little salinity variations between depths at each station indicating that there is a weak halocline. The difference in depth is too small in the compared stations and it can be expected a detection of a stronger halocline in the deeper waters of the station Hanöbukten. There is only one measurement of salinity at each depth and each sampled month, and there is no apparent trend showing decreasing or increasing salinity at these three stations.

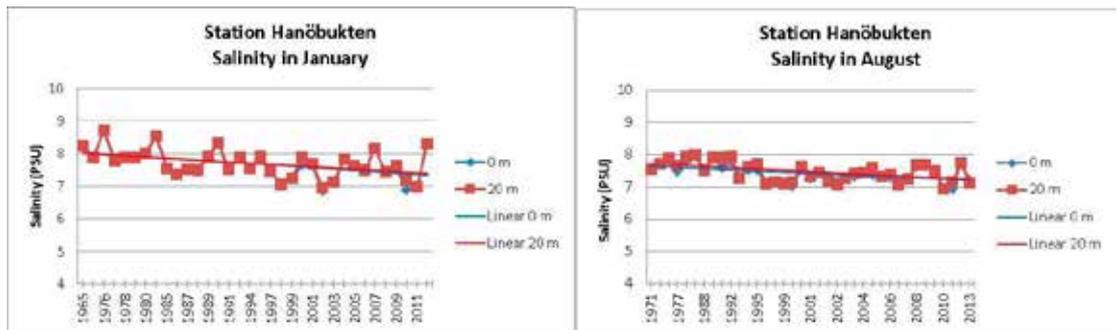


Figure 11 The salinity in January from 1965 to 2011 at 0 m and 20 m depth, and salinity in July from 1971 to 2011 at 0 m and 20 m depth at station Hanöbukten. Source: SMHI, Marine environmental database

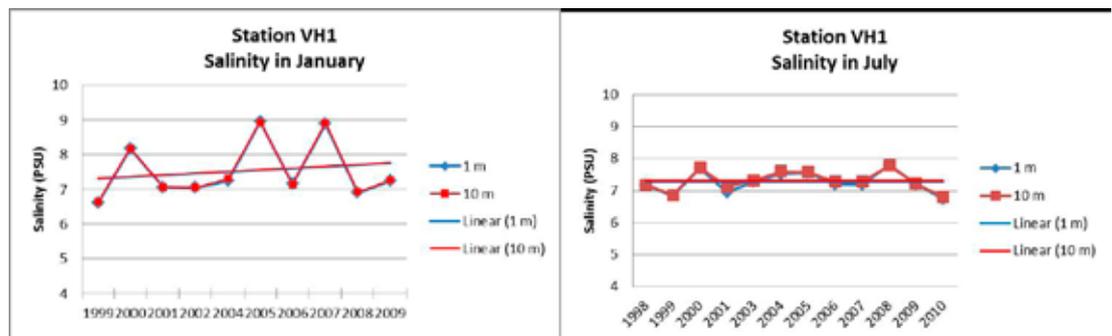


Figure 12 The salinity in January from 1999 to 2009 at 1 m and 10 m depth, and salinity in July from 1998 to 2010 at 1 m and 10 m depth at station VH1. Source: SMHI, Marine environmental database

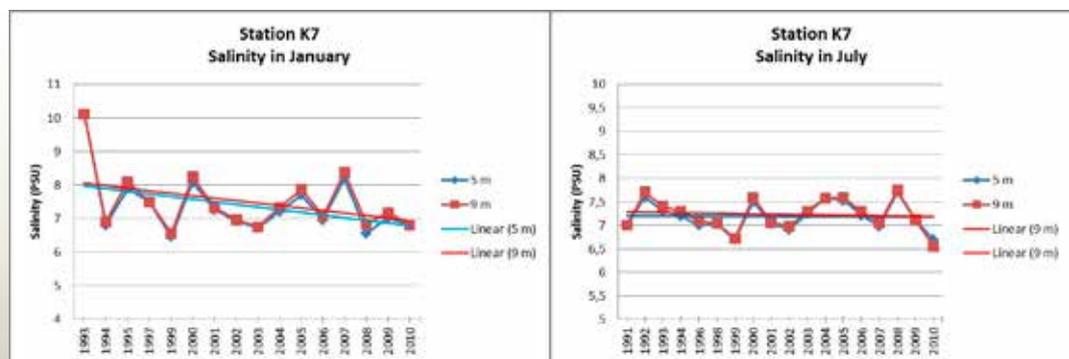


Figure 13 The salinity in January from 1993 to 2010 at 5 m and 9 m depth, and salinity in July from 1991 to 2010 at 5 m and 9 m depth at station K7. Source: SMHI, Marine environmental database

Seabed in a sheltered area in Blekinge archipelago with high levels of organic matter. Source: Lilitha Pongolini

Oxygen

Being an exposed area with high water movement the oxygen levels in Hanö Bight are in general high, with concentration over 5 ml/l. In some part of northern Hanö Bight where the sediments contain high levels of organic material there are however examples of lower oxygen levels. There is a particular area outside the city of Karlskrona where anoxia occasionally occurs (Palmkvist et al. 2013).

The lower oxygen levels often occur during warm periods in late summer with calm weather and high levels of organic matter. The water column in such a condition is not usually oxygenated from the surface and the high level of bacterial degradation of organic matter on the seabed consumes large amounts of oxygen.

Hydrodynamics

The Baltic Sea has in general weak permanent current systems. The Baltic surface current, influenced by various freshwater runoffs, runs in a counter clockwise direction created by the Coriolis Effect. This generally creates a surface current running in a southerly direction in Hanö Bight.

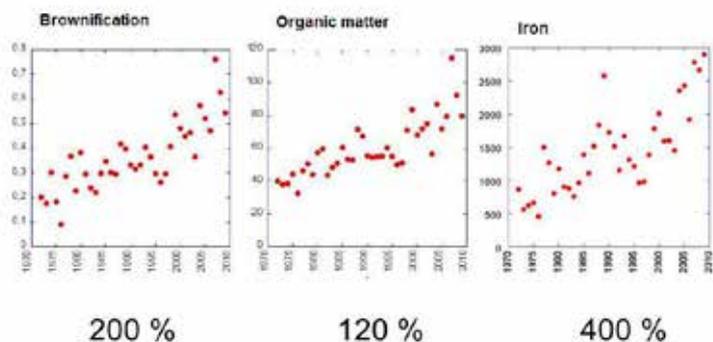
Otherwise currents may appear when strong prevailing winds are present.

The predominant wind direction in the south-east of Sweden is south-westerly or southerly according to wind surveys conducted by Swedish Meteorological and Hydrological Institute (SMHI, Faktblad nr 52-2011). When eastern and western winds are persistent, they cause upwelling along the coast of Hanö Bight. Upwelling brings colder deep waters to the coastal areas with higher salinity and nutrient concentrations (SMHI, Kunskapsbanken. 2014). However investigations during 2010 and 2011 show a shift to a more easterly wind direction on the southeast coast of Sweden (SwAM, Hanöbukten. 2013). Persistent easterly winds can push the water towards the coast of Hanö Bight resulting in an accumulation of water from the runoff areas. The water from rivers and streams has high concentrations of particles, nutrients and pollutants and may cause local deterioration of coastal water quality.

Turbidity

The visibility in Hanö Bight varies between 2.7 m and 14.0 m depending on the monitoring stations and years. In general the visibility is lower near the shore of the northern part of Hanö Bight and improves in the south, but visibility varies depending on seasons, weather and oceanographic phenomena (Palmkvist et al. 2013).

During the summer the visibility in general becomes worse closer to the seashore and runoff areas due to high content of organic matter and algae blooms. Monitoring in runoff areas shows an increasing amount of dissolved organic matter (DOM). The reason why this organic matter is increasingly leached from land areas, especially forest areas, is not completely known. Various explanations may be reduced acid deposition and different climate factors like water temperature and precipitation. This brownification is a general trend and measurements in Helgeå, a river that has its outflow in Hanö Bight, shows a 200 % increase over the last 40 years (SwAM, Hanöbukten. 2013).



Brownification, amount of organic matter and concentration of iron in the water of Helgeå, 1970–2010. Source: SwAM, Hanöbukten. 2013.

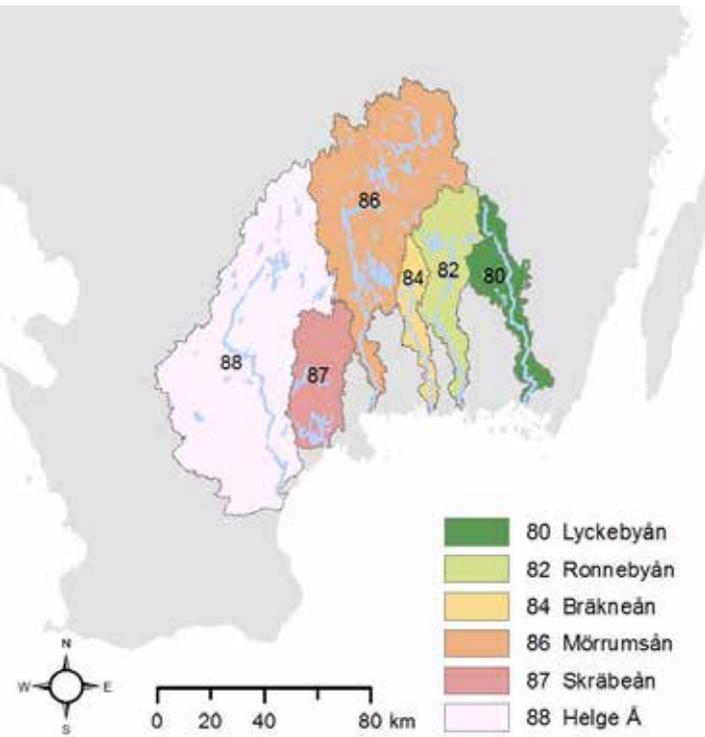
Nutrients

The Hanö Bight is supplied by a large number of rivers and streams. Two of the six largest rivers are Helgeå and Skräbeån that have their outlets on the coast of Skåne County. The coast of Blekinge County is the runoff area for the rivers Mörrumsån, Bräkneån, Ronnebyån and Lyckebyån.

About 93 % of the nitrogen and 75 % of the phosphorus present in the Hanö Bight is transported from the rivers. The largest supply of nutrients comes from the southernmost stream Helgeå, which can be explained by the high



*Agricultural area in the southern coast of Hanö Bight.
Source: Naomi Images*



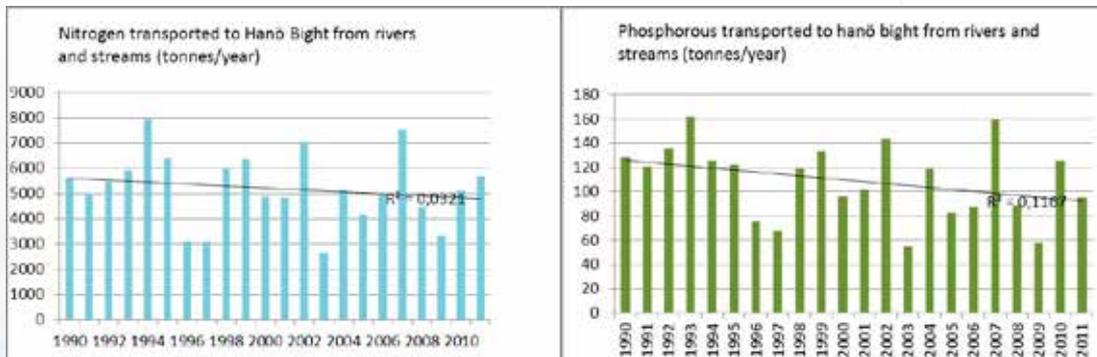
The six largest rivers having their outlets in Hanö Bight. Source: Water Protection Associations of Hanö Bight County of Blekinge and Water Protection Association of Western Hanö Bight

presence of agricultural land surrounding the river. In total the Hanö Bight receives on average 5200 tonnes of nitrogen and 115 tonnes of phosphorus during a year.

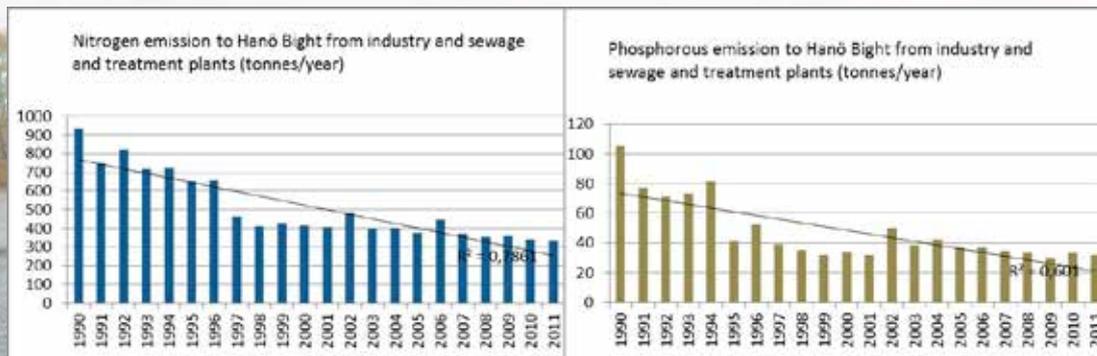
The long-term development of nutrient transport from streams and rivers shows a slight decrease of nitrogen and phosphorus emission into the Hanö Bight, although it is still at a fairly constant level. Preventive work with developing and improving treatment plants the emission of nutrient from industry and other anthropogenic activity has shown a significant decrease.

Phytoplankton

The Water Associations in Blekinge and Western Hanö Bight conduct measurements of chlorophyll *a* in the surface water. This measurement gives the possibility detecting the timing of algal blooms, however since chlorophyll *a* is only measured at the water surface there is no possibility of being able to make a confident estimation of the phytoplankton biomass in the water column.

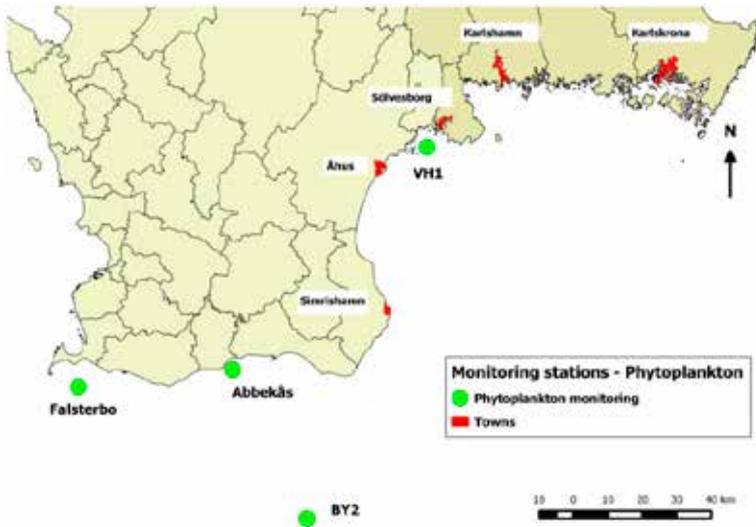


Total nitrogen and phosphorus (tonnes/year) transport from rivers and streams to Hanö Bight. Source: Water Protection Associations of Hanö Bight County of Blekinge and Water Protection Association of Western Hanö Bight



Total emission of nitrogen and phosphorus (tonnes/year) from industry and sewage and treatment plants. Source: Water Protection Associations of Hanö Bight County of Blekinge and Water Protection Association of Western Hanö Bight

Outlet of Skräbeån into the Hanö Bight. Source: Naomi Images



Station Falsterbo (1993–2013), Abbekås (2011–2013), BY2 (2006–2012) and VH1 (2013) for monitoring phytoplankton. Source: SMHI, Marine environmental database.

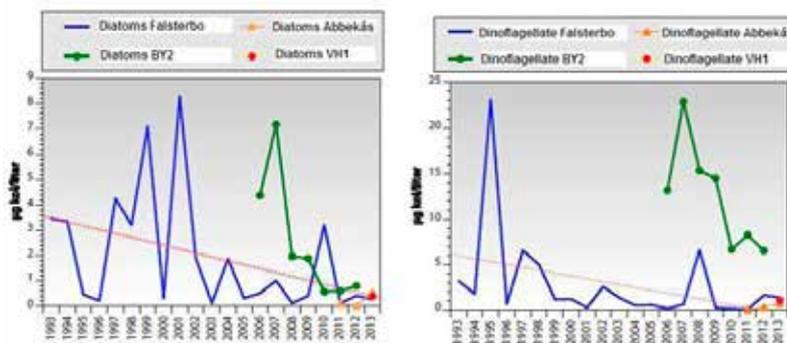
In Hanö Bight there is no sampling conducted of phytoplankton and there is a lack of knowledge about the planktonic species composition. The closest monitoring stations for phytoplankton are situated in the southern part of the island of Öland, i.e. station M1V1, and the south part of Skåne County i.e. station Falsterbo and Abbekås.

Normal annual patterns are low levels of plankton during winter. During spring, in March–April, the abundance of phytoplankton increases strongly in a spring bloom due to the higher

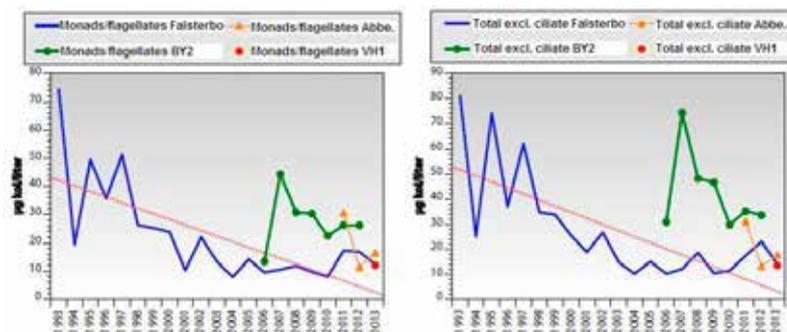
light intensity and nutritional levels. This spring blooming is dominated by diatoms. When the nutrient depletes a shift of the planktonic society occurs and in the early summer small monads/flagellates dominate. When the temperature rises during summer, large blooms of cyanobacteria occur. The cyanobacteria can have an exponential growth because of their ability to fix nitrogen gas in the water. During the autumn a smaller algal bloom can occur, dominated by diatoms and dinoflagellates. As the light reduces in the autumn and winter there is also a reduction of plankton biomass. Species dominating the phytoplankton society during winter are groups of monads/flagellates. From sampling series at the Falsterbo (1993–1913), Abbekås (2011–2013), BY2 (2006–2012) and VH1 (2013) stations a significant trend appears of a decrease in the phytoplankton biomass. This trend may indicate large scale changes in the planktonic ecosystem which can have an impact on ecosystems at many trophic levels.

Zooplankton

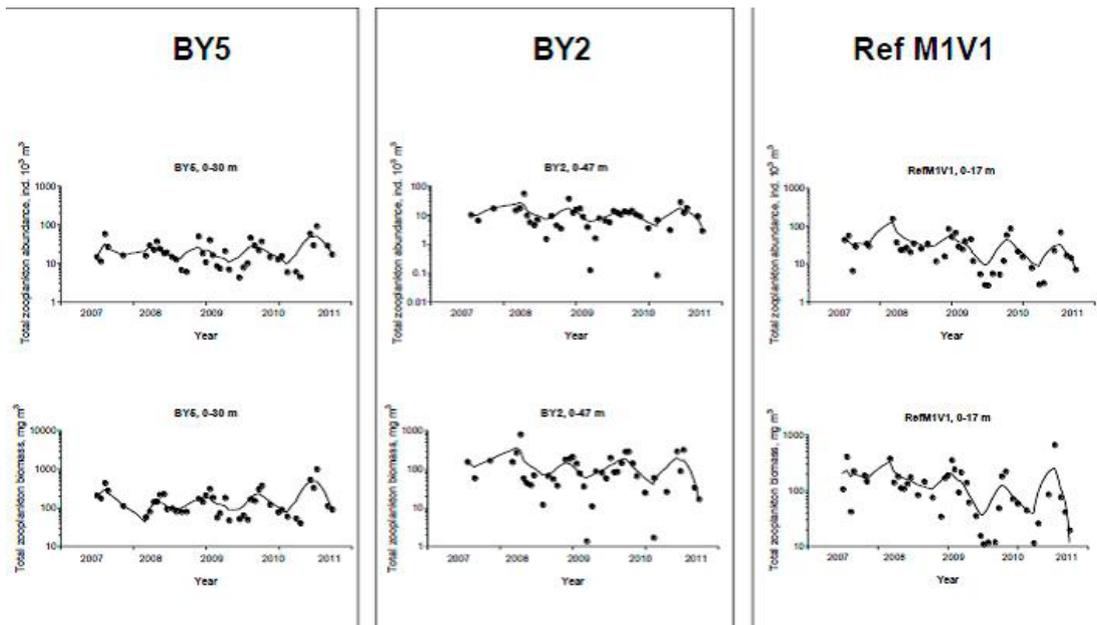
There is no long-term monitoring of zooplankton in the Hanö Bight area. The closest three stations included in the national monitoring programme for zooplankton are RefM1V1 situated in the southern part of the island of Öland, BY2 west of the island of Bornholm and BY5 situated east of the island Bornholm.



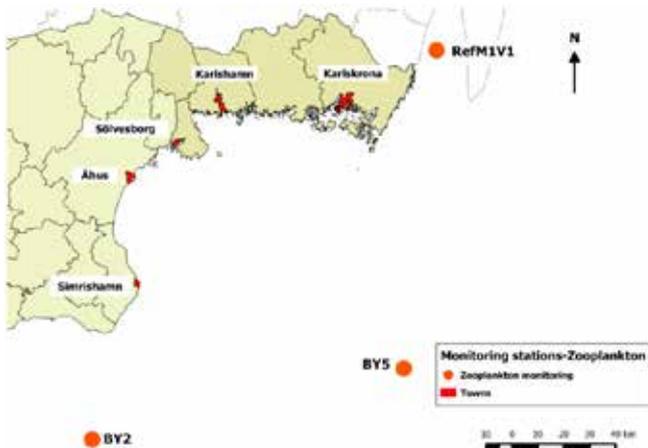
The development of diatoms and dinoflagellates in μg carbon/litre during the summer months (average June–August) at the Falsterbo (1993–2013), Abbekås (2011–2013), BY2 (2006–2013) and VH1 (2013) stations. Source: SzwAM, Hanöbukten. 2013; Toxicon AB. 2013)



The development of monads/flagellates and total exclud. ciliates in μg carbon/litre during the summer months (average June–August) at the stations Falsterbo, Abbekås, BY2 and VH1. Source: SzwAM, Hanöbukten. 2013; Toxicon AB 2013)



Abundance (number of individuals 10^3 per m^3) of zooplankton at the BY5, BY2 and RefM1V1, 2007 to 2011 national monitoring stations. Source: Elena Gorokova, SwAM, Hanöbukten. 2013.



Station RefM1V1, BY5 and BY2 for monitoring zooplankton. Source: SMHI, Marine environmental database.

The time series from these stations are relatively short with sampling from 2007 to 2011. Analysis of data from the offshore station RefM1V1 indicates that there is a decreasing trend of abundance and biomass of zooplankton. No significant trend of abundance and biomass can be detected from the stations BY2 and BY5.

Zooplankton is a fundamental food source for many fish species, particularly in the pelagic ecosystem. Field studies show that small herring and all size classes of sprat are strictly zooplanktivorous. It seems that their principal choice of zooplankton during the autumn is *Temora longicornis* and *Bosmina maritima* and during the winter *Pseudocalanus elongatus*. The study also indicates that both herring and sprat tend to avoid *Acartia* spp.

Selectivity of food may depend on various aspects such as size, nutrient content and abundance of the prey. It is important to follow zooplankton communities as they constitute a central part of the Hanö Bight food web. Their development is affected by abiotic factors such as temperature and salinity as well as by access to phytoplankton which is part of their diet. It is therefore essential to monitor the condition of zooplankton communities since their abundance and species composition may predict or explain the changes that occur at different trophic levels in the ecosystem.

Macrophytes

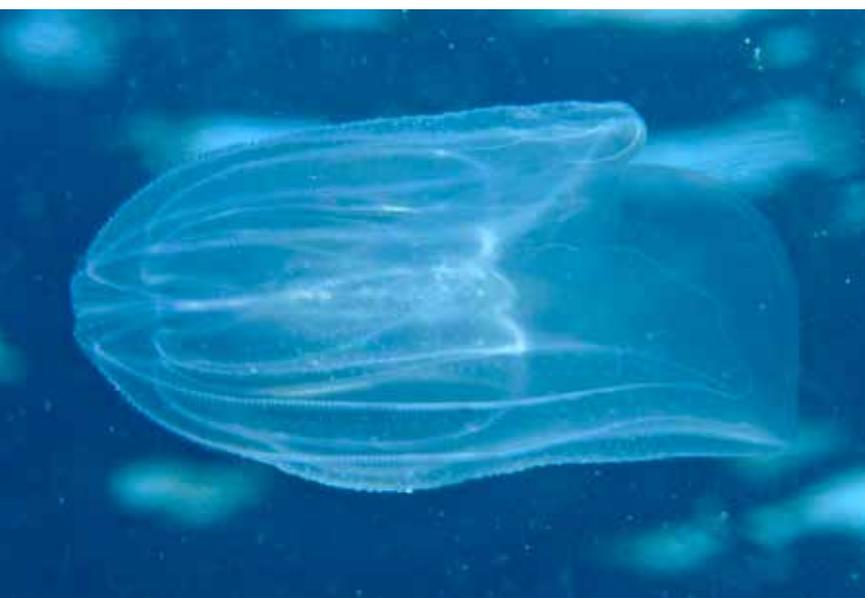
The macrophytic ecosystem is an important substrate for many animal groups. In the Hanö Bight monitoring of the macrophytic society had been carried out since 1990 and 1991 by the Water Protection Associations of Hanö Bight County of Blekinge and Water Protection Association of Western Hanö Bight. The brown algae *Fucus serratus* and *Fucus vesiculosus* are frequent species distributed in the shallow part of the Swedish coastline and used as an environmental indicator. *Fucus serratus* is more high-salinity dependent and has a more southern distribution in the Hanö Bight in comparison to *Fucus vesiculosus*. Along the coast of Skåne County in the Hanö Bight the abundance of *Fucus vesiculosus* in the top 3 m decreased significantly during the 1990s but is slowly recovering in some parts (Hanöbukten, undersökningar i kustvatten 1990-2007). The deeper parts are dominated of the red algae



The red macroalgae *Furcellaria lumbricalis* is a common species on the deeper coastal seabeds. Source: Lilitha Pongolini



Perfoliated pondweed (*Potamogeton perfoliatus*) growing in the shallow areas of Blekinge archipelago. Source: Lilitha Pongolini



American comb jelly (*Mnemiopsis leidyi*). Source: OCEANA/Carlos Minguell

Furcellaria lumbricalis, *Rhodomela confervoides* and *Polysiphonia fucoides*.

There was also a decrease of *Fucus vesiculosus* in the 1990s in the Blekinge archipelago. Most affected were the exposed areas but these are now slowly recovering in some parts (Hanöbukten, undersökningar i kustvatten 1990-2007). The red algae *Furcellaria lumbricalis* and the filamentous *Polysiphonia fucoides* among others are among the most dominant species in the deeper parts of the Blekinge archipelago. In some parts in the northern Skåne County, there are many areas of the seabed with soft substrate consisting of sand and occasionally clay with meadows dominated by eelgrass (*Zostera marina*). Meadows of various angiosperms are also common in the sheltered areas of the Blekinge archipelago where the soft bottom substrate consists of sand, clay and organic matter. According to visual observations during fieldstudies 3013 and 2014, the common angiosperms in these areas appears to be a mix of *Zostera marina*, *Zannichellia palustris* and *Potamogeton sp.* There are also different species of the family Characeae, for example *Chara baltica* and *Tolypella nidifica* (Pongolini. Unpublished).

Alien species

Introduced species have been spread into the Baltic Sea by various human activities. Transportation of aquatic organisms in the ballast water and on hulls of ships is often the most common cause of the introduction of alien species.

The polychaete *Marenzelleria spp.* was by mistake introduced into Swedish waters during the 1980s. The two species, *Marenzelleria viridis* and *Marenzelleria neglecta*, have spread to the southern and central Baltic Sea and are originally from the east coast of North America (Factsheet, *Marenzelleria spp.* 2008). *Marenzelleria spp.* has increased significantly in the Hanö Bight primarily from 2008 and onward. It was previously thought to be able to out-compete the native species *Hediste diversicolor*, that has decreased significantly, but it is not clear if this has happened in the Hanö Bight. *Marenzelleria spp.* is favoured by nutrient-rich conditions and burrows deeper passages (up to 30 cm) than the native polychaete. This means that *Marenzelleria spp.* may have established itself in a new niche not occupied by

any other species and may therefore not be seen as invasive (Factsheet, *Marenzelleria* spp. 2008; SwAM, Hanöbukten. 2013).

Another alien species is the American comb jelly *Mnemiopsis leidyi* that has its origins in the estuaries along the temperate and subtropical coast of North and South America.

It was first observed on the Swedish west coast in October 2006. In the same year there were observations of the American comb jelly along the whole coast of Skåne County, the Danish Great Belt and German Kiel-Bay (Factsheet, *Mnemiopsis leidyi*. 2006). It probably only spread to the southern part of the Baltic Sea since previous reports about the presence of *Mnemiopsis leidyi* in the entire Baltic Sea has been proven wrong. After genetic tests all individuals found from the Gulf of Bothnia and the Gulf of Finland consisted of *Mertensia ovum* which is a similar comb jelly species. In the southern Baltic Sea the examined individuals consisted of both *Mnemiopsis leidyi* and *Mertensia ovum* (Factsheet, *Mnemiopsis leidyi*. 2006). The American comb jelly lives as a plankton and can thrive in many different marine environments since it can tolerate large variation in temperature and salinity as well as low oxygen levels. It feeds on zooplankton, fish larvae and even fish eggs and has an advantage over other species in the same trophic level since it can grow very rapidly when there is good access to food. There were periodically very high levels of *Mnemiopsis leidyi* along the Swedish Coast and in the Baltic Sea of about 100 ind/m³ (Hansson. 2006). But in 2011 and 2012, after several years of high abundance the American comb jelly disappeared from the Norwegian and Swedish coastal waters as well as southern Baltic Sea. In February 2013 *Mnemiopsis leidyi* showed up again on the Swedish west coast, which is a bit unusual since in previous years the period in which the jellyfish appeared and was abundant was during August to January. The American comb jelly usually dominates the zooplanktonic society in those areas where it takes hold. The effect may be a depletion of herring populations and other fish stocks caused by both the predation on fish larvae and eggs and the lack of zooplankton that is the main food source for many pelagic fish species (Factsheet, *Mnemiopsis leidyi*. 2006). Another potential risk with a great abundance

of *Mnemiopsis leidyi* is an increase in phytoplankton as a consequence of the reduction of zooplankton. This would further enhance the problems connected with the large algae blooms and the increase of organic matter on the seabed and the resulting anoxia.

The round goby, *Neogobius melanostomus*, is an alien species coming from the area round the Black Sea, the Azov Sea, the Marmara Sea and the Caspian Sea.

The first find of the round goby in the Baltic Sea was in 1990s in the Gdansk Bay outside the seaport of Gdynia and has likely arrived as egg or fish larvae in ballast water. This species is today found in most parts of the southern and eastern Baltic proper, from southern Denmark up to The Gulf of Finland and the Finnish archipelago. The first finding of *Neogobius melanostomus* in Swedish waters was in Karlskrona archipelago in 2008. In 2012 a large number of round gobies were caught in Visby harbour in southern Skåne. Since the individuals caught were of variable sizes including mature spawners the species is now considered as established in the area (Factsheet, *Neogobius melanostomus*. 2005).

The round goby is a benthic species living in or near brackish and freshwater shoreline areas. It tolerates salinity levels of over 30 PSU as well as temperature variations between -1°C and +30 °C. It feeds on polychaetes, crustaceans, mussels and small fish and therefore competes with other benthic fish species like flounders,



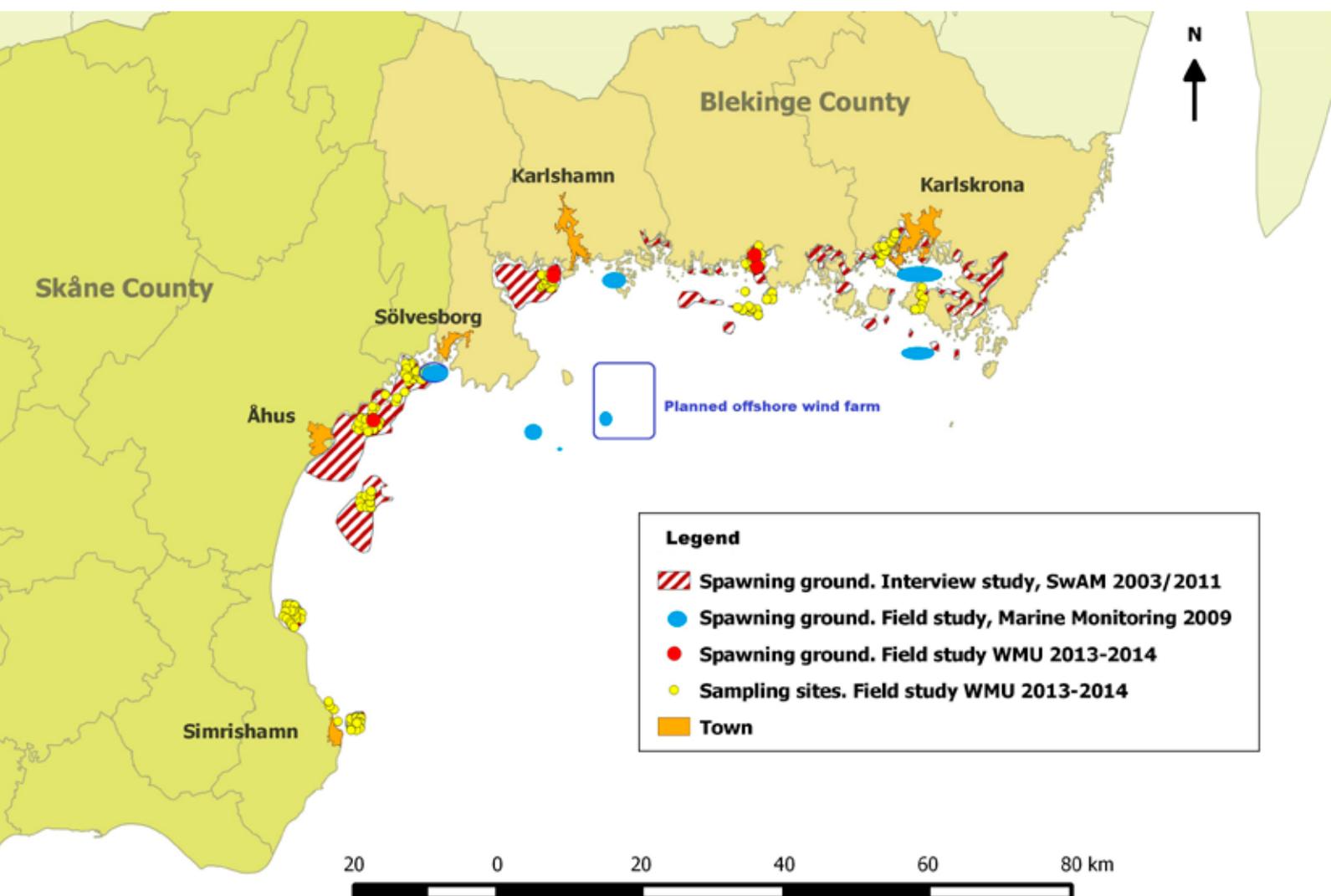
Round goby (*Neogobius melanostomus*) caught outside Karlskrona in Blekinge archipelago. Source: Jenny Herzman

viviparus blenny and native gobies (Factsheet, *Neogobius melanostomus*. 2005). There is a concern that being a relatively voracious species the round goby may also feed on herring eggs and larvae to such an extent that it will have a negative effect on the spawning success. With its aggressive and territorial behaviour the round goby has the ability to scare other fish species from the area where it is established.

Herring spawning areas

There is a general lack of information about herring spawning areas in the Hanö Bight and few studies have been conducted to investigate this topic. The former National Board of Fisheries in Sweden (since 2011 incorporated in Swedish Agency for Marine and Water Management and Swedish University of Agricultural Science) conducted an interview study to collect information about the spawning grounds of a number of commercially important fish species along the Swedish east coast (Gunnartz

et al. 2011). The study was carried out 2003 by interviewing people with extensive local experience of fish and fisheries. This study included identifying the spawning grounds of herring in the Hanö Bight and a summary report was released in 2011. In 2009 a study was conducted by a consulting company to assess the environmental impact on fish prior a planned offshore wind farm in Blekinge County. One of the surveys was to investigate if the area of the actual planning site for the wind farm, as well as other sites in the vicinity, were spawning grounds for herring (Wikström et.al. 2010). On two of the sites sampling was made at depth of 0 m to 15 m and on two sites sampling was made from 15 m to 40 m. One sampling site was in the actual area of the planned wind farm. Field samplings were conducted from February to June and from September to November to cover both spring-spawning and autumn-spawning herring. From the survey they could determine that herring spawn in all five of the sites in-



Results from studies examining location of herring spawning grounds in Hanö Bight. Studies executed by Swedish Agency for Marine and Water Management (SwAM) 2003/2011, Marine Monitoring 2009 and World Maritime University (WMU) 2013-2014

vestigated. The most extensive spawning activity was found in the shallower sites during the spring (Wikström et al. 2010). In association with the HERRING project, the World Maritime University (WMU) conducted field studies in 2013 and 2014 with the aim of verifying the spawning grounds designated in the interview study performed in 2003. The field study was conducted in May and June along the east coast of Skåne and Blekinge, resulting in confirmation of three locations used for spawning of herring of a total of eight locations that were surveyed (Pongolini. Unpublished).



Herring egg found in filamentous red algae during field study 2013. Source: Lilitha Pongolini

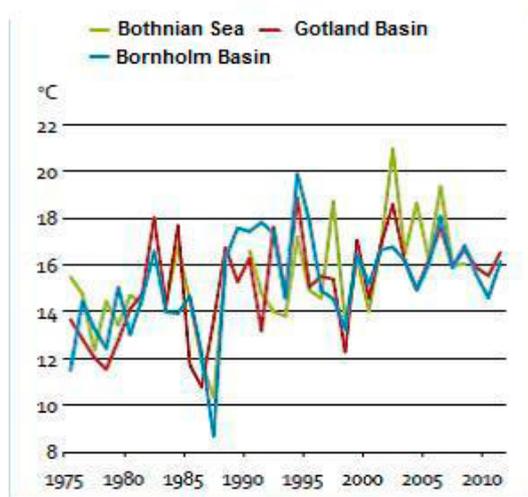
Further studies of herring spawning grounds in the Hanö Bight are essential to be able to incorporate knowledge about the response of herring to ecological variations.

Future consequences of ecological changes

Climate change, temperature and salinity

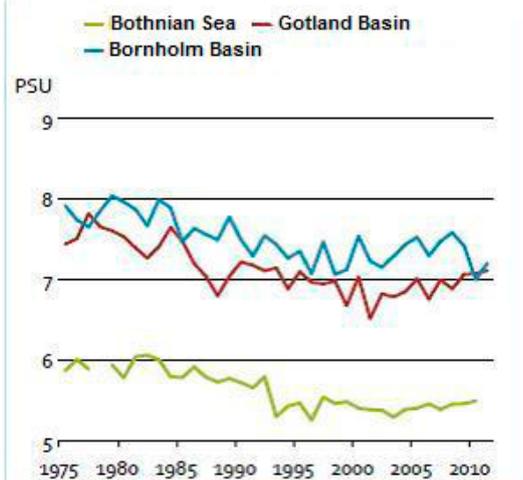
Although no clear trend has been detected of temperature and salinity changes in the Hanö Bight, a long-term series of hydrographic measurements in the Baltic Sea shows a trend of increasing temperatures and decreasing salinity (SwAM, Hanöbukten. 2013; Andersson et al. 2012). The average temperature during the summer indicates an increasing trend over the time period 1975 to 2010 in the surface waters of both the central Baltic and the northern Baltic. Just considering the last two decades the temperature has been at a relatively even level.

Average temperature during summer

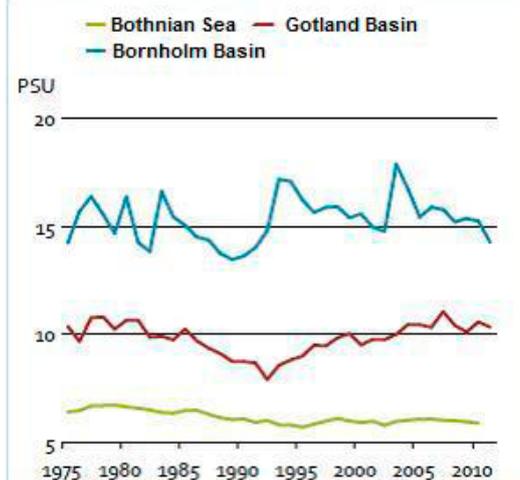


Average temperature during the summer over the period 1975 to 2010 in Bothnian Sea, Gotland Basin and Bornholm basin. Source: Andersson et al. 2012

Salinity in the surface water



Salinity in the bottom water



Salinity in the surface water and bottom water in Bothnian Sea, Gotland Basin and Bornholm Basin from 1975 to 2010. Source: Andersson et al. 2012.

In the central Baltic there is a trend toward a decreasing salinity of the surface water from 1975 to 2010, with the greatest decrease being during the 1980s. The deep waters of the central Baltic on the other hand show no trend of decreasing salinity. In the northern Baltic both surface and deep water shows a trend of decreasing salinity.

Overall developments show that the salinity in the Baltic Sea will decrease and the temperature will increase due to the increase in precipitation and air temperature.

According to the 2013 report from the Intergovernmental Panel on Climate Change (IPCC) the global average temperature will continue to increase by between 0.5°C and 5°C until 2100. At regional levels the temperature increase may be even more substantial and the expected increase in temperature in Sweden is assumed to be between 2°C and 9°C. The marine environment affects fish population in various ways. The ability for fish to have a successful spawning season i.e. a good survival rate of fish egg, larvae and juveniles is strongly affected by factors like temperature and salinity, directly or indirectly. Small pelagic fishes such as herring react quickly and strongly to climate change due to their tight links to environmental abiotic components, which affects key processes such as distribution, growth, spawning and feeding (Rose. 2005).

Hydrography and eutrophication

As with oceans all over the world, the Baltic Sea will be affected by increasing temperature, eutrophication and acidification from CO² emission. Because less oxygen dissolves in warmer water, the consequence of rising temperatures in the Baltic Sea may lead to generally lower oxygen content in the water.

Higher temperatures in combination with the general eutrophication problem will probably lead to larger and more prolonged algal blooms in the future. This is particularly evident in the summers when warm and calm weather is especially beneficial to cyanobacteria. As common species like *Nodularia spumigena* and *Aphanizomenon flos-aquae* can fix dissolved nitrogen gas in the water, they have an advantage over other phytoplankton species when the nitrogen is depleted and there is still phosphorous in the water (SMHI, Kunskapsbanken. 2010). When these large blooms take place and the cyanobacteria die and fall to the seabed there is a high consumption of oxygen in the process of breaking down these large amounts of organic matter.

In areas where there is poor mixing between oxygenated surface waters and the seabed, these blooms may cause anoxia on the seabed and marine organisms present migrate or die. As these anoxic conditions may occur in shallow areas it would have a negative effect on the spawning grounds and the survival of herring eggs, larvae and juveniles.

*Algal bloom in the northern part of
Blekinge archipelago.
Source: Robert Ekholm*



*Filamentous red algae growing on *Furcellaria lumbricalis*. Source: Lilitha Pongolini*

Eutrophication and climate change may also have an impact on the macrophytic composition and distribution. High levels of nutrients and an increase in plankton and particles in the coastal waters, due to intensified algal blooms and increased supply of particles from runoff areas, are factors that increase the turbidity in the coastal waters. This leads to less sunlight reaching down to the vegetation on the seabed and the inhibition of macrophytic growth. As macrophytic vegetation is essential for the demersal herring eggs this may inhibit the embryonic survival (SMHI, Kunskapsbanken. 2009).

Algae that usually benefit from this development are fast growing annual filamentous species. Filamentous algae can be epiphytes and cover large areas of underlying perennial vegetation. This can lead to inhibition of growth of the perennial vegetation, and as this large amount of filamentous algae dies and decomposes, depletion of oxygen may occur.

Phytoplankton and zooplankton

Water temperature and salinity also have an impact on phytoplankton and zooplankton. If the hydrography of the Baltic Sea is altered it may change the abundance and species composition of the planktonic societies which may lead to cascade effects at many trophic levels. Zooplankton is an important food source for herring larvae and juveniles and the feeding preferences of herring may affect their ability to access their food source if it is altered.

Alien species

As oceanic ship transport increases, so will the transportation of alien species around the world. Warmer temperatures in combination with different salinity gradients in the Baltic Sea may be suitable for a range of alien species that are introduced primarily by ballast water and ship hulls as well as aquacultures and waste water.

Species introduced may be invasive and lead to an alteration of ecosystems. If the alien species are successful in adapting to the new environment and successfully and efficiently propagate they may, through competition and predation, wipe out native species. A different development could also occur if the alien species occupy a niche in the ecosystem that does not involve any competition with native species and instead enriches the fauna in the Baltic Sea which is generally poor in species. Because the effects may be unpredictable both at an ecosystem level and at an economic level, it is important to monitor the introduced species and follow their distribution and their propagation. Another consequence of introductions of generally larger alien species may be an introduction of microorganisms and parasites that are in some way associated with them. These small organisms may have a great impact on native organisms at different trophic levels as they can induce diseases and weaken or wipe out native species (Granhag and Lettevall. 2014). Different stages of the herring population may be affected by these threats as the species moves in both open seas and coastal waters.



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*Fishing boat in Romneby harbor in Blekinge
Source: Robert Ekholm*



HUMAN ACTIVITIES AND SPATIAL USES

Coastal zones are widely used for a variety of human activities. These activities are expected to increase in time as both the sea and adjacent land areas provide not only opportunities for enterprise activities but also popular areas for human housing and recreation.

There are a multitude of anthropogenic uses in the case study areas, such as energy extraction and generation, fisheries, tourism and shipping. Getting a clear picture of their spatial location and overlapping with herring spawning and nursery grounds may help to determine and evaluate their impacts on herring population.

German case study area - Greifswald Bay

Overview of human uses and their spatial position

Commercial and recreational fishery

Of the 60 saltwater, freshwater, and migratory fish species that can be found in the Greifswald Bay, 15 are used for commercial fishing. Only passive catch methods are allowed. Based on the KÜFO, 250,000 gill nets, 9,000 eel baskets and 180,000 hooks on long lines are allowed. There are currently 198 sites authorised to use fyke nets throughout the year and 68 sites authorised to use fyke nets in the spring and autumn.

Fish species	2005	2006	2007	2008	2009	2010	2011	2012	average
herring	6415,5	6792,7	5030,2	7851,1	5590,6	4174,5	2591,8	3208,2	5206,8
garfish	59,2	26,5	70,5	46,6	66,8	37	43,3	47,3	49,7
bream	9,6	9,3	28,1	42,4	65,2	71,2	53,5	38,2	39,7
flounder	57,7	56,7	33,4	40,7	47,4	39,7	20,9	14,0	38,8
roach	18,6	21,3	17,8	17,6	24,2	43,0	57,2	46,9	30,9
perch	41,3	24,9	39,3	23,1	9,8	15,9	26,6	30,6	26,4
pike	17,1	16,2	15,1	16,5	7,7	10,6	21,3	20,7	15,7
pikeberch	17,7	10,2	11,3	10,4	9,0	10,0	8,0	15,4	11,5
cod	5,0	10,7	17,5	4,7	2,2	1,6	9,3	7,6	7,3
eel	7,5	6,8	8,9	8,4	4,8	6,3	7,8	4,9	6,9
whitefish	2,45	1,1	0,9	0,6	0,9	0,1	0,4	1,3	1,0

Table 1 Greifswald Bay catch data in tonnes per year (t/a) (2005–2012). Source: LaLLF M-V

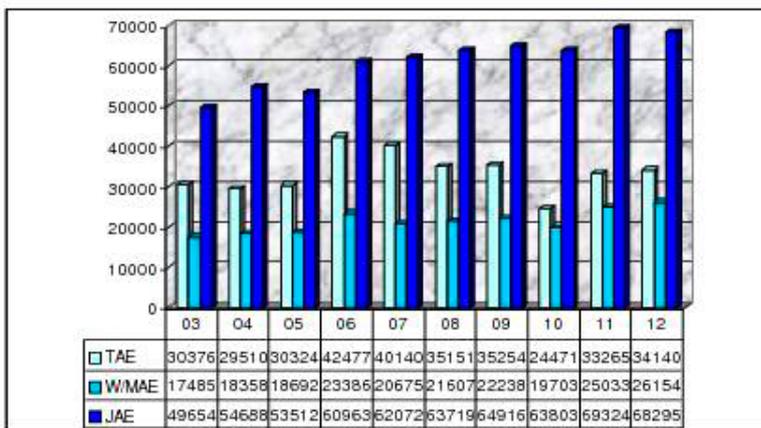
Table 1 shows the most important commercial fish species; 95 percent of the total landed fish is herring (with an average of 5206.8 tonnes per year). The herring catch normally takes place during the spawning migration between February and May. In other words, the highest catch takes places during a very short period of the year. The yearly quota, shown in **table 2**, has decreased within the last years, although in 2012 and 2013 alone the herring quota increased by 23% and 30% because the herring stock recovered.

Several fish species are protected periodically by specific mesh and catch sizes or fish protection areas. For catching herring a mesh size of 32 mm is allowed (KÜVFO). Special spawning protection areas have not been defined.

Fish species	(in tonnes)	2005	2006	2007	2008	2009	2010	2011	2012	2013
herring (in ICES subdivision 22-24)	TAC	46.000	47.500	49.5	44.550	27.176	22.692	15.884	20.906	25.800
	German quota	25.380	26.207	27.999	24.579	14.994	12.519	8.768	11.532	14.234

Table 2 Herring catching quotas (2005-2013), TAC= total allowed catch, German Quota Source: LaLLF, 2012

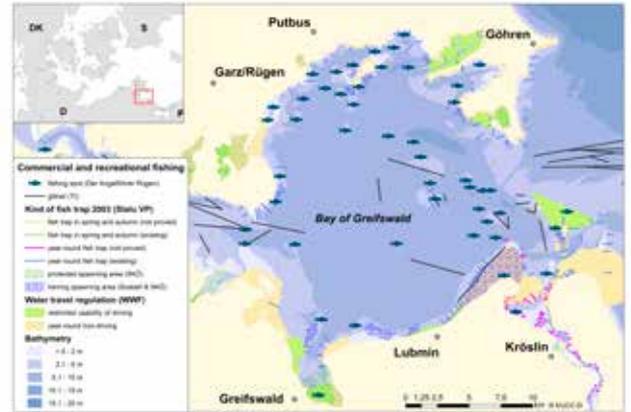
Recreational fishing is becoming increasingly interesting for tourists, especially due to the wide range of species in Greifswald Bay. Currently the angling season is from spring to autumn, but there is an attempt to extend the angling season to the off-season period. Recreational angling accounts for approximately 100 tonnes of fish per year, or approximately 1 % of commercial fishing.



Ausgegebene Angelerlaubnisse für Küstengewässer M-V der Jahre 2003-2012

Angling permits for coastal waters Mecklenburg-Vorpommern (2003-2012) (TAE=day-angling permit, W/MAE=Week/month angling permit, JAE=year fishing permit. Source: LALLF

In addition to the usual angling licences, a fishing permit for tourists has existed since 2005. This allows non-fishermen a time-limited access to fisheries in Mecklenburg-Vorpommern. To ensure a minimum level of fishing knowledge, the tourist is given a brochure which should be read before fishing.



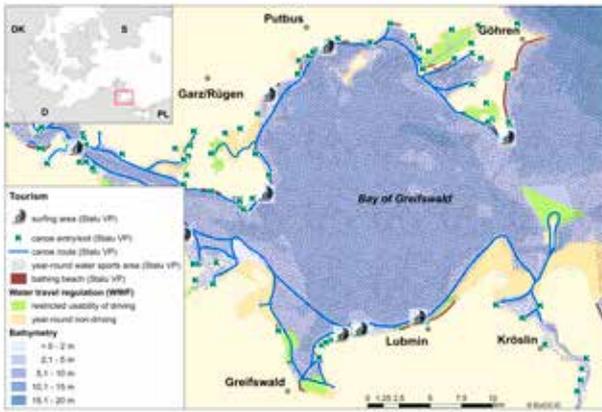
Commercial and recreational fishing in the Bay of Greifswald. Source: Anne Hiller, EUCC-D

Tourism

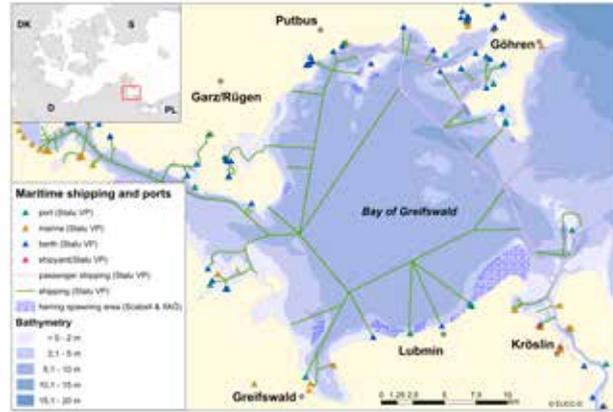
The area around the Bay of Greifswald is considered to be a development area for coastal tourism. The coastal landscape and large body of water are especially attractive for tourism. During the holidays, tourists want to learn or try different kinds of aquatic sports, such as sailing, surfing, or angling. While bathing sites in general have predominantly limited access to infrastructure and sanitary facilities, almost all official bathing sites have very good quality water.

The Bay of Greifswald is the largest body of inland water for sailing on the German Baltic Sea coast. Nearly 20 sailing schools can be found here. In addition to sailing, different canoe and kayak routes around the Bay exist. Fixed entry and exit points along the coast allow for tours of varying length. The area offers optimal conditions for surfers and kite surfers from May until September. Furthermore, there are tours with motorised boats and house boats. Powerboats and jet skis are rare in the Bay of Greifswald.

Besides recreational boating, passenger shipping exists. A favourite tour is the “seal tour”. Moreover, line connections between different cities and places are available. Favoured connections are to the islands of Vilm, Ruden and Oie (StALU-VP, 2011). River cruise shipping



Touristic uses in the Bay of Greifswald i.e. bathing sites, water sport area, canoe and kayak routes.
Source: Anne Hiller, EUCC-D



Marina berths in the Bay of Greifswald.
Source: Standortkonzept für Sportboote, 2004
Source: Anne Hiller, EUCC-D

has also increased in past years, from 31 ships per year in 2001 to 78 ships per year in 2006.

Marine transport – marinas, fishing harbours, industrial ports and waterways

The case study area is one of the most popular bodies of inland water on the Baltic Sea coast, with many marinas and berths for ships, and jetties. There are more than 4,500 berths available for visitors, permanent residents and associations (Standortkonzept für Sportboote, 2004). Marinas have different levels of comfort, from yacht clubs to small marinas. The location strategy for recreational boating (2004) shows a deficit of more than 350 berths in the Bay of Greifswald. However, the data basis is from 2004, so it can be assumed that more berths are available today.

The largest marinas in the Bay of Greifswald are Kröslin with nearly 500 berths, Lauterbach, Ruegen with 300 summer berths, and Greifswald-Wieck, where several yacht clubs have joined together to offer more than 425 moorings.

The Bay of Greifswald is also part of the main waterway to Stralsund – the federal water way Stralsund East. The shipping lanes of Stralsund East have a maximum depth of 7.5 m and lead to such industrial harbours as Greifswald-Ladebow, Vierow, Lubmin, and Wolgast. The freight traffic ranges from bulk

Marina in Lauterbach for recreational boating.
Source: C. Hivert





The shipyard Volkswerft Stralsund. Source: Nardine Stybel

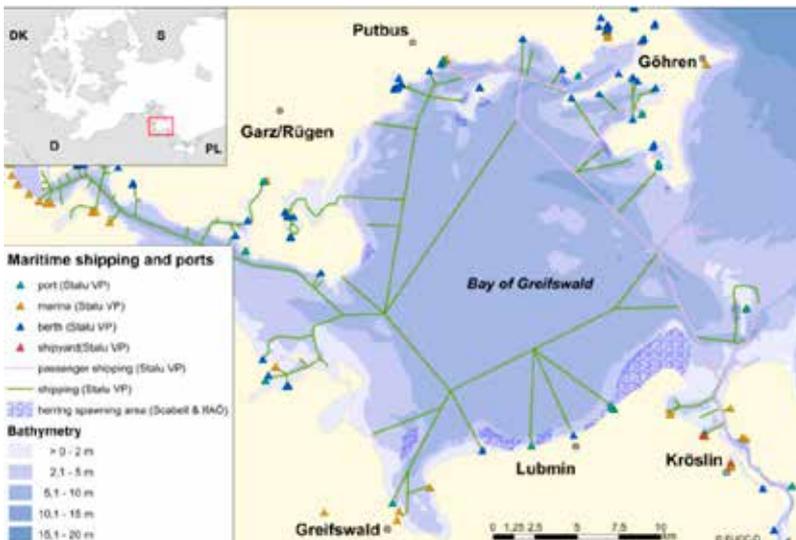
Harbour	Size	Freight Traffic	Infrastructure
Sea port Stralsund	Berth: 25 Draught: 6.60 m Territory: 85 ha	Bulk goods, agricultural goods, construction materials Goods turnover: 1.5 Mio t	<ul style="list-style-type: none"> • Freeway • Railway siding • Inland water network
Sea port Greifswald-Ladebow	Berth: 5 Draught: 6.10 m Territory: 31 ha	Hazardous materials and liquid goods, construction materials, wood, iron, agricultural goods Goods turnover: 300,000 t	<ul style="list-style-type: none"> • Freeway • Railway siding (under construction) • Inland water network
Harbour Vierow	Berth: 2 Draught: 6.50 m Territory: 25 ha	Special agricultural goods: grain, oilseeds, feedstock Goods turnover: 800,000 t	<ul style="list-style-type: none"> • Freeway • Railway siding • Inland water network
Industrial harbour Lubmin	Berth: 6 Draught: 6.10 m Territory: 3,5 ha	Built for large enterprises, project cargo, bulk and general cargo, feeding stuff, logs, construction materials Goods turnover: 250,000 t	<ul style="list-style-type: none"> • Freeway • Railway siding
Harbour Wolgast	Berth: 12 Draught: 6.50 m Territory: 3 ha	construction materials, fertilizers, grain exports Goods turnover: 500,000 t	<ul style="list-style-type: none"> • Freeway • Railway siding

Industrial harbours in the Bay of Greifswald. Source: Hafenstandorte in Vorpommern, 2012

goods, agricultural goods, and construction materials to fertiliser, project cargo, and hazardous material. All harbours have a motorway connection and a railway siding (under construction in Greifswald-Ladbow 2012). The harbours in Stralsund, Greifswald-Ladebow and Vierow also possess a connection to the inland water network. The yearly goods' turnover ranges from 250,000 tonnes at the industrial

harbour in Lubmin to 1.5 million tonnes at the seaport of Stralsund.

The waterways are not only important for the industrial harbours, but also for the P+S Werften wharf in Stralsund. This wharf is one of the latest and most efficient shipbuilding companies in Europe. They build container, cooling, and supply vessels, as well as loading dredg-



Shipping lanes in the Bay of Greifswald, industrial harbours, marinas, berth of ships and jetties.
 Source: Anne Hiller, EUCC-D

ers. Because of the building of large container vessels in the wharf, the requirements for the approach of the harbour in Stralsund have increased, and the shipping lane to the harbour of Stralsund was deepened and broadened.

Energy supply (pipelines) and dredging

Close to the harbour of Lubmin is the site of the former nuclear power plant Bruno Leuschner. Since 2011 the area has a new use as SynergiePark Lubminer Heide, where the North Stream gas pipeline lands. The construction of the pipeline was timed so as to minimise impacts on the environment. The mating season of seals and the spawning of fish were not disturbed by construction. The two gas pipelines

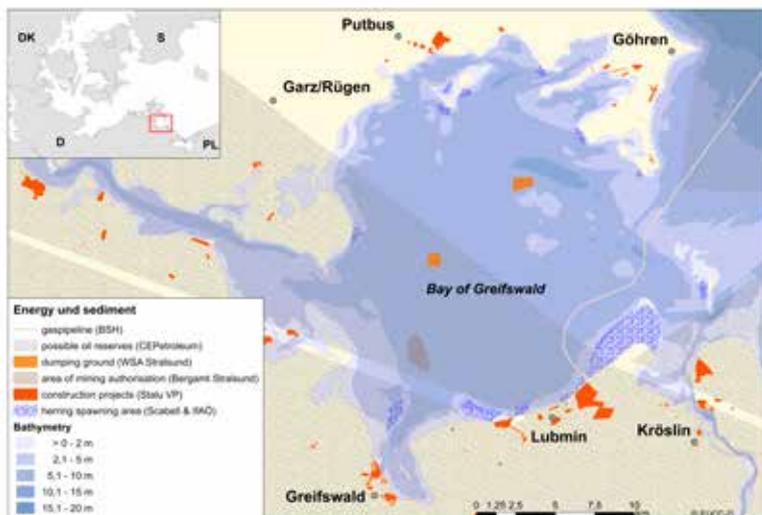
together carry up to 55 million cubic meters of gas from Russia to Germany annually. E.ON Ruhrgas and W&G built two gas transmission lines OPAL and NEL respectively, travelling from Greifswald in the west to the south of Germany, with a total length of more than 900 kilometres. This pipeline was also connected to the European long-distance network, and the gas is forwarded to Belgium, Denmark, France, Great Britain, the Netherlands and other countries (nord-stream).

Industrial area of Lubmin.
 Source: Gerald Schernewski



The intensive shipping in the Bay of Greifswald requires keeping the federal waterways sufficiently deep. Furthermore, the shipping lanes were straightened to minimise the risk of shipping accidents. The dredged sediment is dumped at specific sites and spoil fields. Dumping temporally influences the water in the Bay. According to the StaLU- VP FFH management plan, two dumping sites (506 and 519) and three spoil fields are situated in the Bay of Greifswald. The spoil fields are Wampen, Drigge and the mouth of the Peene, but only Drigge is used continuously. The Wampen spoil field is no longer used and has been left to natural succession (StALU, 2011). Besides the normal dredging for shipping, the seabed in the Bay of Greifswald can also be used for gravel mining.

Gravel extraction in the Bay of Greifswald is prohibited during the herring spawning season because the spawn and juveniles can be injured or killed as a result of extraction.



Landing of the Nordstream gas pipeline in Lubmin, spoil fields, dumping sites and gravel mining. Source: Anne Hiller, EUCC-D

Nature conservation

There are several different types of conservation projects in the Bay of Greifswald, from Natura2000 and biosphere reserves to nature conservation areas, protected landscapes and natural reserves. The EU-Water Framework and Marine Strategy Framework regulate the ecological management of the Bay and its tributaries.

An FFH management plan prepared by StA-LU-VP for the area Greifswald Bay, parts of Strelasund and the northern tip of Usedom DE

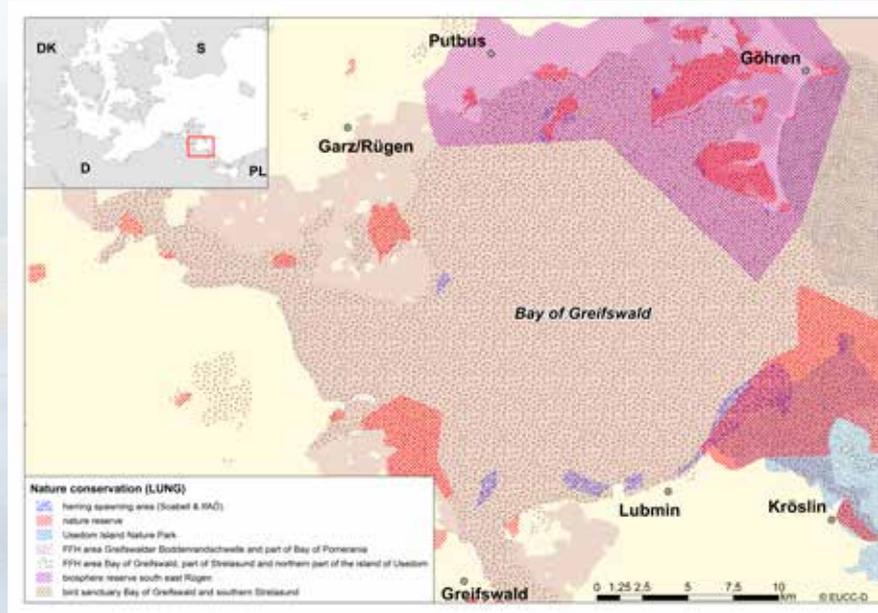
1747-301 has existed since 2011. The management plan determines measures for long-term protection of the conservation area.

Name of the nature reserve	size (in ha)	designation (year)
Schoritzer Wiek	437	1984
Island Koos, Lake Koos and reef Wampen	1566	1994
Peninsula Fahrenbrink	36	1994
Bird daymark Glewitz	89	1984
Cormorant colony by Niderhof	27	1967
Ladower Moor	131	1997
Eldena	420	1961
Kieshofer Moor	30	1938
Mannhagener Moor	45	1938
Peenemünder Haken, Struck and Ruden	7812	2008
Island Vilm	171	1990
Lanken	63	1961
Großer Wotig	212	1995
Greifswalder Oie	215	1995
Mönchgut	2317	1990
Quellsumpf Ziegensteine bei Groß Stresow	4	1990
Goor-Muglitz	142	1990
Wreechener See	72	1990
Lake Kniepower and lake Katharinen	31	1994

Protected landscape areas at the bay of Greifswald. Source: www.mv-regierung.de

The island of Ruegen was made a biosphere reserve South-East Ruegen in 1990. A biosphere reserve is a cultivated landscape with a high natural protection value. The protection goal of the reserve is to promote ecological, social, and economic development. The biosphere reserve serves as a development and testing area for sustainable economic uses in different economic sectors (LUNG, 2013). Nature parks have the goal to encourage nature-based tourism, eco-friendly land use, as well as sustainable regional development of the attractive and traditional cultivated landscape. The island of Usedom was also made a nature park. Figure 13 displays the various protected areas of Greifswald Bay.

A special kind of protection is the voluntary agreement on nature conservation, water sports, and angling in the Greifswald Bay and Strelasund. It is the work of WWF Germany, the State Angling Association, the State Canoe Federation, the State Rowing Federation, the State Sailing Federation, the Ministry of Agriculture, the Ministry of the Environment and Consumerism and the Protection Ministry of Mecklenburg-West Pomerania. The aim of this voluntary agreement is to allow the long-term protection of the area at the same time as it is used as a water sport and angling area. The general framework agreement contains numerous regional agreements. These are freely accessible to the public in the form of map materials and written agreements, i.e. navigability of Bodden and Strelasund. Monitoring surveys aim to show that voluntary agreement is as effective as legal regulations.



Nature conservation in the Bay of Greifswald. Source: Anne Hiller, EUCC-D



*Nest of swan on the protected area of Vilm.
Source: Stefanie Maack*

Adjacent land use (agriculture, industry)

The area around the Bay of Greifswald is used extensively for agriculture. Even areas in the surrounding conservation sites are used for agriculture. 65% (6800 ha of 10.412 ha) of the FFH site and adjacent areas are productive land for agriculture. Arable lands and grasslands dominate, with only 15% (1,575 ha) forests in the area. Along the Bay's steep coast, agriculture is practiced right up to the very edge of the cliffs, without the buffer zones which exist along shallower coastlines such as natural floodplains. 3,230 ha of the total agricultural area are intensively cultivated up to the shoreline. 53% of the agricultural area is grassland (approx. 3,560 ha) which is used as pasture. Major parts of this cultivation correlates with the EU directive for the promotion of conservation-oriented management of grassland areas. 1025 ha, or nearly 29 % of the grassland area, are cultivated as the highly ecologically important salt grassland, a traditional form of agriculture on the coast.

Many heavy metals in trace amounts are essential elements for the construction and function of biological structures (e.g. copper or zinc), while other metals (e.g. cadmium and mercury) are highly toxic (Hammer et al., 2009).

In coastal regions the concentration of certain heavy metals and organic contaminants are much higher than in open waters because these pollutants are discharged into coastal waters. These pollutants accumulate in coastal sediments and have a high persistence. After agriculture and direct discharge of sewage, there are a large variety of sources polluting ecosystems, such as shipping, shipbuilding, recreational crafts, industry and power stations. In GWB, the concentrations of heavy metals in the water and surface sediments were analysed in 2004 at one station, revealing distinct traces of lead, cadmium and zinc, and slight traces of copper and nickel in sediments. The GWB water pollution seems insignificant. However, the results of measurements are underrepresented (LUNG, 2008). The thresholds for the environmental quality standards by the European Union are cadmium (0.2 µg/l annual $\bar{\sigma}$), mercury (0.05 µg/l annual $\bar{\sigma}$), nickel (20 µg/l annual $\bar{\sigma}$) and lead (7.2 µg/l annual $\bar{\sigma}$) (Rat der EU, 2007).

Herring embryos are sensitive to all kinds of low-level environmental changes. Coastal areas with intensive farming or major urban centres have higher levels of embryo deformity than offshore sites (Klumpp and Von Westernhagen, 1995; Dethlefsen et al., 1996). Early development stages of embryos revealed malformations of 32 % in the inner part of the German Bight and 9 % in offshore areas (Cameron and Berg, 1992). Investigations on the effect of cadmium, copper and mercury on fish embryos showed that cadmium concentrations of 80 µg/l and mercury concentrations of 10 µg/l lead to embryo damages (Von Westernhagen, 1988). As a result the negative effect of copper on the survival rate of herring spawn is between 200–800 times greater than the effect of cadmium (Von Westernhagen et al., 1979). Another study showed high mortality rates for copper concentrations of 30 µg/l (Blaxter, 1977). Other possible effects were behavioural changes, activity limitations, embryo deformities, and egg and larval mortality (Von Westernhagen, 1988).



Areas used for agriculture in the Bay of Greifswald (arable land and grassland), as well as phosphorus and nitrogen discharge. Source: Anne Hiller, EUCC-D

Potential ecosystem effects

Pollution and its impacts on herring egg development

Pollutants are produced and emitted by human use of resources, infrastructural and industrial development, agricultural fertilizer and pesticide use, and tourism (Islam and Tanaka, 2004). The major contaminants are persistent organic pollutants, nutrients, oils, radionuclides, and heavy metals (Williams, 1996).

Oil pollution from oil spills can also have detrimental effects (Islam and Tanaka, 2004). One example is the oil spill in San Francisco Bay, where embryos of Pacific herring showed sublethal cardiac toxicity from exposure to oil-derived polycyclic aromatic compounds (PACs). It is reported that high rates of mortality and morphological abnormalities occurred in natural spawn from all oil-polluted sites (Incardona et al., 2011).

Furthermore pollution from sulphur compounds from fossil fuel use is harmful to the early developmental stages of herring. The exposure of herring eggs to different concentrations of sulphuric pollutants leads to reduction of egg survival and increased abnormalities of freshly hatched larvae. Moreover the embryonic growth rate was retarded while heart rate tended to increase (Kinne and Rosenthal, 1967).

Pollutants also indirectly damage herring eggs by affecting the gonads of the adult herring. The reproductive process in fish is negatively influenced by organochlorides and certain heavy metals. These contaminants can reduce fecundity of the spawning population and lead to a decreased survival potential of larvae, thereby impacting following generations (Rosenthal and Alderdice, 1976).

Studies of Australian fish revealed pesticide and herbicide residues in their gonads and livers, with the highest levels found around urban and agricultural areas (Klumpp and Von Westernhagen, 1995).

A study on heavy metal concentrations in Baltic Sea fish found significant concentrations in herring liver, kidneys and muscles, whereas males showed higher cadmium and zinc concentrations in the liver and kidneys than females (Senocak, 1995). The concentrations in the gonads of females were higher than in male gonads, and it is assumed that females displaced metals to the eggs (Senocak, 1995). Another study revealed a reduced egg production of 80% if the parent fish were chronically exposed to low levels of metals or pesticides (Von Westernhagen, 1988).

The effect of chlorinated hydrocarbons on hatching success of herring was analysed and a viable hatch was significantly affected by high PCB and DDE contamination levels. Ovarian concentration thresholds for 50% of the spawn to hatch viably are 120 ng/g for PCB and 18 ng/g for DDE (Hansen et al., 1985).

Agricultural and industrial land use directly at the coastline of the Greifswald Bay



Coastal modification and its impacts on herring egg development

Coastal modification is the mobilisation of coastal sediments, causing increased turbidity and sedimentation in addition to the resuspension of nutrients and pollutants formerly accumulated in sediments. Coastal modification can radically change and impair communities both in the shallow littoral zone and in deeper regions. In this context, brine discharge can be seen as one form of coastal modification, and may change the species composition.



Forms of coastal modification. Source: Dorothee Moll; symbols courtesy of ian.umces.edu/symbols/

Coastal modification not only leads to increased levels of nutrients and pollutants but also to increased turbidity and sedimentation. The effects of suspended sediments on the development and hatching of herring eggs were analysed by a few studies, but conclusions are controversial (Kjørboe et al., 1981; Auld and Schubel, 1978; O'Connor et al., 1976; Oulasvirta and Lehtonen, 1988; Griffin et al., 2009).

One study reported that there is no correlation between silt concentration in the water column and herring egg mortality, and there is no impact on embryonic development at maximum silt concentrations of 300 mg/l – 500 mg/l, similar to levels near dredging areas (Kjørboe et al., 1981). Another study found sublethal

and lethal effects at ecologically relevant concentrations of 250 or 500 mg/l during the first two hours after exposure of Pacific herring eggs (Griffin et al., 2009).

O'Connor et al. (1976) found that there was a relationship between suspended solid concentrations and their effect on egg mortality of different fish species with increasing exposure time.

Another study described the tolerance of herring eggs to dissolved particles and found no effects at concentrations up to 500 mg/l, but a decreased hatching success of two fish species at concentrations of 1000 mg/l (Auld and Schubel, 1978). Other scientists examined the reproduction of Baltic herring before, during and after sediment extraction and found no major effect on spawning activity or spawning areas (situated 1.5 km from a dredging area) (Oulasvirta and Lehtonen, 1988).

However, it was reported that there was high spawning activity in the spawning area in May, but no spawning after this time, and there were less catches in the trapnets in the year dredging occurred. It may be assumed that the noise of sand extraction drove schools of herring away from their spawning areas (Oulasvirta and Lehtonen, 1988). Another possible explanation is that fish avoided areas with suspended solid concentrations above 12 mg/l (Messieh et al., 1981; Johnston and Wildish, 1981). The mortality-related impacts caused by egg burial and related to the development of larvae revealed that reared larvae of Atlantic herring were smaller at silt concentrations above 540 mg/l. A larvae mortality rate of 100% could be observed when larvae were exposed to a silt concentration of 19,000 mg/l for two days (Messieh et al., 1981).

Other investigations considered the sublethal effects of suspended sediments on adult herring. The fine silt particles are able to coat the respiratory epithelia of fish, reducing gas exchange with the water, and larger sediment particles were trapped by the gill lamellae and blocked water flow, leading to asphyxiation (O'Connor et al., 1976). Sublethal responses were found in white perch at concentrations of 650 mg/l and five days exposure (Sherk et al., 1974). Moreover, increased levels of suspended

sediments affect feeding rates of herring larvae, which could lead to mortality of yolk sac larvae, because this larval stage has a sensitive first feeding period (Hjort, 1914; Cushing, 1975).

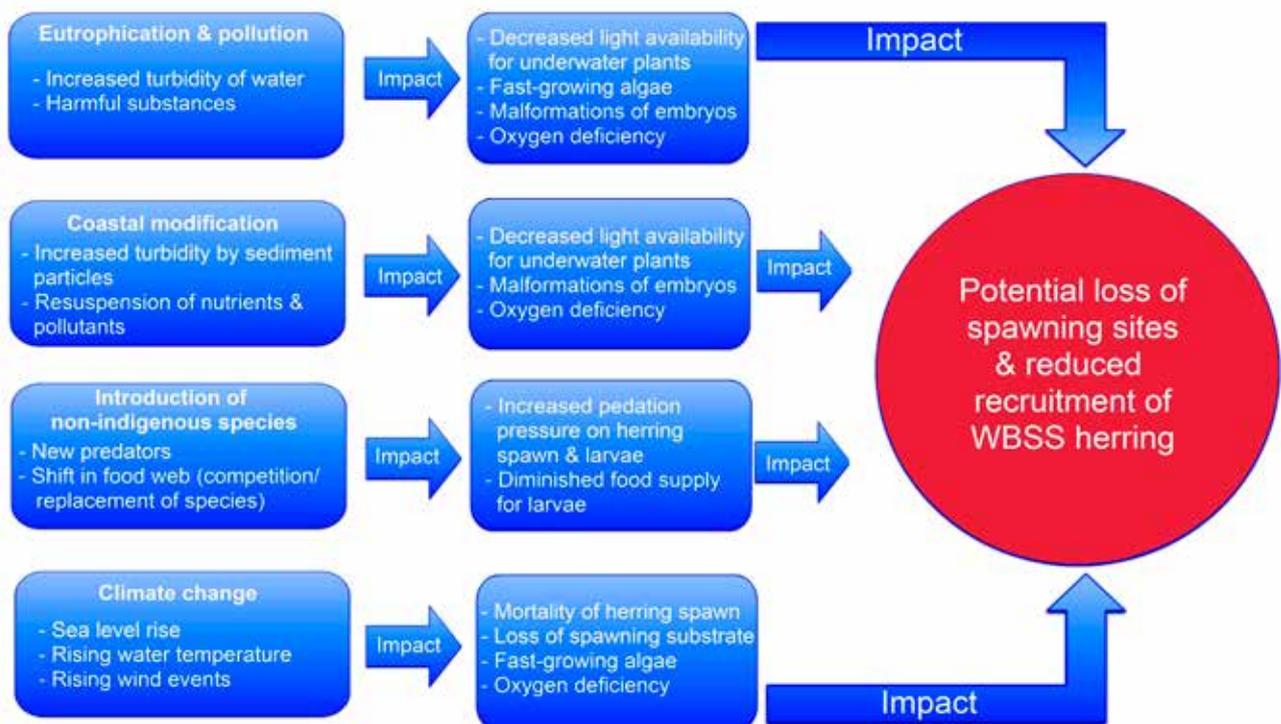
At concentrations of 20 mg/l, herring larvae consumed significantly fewer rotatoria, possibly due to reduced light intensity (Johnston and Wildish, 1982).

Interaction of multiple anthropogenic effects

Herring spawning habitat and the success of reproduction depend on multiple factors expressed in the biotic and abiotic environment. Furthermore, every single anthropogenic effect has a considerable impact on herring reproduction and on ecosystem functioning in that it changes biotic and physicochemical parameters. The interaction of all anthropogenic stressors as mentioned in this report leads to an enhancement of the individual anthropogenic effects, ultimately leading to high ecological stress on the environment and thus on herring reproduction.

A further human induced stressor is commercial and recreational fishing, affecting the success of herring reproduction by influencing the spawning stock size, although it has little or no effect on the actual spawning grounds.

Considering the complexity of these interactions and their ecosystem effects, it is important to preserve the present environmental status before investing in expensive restoration efforts. Some examples of important first steps include minimising nutrient discharge or implementing sustainable management of urban coastal development. Furthermore, it is important to promote research on multiple impact factors in order to understand ecological cascades and to evaluate the ecological response to an increasingly large suite of anthropogenic stressors.



*Interaction of multiple anthropogenic effects.
Source: Dorothee Moll*

Polish case study area – Vistula Lagoon

Overview of human uses and their spatial position

Commercial and recreational fishing

Until 1945, the Vistula Lagoon was in German territory, but following World War II it was divided between Poland and the former USSR. Nearly all the German fishermen were displaced following World War II, and only a very few former experts shared their knowledge with the new fishermen. The organisation of post-war fishery in accordance with socialist ideas began in 1946 with the creation of fishery cooperatives. However, these were either quickly shut down or incorporated into larger organisational units. During the 1950s, there were between one and five such fishery cooperatives. The last of them was liquidated in 2002, and all of the Vistula Lagoon fishermen began operating their own businesses independently. The rules under which the fishery operated in the centrally-planned economy changed gradually. At first, attempts were made to collectivise all fishing resources, including gear, boats, and ter-

restrial infrastructure, but it quickly became apparent that the fishermen lacked the incentive and motivation to take good care of the gear. To combat this, changes were implemented in the 1960s and while the boats, engines, and terrestrial infrastructure remained the property of the cooperative, the fishing gear and fuel costs became the responsibility of the cooperative members. This organisational structure was maintained until the early 1980s when the ownership of all the boats was transferred to the fishermen. Decreased eel and pikeperch abundance, as well as Poland's accession to the European Union in May 2004, resulted in decreased numbers of boats and fishermen. Funds for boat scrapping and the low profitability of fishing contributed to the creation of areas in the Vistula Lagoon that are free of fishing gear.

In different periods, the most commonly deployed fishing gear depended on legislation, the frameworks of organisations, and on the fishing process. By the late 1970s, large fyke nets with five rings and four chambers had become the standard gear, except in the southern and western parts of the Lagoon where the water is too shallow (Grzywacz et al 1982).

*Fyke net situated by the
coast of Vistula Lagoon.
Source: Dariusz Fey*





In 2002, protective sieves, which are bycatch reduction devices, were mounted in the last chamber of all fyke nets following the spring herring season (Psuty-Lipska and Draganik 2005). Since 2003, pound nets that were developed based on gear designed by Russian fishermen for catching herring have become more popular in the Polish waters of the Lagoon during the spring season.

The size of fish caught in gillnets depended more on material and design than on mesh size. Depending on mesh size, set gillnets target smaller fish such as perch or roach or larger fish such as pikeperch or bream. A new design based on the length and location of the vertical shortening ropes determines the quantity of the bycatch of undersized pikeperch.

Pound net deployed in Vistula Lagoon.
Source: Iwona Psuty

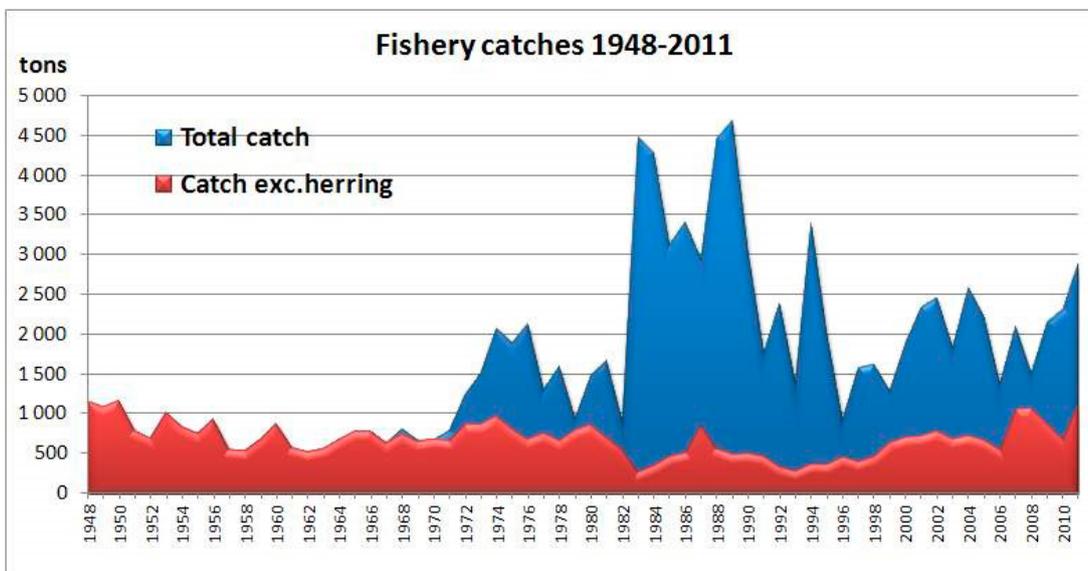


Fishermen preparing to empty the pound net.
Source: Iwona Psuty

Fyke nets and gillnets can have a negative impact on fish resources and lead to tragedies with common property resources if their exploitation is managed inappropriately. Trap gear result in high fry mortality among other fish species, including pikeperch and bream which are both important species to commercial fisheries. Set gear with a small mesh size has a similar impact. When there is a lack of fisheries regulation, both gillnets and fyke nets can inhibit fish migrations along the length of the basin. Herring is exploited using fyke nets and pound nets.

Since the profitability of using eel fyke nets is low, gillnets have gained in popularity. They are relatively cheap, are easy to replace if they become damaged, and provide the fisherman with greater flexibility in changing fishing location.

In the Lagoon, each special fishing permit stipulates the permanent number of gear that can be used, e.g., 24 sets of fishing gear. A set can comprise gear with a maximum length of 120 meters regardless of whether it is a fyke net or a gillnet.



Total landings of herring and other fish in the Polish part of the Vistula Lagoon 1948-2011

With the exception of herring catches, the total catch in the Vistula Lagoon has remained at a comparable level of 600-800 tons for many years at an annual mean for the 1948-2010 period of 678 tons.

The structure of the catch, however, has shifted towards species that command lower prices, which means they are less satisfactory to the fishermen. Currently, roach, bream, and perch comprise the bulk of the catch with decreasing contributions of pikeperch and eel. Herring catches did not become an important element of Vistula Lagoon fisheries until the early 1970s, but the size of these catches is highly variable with environmental factors such as ice cover, water thermal regime, and generation strength of the southern Baltic population, and economic factors impacting it. The size

of catches of this species is currently regulated primarily by demand and the quality of the fish as raw material.

Some species including smelt, ruffe, pike, carp, and vimba disappeared from landing records in the 1960s and 1970s, while others such as ziege, round goby, and flounder, have begun appearing in records in the last ten to 20 years. Still other species such as tench, Crucian carp, and burbot, have been appearing and then disappearing from landing records since the 1980s, and each of these species has its own history depending on the availability of fish and the type of fishery. Another important factor that influences the composition of local fish assemblages is stocking. The comparison of the size and structure of catches between three periods (1958/1960, 1978/1980, 2008/2010), shown in **figure 1-6**, indicates there have been fundamental changes in the catches.

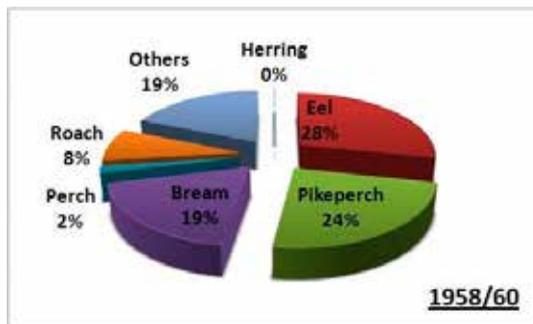


Figure 1 Catches (%) in the Polish part of the Vistula Lagoon during 1958-1960

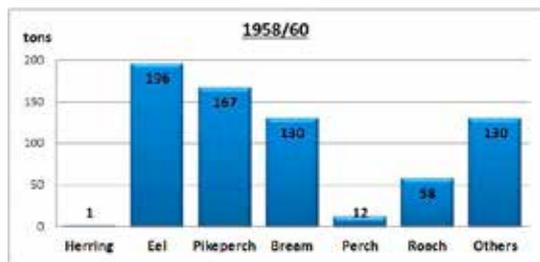


Figure 4 Catches (tons) in the Polish part of the Vistula Lagoon during 1958-1960

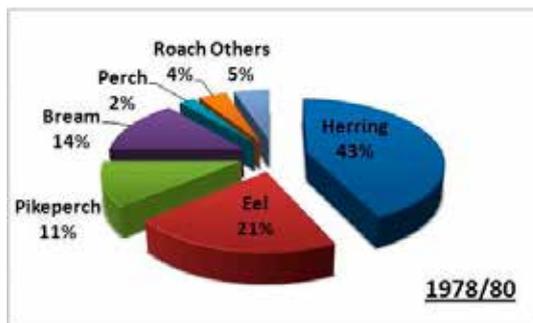


Figure 2 Catches (%) in the Polish part of the Vistula Lagoon during 1978-1980



Figure 5 Catches (tons) in the Polish part of the Vistula Lagoon during 1978-1980

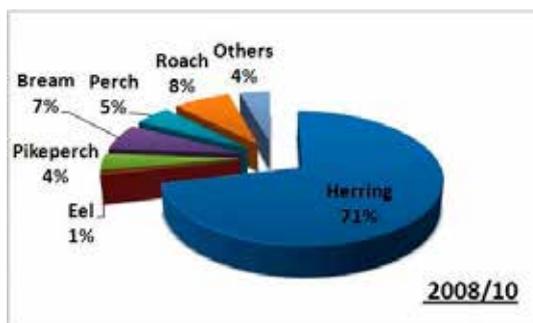


Figure 3 Catches (%) in the Polish part of the Vistula Lagoon during 2008-2010

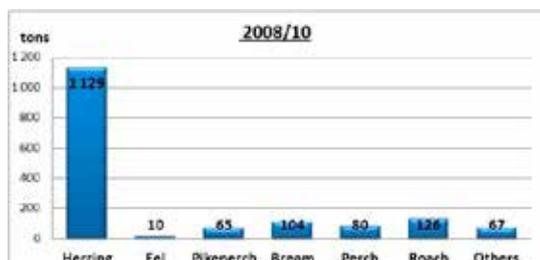


Figure 6 Catches (tons) in the Polish part of the Vistula Lagoon during 2008-2010

During the first period, the primary species were eel, pikeperch, and bream, but by the end of the 1970s while catches of these three species remained at similar levels, herring began to dominate in terms of weight. Currently, herring comprises about 70-80% of all catches, while there have been simultaneous drastic decreases in catches of eel and pikeperch, and to a lesser degree of bream.

Considering the mean sale price of fish, the revenues from the various species differ. Despite small catches of eel, the high sale price for this fish means that it retains its significant revenue position. Similarly, the nearly twenty-fold higher sale price that fishermen can command per kg of pikeperch equalizes the small catches and places this species on a par with the revenues earned from high herring catches. Significant revenues are also earned from the sale of perch, which contrasts with those for roach

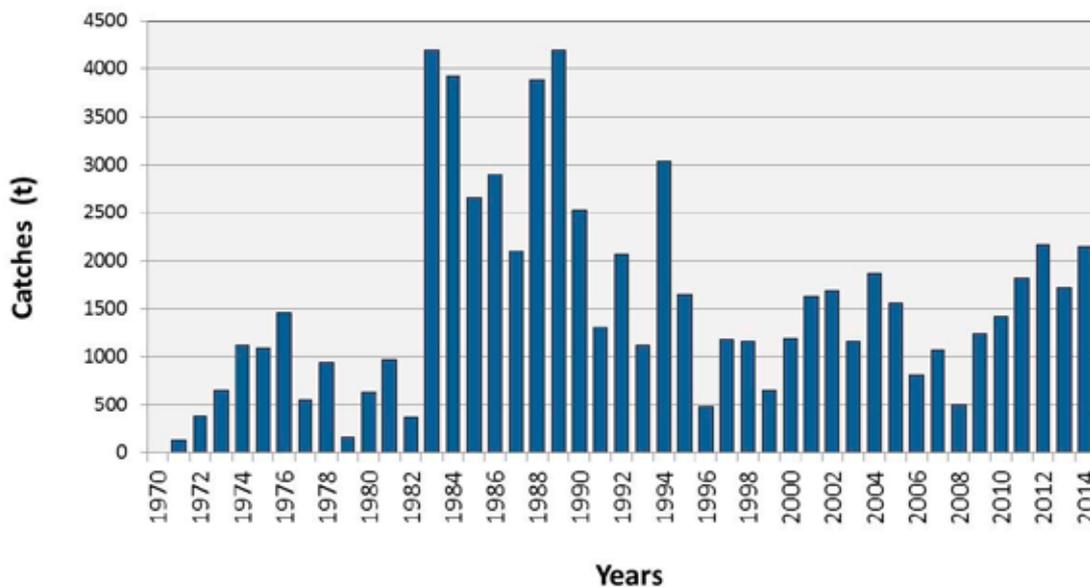


Herring catches with pound nets during the spring season

since the sale price is several times lower than that of perch.

Over the course of sixty years, the most important aspect of herring catches has been its dynamics. Notable landings were recorded in the early 1970s, but herring catches have fluctuated strongly, and have been very weak in some years (e.g., 1977-1982, 1996, 1999). These changes have been studied by Russian scientists since herring plays an important role in the former Soviet and current Russian fishery in the Vistula Lagoon. Generally, temperature and salinity provide the most important information for herring spawners, which have to pass through the narrow Baltiysk Straits (400 m wide) to reach the Vistula Lagoon. Landings in the Polish part of the Lagoon do not precisely reflect the size of spawning aggregations over the year since catches are largely dependent on transport capacity and market demand. Just a few years ago, newly-designed gear targeting herring was introduced. Known as the pound net, this gear was popularised by the Russians (Kanin 1950). Previously, herring was caught with fyke nets and gillnets.

According to data from the Fisheries Monitoring Centre, 1812.5 tonnes of herring were caught in the Vistula Lagoon in 2011, of which 99 % were caught with pound nets. The reported catch in April was 1790.8 tonnes, which is typical of herring catches at the peak of herring fishing in the Vistula Lagoon. In 2014, the herring catches reached over 2100,0 tonnes.

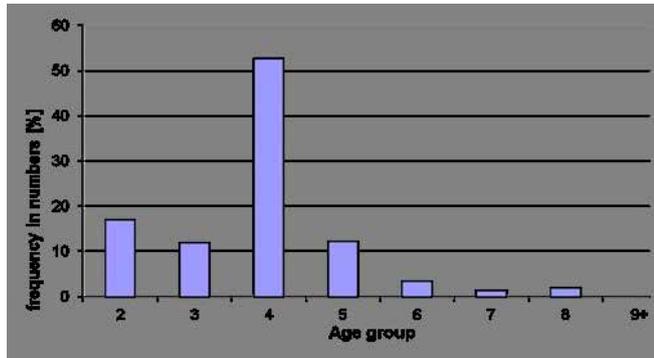


Herring catches in the Vistula Lagoon in years 1955-2014

Year	Month									
	Jan	Feb	Mar	Apr	May	Jun	Oct	Nov	Dec	
2007	0,1		897,6	169,2	6,9		0,3		9	
2008		2,4	258,2	190,1	44,6			0,9		
2009			192	1028	18		1			
2010				1178,3	241	0,2				
2011	0,7	0,5	2,2	1790,8	18,3					

Year	Number
2001	265
2002	217
2003	253
2004	268
2005	356
2006	404
2007	467
2008	661
2011	679
2012	917
2013	977
2014	1240

Registered monthly herring catches (tons) in the Polish part of Vistula Lagoon 2007-2011



Number of permissions for recreational fishing sold 2001 - 2008 by RM Frombork.

Age frequency of herring in the Vistula Lagoon in year 2011

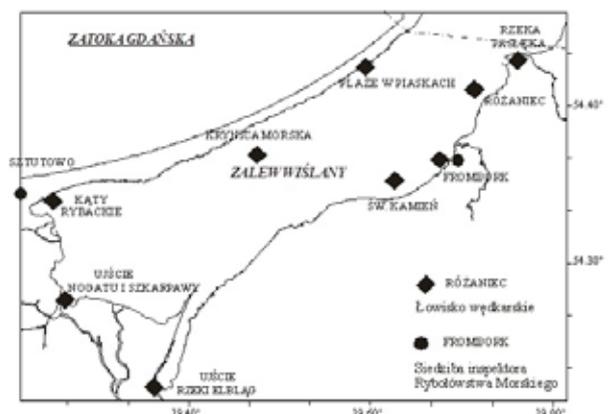
The length of herring caught by Polish fishermen in the Vistula Lagoon in 2011 ranged from 16 to 28 cm l.t, with more than 70 % of the fish caught belonging to length classes 19-23 cm l.t. The herring caught belonged to seven age groups (from 2 to 8), but the catch was dominated by fish aged four years old (Wyszyński 2012).

Recreational fisheries in recent years have grown from cutter and boat fishing to include shore fishing, which is conducted directly from the shore. The greatest concentrations of recreational fishermen are near river mouths where they can take advantage of spawning migrations of freshwater fish that inhabit the sea and which are not protected by any closed periods. No permit is needed for motorboats with an engine capacity of less than 11 hp. The relatively low cost of recreational fishing permits is also encouraging. The Marine Fisheries Inspectorates in Frombork and Sztutowo have in the last decade noted several fold increases in the number of permits issued. In 2014, over 1200 permits were sold in comparison to just 138 in 1998. Preliminary research results by Ramutkowski (2008) indicate that the mean annual catches of pikeperch and perch at Różaniec, the most popular recreational fishing grounds in the Vistula Lagoon, was 6.5 tons. In comparison to commercial fisheries, this is not a significant amount, but the growing popularity of the Lagoon among recreational fishermen must be borne in mind.

The Vistula Lagoon recreational-fishing grounds can be divided into two categories according to which species are fished (Ramutkowski, personal communication). The first, pikeperch fishing grounds where perch are also caught, are located at a distance from the shore and can only be reached by boat, while the second are cyprinid fishing grounds located along the shoreline and in the mouths of rivers that flow into the Lagoon.

Pikeperch are fished mainly near Różaniec, and to a far lesser extent near Frombork, Święty Kamień, and Krynica Morska. In the vicinity of Różaniec perch are fished primarily from boats, while cyprinids and eel are fished from the shore. Recreational fishermen fish for cyprinids and perch from all other areas, especially during spawning migrations.

The distribution of main activities related to recreational fishing is summarised on a map.



Main areas used for recreational fishing

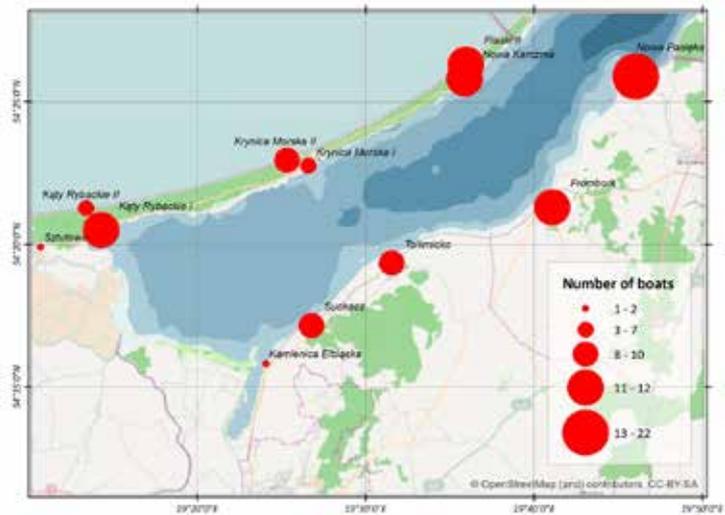
Marine transport – marinas, fishing harbours, industrial ports and waterways

Marine transport includes several types of activities: fisheries, recreational fishing, passenger shipping, and cargo shipping.

The 2004 Vistula Lagoon fishing fleet (before EU accession) comprised 124 vessels in the registry of fishing vessels. These vessels were licensed and had special fishing permits. Additionally, 22 so-called fishing boats were allowed to exploit the fisheries under special conditions. These were used as auxiliary boats during the spring herring catch and were charged with servicing gillnets and transporting fish and equipment. These boats were withdrawn from the fisheries in 2010. As part of the Sectoral Operational Programme entitled Fisheries and Fish Processing 2004 - 2006, financial compensation was offered in exchange for permanently ceasing fishing activities. To date, 60 owners of fishing vessels operating in the Vistula Lagoon have volunteered to participate in this programme, with four of them volunteering for the vessel scrapping programme in 2011-2012.

Currently, eight fishing ports and bases are operational in the Vistula Lagoon where the vessels permitted to fish in this aquatic basin are located. All of these ports and bases are pres-

ently supervised by the Director of the Maritime Office in Gdynia. According to records, 78 licensed fishing boats were registered and operating out of fishing bases in the Vistula Lagoon as of 03.12.2012. Most of these were registered in Nowa Pasłęka.



Fishing bases in the Vistula Lagoon

The catch structure at the various fishing bases differs according to local conditions (Psuty, 2012). The decisive factor is determined by the economic difference between fuel and labour costs in relation to anticipated results. The low



Various fishing vessels in the Polish part of Vistula Lagoon

Fishery base	Number of boats	Mean length [m]	Mean engine power [kW]	Mean GT
Nowa Pasłęka	22	7,2	39,4	2,1
Frombork	11	8	53,9	2,9
Tolkmicko	8	6,7	35,5	2,2
Suchacz	9	7,2	47,4	2,7
Kamienica Elbląska	2	6	43,4	1,6
Kąty Rybackie	11	7,5	49,4	3
Krynica Morska	5	7,2	37,6	3
Piaski	10	7,5	59,9	2,8
SUM	78			

Characteristics of individual boats at fishing bases (2012).

yield of eel catches with gill nets prompted many boat owners operating from bases located near the border to stop fishing with this gear in this location.

Nowa Pasłęka. Fishermen operating from the Nowa Pasłęka base compensate for the drastic decline in eel catches by making mass herring catches in the spring using pound nets. They have also invested in specialised equipment permitting them to quickly transport fresh fish of the highest quality. Sea trout catches are also profitable thanks to the stocking done in recent years by Polish Marine Districts. Sea trout migrate from the Baltic and can spawn in the Pasłęka and Bauda rivers. The largest catches are in the months of January and February and from August to October.

Frombork. Fishermen from the Frombork fishing base are very flexible in the range of gear they deploy. While some of them specialise in gillnets, the most important factor impacting the catch structure remains fyke nets deployed in the border region. As in Nowa Pasłęka, spring herring catches with pound nets are becoming more and more common. The weak market demand for sichel means that potential catches of it are not fully exploited.

Tolkmicko. The greatest changes in catches are at the Tolkmicko fishing base. Fishermen from this base have traditionally specialised in fyke net catches, and many of them were employed by the Zalew Cooperative, one result of which, and this applies particularly to the period of the centrally-planned economy, is that the ability to rationalise exploitation costs is very poor. In the period 2005–2007, it was here that the majority of fishermen decided to scrap their boats and leave the fisheries in exchange for financial compensation. The remaining boat owners be-



*Herring catch in the Frombork fishing base.
Source: Iwona Psuty*

came more flexible with regard to the choice of fishing gear. The relatively great distance from the border area and the prohibition of deploying larger numbers of fyke nets are the reasons why the fisheries in this area are generally less profitable. Currently, the species comprising the bulk of the catches are bream, sichel and roach. Herring catches depend on the willingness of the fishermen to cooperate since deploying pound nets requires two boats with full crew.

Suchacz. Fishermen operating from the base in Suchacz also use fyke nets as well as gill nets, including those with small mesh sizes to target freshwater fish such as the crucian carp and tench. Currently, the principle catches here are of perch, bream, and pikeperch.

Kamienica Elbląska. The fishermen still operating from the Kamienica Elbląska currently prefer small-mesh gillnets for catches of perch, roach, and crucian carp, which comprise the bulk of their catches.

Kąty Rybackie. The fishermen from Kąty Rybackie use smaller fyke nets than those fishing the eastern part of the Lagoon, as the waters are shallower in the area. Individual boat owners specialise in small-meshed fyke or pound net catches targeting bream. Often, the mesh of the pound nets deployed is larger than the minimum size permitted by regulations of a mesh bar length of 60 mm. The mesh bar length of gear used in catches targeting larger bream is 70 – 90 mm. Spring catches of herring are determined by the mass occurrence of this species in the western part of the Vistula Lagoon, which does not happen every year.

Krynica Morska. Fishermen from Krynica Morska and Piaski use more pound nets targeting pikeperch than they do fyke nets. In re-

cent years attempts have been made to deploy pound nets; however, because of the lack of experience, spring herring catches with this gear are smaller than those of the fishermen from Nowa Pasłęka and Frombork.

Cargo shipping is based entirely on the services offered by industrial port of Elbląg. In the 1990s the city of Elbląg started efforts to reactivate the harbour in Elbląg. The boundaries of the harbour were updated and the sea boarder cross point was created. All institutions necessary for passenger traffic and goods traffic service are now working there. There is a Border Guard, Customs House, Port Authority and Management Board of the Harbour. There has been a revival of passengers and goods transport since 1993.



Fishermen hauling herring from pound net onto the boats, Vistula Lagoon. Source: Iwona Psuty

Detailed description of Elbląg harbour history, infrastructure, and activities can be found on the harbour web page (<http://www.port.elblag.pl/>)

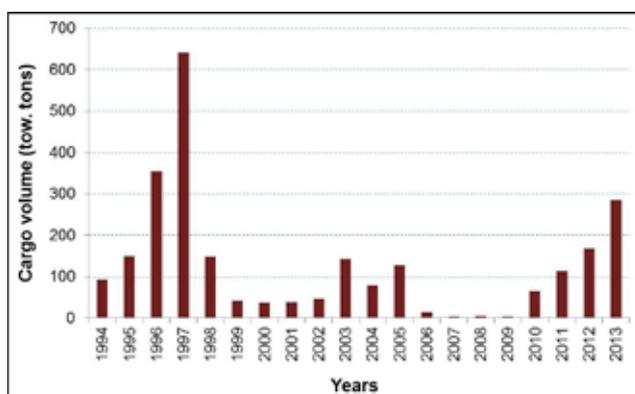
The harbour of Elbląg is the biggest Polish harbour on The Vistula Lagoon. It is located on the river Elbląg, 6 km from its estuary in The Vistula Lagoon. The harbour has road and railway connections with Kaliningrad District (Russia), Warsaw, Gdańsk, Olsztyn, Malbork, Braniewo.

Port Elbląg is designed for inshore goods, passenger and tourist navigation in The Vistula Lagoon and The Gulf of Gdańsk. The total site area is 470 hectares and is 4.5 km in length. Total quay length is 2.5 km and the depth of the fairway is 2.5 m, apart from extreme conditions when the depth may be 1.8 m.

There is a 12 m wide loading platform for ro-ro ships and it is possible to serve two units simultaneously. Maximum ship capacity in Port Elbląg is 83 m length, 15 m width, 3.30 m draught and a carrying capacity of up to 1500 tons.



Port Elbląg on the river of Elbląg.
Source: Albert Rzeczycki



Cargo landings in the Port of Elbląg.
Source: <http://www.port.elblag.pl>

The highest cargo landings were reported in 1995–1998, primarily of coal, and 2003–2005, also primarily of coal, while the smallest were in 2006–2009 (Fig. 29). Since 2010, increasing landings of cargo tonnage, primarily of building materials, have been reported in the Port of Elbląg.

In 2006 the passenger and ferry terminal in the Port of Elbląg had the capacity to simultaneously serve 200 people and 30 cars. The destinations of the international passenger route were Kaliningrad and Bałtijsk. However currently, those routes are not accessible. The national ferry destinations from the Port of Elbląg are Frombork, Tolkmicko, Krynica Morska, Kąty Rybackie as well as the urban area of the ports of Gdańsk and the Masurian Lakes (Elbląg Canal).

Elbląg, Tolkmicko, Frombork, and Nowa Pasłęka are seaports, while a marine marina is located in Kamienica Elbląska, and marinas are found in Nadbrzeże, Suchacz, Kadyny, Kąty Rybackie, Piaski, and Jagodna.

The estimated capacity of the Vistula Lagoon is three thousand yachts, but, until recently, there were moorings for just three hundred. The Żuławy Loop project has changed this situation dramatically. Entirely new facilities are being built, including harbour master's buildings with public toilets and showers, electricity and water connections, and communal areas for socialising.

In order to use the port facilities located in the Vistula Lagoon, one has to gain access to the Lagoon. And this is a problem. The route from the Gulf of Gdańsk into the Lagoon is through the Strait of Bałtijsk, but this is not recommended because of the difficulties the Russian authorities can impose on passage through their territory. Another option is to use rivers and canals; the main route from Gdańsk is 25 km in length, but the challenges encountered along the way include numerous shoals and navigational difficulties including several bridges and locks, all of which lengthen the time required to reach the Lagoon.



Ferry for tourists in Frombork harbour. Source: Iwona Psuty



Water taxi. Source: <http://tramwajwodny.com.pl/zalewwislany>



The water taxi route. Source: <http://tramwajwodny.com.pl/zalewwislany>

The number of yachts entering the Lagoon would undoubtedly increase significantly if the difficulties of sailing through the Strait of Baltiysk were to be resolved.

Passenger routes on the Vistula Lagoon are primarily run by Żegluga Gdańska (www.zegluga.pl), which operates the connections between Elbląg and Krynica Morska and between Krynica Morska and Frombork.

Passenger transport is also provided by the *Generał Kutrzeba* water taxi that can transfer 75 passengers an hour from Braniewo, Nowa Pasłęka, and Frombork to the beach in Piaszki across the Lagoon. Unfortunately, the water

The ferry Krystyna with tourists. Source: Dariusz Fey



taxi does not run regularly every year, and it is still uncertain whether or not it will be in operation.

Other opportunities to cruise the Vistula Lagoon can be found aboard the *Krystyna*, which docks at the fishing port in Kąty Rybackie, right next to the Vistula Lagoon Museum.

There are also cruises organised by the German tourist company Nicko Tours – River Cruises. The 8-day tour runs Gdańsk-Elbląg-Tolkicko-Frombork-Kaliningrad-Gdańsk.

A significant increase in the quality of available tourism services has been noted since the initiation of the Żuławy Loop project, as this provides opportunities for significantly increasing the interest of tourists in the area of the Vistula Lagoon and the development of a range of activities in its waters.

Tourism

With its diverse cultural and natural resources, the Vistula Lagoon and its surroundings are very attractive areas for tourism (official web page of the Vistula Lagoon, <http://www.zalew.org.pl>).

There are two main natural areas:

- The Elbląg Upland (Wysoczyzna Elbląska) – comprises interesting, highly varied terrain that is rich in nature, history, and culture. Numerous ravines with picturesque streams support a vast variety of vegetation including, for example, mountainous species.
- The Vistula Marshlands (Żuławy Wiślane) – occupies an area of the Vistula delta measuring about 2,000 km². One of the most interesting features of the marsh landscape of the Żuławy is the very dense network of natural and artificial streams and the associated embankments and dikes. There are over 5,000 km of canals, nearly 11,000 km of drainage ditches, and almost 600 km of embankments.

The Vistula Lagoon is also a very important component of southern Baltic bird migration routes, and during each migration season, hundreds of thousands of birds, both aquatic and marsh species, stop there.

The area of the Vistula Lagoon and the Vistula Spit are also included in the European nature protection network Natura 2000, within which it is prohibited to undertake any actions that would significantly degrade natural habitats.

View of the City of Frombork from the Lagoon.
Source: Dariusz Fey



Although the natural beauty of this area is important, a number of historical sites are also of interest. These are located mainly in the region's towns and cities, and include the following:

- Elbląg – old town, the Elbląg Canal rise;
- Braniewo – the Gothic church of St. Catherine;
- Frombork – the cathedral complex and the Nicolaus Copernicus Museum;
- Kadyny – the summer residence and stables of Kaiser Wilhelm II;
- Krynica Morska – the church in Stegna, the pier, and the lighthouse;
- Sztutowo – the former Nazi concentration camp

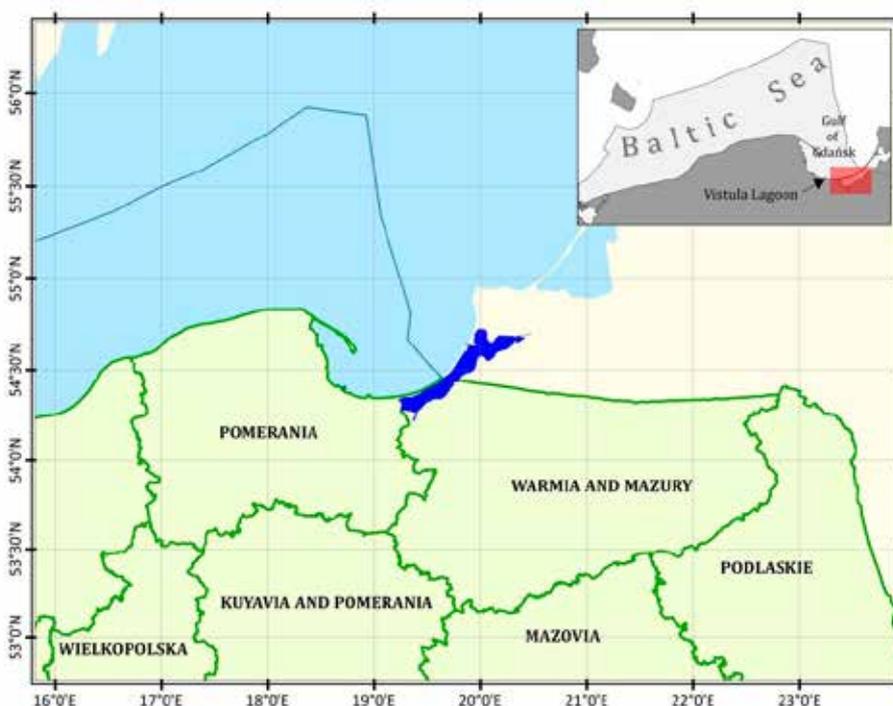
The Vistula Lagoon is located in the centre of the longest, most diverse, and, therefore, the most attractive waterway in Poland that extends from Gdańsk to Iława and provides access to the Gulf of Gdańsk, the waterways surrounding Gdańsk, the rivers of the Vistula River Delta, the Elbląg Canal, and the lakes in the vicinity of Iława. The Vistula River and Lagoon waterways, which are known as the Żuławy Loop, comprise part of the Polish section of E-70 International Waterway that

runs from Antwerp, through Berlin, Gorzów Wielkopolski, Bydgoszcz, Gdańsk, Elbląg, and Kaliningrad to Klaipėda (http://pomorskie.eu/pliki_duze/dif_zamowienia/PetlaZulawska_EN.pdf).

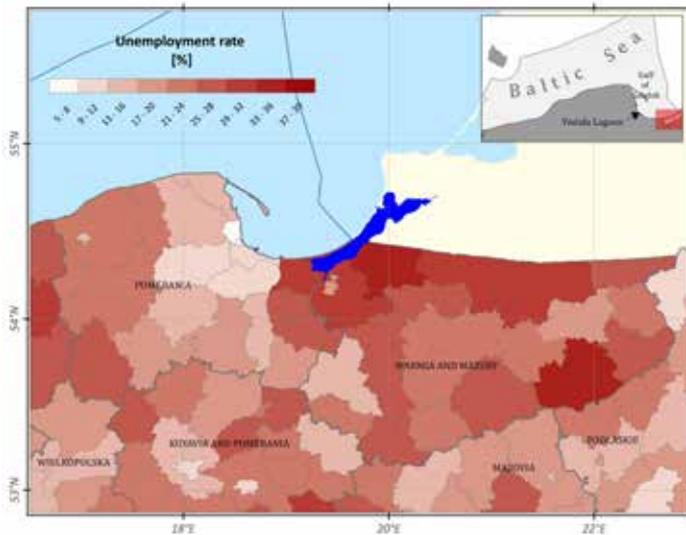
Considering the numerous potentials and advantages of the Vistula Lagoon area described above, it can be concluded that the Vistula Lagoon provides opportunities for the following types of recreation: water sports including sailing, windsurfing, kayaking, waterskiing and iceboating in winter, residential tourism, sunbathing, passenger boats, hiking, biking, horseback riding, recreational fishing, ice fishing in winter, hunting, bird watching, hang gliding, air ballooning as well as accommodation for excursions to Gdańsk, Malbork, and Kaliningrad. Despite the potentials, the intensity of touristic activities in the Vistula Lagoon area is still very low.

Bordering land use

According to the most recent administrative divisions, the Polish waters of the Vistula Lagoon and the shoreline are located in the Pomeranian and the Warmian-Masurian Voivodeships. Additionally, the border between Poland and the Kaliningrad Oblast, which is part of the Russian Federation, runs across the Lagoon. This is also the border between the European Union and the Russian Federation.



Geographic and administrative position of the Vistula Lagoon in Poland



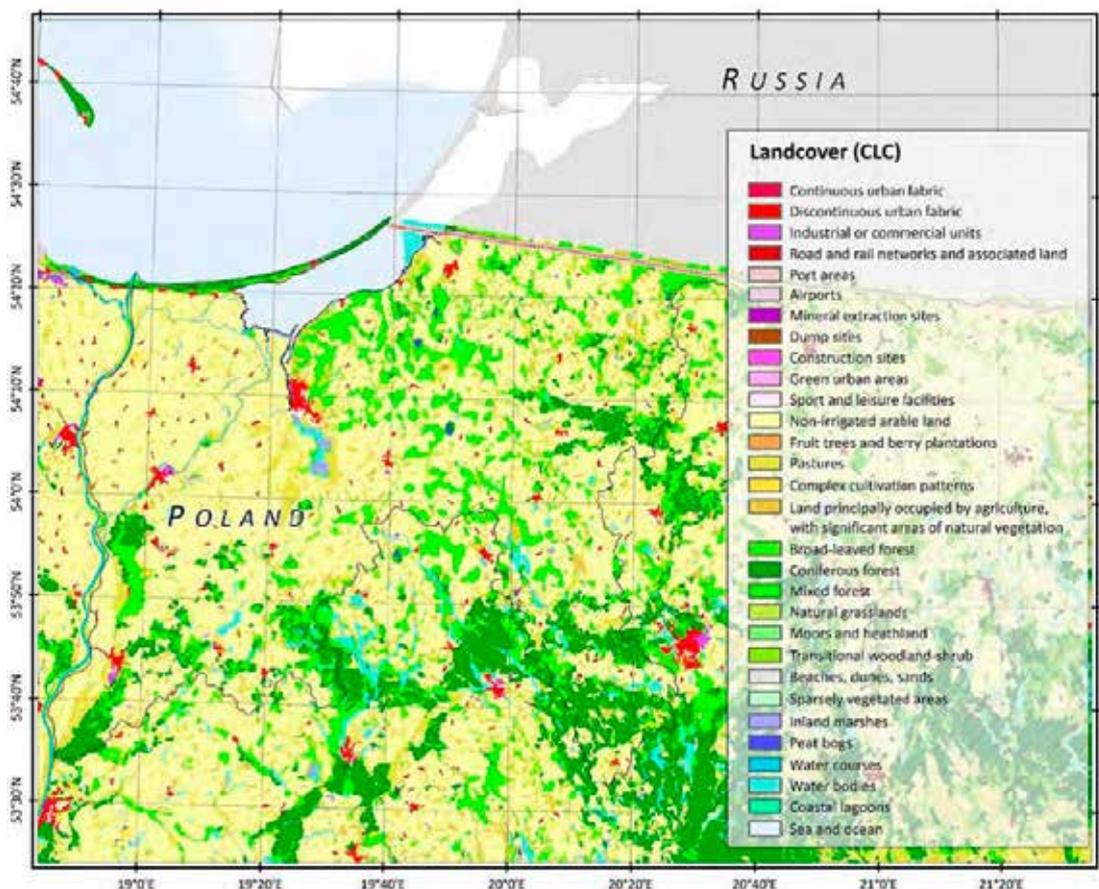
Unemployment rates by municipality in the Pomeranian and Warmian-Masurian Voivodeships

Six smaller administrative districts are located along the shores of the Polish part of the Vistula Lagoon, two, Sztutowo and Krynica Morska, are in the Pomeranian Voivodeship and are bordered in the north by the waters of the Lagoon. The four other smaller administrative districts, Elbląg, Tolkmicko, Frombork, and Braniewo, are located in the Warmian-Masurian Voivodeship and comprise the southern shore of the Lagoon (GUS 2012).

The socioeconomic conditions of Vistula Lagoon communities are linked inexorably with the manner and intensity of Lagoon exploitation. According to the most as of 31 December 2012, the unemployment rate in the Pomeranian Voivodeship is 13.4% (UStat 2013a), while that for the Warmian-Masurian voivodeship is 21.2% (UStat 2013b), which places it among the regions with the highest unemployment rates in Poland. This has been the situation for a number of years, and small administrative districts with higher unemployment rates are clearly clustered within the vicinity of the Vistula Lagoon.

The socioeconomic situation varies among the municipalities located immediately adjacent to and near the Vistula Lagoon.

Small enterprises and family-run businesses dominate in the municipalities near the Lagoon, while there are no large industrial enterprises in the area, with the exception of the MASFROST S-p. z o. o. processing facility in Tolkmicko. Intensifying industrial development in this region is difficult because of environmental impact limitations imposed by the area's inclusion in the Natura 2000 network as



Land cover (CLC) classification in the Polish part of the Vistula Lagoon drainage area (prepared by Lena Szymanek.

Source: European Environment Agency (EEA) - <http://www.eea.europa.eu/themes/landuse/interactive/clc-download>

well as by problems related to poor infrastructure, like roads and railways. Besides agriculture the region's largest employers are local schools, hospitals, and municipal enterprises.

The drainage area of the Polish part of Vistula Lagoon is characterised by variable landscape where arable land, pastures and forests dominate (Fig. 28)

The first mechanical sewage treatment plant in a community adjacent to the Lagoon did not open until 1988, and Elbląg, the largest city in the Polish part of the Lagoon, did not finish construction on its mechanical-biological sewage treatment plant until 1992. According to data for year 2011 (GUS, 2012), the lowest usage of sewage treatment plant was noted in Elbląg municipality at 26.9 %, followed by that in Braniewo municipality. In the other municipalities, this figure fluctuated at about 60 to 70 %, with the exception of Krynica Morska, where more than 90 % of the inhabitants used the municipal sewage system. It is still therefore important to increase the percentage of the population using the municipal sewage system. The loads of the pollutants (e.g., nutrients) of the Vistula Lagoon sewage treatment plants - Elbląg (the highest input), Tolkmicko, Frombork, Braniewo, Piaski, Krynica Morska, and Stegna - play a minor role in comparison to the loads from rivers.

Dredging in Vistula Lagoon.
Source: Iwona Psuty

Energy supply, dredging, channelling, and sand extraction

No sources of energy such as wind, crude oil, gas, or nuclear power are available in this region, neither in the waters of the Vistula Lagoon nor the areas within a short distance of the Lagoon coastline. Neither are there any pipelines or cables on the bottom of the Lagoon.

In the Polish part of the Vistula Lagoon, all kind of dredging and sediment movement is conducted under supervision of the Maritime Office in Gdynia, the Regional Water Management Authority, and local administrative bodies. Such work includes dredging fairways and ports, reinforcing shores and refurbishing ports and harbours.

These kinds of projects are always treated as activities that have a direct impact on the environment. Especially regarding sound emissions that disturb both waterfowl and aquatic animals, sediment resuspension from the seabed where very fine sediments obstruct light penetration and the elimination of benthic species in both bottom sediment donor and deposition sites.

A full inventory of flora and fauna in the Lagoon and river mouths is lacking and a cautious approach when dredging aims at reducing the disadvantageous impacts the activities may have on the ecosystem. This is done by implementing various measures, for example dredging in the early autumn or sometimes in winter (September – February), to avoid disturbance during the nesting season for birds and the spawning season for fish. Turbidity or silt curtains, which are one of the basic methods em-



ployed in industrial-scale projects to mitigate disadvantageous environmental impacts, are deployed on worksites. These floating curtains limit the dissipation of silt that is resuspended during dredging, and are anchored on the water surface with buoys and connected together with ballast chains to the sea bottom.

Limiting the impact on benthic species is achieved primarily by selecting appropriate donor and deposition sites in accordance with available information and the results of environmental impact studies with a special focus on species that are of particular value to the natural environment.

An additional issue is to determine whether or not sediments are dangerous, which depends on the degree of sediment contamination. This determines the selection of deposition sites, and is also linked to the question of how much pollution is released into waters during dredging work.

Designated nature conservation areas and protection areas

The conservation areas within the Natura 2000 network – the Vistula Lagoon Special Protected Area (SPA) (PLB 280010) and the Vistula Lagoon and Vistula Spit Special Area of Conservation (SAC) (PLH 280007) - which have a combined surface area of over 70,000 ha, were created to guarantee the preservation of these sites for future generations. The aim of the ef-

fective management of Natura 2000 sites is to conserve natural habitats and key species in order to preserve the natural heritage of Europe, while taking into consideration social, economic, and cultural needs.

There are designated Special Protection Areas (SPA) for birds that encompass one of the most important staging areas on one of the most important avian migratory routes in Europe. At least 27 bird species that are listed in Appendix 1 of the Birds Directive, and at least nine of these are species found in the Polish Red Book of Animals, have been sighted here. The Vistula Spit is home to Poland's largest breeding colony of great cormorants, which comprises more than half of the total number of this species in Poland.

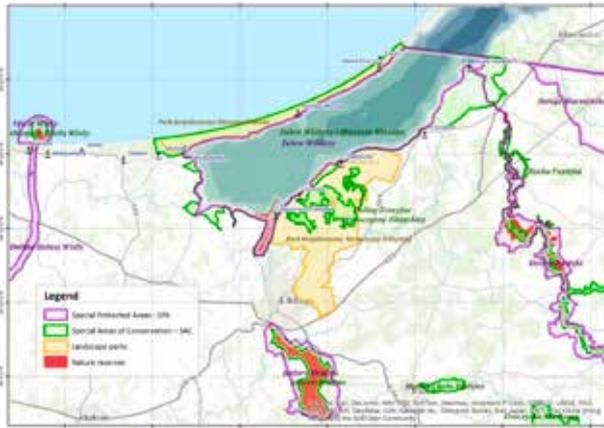
There are also designated Special Areas of Conservation (SAC), situated in the area of the Vistula Lagoon, the Vistula Spit, and a slim strip of land along the southern coast of the Lagoon. Within these areas are numerous habitat types that are significant on a European scale.

Two landscape parks have been established in the vicinity of the Vistula Lagoon. The Wysoczyzna Elbląska in Elbląg Highland has an area of 135 km² and the Mierzeja Wiślana in Vistula Split has an area of 44 km².

In addition to the Natura 2000 areas and Landscape parks there are 15 nature reserves in the Vistula Lagoon area.

Coastal marshlands are favourable areas for nesting and feeding birds

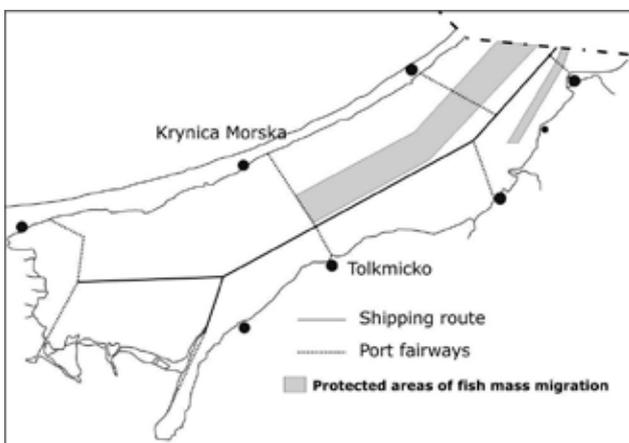




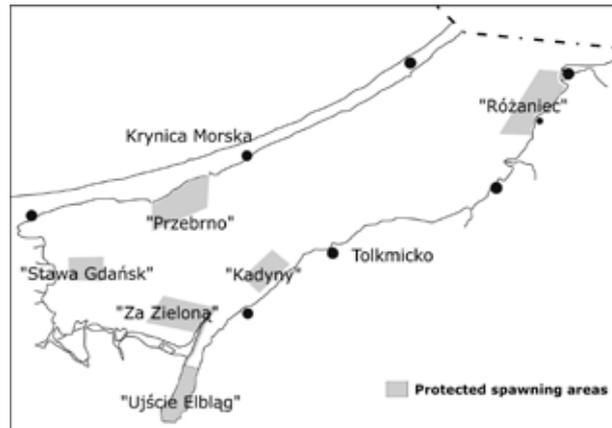
Natura 2000 network in the Vistula Lagoon area

Two corridors have been established in the Vistula Lagoon in an effort to ensure unhindered fish migrations in the border zone, where there is the most intense fishing pressure since this area provides the highest catch yields. The northern corridor is 1500 m wide and extends from the Polish–Russian border to the Tolkmicko–Krynica Morska fairway. The southern corridor is 600 m wide and extends from the Polish–Russian border to the area located in the coastal zone known as the Różaniec spawning grounds. These two regions are closed to fishing and the use of any type of gear is banned throughout the year.

The state of pikeperch and bream resources depends on their successful spawning in the shallow regions of the Polish part of the Lagoon. The state of these spawning grounds, in turn, is determined largely by the physicochemical conditions of the aquatic environment and the substrates on which the fish deposit their eggs.



Location of shipping routes, port fairways and protected areas of fish mass migration closed to fisheries on the Polish part of Vistula Lagoon



Location of protected spawning areas and river mouths protected areas on the Polish part of Vistula Lagoon.

In order for spawning to be successful, conditions must allow the eggs to be deposited on suitable environmental substrates with properties that allow for the optimal development not only of eggs, but also of the subsequent development of hatching, larval, and juvenile stages.

Six spawning ground areas are protected periodically throughout the Lagoon. Fishing is closed in these areas from 10 April to 20 June.

Ecosystem effects and future consequences

Commercial and recreational fishing

Perspectives for the development of Vistula Lagoon fisheries are linked closely with current socioeconomic conditions, the state of fish resources, and trends in environmental protection. In the future the administrative position of the Polish part of the Vistula Lagoon can impact the economic development of the areas adjacent to the Lagoon as well as the way its resources are exploited. The Warmian-Masurian Voivodeship has among the highest unemployment rates in Poland. Employment opportunities here are limited because the region is not industrialised, and the work available in the vicinity of the Vistula Lagoon is primarily in either the development of the tourism sector or fisheries. While it is possible to entertain the possibility of increasing employment in the tourism sector, the same does not apply to Vistula Lagoon fisheries because of the current fishing quotas for the most popular commercial fish species (i.e., 160 tonnes for bream and 100 tonnes for pikeperch in 2013). These

limits were set based on conclusions drawn by the Polish–Russian Bilateral Commission for Fisheries Management. The profitability of catching other fish species in the Lagoon is not guaranteed because of low market prices and the lack of local processing facilities. The lack of opportunities for permanent employment in other economic sectors is resulting in the successive emigration of residents from the areas to more developed urban areas that offer better employment opportunities.

Vistula Lagoon fisheries are currently based on three fish species. Herring are targeted in spring, while pikeperch and bream are targeted in other catches. Eel, which was the economic foundation for family-run fishing enterprises in the past, are observed with increasing rarity. It may be changed, however, as a result of current eel restocking program. The state of the stocks and the fishing limits imposed on the species mentioned above will determine any potential transformation of strategies for developing Lagoon fisheries. Additional factors could be the relationship with the Russian Federation, which is the Lagoon’s co-manager, environmental protection legislation, and fisheries economics. One solution to the problem of low catch limits is to effect a shift in consumer preferences by promoting, and thus increasing demand for,

less popular fish species with abundant stocks. Disseminating information about fisheries traditions and promoting fish consumption has been undertaken by the Vistula Lagoon Spit Fisheries Brotherhood Local Action Groups for Fisheries. Additionally, these groups are working to integrate the fisheries communities with the local communities, supporting environmental conservation measures, and promoting the sustainable exploitation of areas that are dependent on the fisheries. They also promote measures to diversify the incomes of local residents, which also helps these communities to adapt to changing economic conditions in the region. In future, these groups could also play important roles in negotiations between fisheries organisations and bodies responsible for the sustainable development of Vistula Lagoon fisheries, especially with regard to the protection of commercially valuable species. In addition to legislative restrictions, the development of fisheries could be impacted by the proposed Vistula Spit canal project that will have an immediate impact on the Lagoon. The detailed environmental impact study of this project is only a prognosis. Realising this project could see the banning of fisheries in a section of the northern Vistula Lagoon shoreline. It is also possible that increased vessel traffic could result in certain limitations, and the project could



Small fishing boat.
Source: Iwona Psuty

also have a negative impact on the spawning and rearing grounds of fish species that are commercially important to the fisheries of the Vistula Lagoon.

The Vistula Lagoon and its adjacent areas are, first and foremost, a region of rich natural beauty and resources inhabited by flora and fauna linked inextricably with aquatic environments that are unique on a European scale. From those reasons, the lagoon is included in the Natura 2000 network. Potential restrictions related to Natura 2000 regulations could result in conflicts between the fisheries and the development of active forms of tourism on the one hand and guidelines for environmental protection on the other.

On the one hand, the implementation of diverse forms of nature conservation such as Natura 2000 areas and the Mierzeja Wiślana and Wysoczyzna Elbląska landscape parks could generate income from bird watching tourism, for example, while on the other hand it could limit access to the natural resources available in the Vistula Lagoon. Consequently, the fishermen, who are the primary users of this basin, will have to adapt to these new conditions. The enforceability of the regulations in the conservation plans will be the key to the further development of the Lagoon region, especially with regard to the fisheries. All attempts in these documents to forecast trends in Vistula Lagoon fisheries are of a purely theoretical nature.

The intensity of recreational fishing will certainly increase along with growing tourism however this does not pose any great threat to the environment. The biggest possible negative impact would be from water pollution from boat engine oil or fuel. While this is an important factor, the small number of boats, even when taking into consideration significant growth, means that this threat is and will remain rather moderate. The low intensity of recreational fisheries should not impact the state of spawning sites and fish resources, especially if appropriate monitoring is done to ensure compliance with closed seasons and minimum fish catch sizes. Obviously, very significant increases in recreational fisheries intensity could have a negative impact on the environment, but such increases in intensity are unlikely.

Marinas and harbours

The Żuławy Loop project includes rebuilding ports to increase capacity and the standard of services. These improvements will undoubtedly increase the attractiveness of the Vistula Lagoon to tourists and will help to develop tourism in the region. The numbers of motor boats, crews and passenger ferries will increase, but it is difficult to forecast to what extent. A suggestion is that the current low levels of tourism in the Lagoon areas gives room for further logistic and tourism development without affecting the environment significantly.

*Harbour in Kąty Rybackie.
Source: Adam Lejk*



Tourism

The greatest threats to herring spawning grounds posed by tourism are as follows:

- increased concentrations of pollutants such as petroleum-based substances and heavy metals (sources include vessel, hydrofoil, motor boat traffic);
- decreased oxygen contents and increased hydrogen sulphide concentrations on the Lagoon bottom (sources are eutrophication from increased supplies of terrestrial nutrients and the recycling of nutrients re-suspended from the Lagoon);
- increased amounts of suspended matter in Lagoon waters and sedimentation in spawning areas (sources are fairway dredging, hydrofoil and boat traffic);
- changing bottom structure from sand to mud and the disappearance of aquatic vegetation (sources are increased eutrophication, bottom sediment resuspension).

The shallow Lagoon depths that range from an average of 2.4 m to 5 m and limited water exchange that only flows through the Strait of Baltiysk mean that the ability of Lagoon waters to self-purify is very limited. Therefore, the risks of the effects outlined above should be considered seriously. The impact of tourism on the Vistula Lagoon, its surroundings and natural environment is currently low since this sector remains underdeveloped on land as well as at sea. One can conclude that human activities related to tourism currently pose very little threat to herring spawning grounds, and do not affect the intensity or effectiveness of the reproduction of the species.

While the development of tourism in the Vistula Lagoon is very likely to increase it does not appear that the impact of this will be strong enough for the potential effects of it to pose a significant risk to herring spawning, not, at least, in the nearest future. The risk of adverse impacts would increase, however, if the plan to build a canal through the Vistula Spit is realised, but the risk stemming from this project would not be linked so much to the development of tourism, as it would with increased cargo vessel traffic and the greater intensity of dredging.

Bordering land use

The potential negative impact of factors associated with the exploitation of agricultural areas and forests in the Vistula Lagoon catchment are not expected to increase in the future. Nothing indicates that inputs of nutrients will increase; if they did this would undoubtedly result in decreased water transparency, changes in bottom structure, and the creation of areas with near-bottom oxygen deficits. It is more challenging to predict changes associated with the development of industry in the vicinity of the Vistula Lagoon. Currently, the low level of industrialisation indicates it is more likely that new industrial facilities will appear than it is that industrial activity will decline even further. However, there are no indications that any type of large industrial facility will be constructed in the immediate vicinity of the Lagoon shores.

Marine transport

Significant increases in shipping and passenger vessel traffic could occur if the Vistula Spit canal construction project is realised. Access to the Lagoon without having to sail through the Strait of Baltiysk and improved navigation conditions, including those at night, would certainly exert more pressure on the environment from marine transport. The development of marine transport requires deepening fairways and increases the risks of environmental pollution with petroleum products such as fuels and lubricants. The decision to construct the canal has not yet been made. Although there are possibilities to develop marine transport even if the canal project is rejected, the scale of this will probably not be comparable with that if new waterways are created.

Energy supply

It is currently impossible to estimate the potential impact of the development of energy extraction, because there are no concrete plans that outline the type and intensity of potential exploration. The most probable scenario involves constructing wind farms in areas near the Lagoon, although constructing wind farms in the Lagoon itself appears to be unlikely. According to the Act concerning the maritime areas of the Republic of Poland and the maritime administration it is allowed only in EEZ. Other sources of energy such as crude oil, gas, or nuclear are not extracted or produced in this

region, and there are no indications that this is to change.

Dredging and sand extraction

Current levels of these kinds of activities can also be expected in the future. The really significant change could occur as a result of the implementation of the plan to build a canal through the Vistula Spit. Regular dredging and sand extraction would be required to maintain the shipping corridor between the Spit and Elbląg. Possible consequences for spawning grounds in that area may be unfavourable and very significant in their magnitude.

Swedish case study area – the Hanö Bight

Overview of human uses and their spatial position

Commercial and recreational fishing

Due to the collapse in the late 70s of the North Sea herring stocks, new sets of international regulations were applied to protect the fish stocks. As fishing waters extended to 370,4 km from the coast it diminished the areas where the Swedish fishing fleet could access. Instead a large part of the Swedish fishing fleet moved to the Baltic Sea (Fisket på Sydkusten. 2002). On the south coast of Sweden the commercial herring fishery was a large industry until mid-1990s using mostly coastal trawlers. When in the early 1990s there was a decline in large herrings and government subsidies were removed, fishing herring for human consumption dropped. Instead industrial fishery targeting sprat with herring as bycatch increased. Sprat and small herrings were used for fodder, e.g. fishmeal and fish oil, and industrial fishery accounted for the total increase of landings during the 90s. However this fodder fishery also decreased during early 2000s due to lower profitability. During this period discussions also arose concerning the presumed negative effect of this fodder fishery had on the fish

*Landfill area from dredging in Vistula Lagoon.
Source: Iwona Psuty*



stocks as well as whether it was morally and environmentally justifiable to use fish as fodder for animals. In recent years fisheries targeting herring have increased slightly because of a higher evaluation and a slight increase of larger herrings. This fishery is mainly using pelagic trawlers (Fisket på Sydkusten. 2002).

Year	Total thousand tonnes	Herring for human consumption	Total fodder fish	Of which is sprat (herring as a bycatch) from the Baltic Sea
1990	240	87	89	8
1991	230	96	73	9
1992	300	94	170	54
1993	340	65	230	93
1994	380	53	270	140
1995	400	56	290	140
1996	360	58	250	160
1997	350	45	250	150
1998	400	36	320	190
1999	330	46	240	140
2000	330	56	230	120
2001 (prel)	300	68	180	

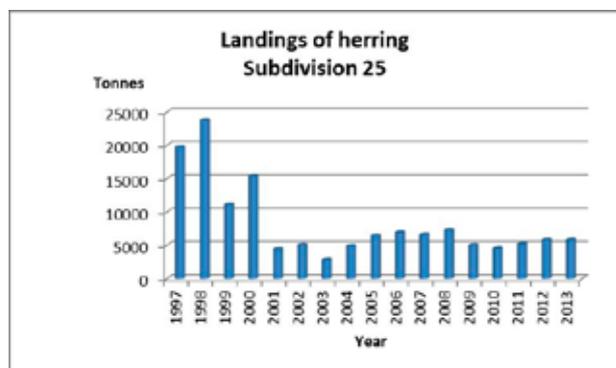
Development of herring fishery for human consumption and fodder fishery 1990-2001. Source: Lindquist et al. 2004

The Hanö Bight is situated in subdivision 25, within the herring population identified by ICES as the Central Baltic herring population (including subdivisions 25-29 + 32 excluding the Gulf of Riga). The landings of herring decreased significantly in 2001 and 2004, but have increased slightly from 2005 and forward.

At the present most landings of herring and sprat from the Baltic are still used in the fodder industry. The small-sized herrings have lower value and are a central problem for the fisheries in south Sweden making the herring hard to sell for human consumption.

The economically important fish species in the central Baltic which includes the Hanö Bight are in addition to herring also cod, sprat, plaice and salmon. Total Allowable Catch (TAC) for these fish species is determined annually by the EU Council for Agriculture and Fisheries.

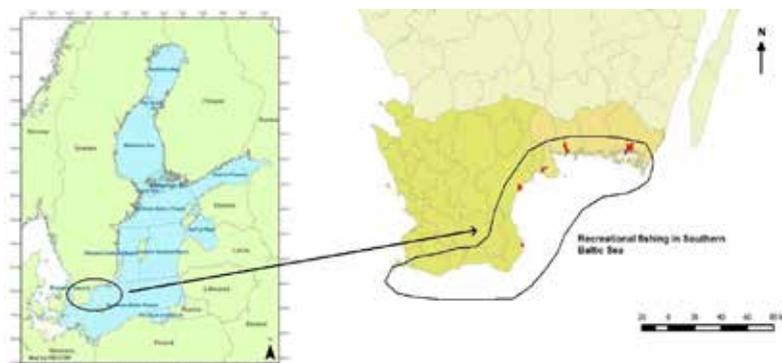
Recreational fishing is one of the most popular leisure activities in Sweden. Recreational fishing refers partly to anglers (e.g. rod or line passed from hand), and partly subsistence fishery that mainly uses gillnet, trap/cage and similar fishing gear. This separation in recreational fishing aims to show the purpose of fishing activity rather than what effect it has on the fish stock. In a management perspective the Fisheries Regulation generally controls the amount of fishing gear (e.g. gillnets, trap/cages and other fishing gears able to catch larger amounts of fish) for recreational fishing that is allowed in public waters. These regulations have



Landings of herring from 1997 to 2013 in ICES subdivision 25 in the Baltic Sea. Includes Hanö Bight. Source: Swedish Agency for Marine and Water Management, pers.comm. 2014

Species	ICES subdivisions	Swedish quota (tons) 2013	Swedish quota (tons) 2014
Herring	25-27, 28-2, 29, 32	37701	37703
Sprat	22-32	46699	45763
Cod	25-32	15345	15331
Plaice Scholle	25-32	181	184
Salmon	22-31	29857 piece	29856 piece

Total Allowable Catch (TAC) determined by the EU Council for Agriculture and Fisheries for 2014



Area part of the Southern Baltic Sea, included in a recreational fishery study conducted 2002-2007. Source: Thörnqvist et al. 2009

arisen to protect fish stock from being over exploited (Thörnqist et al. 2009). There is a general lack of knowledge about the impact recreational fishing has on fish stocks. To gain more awareness various sub-studies were carried out in 2002–2007 by the former National Board of Fisheries (currently Swedish Agency for Marine and Water Management) (Thörnqist et al. 2009). By conducting interviews nationally the studies aimed to get an overview of the various aspects of recreational fishing in Sweden. In this study the Hanö Bight is included in the subdivision called Southern Baltic Sea, an area from Falsterbonäset in southwest of Skåne to Cape Torhamn in northern Blekinge.

Compared to other subdivisions in Sweden the study showed that the Southern Baltic Sea had the lowest share of recreational fisheries. In 2006 the most dominant fishing gear was angling gear (e.g. rod, line and other gear passed from hand) both in terms of the number of practitioners and in terms of the number of days spent fishing. As in the rest of the Baltic Sea the fishery utilising gear catching larger quantities (e.g. gillnets trap/cages and other) was significantly more common than on the Swedish west coast. The catch targeted with angling gear (e.g. rod or line passed from hand) was predominantly perch and cod, which together stood for half of the total catch. Pike fishing is concentrated to Blekinge where for example the archipelago outside Karlskrona is known for its good pike fishing. Fishing for cod is concentrated in the southern part of the area and in both Ystad and Trelleborg there have been tour boats operations specialising in cod fishing (Thörnqist et al. 2009).



Pike fishing is popular among anglers in Blekinge archipelago. Source: Jenny Hertzman

Fish species	Angling gear (e.g. rod or line and other, passed from hand)		Larger quantity catching gear (e.g. gillnets trap/cages and other)		Amount (%) of catch and release of total catch
	Retained catch (tons)	Catch per practitioner (Kg)	Retained catch (Tons)	Catch per practitioner (Kg)	
Pike	164	3,3	162	6,5	42
Eel	1	<0,02	150	6	4
Cod	101	2	21	0,8	14
Perch	39	0,8	50	2	16
Flatfish	35	0,7	55	2,1	21
Trout	31	0,6	3	0,1	49
Herring	45	0,9	18	0,7	1
Salmon	20	0,4	7	0,3	27
Other fish	21	0,4	69	2,7	37
Total	156	9,1	535	21,5	28

Catch statistics of recreational fishery in Southern Baltic Sea. Source: National Board of Fisheries/SCB 2006

The Swedish Agency for Marine and Water Management has an overall responsibility for managing fish stock in a sustainable way. It also includes the public interest of recreational fishing. The administrative goal is also to promote activities involving recreational fishing.

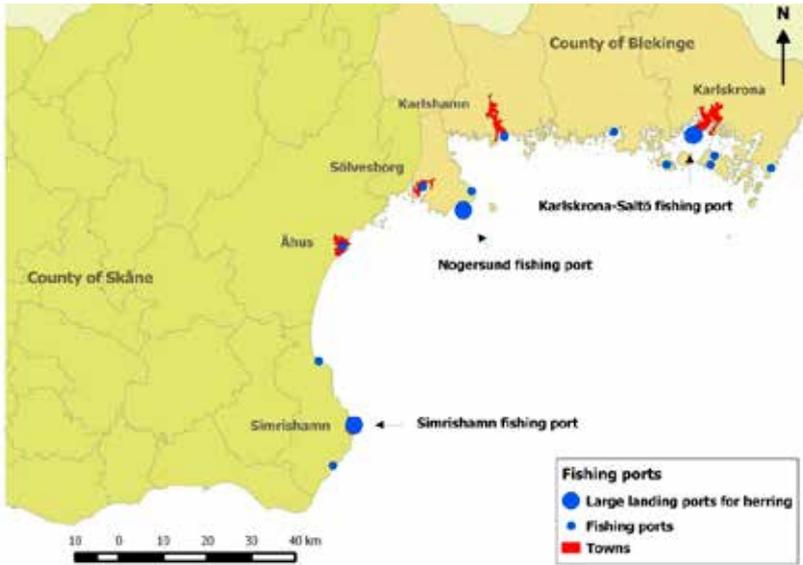
Marine transport - marinas, fishing harbours, industrial ports and waterways

The counties of Skåne and Blekinge have a relatively large number of fishing ports. According to 2001 statistics of Swedish Board of Fisheries, there are 35 harbours along the coast of the Hanö Bight of which 14 are fishing ports. There are probably several other harbours used as fishing ports but these are not included in the statistics, since fisheries with vessels below 10 m in length are not obligated to specify in their monthly records the name of the port where fish are landed.

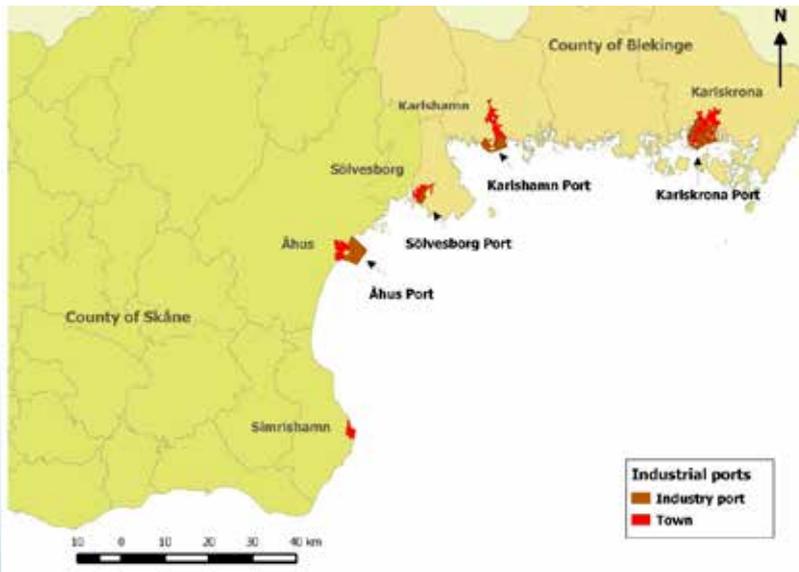
Three fishing ports, Simrishamn, Nogersund and Karlskrona are major herring landing sites. In 2013 the port of Simrishamn in Skåne County landed in 2649 tonnes of herring. In Blekinge County the fishing port of Nogersund landed 1657 tonnes and the port of Karlskrona landed 631 tonnes (Swedish Agency for Marine and Water Management, pers. comm. 2014).

There are four major industrial ports located in the Hanö Bight, Åhus in the county of Skåne and Sölvesborg, Karlshamn and Karlskrona in the county of Blekinge.

The Port of Åhus is situated adjacent to the city of Åhus and an outlet of a branch of the Vegeå stream. It is one of the most important bulk-handling ports in the south of Sweden,



*Fishing ports in the Hanö Bight.
Source: Länsstyrelserna karttjänster (webbGIS)*



*Industrial ports in the Hanö Bight
Source: Länsstyrelserna karttjänster (webbGIS)*

with bulk cargoes accounting for about 60% of the total cargo volume. Åhus is also the largest container-port in southeast Sweden (<http://www.ahushamn.se/>).

The Port of Sölvesborg is situated adjacent to the city of Sölvesborg in the south of the County of Blekinge. It is mainly a bulk-handling port and most products are related to the forestry and paper industries (<http://sbgport.com/>).

The largest port in southeast Sweden is the port of Karlshamn. Most of the vessels permitted to enter the Baltic Sea can call Karlshamn as HandySize and small Panamax for dry goods and tankers up to about 100,000 dwt. The Port has the capacity to handle all types of cargo and all size of vessels (<http://www.karlshamnshamn.se/>).

The industrial port of Karlskrona is situated on the island of Verkö outside the city of Karlskrona and has the capacity to handle all types of cargo. There is a 240 m ro-ro berth, two industrial quays each 70 m long and direct links to road and rail networks. The industrial port is located adjacent to a ferry port owned by Stena Line AB and the municipality of Karlskrona. These ferries carrying passenger and cars sail to Gdynia in Poland twice a day. Karlskrona has a history of naval activity and besides the active marine base in the vicinity, with education, training and surveillance activity, there is an old naval port from the late 17th centu-



*The harbour in Simrishamn, looking north
with a view of Hanö Bight.
Source: Naomi Images*

The Port of Åhus.
Source: Naomi Images

Industrial ports	Capacity for maximum vessel size (length * with * depth)
Åhus	135 m * 18 m * 7,1 m
Sölvesborg	160 m * 23 m * 8,2 m
Karlshamn	180 m * 32 m * 10 m
Karlskrona	240 m * 32 m * 9 m

Industrial ports and their capacity in the Hanö Bight

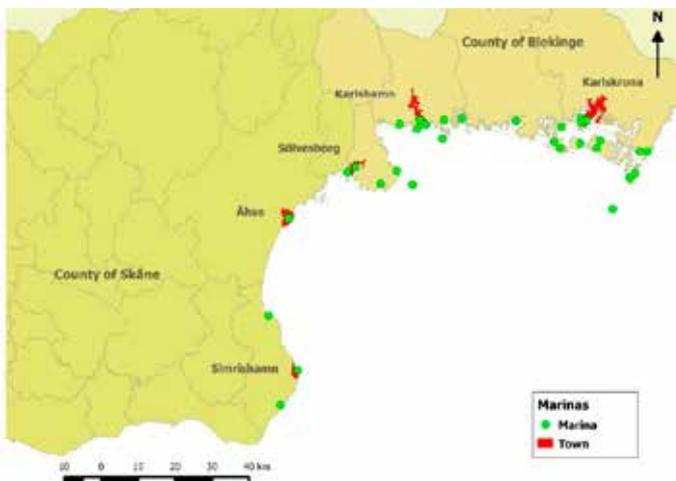


Figure 7 *Marinas along the coast of Hanö Bight*
Source: Länsstyrelserna karttjänster (webbGIS)

ry. This historic port is very well preserved and was named as a World Heritage Site by UNESCO in 1998 (<http://www.karlskrona.se/sv/Arbete--Foretag/Foretagande/Infrastruktur/Karlskrona-Hamn>).

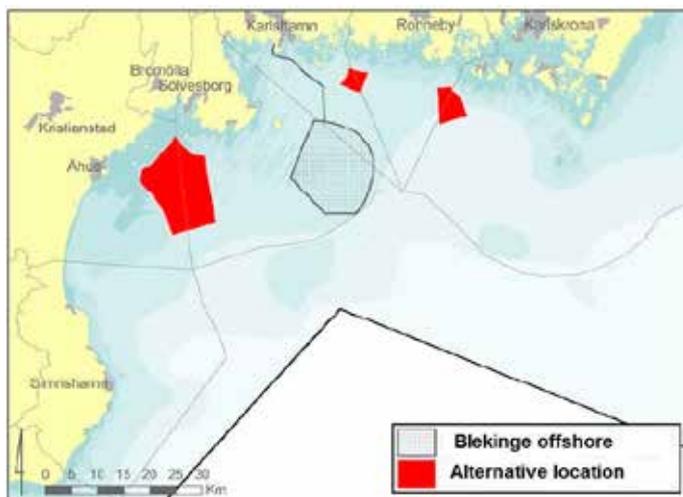
Sweden is a country with a strong boating culture and there are almost one million recreational boats in use. The most common boat types are the small open motorboats. In Skåne County along the coast of the Hanö Bight the numbers of marinas are relatively few. The four largest marinas have about 400 moorings. Along the coast of Blekinge the number of marinas increases significantly and 26 of the largest harbours, shown in **figure 7**, provide about 2820 moorings.



A marina in Blekinge County.
Source: Lilitha Pongolini

Energy supply, dredging and other human activities

There is a national objective to develop technology that reduces or replaces fossil fuels. Renewable energy like wind, solar and hydropower reduce the emission of greenhouse gases. An area in the Hanö Bight is highlighted as being of national interest for an offshore wind farm. The plan is to build a wind farm outside the municipalities Karlshamn and Sölvesborg. Blekinge Offshore is the company responsible for the assessment and planning of the wind farm. The area suitable for the project covers an area of 200 km² and is situated about 5 km east of the island of Hanö. About 350 or 700 wind turbines with the effect of about 1000 MW or 2500 MW respectively and the distance to the electrical infrastructure on land is about 15 km. The wind farm would cover an area with a depth of 10 m to 40 m. An environmental impact assessment of the wind farm project looking at what effect it would have on spawning fish was conducted 2009. The survey showed that herring spawned in the shallower part of the wind farm area but not to a great extent. To an extent the area was assumed to be passed by herring on their way to shallower parts of the coast to spawn (Wikström et al. 2010; <http://blekingeoffshore.se/>). The Land and Environment Court give their approval to Blekinge Offshore to continue with the wind farm project. The case has now been submitted to the Government for a final decision.



Planned area for the Blekinge Offshore wind farm in the Hanö Bight. . Source: Wikström et al. 2010.

Most dredging projects in the Hanö Bight are conducted in association with harbours. At industrial ports, fishing ports and marinas it is performed as part of continuous maintenance activities like dredging of the harbour basins and harbour channels to secure suitable depths for vessels. In general all dredging activities require authorisation from or notification to the authorities i.e. the County Administrative Boards and Swedish Agency for Marine and Water Management according the Environmental Act. The dumping of dredged material at sea is regarded as waste dumping, and always requires dispensation from the current ban. If an application for dredging is approved or rejected depends on factors like how ecologically sensitive the area for the planned dredging and dumping is, the toxicity of the sediment, the amount of the dredging material extracted and how well suited the dumping site is to retain the dredged material. If an application for dredging and dumping at sea is rejected by the authorities and an appeal is subsequently lodged by the company, the decision goes to the Environmental Court. Although information regarding dumping sites at sea is not easy accessible, there are three areas identified in the Hanö Bight known to be used or have been used as dumping sites for dredge materials, shown in **figure 8** (County Administrative Board of Skåne and Blekinge. Pers.comm).

There are two paper mills in the vicinity to Hanö Bight. The Nymölla Mill is situated between the city of Åhus and Sölvesborg in Skåne County and the Södra Cell Mörrum paper mill is situated just south of the city of Karlshamn in Blekinge County, shown in **figure 8**.

Nymölla Mill started production in 1962 and employs about 700 people today. The production is about 325,000 tonnes of paper pulp ev-



The nymölla Mill in Skåne County. Source: Naomi Images

ery year. Nymölla Mill started to use a sludge plant for waste water in 1994. The residual water from the production is released, together with the residual water from the municipality of Sölvesborg treatment plant, through a pipe about 3 km into the Hanö Bight.

The Södra Cell Mörrum paper mill started production in 1962 and employs about 400 people today. It has a capacity of 435,000 tonnes a year and the consumption of raw material is about 2 million cubic metres of wood.

In 2002 Södra cell started to use a biological waste water treatment plant and freon-free cooling of the whole mill. Their waste water is released to the Hanö Bight through a 5 km long pipe.

Nymölla Mill and Södra Cell Mörrum have a control programme for monitoring the impact of the residual water. The monitoring of metals and organic halogenated substances complemented with analysis of how viviparous blenny (*Zoarces viviparus*) is affected of the emission started in 1998 by the Water Protection Association of the Hanö Bight in Skåne and Blekinge. The environmental impact from paper mills is well known and historically there have been several observations instigated by emissions, such as anoxia caused by degradation of fibres after being emitted during production, lesser Secchi depth, foaming of the water and the toxic effects of hormonal disorders (Munkittrick et al. 1997). The paper mill industry has taken extensive measures to diminish the harmful emissions, and the control monitor programme in the Hanö Bight shows no direct effect from the paper mills activity. Although there are few observations from the fish monitoring programme that may indicate a negative effect on fish physiology caused by exposure of the residual waters of Södra Cell Mörrum. The nutrient load and toxicity of the industrial residual water has decreased but effects of previous emissions may still affect the environment through for example disturbances of polluted sediments.

It is therefore important to follow the results from the monitoring analysis.

There are two fish farms situated near the shore in the Blekinge archipelago, between

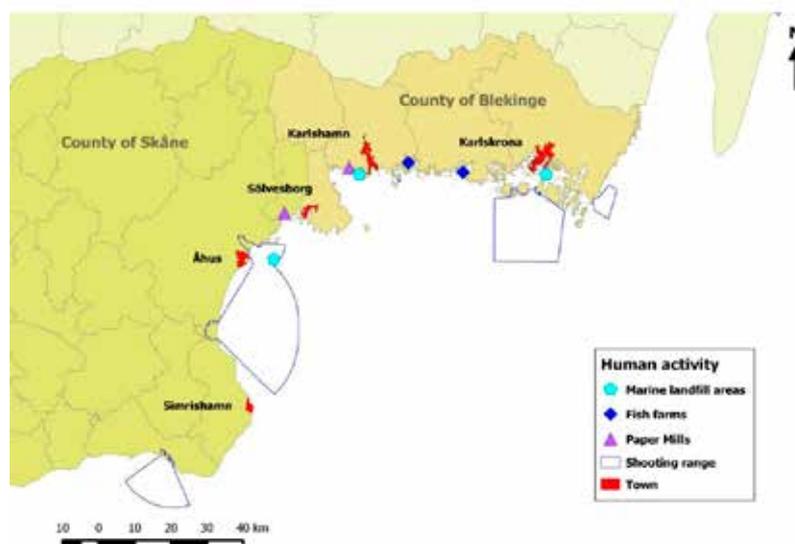


Figure 8 Human activities in the Hanö Bight. Dumping sites of dredge material, paper mills, military shooting range and fish farms. Source: Länsstyrelserna karttjänster (webbGIS); pers comm.

Karlshamn and Sölvesborg, shown in figure 8. Rainbow trout is reared in these fish farms to be sold to the food industry. The consumption of fish fodder is more than 40 tonnes annually.

There are offshore military shooting ranges in both Skåne and Blekinge County, shown in figure 8. In Skåne the Ravlunda and Rinkaby shooting range reach out in the central part of the Hanö Bight. In Blekinge the Harö shooting range is limited to the island of Harö just outside Karlshamn, a shooting range outside Karlskrona consist of several islands and skerries and the Torhamn shooting range is situated in the northeast Blekinge. In an Investigation Report about the environmental load on the Hanö Bight conducted by Swedish Agency for Marine and Water Management, there was an assessment of the environmental impact of the military shooting range. According to surveys in the affected military areas documented in a report of SWECO, a consulting firm in sustainable engineering and design, the levels of lead and copper in the streams and near shore sediments are under the concentration that would affect organisms living in the sediment. Although two areas in the sea were identified as highly contaminated and the SWECO report indicated that there may be about 400 tonnes of lead on the seabed from Ravlunda and Rinkaby military shooting range (SWEKO. 2008; 2009). A survey just north of the shooting range showed that mussels contained

a significantly higher level of lead (Ljungman et al. 2012). This indicates that further surveys in the area of the military shooting range are necessary to assess the impact on the environment.

Bordering land use and tourism

Simrishamn is the southernmost municipality bordering the Hanö Bight. The landscape is dominated by plains in the south with intensive agricultural activity. Further north there is a transition in the landscape to hills with forest and meadows. The coast varies from rocky shores to sandy beaches.

The population of the municipality of Simrishamn is about 19,000 of whom 6000 live in the main town of Simrishamn.

There are 3000 registered businesses in the municipality of Simrishamn municipality and the business community is characterised by variety with no dominant company constellations. The largest industries are agriculture, hunting, forestry together with business services and trade.

Tourism and fruit orchards are examples of successful business as well as culture and fishery.

Due to the municipal ventures Simrishamn has a large percentage of new businesses, women entrepreneurs and growth enterprises. The Marine Centre in Simrishamn is an example of a business activity that aims to create a meeting point for entrepreneurship, research and marine environmental management.

There are many outdoor activities in Simrishamn like horseback riding, golf, hiking and riding bikes along trails and guided nature walks. There are also several cultural places of interest like gardens, museums, arts and galleries, churches and heritage sites. As the main town Simrishamn is a large landing port for herring, every last Saturday in August there is a local event arranged called the Day of the Herring. On this day different activities in the harbour area take place related to herring, fishery and the city of Simrishamn (<http://www.simrishamn.se/>).

The municipality of Kristianstad is situated north of Simrishamn and has a variable landscape. The topography changes from being hillier and is characterised by forests in western areas to more cultivated landscape and lowlands towards the eastern borders on the Hanö Bight. The river Helgeå has its catchment area in the south and the municipality is known for its lakes and wetlands with associated flora and fauna and not least the rich birdlife. The population of the municipality of Kristianstad is about 81,000 of whom 30,000 live in the main town of Kristianstad. Åhus, the second largest town in the municipality, has a population of about 10,000 and is on the coast of the Hanö Bight.

The apple orchard in Kivik in Simrishamn municipality.
Source: Naomi Images



The municipality of Kristianstad is an economically strong and expanding part of the region. There are about 8000 companies where manufacturing is the largest industry employing about 30 % of the population with food industry dominating. Being the commercial centre of northeast Skåne means that the service sector employs more than half of the population of Kristianstad.

For tourists there are several guided tours within natural scenery, animal and bird watching and recreation. There are canoes and kayaks for hire as well as several hiking and bike trails. Recreational fishing and golfing are among other popular activities (<http://www.kristianstad.se/sv/Kristianstads-kommun/>).

Bromölla is the most northerly municipality in Skåne County on the Hanö Bight. In the northern part there are mountains with boulder rich moraine and beach forests. Further down the valleys cultivated landscape spreads out and in the southern part, bordering the lime rich plains of Kristianstad there is pastureland with flora and fauna dependent on the continuing grazing of animals. Bromölla shares the lake system with the municipality of Kristiansand and the Skråbeån stream has its outlet in the east. The coast with its small archipelago is a popular area for breeding, resting and overwintering birds.

In Bromölla there are 900 registered businesses. About 30% of the employment in the municipality is within the manufacturing sector. The largest industries in Bromölla are the Nymölla paper mill, Ifö Sanitär an interior design company for bathrooms, IT Company CGI and Ifö Ceramics among others.

Activities for tourists in Bromölla include boat trips on the Ivö Lake, canoe and kayaking, bike and hiking trails and recreational fishing among other things (<http://www.bromolla.se/>).

Sölvesborg is the southernmost municipality in Blekinge County on the Hanö Bight. Its landscape is similar to Bromölla with the same mountain complex in the northwest with large beach forests. To the east between the mountains and the coast there are plains with agricultural and pastoral landscape.

There are about 1500 registered companies in the municipality of Sölvesborg. Among the larger companies are Titanx Engine Cooling AB, a die casting company Blekinge Pressgjuteri AB and C.T. Cell Tech Energy System AB.

The municipality is involved in a project of building an offshore wind farm in the Hanö Bight. The cooperation with the Blekinge Off-



Recreational fishing is a common activity among tourists and locals. Source: Robert Ekholm

shore will generate about 1000 temporary job opportunities and several hundred new permanent jobs within maintenance.

Among activities for visitors in the municipality of Karlshamn are golfing, boat trips to the island of Hanö, bike and hiking trails, recreational fishing, art galleries and museums (<http://www.solvesborg.se/>).

The municipality of Karlshamn has a large area of forests in the northern part with scattered lakes. Large areas are used for forestry management and forest conservation. Several streams issue into the Hanö Bight, various lakes and the archipelago make the municipality of Karlshamn a popular area for recreational fishing.

There are about 2800 registered businesses in the municipality of Karlshamn and the most common industries are farming, forestry and fishing followed by trading and activities in law, economics and science.

Among the various activities in Karlshamn are sailing, speedboat tours and golf. The recreational fishing activities are many and the largest stream Mörrumsån is famous for its salmon and trout fishing (<http://www.karlshamn.se/>).

The municipality of Ronneby like Karlshamn has large areas of forests, mostly in the northern part. The forests are variable with both deciduous and coniferous trees with lakes scattered throughout the landscape. The agricultural areas are concentrated along the larger streams Bräkneån and Ronnebyån that issue into the Hanö Bight. The whole coastline is characterised by islets and skerries forming the archipelago. The population in the municipality is about 27,800 of whom about 12,000 live in the main town Ronneby. Ronneby is the oldest town in the county of Blekinge and belonged for a long time to Denmark before becoming Swedish in 1658.

Historically Ronneby was for long periods an important centre for trade and later developed into an important cultural and industrial town.

The manufacturing sector is significant in Ronneby and among the 2300 businesses one can mention the electronics manufacturers Orbit One, Flextronics and Nordic Industries and Technology. There are also the water jet cutting companies Water Jet Sweden, Swede Matic and KMT and the flooring companies Tarkett, Berg & Berg and the timber company Southern Interior. Good communications with 220,000 using Ronneby Airport each year and



Long distance ice skating along the coast of Blekinge is popular during cold winters. Source: Robert Ekholm

The teams competing on the river Ronneby å during the “Sillarodden”.

Source: Robert Ekholm



the vicinity to the European route E22 are key factors for businesses and tourism.

The archipelago, streams and lakes provide the opportunity for various activities for tourists in Ronneby including sailing, canoeing, kayaking and recreational fishing. There are also good opportunities for hiking and biking. Other tourist attractions available in the area include the Old Town in Ronneby with its historic buildings and parks. In memory of the importance of the local herring fishery each year there is an event organised, called “Sillarodden”, roughly translated to “The herring rowing”. The event takes place in June in the city of Ronneby where a number of voluntary teams fill up their traditional wooden boats with herring from the harbour. These teams are then competing who rows the fastest 3 km up for the Ronneby å and gets their herring sold the quickest to the public (<http://www.ronneby.se/sv/ronneby-kommun/visitronneby/evenemangslista/sillarodden/>).

Karlskrona is the northernmost municipality in Blekinge County having large areas of forest with lakes and scattered smaller cultivated areas. Larger farms are concentrated in the southern part. The archipelago with various sizes of islets and skerries off the coast of Karlskrona



Herring is carried to the public to be sold during the “Sillarodden”. Source: Robert Ekholm

is the largest in Blekinge. The four largest islets are connected to mainland through bridges and roads. The population in the municipality of Karlskrona is about 3,500. The main town is Karlskrona with about 34,500 inhabitants. The town of Karlskrona was founded in 1680 and the Swedish Navy has had a base here for the last 300 years. The town is characterised by its maritime history, the constant presence of the archipelago and various naval activities; in 1998

Karlskrona was named as a World Heritage site by UNESCO.

Karlskrona has a diversified business community with 5152 registered companies. Among the largest employers are the municipality of Karlskrona, the armed forces, Blekinge County Council and Blekinge Institute of Technology.

Tourism continues to increase in Karlskrona. The most common travellers come from Poland, Germany and Denmark. The Stena Line ferry between the town of Karlskrona and Gdynia in Poland has departures twice every day and approximately 400,000 people are transported to Karlskrona on the ferry each year. Common activities offered in the Karlskrona archipelago are boat taxi to the various islets, customised sailing trips for private individuals or businesses, renting of various boats, canoes and kayaks and various fishing activity in the archipelago, lakes and streams. There are several museums and cultural sites as well as restaurants and farm shops (<http://www.karlskrona.se/>).

Protected areas

It is the County Administrative Boards or the Municipalities that have the authority to establish Nature reserves. After surveys and evaluations of the area, it is decided together with Swedish Environmental Protection Agency how the specific nature reserve is to be managed. There are six nature reserves associated to the Hanö Bight in Skåne County, one of which is also a national park, and 38 nature reserves in Blekinge County.

As part of the Natura 2000 network there are 13 areas designated as SAC (Special Areas of Conservation) and 2 areas to SPA (Special Protection Areas for birds) in the County of Skåne along the coast of the Hanö Bight. The larger areas are concentrated in the shallow, northern part of the Hanö Bight. In the Blekinge archipelago there are 51 areas designated as SAC and 16 areas designated as SPA.

In both Skåne and Blekinge there are areas designated as Biosphere reserves. The Biosphere reserves are described as areas combining nature conservation with human development. They are meant to be model areas where it is possible to test new knowledge and practical approaches to achieve sustainable relationship between man and nature, and between use and conservation. The Kristianstad Vattenrike Biosphere reserve was named as a World Heritage Site by UNESCO in 2005 and the Blekinge Archipelago Biosphere reserve in 2011. Nomination as biosphere reserves however does not by itself provide a protection in a legal sense or any further restrictions or additional demands on existing protected areas.

In association to certain protected natural areas there are established information centres called naturum. There are about 30 naturum in Sweden and their main purpose is to be an informational platform for the public. With exhibitions, lectures and organized excursions mainly concerning topics within natural science, ecosystems and conservation these centres are popular for educational institutions, the general public and tourists.



Naturum in Blekinge is an information centre connected to protected areas in Blekinge County.
Source: Robert Ekholm

*View over “Stenshovud”, a nature reserve and national park with its highest peak of 97 m.
Source: Naomi Images*



*Hiking trail in the beech woods of “Stenshovud”.
Source: Naomi Images*

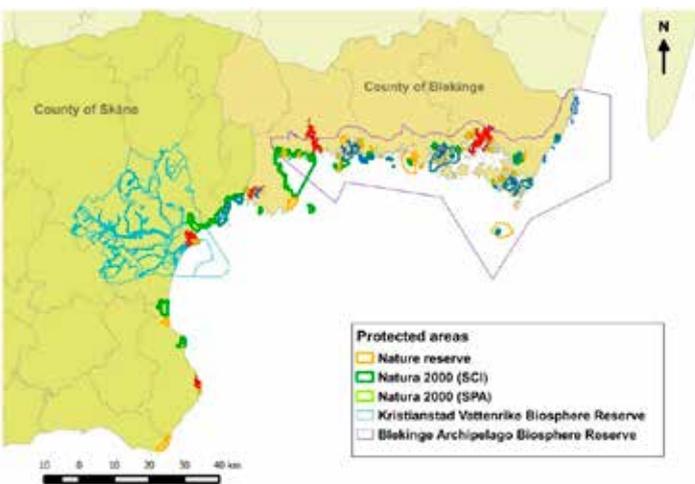
Ecosystem effects and future consequence

Fish stock and commercial fishery

In recent years, in the southern part of the Hanö Bight, there have been observations of a decrease in coastal fish abundance and occasional worsening water quality. Observations, mostly of cod, show smaller individuals, signs of starvation, open wounds and disease.

The County Administrative Board of Skåne and the Swedish Agency for Marine and Water Management carried out an investigation and have examined the problem based on four issues – environmentally hazardous substances, water quality, fish and fisheries, and ecosystem effects. Several plausible sources have been investigated, but no definite cause has so far been found. Further investigations and proposals for action will be made.

As combination of several stressors may have cascade effects at different trophic levels, specific reasons for unhealthy fish stock are hard to define. There have not been any reports of observations of herring that are in bad condition in the Hanö Bight although fishermen have reported that in recent years herring within the coastal area have decreased substantially as well as the quantity of spawning herring



*Protected areas in the Hanö Bight.
Source: Länsstyrelserna karttjänster (webbGIS)*

(Wagnström, 2012). The mean weights-at-age of the economically important cod, herring and sprat have all decreased in the Baltic Sea (ICES, 2013) indicating that these fish stocks are not in a good condition. There is an ecological interaction between these species as cod is the dominant predator of herring and sprat, herring and sprat are in competition with each other and may also affect cod recruitment by predation on cod eggs and larvae. Pressure from fisheries may, with other human induced stressors like eutrophication, toxic emissions and climate change, be imposing an imbalance in the ecosystem that lower the resilience of fish populations. Although the pressures from fisheries on cod and herring have reduced, it is uncertain if and how the fish populations will recover.

Ports and marinas

As trading and transport by sea are very extensive and are presumed to increase, most industrial ports in the Hanö Bight will expand in the future. With the increasing traffic of cargo ships, ferries and recreational boating there may be an increase of emission of fertilisers and toxic substances, disturbance from propellers suspending sediment, swell from the ships as well as noise pollution. If and how these stressors affect the spawning areas and actual spawning of herring is not fully understood.

Dredging and dumping sites at sea

When maintenance, developing and expansion projects are planned for harbours along the coast of the Hanö Bight this often involves dredging. Dumping of dredged material at sea is regarded as waste dumping, and permission is always required from the authorities giving specific requirements depending on the toxicity of the sediment, the amount of the dredging material extracted including the ecological sensitivity, and the quality of the dumping site. One of the negative disturbances from dumping dredge materials at these sites is the purely physical where large amounts of sediments are laid over the seabed whose benthic organisms will have difficulty in surviving due to suffocation. The toxicity of the dredged material is another issue. The sediments in ports and marinas are contaminated with toxic substances from antifouling paints, sewage and other discharges. Although there are specific limits on how much toxic substance such as tributyltin (TBT) and heavy metals sediment may contain in order to be dumped at sea, the toxic substances are present and may affect the benthic and pelagic ecosystems negatively. It has been shown that very small amounts of TBT can cause damage to marine organisms. Sweden has no national guidelines on concentration levels of TBT in sediments and instead follows the guidelines of

*Sailing in the archipelago.
Source: Lilitha Pongolini*



Finland when it comes to legal decisions in the Baltic region. The limits of TBT in sediments are thereby set to not exceed 200 µg/Kg TS (Naturvårdsverket, 2009). If dumping sites for dredge materials from harbours are located in spawning areas for herring it would most likely have a negative impact on the survival of egg and larvae. Since many toxins like TBT are persistent the negative impact on spawning may also persevere in the future.

Offshore wind farm

How the planned offshore wind farm outside the municipalities of Karlshamn and Sölvesborg would impact herring spawning grounds has been considered in the environmental impact assessment made in 2009. The survey showed that herring spawned on the shallower part of the wind farm area but not to a great extent. The planned windfarm area was also assumed to be passed by herring on their way to areas closer to the coast to spawn. Although the conclusion of the assessment was that the offshore wind farm would have little impact on the herring spawning grounds it was pointed out that the survey was conducted in a short period of time during the spawning season in 2009. Extended surveys, of the herring spawning grounds in the planned wind farm area, which stretch over several years would be preferable and give more accurate information about how the construction will impact the spawning grounds. It can be concluded that during the construction of the wind farm, major disturbance will be imposed on the seabed. It is of importance to follow up how great the impact is in terms of physical disturbance, increased turbidity and release of toxic substances that may have been stored in the sediment.

Paper mill

The Nymölla Mill, situated between the city of Åhus and Sölvesborg, has its wastewater passed through a sewage pipe that discharges into the sea. Nymölla Mill has submitted an application to The County Administrative Board of Skåne to replace this pipe as it is getting old and there is an increased risk of the pipe leaking.

The change to a new sewage pipe would mean that a 280 m long and 3 m deep channel would have to be dredged from the shore and in the same direction as the old pipe. The new pipe would be placed in the dredged channel with

a sloping angle to the sea and reach about 3 km out into the Hanö Bight. A study has been commissioned by Nymölla Mill on the concentrations of toxic substances found in surface sediment at two sites near the shore. The investigation revealed no values above the permitted limits.

One question that arises is whether this survey is representative and if there is contaminated sediments deeper and farther out along with the old pipe. The question is also whether to let the old pipe remain or remove it and run the risk of releasing toxic substances into the environment.

The application from Nymölla has been rejected as the dredging would occur in a Natura 2000 site and the consequence of an exchange of the drainage pipe has not been sufficiently investigated. The application is now at governmental level for further decisions (County Administrative Board of Skåne, pers.comm). According to the compiled interview study from 2011 (Gunnartz et al. 2011) the area in question is a spawning ground for herring. The replacement of the sewage pipe would have a negative impact on the spawning success due to the physical disturbance of the seabed and resuspension of particles. There is also a risk that toxic pollutants from previous emission would be released and have a negative effect in the future.

Tourism

Tourism around the Hanö Bight area can be expected to increase. Sailing, use of motor boats, surfing and recreational fishing are examples of activities especially common in the northern part of Skåne and the Blekinge Archipelago. There may be some increase of physical disturbance, such as of sea bed sediments as well as noise pollution, although it is not assumed to be substantial. No research addressing these stressors has been conducted. How extensive the recreational fishing targeting herring is in the study area is not well known and quantification of the fishing activity is needed. The discharge of nutrient and toxic substances from sewers, marinas and boating activities may also rise with increasing tourism.



*Boats of Regional Maritime Fisheries Inspectorate in Frombork harbor
Source: Iwona Psuty*

GOVERNANCE STRUCTURE

Introduction

The governance structure pertaining to the protection of herring spawning areas vary between the three different case study areas and is in this chapter explained in more detail. The chapter focuses in particular on five selected subjects: fisheries, nature conservation, spatial planning, resources extraction, and shipping.

Institutional framework for fisheries

Germany

The State Fishery Law and the Coastal Fisheries Law

The state fishery law (Landesfischereigesetz, LFischG M-V) was passed in 2006 and constitutes the legal basis for the Coastal Fisheries Law (Küstenfischereiverordnung, KüFVO M-V) that is now under revision. The latter provides the legal regulations for the coastal fisheries in Mecklenburg-Western Pomerania (M-V). It is applicable in the German coastal territorial sea (from the water baseline up to 12 nm). There are clear regulations determined regarding species and gear restrictions, minimum landing sizes as well as closed seasons and areas (LUMV 2006 §3 - §5). Additional there are spawning areas designated where fishing activ-

ity is banned between 1 April and 31 May each year in order to ensure the smooth spawning activity of different vulnerable fish species. This regulation is obviously adopted only for pike and pikeperch, but is not suitable for protecting herring stock recruitment as spawning time has already started much earlier and major identified herring spawning areas are not even mentioned.

There is a fishing ban exclusively for threatened fish species that are particularly protected through the EU's FFH Directive (LUMV 2006 §3).

*Fisher boat and smoking house in Wiek
Source: Hivert, C*





*Fishery houses and eel nets near Freest
Source: Leonard G*

Political Level	Administrative bodies	Laws and formal competencies
EU-Level and Common Fishery Policy	Directorate-General for Maritime Affairs (DG MARE)	Integrated Maritime Policy
Federal government of Germany	Federal Ministry of Food and Agriculture (BMEL)	
	Federal Institute of Agriculture and Nutrition	
State/ Land	State Ministry of Agriculture, Nature Conservation and Consumer Protection [Highest regional fishing authority]	State Fishery Law
	State Research Institute for Fishery	
	State Office for Agriculture, Food Safety and Fishery [High fishing authority]	Coastal Fishery Law
Region	Fisheries supervisory authority	Freshwater Fishing Law
Community level	Elected head of the administration of the Landkreis (Landrat/Landrätin) and community mayors [Lower nature conservation authority]	Fishing Licence Law

Fishing authorities at different political levels in Mecklenburg-Western Pomerania/ Germany



Fishermen in Lauterbach-Ruegen. Source: Stefanie Maack

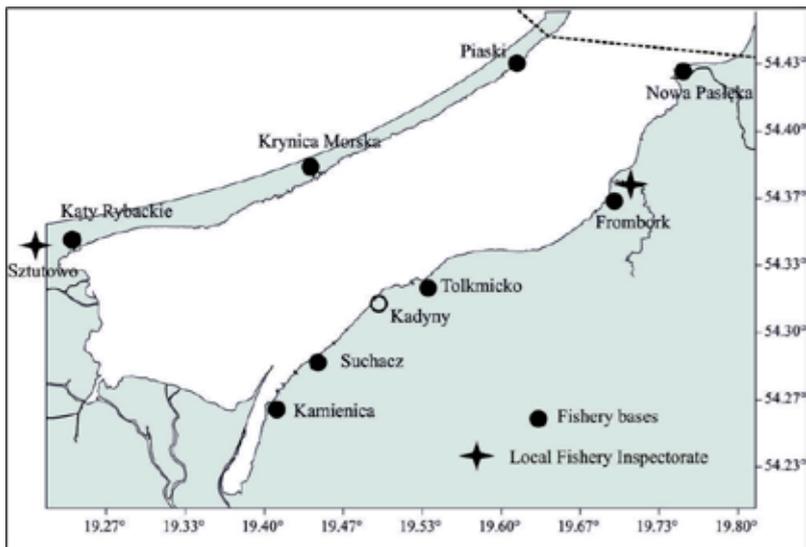
Poland

Fisheries management in Poland is the responsibility of the Department of Fisheries of the Ministry of Agriculture and Rural Development. The Department of Fisheries directly supervises the work of three Regional Maritime Fisheries Inspectorates in Gdynia, Słupsk and Szczecin. They cover the entire Polish coast. The Vistula Lagoon is under the jurisdiction of the Regional Maritime Fisheries Inspectorate in Gdynia.

The Regional Maritime Fisheries Inspectorate, RMFI, in Gdynia is the non-integrated government administrative body subordinate directly to the minister responsible for fisheries who appoints it. The responsibilities of the Regional Inspector are set forth in the law of 19 February 2004 on fisheries, Ch. 3, Art. 50-62 (Journal of Laws of 2004 no. 62 item 574), which authorises the Inspector to issue independent decisions and regulations. A second important document authorising the actions of inspectors is the law of 21 November 2008 on civil service, Ch. 7,

Art. 85-105 (Journal of Laws of 2008 no. 227 item 1505), which specifies the principles for access to the civil service, and the principles of its organisational structure, functioning, and development.

The organisational structure of the RMFI in Gdynia comprises the Regional Inspector and the Deputy Regional Inspector who are responsible for managing two divisions – the Fisheries Inspectorate Division and the Marine Fisheries Division. The first division is responsible for, among other things, supervising and monitoring fishing vessels in the Polish exclusive economic zone and in coastal waters and supporting field offices in their monitoring activities in ports and fishing harbours. The responsibility of the second division is to supervise fishing in coastal waters, internal marine waters, and the Vistula Lagoon. This division has five field units, with two administering the Vistula Lagoon from Frombork and Sztutowo; the other three units are in Władysławowo, Hel, and Gdynia.



Location of fishery bases on the Polish part of Vistula Lagoon

The inspectors are responsible for supervising the implementation of the fisheries, enforcing regulations among commercial and recreational fishers, supervising stocking programmes, combating poaching, supervising research catches and other forms of exploitation and management. Additionally, they are responsible for documenting fishing vessel scrapping, conducting the collection and preliminary verification of fishing logs that are delivered to the Fisheries Monitoring Centre in Gdynia, and supervising the activities of bodies purchasing, transporting, and processing marine organisms. The official adviser to the RMFI in Gdynia is the National Marine Fisheries Research Institute.

The classification of the Vistula Lagoon as internal Polish marine waters means that the conditions for fishing in this basin are under the jurisdiction of the regulations in the Law on Fisheries of 19 February 2004, (Journal of Laws no. 62 item 574). According to this law, fishing vessels which have fishing licenses and special fishing permits are allowed to fish in this region. Special fishing permits are issued by the Regional Maritime Fisheries Inspectorate in Gdynia, and they are valid for one calendar year. Vessel captains who wish to fish in subsequent years must apply for special fishing permits by 31 October of the preceding year. Each special fishing permit stipulates the permanent number of gears that can be used, e.g., 24 sets of fishing gear. A set can comprise gear with a maximum length of 120 metres regardless of whether it is a fyke net or a gillnet. The maximum permissible number of gears in the Polish part of the Vistula Lagoon was designated at the beginning of 2009 at 1,680 sets. The lateral distance between sets of fishing gear must be no less than 120 m (between two sets of fyke nets placed in one line), while the frontal distance between two sets of fyke nets cannot be less than 300 m.

Fishing vessel owners in the Vistula Lagoon are physical persons conducting individually-owned businesses. Many vessels are the property of two people; this is because of changes in the way fisheries are conducted in the Vistula



Fishery base in Katy Rybackie
Source: Adam M. Lejk

Political level	Administrative bodies	Laws and formal competencies
EU tier	Directorate-General for Maritime Affairs (DG MARE)	Common Fishery Policy Integrated Maritime Policy
Transnational	Polish-Russian Joint Commission	Agreement of 5 July 1995 – agreement between the governments of the Republic of Poland and the Russian Federation on mutual relations and cooperation in fisheries management
National	Sejm and Senate	Law on Fisheries of 19 February 2004 (Journal of Laws no. 62, item 574) Law of 5 December 2008 on the organization of the fish market (Journal of Laws no. 34, item 168) Law of 3 April 2009 on supporting sustainable development in the fisheries sector with funding from the European Fisheries Fund (Journal of Laws no. 72, item 619)
Governmental	Department of Fisheries of the Ministry of Agriculture and Rural Development	Regulation of the Minister of Agriculture and Rural Development of 24 September 2004 on headquarters and field jurisdiction for regional marine fisheries inspectors (Journal of Laws no. 223, item 2267) Regulation of the Minister of Agriculture and Rural Development of 21 April 2005 on monetary penalties for violations of fisheries regulations (Journal of Laws no. 76, item 671 of 2 May 2005 with amendments) Regulation of the Minister of Agriculture and Rural Development of 16 July 2002 on specific conditions for practicing marine fisheries (Journal of Laws no. 121, item 1038) Regulation of the Minister of Agriculture and Rural Development of 27 April 2010 on changing regulations regarding minimum sizes and closed seasons for marine organisms and specific conditions for conducting marine fisheries (Journal of Laws no. 71, item 460) Regulation of the Minister of Agriculture and Rural Development of 11 June 2010 on changing regulations on fishing and breeding, rearing, and catching other organisms inhabiting waters (Journal of Laws no. 104, item 654) Regulation of the Minister of Agriculture and Rural Development of 12 April 2011 on changing regulations on detailed modes and conditions for sport and recreational fishing and forms for sport fishing permits (Journal of Laws no. 87, item 490) Regulation of the Minister of Agriculture and Rural Development of 23 December 2011 on the mode and conditions for exploiting the total fisheries quota (Journal of Laws no. 282, item 1653)
Regional	Regional Maritime Fisheries Inspectorate in Gdynia	Decree no. 2 of the Regional Maritime Fisheries Inspector in Gdynia of 26 August 2004 on fisheries conservation, organization of fishing, and labeling fishing gear in the Vistula Lagoon (Journal of Laws of the Pomeranian Voivodeship no. 111, item 1965 with amendments) Annual Enactment of the Regional Maritime Fisheries Inspector in Gdynia on designating marine organisms included in overall fishing quotas in a given calendar year in the Vistula Lagoon and how this quota is divided

Fishery authorities at different political levels in relation to the Polish part of the Vistula Lagoon.

Lagoon that were implemented while adapting Polish regulations to the requirements of the European Union. In place of the previous limit on the number of fishers licensed to work in fisheries, the licenses and special fishing permits mentioned above which define the vessel owner and the person authorised to fish as opposed to a physical person working as a fisher were introduced in 2004. In conducting his or her business, every vessel employs the necessary crew and organises his or her own fish sales.

In 1995, the Directors of the Maritime Offices in Gdynia, Słupsk and in Szczecin introduced the requirement of submitting statements regarding the size of catches made. This was sanctioned by the Act of 18 January 1996 on marine fisheries (Journal of Laws of 1996 no. 34, item 145), and the Act of 19 February 2004 on fishery (Journal of Laws no. 62, item 574), which set forth detailed requirements regarding monthly catch reports, and since then these are forwarded to the Fisheries Monitoring Centre in Gdynia (FMC).

Sweden

As of July 2011 Sweden has a new national authority responsible for management of fisheries – Swedish Agency for Marine and Water Management (Swam). It operates under the ministry of Environment and succeeds the National Board of Fisheries which functioned under the ministry of Agriculture. Swam is responsible for the control of all fish that is caught, landed, imported, exported and transported in Sweden. At sea, fisheries control is the responsibility of the coast guard. On a regional level the County Administrative Boards (national representative in the county) works to re-establish and preserve healthy fish populations by supporting different types of projects and distributing national and EU funding. The County Administrative Boards also coordinate and conduct fish sampling in the county to monitor the development of fish populations. It is also the authority that is responsible for the regional development of leisure fisheries.

The national fisheries policies of the member states in the EU are subordinate to the common fisheries policy of the EU (CFP) and the member states are thereby obliged to follow the

Political level	Administrative bodies	Laws and formal competencies
EU-level	Directorate-General for Maritime Affairs (DG MARE)	Common Fishery Policy Integrated Maritime Policy
National	Swedish Agency for Marine and Water Management Coast Guard	- Fisheries law/Fiskelag 1993:787 - Ordinance on fishing aquaculture and commercial fisheries/Förordningen (1994:1716) om fisket, vattenbruket och fiskerinäringen - Law about EU ordinances on common fisheries policy/Lagen om EGs förordningar om gemensamma fiskeripolitiken 1994:1709 - Board of fisheries' regulations: FIFS 2004:25, 2004:36, and 2004:37
Regional	County Administrative Board	- Grants licences for introduction of fish and crayfish - Conduct sampling in the county

Authorities at different levels with responsibility for management of fisheries in Sweden.

Fishing harbor in Simrishamn





*Fishermen at Baskemölla
harbour north of
Simrishamn 1972.
Source: Stieg Eldh*

CFP. Member states may however adopt national regulations to complement and implement the CFP as long as they do not conflict with the CFP (SOU, 2010).

This transfer of legislative authority to the EU is in principle complete with respect to fishing in the Exclusive Economic Zone, EEZ, member states holding the sole right to legislate on matters concerning fishing vessels flying the member state's own flag. With respect to the territorial sea, individual member states are only entitled to adopt special resources protection and management measures provided these are non-discriminatory towards other member states. The EU has not adopted any specific measures for the same area, the measures are in line with the objectives of the EU and are not less stringent than the applicable EU regulations and there are no specific agreements concerning fisheries in the area.

The fundamental rights of states concerning access to and management of fishery resources have been codified in the UNCLOS, namely in Article 2, which extends coastal state sovereignty to include the territorial sea thereby granting these states the right to exploit resources therein. Furthermore, Article 56, also

extends the exclusive sovereign rights and obligations of “exploring, exploiting, conserving and managing the natural resources, whether living or non-living” to the waters and seabed of the 200 NM EEZ (Carneiro, G. 2013).

Institutional framework for nature conservation

Agenda 21 of the United Nations Conference on Environment & Development in Rio de Janeiro

An international agreement targeting nature conservation is the United Nations Agenda 21 which is a non-binding, voluntary action plan with regard to sustainable development. It has been elaborated during the UN Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in 1992. There is a full range of provisions regarding the conservation and management of resources, the strengthening of major groups and possible ways of implementation. Chapter 17 deals with the protection of oceans and coastal areas. It states that marine and coastal management at the national, sub-regional, regional and global

levels needs further approaches that are integrated in content and are precautionary and anticipatory in ambit. It demands an integrated policy and decision-making process, including all involved sectors, to promote compatibility and a balance of uses (Chapter 17 17.5 a). For this reason the existing and projected uses of coastal areas and their interactions have to be identified (Chapter 17 17.5 b). Furthermore the Agenda stipulates the application of *preventive and precautionary approaches* in project planning and implementation (Chapter 17 17.5 d). However in current environmental management the precautionary approach is not always applied for various reasons. The precautionary approach is to forbid actions or policies having suspected risk of causing harm to the public or the environment in terms of degradation. The burden of proof that something is *not* harmful to the environment and complies with the existing protective framework has to be provided by those taking the action. The absence of scientific consensus must not be taken as a pretext to realise projects that might have detrimental impacts on ecosystems. Therefore Chapter 35 (3) states that:

“[...] In the face of threats of irreversible environmental damage, lack of full scientific understanding should not be an excuse for postponing actions which are justified in their own right. The precautionary approach could provide a basis for policies relating to complex systems that are not yet fully understood and whose consequences of disturbance cannot yet be predicted.”

The uncertainty with respect to the selection of a certain policy option can be reduced due to the implementation of the precautionary approach. The role and the use of science in supporting the prudent management of the environment are specified in the same chapter. Accordingly one objective of science should be to support the decision-making process by providing information to better enable the formulation and selection of environmental and development policies. To ensure that science is responsive to emerging needs, it is essential to enhance scientific understanding, improve long-term scientific assessments and strengthen scientific capacities (Chapter 35 35.1). Current environmental management has to be constantly re-evaluated in the light of new findings in scientific research. The report states that there

is an obvious communication gap among scientists, policymakers, and the public at large, that is shown by both governmental and non-governmental organisations. To find sustainable and coherent solutions in regard to environmental degradation, better communication is required among scientists, decision-makers, and the general public (Chapter 35 35.5).

Germany

The German National Strategy for Sustainability

In 2002 the Federal German government passed the National Strategy for Sustainability (Nationale Nachhaltigkeitsstrategie) and published a progress report in 2012. One chapter of the report deals with the pressure on oceans, coastal waters and coastal zones due to immensely increased anthropogenic use. The designation of 10 marine Natura 2000 areas – four in the North Sea, six in the Baltic Sea – is seen as a first step to meet the goals stated with regard to marine and coastal nature protection (Federal German Government 2012: 167). The strategy strives to set up sustainability as a priority goal in the new CFP (Federal German Government 2012: 42). It is stated that the pollution of the sea due to shipping has been reduced in a satisfactory way according to the MARPOL Agreement (Federal German Government 2012: 168). Furthermore, the strategy refers to the Water Framework Directive (2000/60/EC), the Marine Framework Directive (2008/56/EC) and the Directive on the assessment and management of flood risks (2007/60/EC). All of these directives support the ecological integrity of surface and ground water, coastal waters and oceans (Federal German Government 2012: 168) and may thus have a positive impact with regard to sustain coastal spawning areas in the GWB.

European legislation has an apparent great influence on the GWB. The most important European laws and management instruments influencing national environmental law are summarised and put into context below.

NATURA 2000

NATURA 2000 is a coherent ecological network of protected terrestrial and marine areas within the EU. These areas enjoy a particular

Political Level	Administrative bodies	Laws and formal competencies
UN-Level		Agenda 21 of the United Nations Conference on Environment & Development in Rio de Janeiro
EU-Level		1. Natura 2000 Directives (Flora-Fauna and Habitat Directive 92/43/EEC and Bird Protection Directive 2009/147/EC) 2. Marine Strategy Framework Directive (2008/56/EC) 3. Water Framework Directive (2000/60/EC)
Federal government of Germany	German Ministry of Environment, Nature Conservation and Nuclear Safety (BMU) with the Federal Agency of Nature Conservation (BfN) and the Federal Environmental Office (UBA)	1. German Nature Conservation Act (BNatSchG) 2. Federal Water Resource Law (WHG) 3. German Species Protection Act (BArtSchV) 4. Federal Immission Protection Law (BImSchG) 5. National Strategy for Sustainability
State/ Land	State Ministry of Agriculture, Environment and Consumer Protection [Highest regional nature conservation authority]	State Water Resource Law (LWaG) Nature Conservation Execution Law (NatSchAG M-V) Expert Landscape Program (GLP) Regulation of the Landscape conservation area of the Greifswald Bay (2008)
	State Office of Agriculture, Nature Conservation and Geology [High nature conservation authority]	Expert Landscape Structure Plan
Region	Regional Agencies for Agriculture and Environment [Authority for nature conservation]	FFH-Management Plan Voluntary agreement on nature conservation, water sports and recreational fishing in the GWB and Strelasund
	Department of the national parks and offices of biosphere reserve [Administration of large conservation areas]	Regulation of the Southeast Rügen Biosphere Reserve
Community level	Elected head of administrative district (Landrat/Landrätin) and community mayors of the independent cities (kreisfreie Städte) [Lower nature conservation authority]	Communal landscape plan Green ordinance plan
	Head officials and community mayors	

Environmental authorities at different political levels in Mecklenburg-Western Pomerania/Germany

conservation status through the European Habitats Directive (92/43/EEC) and the European Birds Directive (2009/147/EC). The overarching goal is to ensure a transboundary protection of endemic wildlife, endemic plants and their habitats. In Germany NATURA 2000 became legally binding when its statutory provisions were transposed into the Federal Nature Conservation Act (BNatSchG) in 1998 and later on in its amendments from 2002 and 2007. Terrestrial nature conservation as well as marine nature conservation along the coast up to 12 nautical miles are the responsibility of the state and thus belong to the political mandate of the highest regional nature conservation authority in M-V. The GWB, parts of the Strelasund and the northern top of Usedom were classified as 'sites of community importance' as it is stated in the demands of the European Habitats Directive (FFH area coda DE 1747-301). Therefore a special FFH Management Plan was developed to determine the protective purposes and conservation goals in the GWB.

The FFH Management Plan

The FFH management plan of the Greifswald Bay comprises 55970 ha marine and 4249 ha terrestrial area. Until June 2014 there have been 30 different natural habitat types (Lebensraumtypen) and 16 FFH species identified that are explicitly protected through annex I and annex II of the FFH directive (LUNG 2014).

The maps of the FFH management plan disclose 'shallow huge estuaries and bays' (EU-Code 1160) as one of the largest natural habitat that is found in the GWB. Referring to a best-case scenario these habitats should be characterized by high diversity in macrophytes. The deepest growth limit of submerged vegetation in the GWB lies around 2.5 - 3 meters in the southern part and 4 meters in the northern part (Ifaö 2005 according to StaluVP 2011). The most widespread plant community in this habitat is *Myriophyllum spicatum* (Eurasian watermilfoil) and/or *Potamogeton pectinatus* (fennel pondweed) (without charales), *Najas marina* (spiny naiad), *Zostera marina* (common eelgrass) and *Ruppia cirrhosa* (spiral ditchgrass)/ *Ruppia maritime* (ditch-grass) (MariLim 2009 according to StaluVP 2011). Especially *Zostera marina*, *Furcellaria fastigiata* and *Fucus vesiculosus* serve as important and excellent spawning substrate for herring eggs (Scabell 1988). The high

eutrophication rate, especially caused by the extensive nutrient discharge into surface waters from agricultural cropland, is held responsible for having negative impacts on the density and the species diversity of macrophytes in the GWB. It could be observed, and empirically studied that macrophytes drastically decrease during the last decades (Munkes 2005; Hammer, Zimmermann et al. 2009). In deeper water regions of the GWB macrophytes have disappeared to a large extent. For this reason the habitat preservation status was classified as 'unfavorable' (StaluVP 2011). This classification is based upon a deficit analysis that assessed whether the state of an area deteriorated or ameliorated. The reference data therefore was in 2004 when the defined area was designated as a Natura 2000 site what comprised the completion of a standard data sheet. This comparative method revealed and emphasized the need for action with respect to (i) habitat preservation, (ii) habitat restoration or (iii) habitat development (StaluVP 2011).

There are also other marine FFH habitat types like, for example, 'estuaries' (EU-Code 1130) that have a potential function as spawning and nursery grounds for herring in the GWB. Most of these marine habitats are in an unfavorable, or even bad, ecological state. Several causes provoking habitat deterioration are mentioned e.g., interventions in the morphologic structure of estuaries (deepening of fairways), embankment, speed boat traffic, shore degradation through angling activities, the construction of harbor facilities, straightening of rivers as well as nutrient discharge into the surface water (StaluVP 2011).

The Voluntary agreement on nature conservation, water sports and recreational fishing in the GWB and Strelasund

An essential tool for implementing measures resulting from the FFH Management Plan was the joint development of voluntary agreements with different private and public actors as well as with resource user groups. As a result, the Voluntary agreement on nature conservation, water sports and recreational fishing in the GWB and Strelasund was established in 2004 and is based on a consensus between different resource users. The agreement was initiated by the WWF and involved different associations promoting water sport activities like sailing, ca-

*Cliff coast of Vilm.
Source: Stefanie Maack*



noeing, rowing, wind and kite surfing as well as recreational fishing. Furthermore, environmental associations and authorities were consulted during the negotiation process. A consensus, combining nature conservation goals with the sustainable and thus temporarily restricted use of certain areas, was compiled. The agreement is now regularly monitored with the aim of raising the consciousness of users to avoid disturbing and destructive effects on habitats.

The Marine Strategy Framework Directive

One important European law for protecting the marine environment is the Marine Strategy Framework Directive, 2008/56/EC (MSFD) which was adopted by the European Commission in June 2008 as the environmental pillar of the European Union's Integrated Maritime Policy. The MSFD aims to achieve a good environmental status of the EU's marine waters by 2020 through the application of an ecosystem-based approach to the management of human activities having an impact on the marine environment (Art. 8 2008/56/EC). The Directive emphasises that the pressure on natural marine resources and the demand for marine ecological services are often too high and that the Community needs to reduce its impact on marine waters regardless of where these effects occur (Art. 2 2008/56/EC). At the same time the Directive promotes the integration of environmental considerations into relevant policy



*Comorants and seagulls on a sand bank on the island Vilm
Source: Stefanie Maack*

areas (Art. 3 2008/56/EC) as well as the active involvement of the general public in the establishment, implementation and updating of marine strategies (Art. 36 2008/56/EC). For fishery management to be compatible with the Directive's aims it is stated that measures to regulate fishing activities can be taken in the context of the CFP to ensure the conservation and sustainable exploitation of fisheries resources. These measures may include the full closure of fisheries in certain areas to enable the integrity, structure and functioning of ecosystems to be maintained or restored and, where appropriate, in order to safeguard, inter alia, spawning, nursery and feeding grounds (Art. 29 2008/56/EC).

In October 2011, the MSFD was transposed into German federal legislation and passed by the German Bundestag. After defining the meaning of a “*Good Environmental Status*” and setting up environmental goals, a monitoring program was developed and further implemented in July 2014. A program of measurement is to be completed by the end of 2015 (BLMP 2009).

The MSFD promotes an ecosystem-based approach to the management of marine resources and is therefore of very high importance concerning reliable and effective herring spawning area management in the GWB and elsewhere, as ecosystem coherence and the consideration of cumulative effects are explicitly emphasised. Moreover, the integration of environmental concerns into different other policies, such as the CAP, the Common Agricultural Policy and other relevant Community policies may strengthen a sustainable area management with binding regularities ensuring a high WBSSH stock recruitment.

The Water Framework Directive 2000/60/EC

The Water Framework Directive (WFD) was adopted in 2000 by the European Parliament and the Council to establish a framework for Community action in the field of water policy. It requires the EU Member States (MS) to achieve a good qualitative and quantitative status of all water bodies (including marine waters up to one nautical mile) by 2015. The directive promotes the aim to establish a ‘good status’ for all ground and surface waters like rivers,

lakes, transitional waters, and coastal waters in the EU. The assessment of the ecological and chemical status of coastal waters includes the following criteria (EC, 2000):

- **Biological quality elements** (e.g. fish, benthic invertebrates, aquatic flora, abundance and biomass of phytoplankton)
- **Hydromorphological quality elements** (e.g. depth variations, structure and substrate of the coastal bed)
- **Physiochemical quality elements** (e.g. transparency, thermal and oxygenation conditions, salinity, nutrient conditions)
- **Specific pollutants** (all priority substances being discharged into the body of the water and substances being discharged in significant quantities into the body of the water).

The implementation of the WFD is coordinated by the Ministry of Agriculture, Nature Conservation and Geology (LUNG M-V, Landesministerium für Umwelt, Naturschutz und Geologie M-V). This authority was responsible for setting up a river basin management plan and measurement programmes that were published in 2008. It has the task of regularly informing the European Commission about progress in implementation etc. In 2008, the LUNG concluded that almost all surface water and coastal waters in M-V have failed the criteria for a ‘good ecological status’, whereas most of them achieved a ‘good chemical status’. The GWB, most of its inflows and the Strelasund were reported as being in an unsatisfying condition, not complying with the requirements of the directive. The reduction of diffuse and selective nutrient discharge from the catchment area is mentioned as a substantive measure to improve the ecological status of the coastal waters and marine ecosystems (Bachor and Weber 2008). Therefore, the management must be coherent and should take into consideration the whole catchment area and not only parts of it. The state M-V has already signalled that it needs more time to realise the environmental goals for the Warnow River and the Peene river according to the WFD and the appropriated management plan. About 4 km³ per year drain from the Oder, the Ziese, the Ryck and the

Peene rivers into the GWB, whereas the last has the largest catchment area. Most of the surface waters do not have a ‘good status’ because of deficits in the biological quality requirements. In this regard there is a special focus on the reduction of nutrient discharge. Currently 3359 tons of nitrate are discharged into the GWB annually (LUNG 2003). This may have serious negative impacts on herring spawning habitats and egg and larval development.

The Federal Water Resource Law (Wasserhaushaltsgesetz, WHG)

The purpose of the Federal Water Resource Law (WHG) is to protect all water resources by means of sustainable water resource management. This includes surface and groundwater resources as well as coastal waters and the territorial sea (BMJV 2009 §3). The WHG emphasises the realisation of the aims promoted by the EU’s MSFD (BMJV, 2009 §45b). Detrimental anthropogenic interferences into marine ecosystems must be avoided or reduced until an environmentally acceptable level is reached. Particularly the direct and diffuse discharge of nutrients are mentioned as a major challenge that has to be dealt with in the future.

The WHG provides the set-up of riparian buffer strips. These strips serve to maintain and

improve the ecological function of surface and groundwater bodies by storing water, ensuring water runoff and reducing discharges. The WHG has foreseen a buffer strip of at least five metres, but allows the state governments to enact different regulations (BMJV, 2009: §38). Within these buffer strips the German Fertiliser Ordinance is applicable. In most of the German states a width of between 5 and 10 metres is required. Also the application of fertiliser and pesticides is regulated by each state government. In December 2007 the minimum distance to the water body when using fertiliser and pesticides on cropland was reduced from seven metres to three metres in M-V. Under certain conditions the buffer strip may be even reduced temporarily up to only one metre (LUMV, 2008c: Sixth part §81 (3)). As buffer strips ensure at least a certain amount of nutrient retention their ecological function might be undermined. As long as surface and groundwater bodies still do not achieve a good environmental status according to the goals of the WFD this “progress” might be critically questioned.

Federal Nature Conservation Law (Bundesnaturschutzgesetz, BNatSchG)

The Federal Nature Conservation Law (BNatSchG) was passed in 1977 and has un-



Herring eggs Source: Philip Kanstinger



Zostera Marina Source: Anke Hofmeister

dergone several revision processes during the last years. As a major piece of legislation to conserve nature and landscapes, their functionality and services, it covers all territorial and coastal areas in Germany. In terms of the protection of marine areas it aims at their sustainable preservation and their integration into a coherent network of marine protected areas that are foreseen by the MSFD (BMJV, 2010: §56 (2)). Furthermore, article 30 of the BNatSchG declares that certain ecosystem components that have a particular function as habitat are to be legally protected. This includes seaweed and other submerged macrophytes as well as species-rich gravel, coarse sand or coquina bottom substrate in marine and coastal areas. This is of great importance as herring preferentially spawn on dense submerged vegetation. If submerged, aquatic vegetation, such as macrophytes, is destroyed by natural or anthropogenic impacts, spawning conditions may deteriorate impacting stock recruitment. This is particularly relevant, since the GWB has seen a severe decrease of submerged vegetation from over 90% to less than 10% during the last decades. These numbers vary considerably in the literature, as until now no reliable marine vegetation assessment has been carried out.

Since 1990 the southeastern part of Rügen has gained the legal protection status of a biosphere reserve that is described in § 25 of the federal nature conservation law. Biosphere reserves

are particularly dedicated to the protection and maintenance of natural and cultural landscapes. According to a different degree in human influences and uses biosphere reserves are divided into core areas, buffer zones and transition areas. The core area has the same legal protection status as nature reserves (Naturschutzgebiete) or landscape conservation areas (Landschaftsschutzgebiete) have. Buffer zones serve to conserve genetic, biological and structural diversity. Dependent on their worthiness they are protected as a national park or nature reserve. Areas within the transition area that are worthy of protection should be legally protected (MAB 1996: 6). Parts of the coastal waters of the GWB fall within this protective framework.

Additionally the area on both sides of the Peene estuary and nearby the two islands of Struck and Ruden are protected as nature reserve encompassing 7824 hectare. This nature reserve is one of the oldest in Germany and is characterised by its salt meadows that are used as resting habitats for a variety of waders (120 breeding and 250 migrating bird species observed). In the shallow waters around the two islands and along the coastline grows *Potamogeton pectinatus* (fennel pondweed), *Ruppia cirrhosa* (spiral ditch-grass), *Zannichellia palustris* (horned pondweed), and Charophyceae (charales). Seaweed meadows occur in deeper water. These areas are likely to be of great importance for herring spawning activities and hence serve as nursery grounds for herring larvae (Hammer et al 2009: 49f). All actions and interferences that destroy, damage or change the nature reserve or parts of it are prohibited (BMJV, 2010: §23). Almost the same area (the eastern coastline of the municipality of Lubmin, the Freesendorfer Haken and the Spandower Hakener Wiek as well as the two islands of Struck and Ruden) are additionally protected as a nature park (BMJV, 2010: §27). Nature parks are often nature reserves or landscape conservation areas at the same time.

The entire GWB and all of its shore areas enjoy the protective status of a landscape conservation area through the federal nature conservation law (BMJV, 2010: §26). These areas are legally designated to maintain, develop and re-establish ecosystem services and ecosystem functionality.

Different protective provisions are made within the overall nature conservation law concerning the GWB. In many cases protective statuses are even overlapping (e.g. nature reserve with nature parks, landscape conservation areas and FFH regulations).

Poland

Polish and international laws of an ecological character that address the range and modes of land use in the Vistula Lagoon basin and specify actions to be taken in the event of threats to the natural environment are applied in the management of the Vistula Lagoon and its basin. This is important for the creation of special conservation areas and in coastal zone management.

Pursuant to the law of 3 October 2008 on disseminating information about the environment and its conservation, public participation in environmental conservation, and environmental impact assessments (Journal of Laws no. 199, item 1227, with amendments), the General Directorate for Environmental Protection in Warsaw was established and is led by the General Director for Environmental Protection. This institution is directly subordinate to the Republic of Poland's Minister of the Environment. This body operates pursuant to the regulation of the President of the Council of Ministers of 12 November 2008 on granting institutional status to the General Directorate for Environmental Protection (Journal of Laws no. 202, item 1250). It is responsible for implementing environmental conservation policy in terms of managing environmental conservation, including, among others, Natura 2000 areas and monitoring investment processes. The General Director for Environmental Protection appoints and dismisses the 16 regional directors for environmental conservation who are responsible for their respective voivodeships, as well as fulfilling the role of the supervisory body with regards to them. The Vistula Lagoon basin lies in a region administered by the Regional Directorate for Environmental Protection in Gdańsk and the Regional Directorate for Environmental Protection in Olsztyn.

The Regional Directorate for Environmental Protection in Gdańsk functions pursuant to

the directive of the Minister of the Environment of 10 November 2008 in granting institutional status to the Regional Directorate for Environmental Protection in Gdańsk (Journal of Laws no. 202, item 1253). This government administrative office operates throughout the Pomeranian Voivodeship. The Regional Directorate for Environmental Protection in Olsztyn functions pursuant to the directive of the Minister of the Environment of 10 November 2008 in granting institutional status to the Regional Directorate for Environmental Protection in Olsztyn (Journal of Laws no. 202, item 1260). This government administrative office operates throughout the Warmia and Mazury Voivodeships. The primary documents upon which both institutions fulfil their responsibilities are the law of 16 April 2004 on environmental conservation (Journal of Laws of 2004 no. 92, item 880) and the law of 13 April 2007 on preventing the destruction of the environment and restoring it (Journal of Laws 2007 no. 75, item 493).

The tasks of the Regional Directorates for Environmental Protection in Gdańsk and in Olsztyn include preparing policies and positions on draft legislation and other documents produced by other departments and governmental bodies participating in implementing environmental policy for nature conservation and monitoring investment processes, including performing strategic environmental assessments and investigations of transboundary impacts on the environment.

This body is also responsible for compiling proposals for programmes to protect endangered species of flora, fauna, and fungi, and performing tasks associated with developing lists of Natura 2000 areas. It also implements tasks regarding the prevention and restoration of environmental damage. It is also responsible for managing information about the natural environment, and registering organisations in a national register under the Eco-Management and Audit Scheme (EMAS).

The institution responsible for monitoring compliance with environmental protection regulations, monitoring the state of the environment, and taking measures to counteract extraordinary environmental threats is the Inspectorate of Environmental Protection. This

Political level	Administrative bodies	Laws and formal competencies
UN-Level		Agenda 21 of the United Nations Conference on Environment & Development in Rio de Janeiro
EU-Level	European Commission	NATURA 2000 Directives (Flora-Fauna and Habitat Directive (92/43/EEC) nad Bird Protection Directive (2009/147/EC) Water Framework Directive (2000/60/EC) Marine Strategy Framework Directive (2008/56/EC)
National	Sejm and Senate	Law of 18 July 2001 on water (Journal of Laws 2001 no. 115, item 1229) Law of 16 April 2004 on environmental protection (Journal of Laws of 2004 no. 92, item 880)
Governmental	Ministry of the Environment	Law of 27 April 2001 on environmental protection law (Journal of Laws of 2008 no. 25, item 150, with amendments)
	General Directorate for Environmental Protection in Warsaw	Law of 3 October 2008 on disseminating information about the environment and its conservation, public participation in environmental conservation, and environmental impact assessments (Journal of Laws 2008 no. 199, item 1227 with amendments)
Regional	Regional Directorate for Environmental Protection in Gdańsk	Law of 12 September 2002 on port waste and cargo residue removal facilities (Journal of Laws 2002 no. 166, item 1361)
	Regional Directorate for Environmental Protection in Olsztyn	Law of 16 March 1995 on preventing vessel pollution (Journal of Laws 1995 no. 47, item 243) Law of 13 September 1996 on maintaining cleanliness and order in communes (Journal of Laws no. 236, item 2008 with amendments) Law of 27 April 2001 on waste (Journal of Laws 2001 no. 62, item 628 with amendments) Law of 7 June 2001 on public water supply and waste water disposal (Journal of Laws 2001 no. 72, item 747 with amendments) Regulation of the Minister of the Environment of 18 November 2014 on the conditions that must be met for waste water disposal into waters or soils, and with regard to substances those are particularly harmful to the aquatic environment (Journal of Laws 2014, item 1800)
Governmental	Chief Inspectorate of Environmental Protection in Warsaw	Law of 26 July 2000 on fertilizers and fertilization (Journal of Laws 2000 no. 89, item 991) State Environmental Monitoring Programme
Voivodeship level	Voivodeship Inspectorate of Environmental Protection in Gdańsk	Law of 20 July 1991 on the Inspectorate of Environmental Protection (Journal of Laws of 2007 no. 44, item 287 with amendments)
	Voivodeship Inspectorate of Environmental Protection in Olsztyn	Law of 13 April 2007 the prevention and restoration of environmental damage (Journal of Laws no. 79, item 493 and of 2008 no. 138, item 865)
	Voivodeship Inspectorate of Environmental Protection in Olsztyn Local Branch in Elbląg	Law of 14 March 1985 on the State Sanitary Inspectorate (Journal of Laws 1985 no. 12, item 49 with amendments)) Law of 15 April 2011 on medical activity (Journal of Laws of 2011, no. 112, item 654)
	Voivodeship Sanitary-Epidemiological Station in Gdańsk	
	Voivodeship Sanitary-Epidemiological Station in Olsztyn	
Community level	Community	Waste water management Solid waste management

Environmental authorities at different political levels in relation to the Polish part of Vistula Lagoon.

organisation is led by the Chief Inspector of Environmental Protection, who is the central governmental official subordinate to the President of the Council of Ministers. Pursuant to the law of 20 July 1991 on the Inspectorate of Environmental Protection (Journal of Laws of 2007 no. 44, item 287 with amendments), the law of 27 April 2001 on environmental protection law (Journal of Laws of 2008 no. 25, item 150, with amendments), and the law of 23 January 2009 on voivodes and government administration in the voivodeships (Journal of Laws no. 31, item 206 with amendments),

Voivodeship Inspectorates of Environmental Protection are operational in both Gdańsk and Olsztyn. Additionally they are supported by a local branch in Elbląg. They are immediately subordinate to the respective Voivodes. The Inspectorate of Environmental Protection is commissioned with performing monitoring and observations of the natural environment and changes occurring in it, including, among other things, monitoring the purity of rivers and lakes, enforcing compliance with environmental protection regulations, restoring the environment to its natural state, organising and coordinating the work of the State Environmental Monitoring Programme.



Southern coast of Vistula Lagoon Source: Iwona Psuty



Location of protected spawning areas in the Polish part of Vistula lagoon

Pursuant to the law of 14 March 1985 on the State Sanitary Inspection (Journal of Laws of 2006 no. 122, item 851 with amendments) and the law of 15 April 2011 on medical activity (Journal of Laws of 2011, no. 112, item 654), there are Voivodeship Sanitary-Epidemiological Stations in Gdańsk and Olsztyn, which are responsible for supervising, among other tasks, environmental hygiene, and hygiene in places of work, relaxation, and recreation. These stations are directly subordinate to the respective Voivodes. Their tasks also include monitoring water quality at recreational swimming areas located in the Vistula Lagoon.

*Elbląg Bay
Source: Iwona Psuty*



Sweden

The overarching rights and obligations of states concerning the protection and preservation of the marine environment are contained in Part XII of the UNCLOS. Alongside the right to exploit resources within their jurisdictions, states also have duties relative to environmental conservation and restoration. Such duties are in part to be carried out through the adoption of policies and legislation at regional, national and global levels to control the various causes of marine environmental degradation (Carneiro, G. 2013).

The 1971 Ramsar Convention has as its main purpose the establishment of a framework for states to afford special protection to wetlands and their resources. It does so by designating so-called “Ramsar sites” and promoting the concept of “wise use”, defined as “the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development”. Of the close to 2,100 Ramsar sites so far declared, three are located in the area around Hanö bay namely the Blekinge archipelago, the Helge river and the Mörrumsån/Pukavik bay.

On a Baltic Sea region level one of the most important instruments for nature conservation is the Helsinki convention on the protection of the marine environment of the Baltic Sea area, which entered into force on 17 January 2000. It states that all parties to the convention, i.e. all 9 countries surrounding the Baltic Sea, shall take all appropriate legislative, administrative or other relevant measures to prevent and eliminate pollution in order to promote the ecological restoration of the Baltic Sea Area (Helsinki convention, Art 3). In addition an action plan has also been developed - the HELCOM Baltic Sea Action Plan – with the aim to restore the good ecological status of the Baltic marine environment by 2021. The action plan corresponds to the EU Baltic Sea strategy which is the first macro-regional strategy in Europe within which saving the sea is one of three prioritised areas.

Skerries in the Blekinge archipelago



Political Level	Administrative body	Laws and formal competencies
Global	UN	Agenda 21
EU	European Commission	NATURA 2000 Directives (Flora-Fauna and Habitat Directive (92/43/EEC) and Bird Protection Directive (2009/147/EC)) Water Framework Directive (2000/60/EC) Marine Strategy Framework Directive (2008/56/EC)
National	Environmental Protection Agency	Environmental code (1998:808)
Regional	County Administrative Board	Environmental code (1998:808)
Local	Municipality	Municipal master plans (Översiktsplan) Municipal detailed plans (Detaljplaner)

Environmental authorities at different political levels in Sweden

Relevant EU directives include the Water and the Marine Strategy Framework Directives (2008/56 EC and 2000/60 EC), as well as the Birds and the Habitats Directives (2009/147 EC and 92/43 EEC) These last two, aimed respectively at protecting all naturally-occurring species of wild birds and at conserving natural habitats for the sake of preserving biological diversity, provide the framework for designating nature conservation areas that together form the EU-wide Natura 2000 network. A 2005 ruling of the European Court of Justice established that application of the Habitats Directive extends beyond the limits of the territorial sea to encompass all areas over which member states exercise sovereignty, this necessarily including the EEZ (Carneiro, G. 2013).

The WFD and MSFD have a similar structure and implementation mechanism, key distinctions lying 1) in their domain of application – internal waters, including groundwater and coastal waters up to 1 NM from the coastline in the case of the former, and all marine waters from the coastline up to the outer limit of the EEZ in the case of the latter; and 2) in the fact that the WFD assesses ecological and chemical status separately, whereas the MSFD only considers an aggregate measure of environmental status. Within their respective domain of application both directives require states to adopt measures enabling good environmental status

to be reached by 2015 and 2020 for the WFD and the MSFD respectively. Implementation proceeds along six-year programming cycles involving environmental status assessment and definition of good environmental status; establishment of monitoring programmes; elaboration of programmes of measurement and their implementation; and following-up, reporting and reviewing EEZ (Carneiro, G. 2013).

At the national level the main legal instrument pertaining to nature conservation in Sweden is the Environmental code (Law 1998:808). It merges regulations from 16 previous environmental laws into a consolidated code with the aim to foster a sustainable development for current and future generations. The Environmental Protection Agency is the main national authority with responsibility to implement environmental policies in accordance with the environmental code.

At the county level the County Administrative Board is the main actor with responsibility for nature conservation. It is a national authority which grants licences for different kinds of activities as well as conducting environmental monitoring programmes.

Institutional framework for spatial planning

Germany

Dependent on the spatial dimension of the area that has to be planned or re-planned, there are different political levels foreseen. Accordingly, institutional competencies, spatial scales as well as the depth and sharpness of the plans are different. There is a hierarchical procedure prescribing that the subordinated planning level must not contradict the planning effort of its superior authority, whereas the latter has to appropriately take into account the concerns and interest of the subordinated levels.

The European Spatial Development Perspective

The European Spatial Development Perspective (ESDP) is a document, which was approved in 1999 by the informal council of EU ministers responsible for spatial planning. It is a legally non-binding document forming a policy framework intending to strengthen an integrated approach in European spatial planning. It recognises the threat to the marine environment due to the discharge of nutrients and harmful substances. A coherent and integrated marine management is proposed as a political option to sustain and enhance ecosystem health (EC 1999).

Political Level	Administrative bodies	Laws and formal competencies
EU-Level	European Commission	European Spatial Development Perspective (ESDP) EU recommendation 2002/413/EC concerning the implementation of Integrated Coastal Zone Management in Europe
Federal government of Germany	Ministry of Transport, Building and Urban Development with the Federal Office of Civil Engineering and Spatial Planning	Federal Spatial Planning Act (ROG) Regulation on Spatial Planning in the German Exclusive Economic Zone of the Baltic Sea from 2009
	Federal Institute for Shipping and Hydrography	National Strategy of the Federal German Government for an Integrated Coastal Zone Management (informal, legally-non-binding instrument)
Ministerial conference for spatial planning composed of the national minister for spatial planning and the ministers of the state departments (MKRO)		Guidelines and Strategies for Spatial Planning in Germany
State/ Land	State Ministry of Energy, Infrastructure and State Development of Mecklenburg-Western Pomerania	State Development Program (LEP)
Region	Department of Spatial Planning and Regional Development Western Pomerania with the Regional Planning Unit (Amt für Raumordnung und Landesplanung Vorpommern mit dem regionalen Planungsverband)	Regional Spatial Development Program (RREP)
Community level	Elected community mayors	Land-use Plan and Building Plan

Spatial planning authorities at different political levels in Mecklenburg-Western Pomerania/ Germany

The Federal Spatial Planning Act and the Regulation on Spatial Planning in the German Exclusive Economic Zone of the Baltic Sea

The Federal Spatial Planning Act sets a framework for the functioning of the spatial planning in Germany. Nowadays, spatial planning encompasses not only terrestrial areas, but also marine areas that are increasingly subject to the divergent spatial claims of different user groups.

The Federal Institute for Shipping and Hydrography developed a maritime spatial plan to define areas of economic and scientific uses in order to guarantee the facility and safety of shipping and to ensure environmental sustainability in the German exclusive economic zone. Its overarching aim is to negotiate between different users of the sea. The regulation on spatial planning in the German exclusive economic zone of the Baltic Sea that was passed in 2009 has a strong environmental focus. It proposes the integration of an ecosystem-based approach into the EU's Common Fishery Policy. Furthermore different forms of anthropogenic use (e.g. off-shore electricity generation, transfer of cables and pipelines, fishing activities) have to comply with environmental standards. The regulation explicitly supports the aims of the MSFD and the Baltic Sea Action Plan (BSAP) of the Helsinki Commission that strive to re-establish the good ecological status of the Baltic Sea.

The ministerial conference for spatial planning and the guidelines and strategies for spatial development in Germany

The ministerial conference for spatial planning is a committee that consists of the 16 state ministry representatives for spatial planning and the federal minister responsible. They are responsible for the development of guidelines for spatial development and the joint coordination and planning of cross-border projects. The three German states Mecklenburg-Western Pomerania, Schleswig-Holstein and Lower Saxony bordering the Baltic Sea or the North Sea have the power to regulate marine spatial planning up to 12 nautical miles, whereas the federal German government is provided with the responsibility in the exclusive economic zone. In 2013, the ministerial conference for spatial planning passed guidelines and strategies for spatial development in Germany. This

report emphasises the role of a comprehensive, holistic and anticipatory spatial planning as an important tool for balancing and integrating conflicting demands (MKRO 2013).

The National Strategy for an Integrated Coastal Zone Management

The contribution of a holistic spatial planning lies in its cross-cutting and supra-local powers to negotiate between different claims of usage, development potentials and protection interests (BMU 2006: 3). In this context the National Strategy for an Integrated Coastal Zone Management in Germany that was passed in 2006 is seen as a milestone toward the sustainable development and preservation of coastal zones. Integrated Coastal Zone Management (ICZM) is an informal planning approach that tries to integrate conflicting interests into maritime spatial planning by means of strong stakeholder participation and transfer of experience. This national strategy is based upon the EU's recommendation 2002/413/EC concerning the implementation of integrated coastal zone management in Europe.

The State Development Plan for Mecklenburg-Western Pomerania

In August 2005, the State Ministry of Labour, Construction and Spatial Planning (AMMV) (nowadays the State Ministry of Energy, Infrastructure and State Development) passed the legally binding State Development Program (Landesraumentwicklungsprogramm, LEP) that is now being revised. The program is a cross-cutting planning instrument that strives for balancing different anthropogenic usages. For the first time coastal marine areas were included in the program. Furthermore the plan defines certain 'priority areas' (Vorranggebiete) and 'reserved areas' (Vorbehaltsgelände) for different uses. Priority areas are areas being designated for exclusively one particular kind of usage that excludes other usages in the same area if they are not compatible (BMJV 2008: Section 2 §8 (7) No.1)). (On the other hand, reserved areas consider one determined usage as priority usage when evaluating other usages (BMJV 2008: Section 2 §8 (7) No.2) Regarding the economic, social and ecological situation of Mecklenburg-Western Pomerania, the creation and the maintenance of jobs are given high priority in any evaluation process (AMMV 2005). . The increasing pressure on

coastal zones is stressed while ICZM is emphasised as an important tool to coordinate diverging usages (AMMV 2005). Coordination is needed when considering:

- Areas suitable for wind energy generation
- Pipelines and cable trays
- Areas for nature conservation
- Tourism
- Resource extraction
- Securing the safety and facility of shipping
- Sustaining cultural heritage
- Sustaining and developing fishery
- Conflict avoidance arrangements of aquaculture facilities
- Defence
- Conflict avoidance ocean dumping

This implies the replacement of a sectorial management perspective in favour of a holistic reflected management involving all relevant stakeholders, societal groups, policy departments and administrative units at different political levels. Spatial planning at state level has a very important role regarding the balancing process (AMMV 2005).

Furthermore, the importance of the Baltic Sea as a traditional fishing ground is recognised. One objective is to ensure commercial fishery in the Baltic Sea, thus ensuring that the main fishing grounds are kept free from usages that disturb or exclude fishery. The spawning grounds in shallow water along the coast and further away in particular are to be protected (AMMV 2005).

In addition to the sustainable management of fish stocks, the LEP underlines the importance of taking appropriate measures to ensure the existence of coastal fishery itself. Fishery as one of the main usages of marine waters is still not integrated in marine spatial planning. Hence, the integration of reserved areas for fishery is envisaged in the upcoming LEP. (AMMV 2005). The designation of reserved areas for fishery was not realised until now, because of the lack of cooperation from those fishermen who insist on claiming the entire sea as an important catch area. For this reason, the State Ministry for Development decided not to take into account fishing grounds, but to see spawning and nursery areas as playing an important role for stock recruitment, and hence for the preserva-

tion of coastal fishery in Mecklenburg-Western Pomerania. It is obviously, that the LEP puts a strong focus on the preservation of coastal fishery as one important economic sector. In autumn 2013 the first public hearings were held to hear all the objections brought forward by bodies representing the public interest and the public in general.

In marine priority areas for nature and landscape conservation, contradicting usages are to be excluded. Coastal areas serve in a particular way as areas for (aquatic) bird migration, rest and hibernation. Equally, coastal areas are of great importance as habitats for aquatic fauna and flora. The designation of areas with priority in nature conservation is thought to sustain biodiversity and population density (AMMV 2005). Until now, herring spawning and nursery grounds in the GWB do not have any legal status in spatial planning, even if it is assumed that these areas are of a very great importance for herring stock recruitment.

The Regional Spatial Development Programs

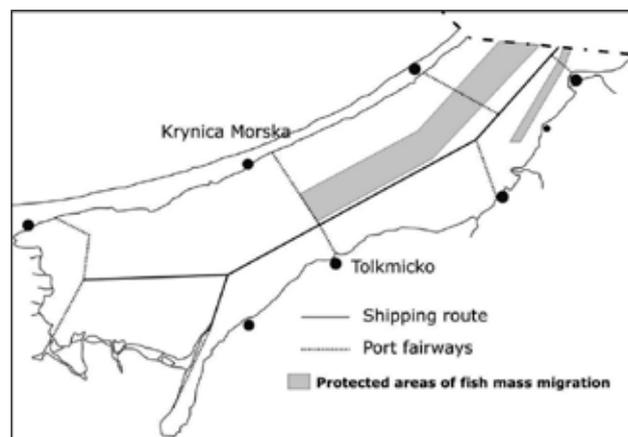
The State Development Program constitutes the basis for the Regional Spatial Development Programs (Regionale Raumentwicklungsprogramme, RREP). In Mecklenburg-Western Pomerania there are four different Regional Planning Units (Planungsverbände in Westmecklenburg, Central-Mecklenburg with Rostock, Western-Pomerania and Mecklenburg Lake District) that implement the legal requirements of the State Development Program and integrate their own development targets on a regional scale (EMMV 2014). The RREP in Western-Pomerania was passed in 2010 and consists of a text part, a map (scale 1:100.000), an environmental report and documentation that contains all the different considerations brought forward from stakeholders during the public hearing (Abwägungsdokumentation). The programme addresses regional problems, e.g. a steady decrease in population challenging the communal supply of public infrastructure. It emphasises the importance of effective nature conservation and constant economic development. The efficiency of agriculture has to be ensured and supported by the development of new technologies, always taking environmental concerns into account. The discharge of nutrients into rivers and lakes especially has

to be reduced (RPVVP 2010) to achieve the targets claimed in the WFD and the WHG (RPVVP 2010). Aquaculture is required the development of environmental-friendly production and a steady reduction of stressing discharge. Coastal areas and surface waters shall remain barrier free to allow fish to move up and down. It is stated that resource extraction, energy generation, the expansion of fairways or shoreline buildings and boat traffic have to take fishery concerns into account (RPVVP 2010). The environmental report is an integral part of the RREP and summarises all relevant projects (e.g. highway expansion, wind farms, areas of permanent resource extraction, flood prevention measures) and evaluates those for their possible environmental impacts with reference to plan approval procedures that have been already carried out prior to project permission.

Western-Pomerania is divided administratively into two districts – Western-Pomerania Rügen and Western-Pomerania Greifswald. The former encompasses 106 municipalities, while the latter has 144 municipalities to administer with altogether 465,722 inhabitants. At the municipal level – the lowest planning unit – each municipality has implemented land-use plans (Flächennutzungspläne) and building plans (Bebauungspläne). These have to achieve the regional planning goals and specify municipal needs and ideas. The municipal area and thus administrative responsibility ends at the landward water baseline that separates territorial waters from coastal waters and conforms with the mean spring low water. Exceptions are re-municipalised areas of water, e.g. marinas that are also the responsibility of the municipality. Hence, municipalities may also have an impact on spawning habitats as those facilities are established in shallow coastal waters. Furthermore, municipalities are in charge of developing a land-use plan and thus, determine agricultural or industrial land use within the municipal area. Expanding industry e.g. new power plants as planned on the shoreline of Lubmin might have a serious impact on spawning grounds through the discharge of waste heat into the GWB.

Poland

Managing such a vast area as the Vistula Lagoon basin requires comprehensive action within the scope of spatial planning and planning its role in the future. Since the administrator of the Vistula Lagoon is the Maritime Office in Gdynia, it is responsible for the “maritime” zone of the basin by virtue of the law of 21 March 1991 covering the maritime areas of the Republic of Poland and maritime administration (Journal of Laws of 2003 no. 153, item 1502, with amendments). The Integrated Maritime Policy (EU) sets forth tasks in this area, and in accordance with the principles of transparency in maritime spatial planning, interested parties also participate. Spatial planning in maritime areas must take into equal consideration the proper state of ecosystems and economic interests. Additionally, it is to prevent conflict and facilitate cooperation among the various economic sectors including fisheries, tourism, mineral extraction, and environmental protection. Part of the work the Maritime Office in Gdynia has performed to date includes participation in the international projects Plan-Coast, PartiSEAPate and BaltSeaPlan, the aims of which are to develop a cooperative approach to maritime spatial planning issues and to develop an institutional framework concept and a management model that would facilitate decision making by responsible institutions. In November 14, 2013 the Directors of Maritime Offices in Gdynia, Szczecin and in Słupsk signed an agreement on cooperation in the development of following documents: “Study of the determinants of Polish Marine Areas spatial planning” and “Spatial planning of Polish Marine Areas”. The result will be drawn up one



Location of shipping routes, port fairways and protected areas for fish mass migration in the Polish part of Vistula Lagoon

Political level	Administrative bodies	Laws and formal competencies
EU-Level	European Commission	European Spatial Development Perspective (non-binding) Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning
National	Sejm and Senate	Law of 27 March 2003 on planning and spatial management (Journal of Laws 2003 no. 80, item 717) Law of 3 October 2008 on disseminating information about the environment and its conservation, public participation in environmental conservation, and environmental impact assessments (Journal of Laws 2008 no. 199, item 1227 with amendments)
Governmental	Ministry of Transport, Construction and Maritime Economy	Regulation of Minister of Transport, Construction, and Maritime Economy and the Minister of Regional Development of 5 August 2013 on the management of spatial planning in Polish maritime areas (Journal of Laws 2013, item 1051)
Regional	Maritime Office in Gdynia	Agreement of 14 November 2013 between the Directors of Maritime Offices in Gdynia, Szczecin and in Słupsk on cooperation in the development of documents “Study of the determinants of Polish Marine Areas spatial planning” and “Spatial planning of Polish Marine Areas”
	Regional Directorate for Environmental Protection in Gdańsk	Law of 3 October 2008 on disseminating information about the environment and its conservation, public participation in environmental conservation, and environmental impact assessments (Journal of Laws 2008 no. 199, item 1227 with amendments)
	Regional Directorate for Environmental Protection in Olsztyn	
Voivodeship level	Pomeranian Voivodeship Office in Gdańsk	Development Strategies for the Pomeranian Voivodeship until 2020
Voivodeship level	Warmia and Mazury Voivodeship Office in Olsztyn	Socioeconomic development strategies for the Warmia and Mazury Voivodeship until 2020
Local governmental/ Marshal level of Pomeranian Voivodeship	Landscape Park „Mierzeja Wiślana“	Resolution no. 148/VII/11 of the Sejmik of the Pomeranian Voivodeship of 27 April 2011 on the Mierzeja Wiślana Landscape Park (Journal of Laws of the Pomeranian Voivodeship no. 66, item 1463)
Local governmental / Marshal level of Warmia and Mazury Voivodeship	Landscape Park „Wysoczyzny Elbląskiej“	Regulation no. 8 Warmia and Mazury Voivode of 26 January 2006 on the Wysoczyzny Elbląskiej Landscape Park (Journal of Laws Warmia and Mazury Voivodeship no. 20, item 505)
Community level	Community	Local Spatial Management Plans
	Municipality	Studies of the conditions and directions of spatial management Zoning and land use decisions

Spatial planning authorities at different political levels in relation to the Polish part of Vistula Lagoon.

coherent spatial plan. Currently, works on plans for the spatial management of Polish Marine Areas are being developed. Part of the work is in the public consultation phase. The first order of business is to create a strategic plan. The subsequent stage will see the development of plans for internal marine waters and hot spots, which are areas that are particularly susceptible to anthropogenic pressure. In the final stage, the minister responsible for maritime management and the minister responsible for regional development will consult with the minister responsible for fisheries, and through regulations, will determine the required range of plans for maritime spatial management in internal waters, territorial seas, and the exclusive economic zone.

The preparation of spatial management plans for the Vistula Lagoon basin is at a more advanced stage. Their development has been delegated to the various local governments surrounding the Vistula Lagoon, and will be based on various instruments.

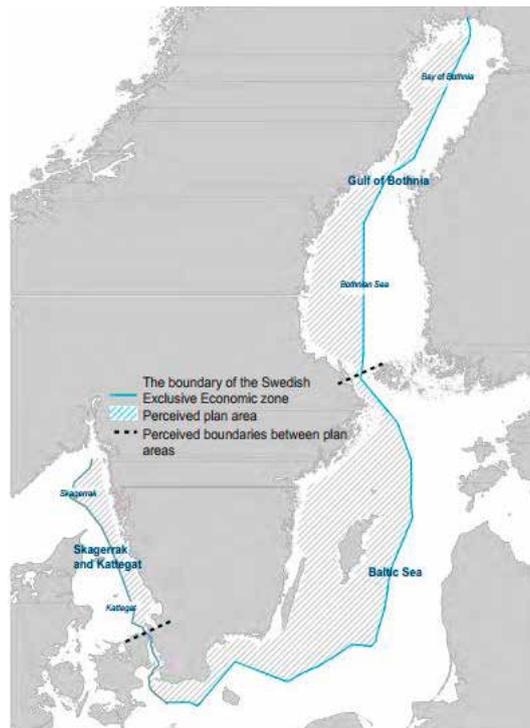
Sweden

Worldwide, the first plan that regulated the use of marine areas was developed in Australia in the mid 80-s but the breakthrough in Europe only took place in the recent decade (Lawrence et al. 2002). In Sweden, Maritime spatial planning (MSP) is a relatively new concept and until 2014 there was no national legislation pertaining to spatial planning of sea areas.

Spatial planning in Sweden has its foundation in the Planning and Building act (Law 2010:900) which spells out the responsibilities of different state organs, the generic procedures to be observed, the hierarchy of planning instruments and measures that can be adopted and the minimum technical requirements for new constructions. Sweden has no planning on national level that sets a framework for spatial planning on regional and local level. However the state can influence the spatial planning by pointing out national goals and state interests. Most of the spatial planning in Sweden is instead done on a local level where the municipalities have the responsibility to plan land and water usage within their territories. This includes not only the land area but also the



Municipal borders extends to the outermost limit of the territorial sea in Sweden.



Marine spatial plans will be developed for three different areas in Sweden: Gulf of Bothnia, Baltic Sea and Skagerrak/Kattegat

Source: Swedish Agency for Marine and Water Management

territorial sea which extends 12 NM (approx. 22km) into the sea from the baseline. Municipalities are obliged to have a comprehensive plan that outlines the political vision how the municipality should develop. In addition, municipalities are also entitled to develop and decide on legally binding detailed development plans that set out precise instructions regarding land use in specific locations.

In 2009 an investigation about maritime spatial planning was initiated by the Swedish government. It generated two reports which lay the foundation for further development of MSP in Sweden; *Kunskap på djupet 2011* and *Planering på djupet 2012* (SOU 2010:91 and 2011:56). Based on the finding in the investiga-

Spatial planning authorities at different political levels in Sweden

Political Level	Administrative bodies	Laws and formal competencies
EU	European commission	European Spatial Development Perspective
National	Swedish National Board of Housing, Building and Planning Swedish Agency for Marine and Water Management	Planning and Building Act (Law 2010:900) Environmental Code (Law 1998:808)
Local	Municipalities	Master plans (Översiktsplan) Detaild plans (detaljplan)

tion a promemoria was sent to the government in 2013 proposing a new system for planning and preserving the sea. The proposal was adopted by the parliament in June 2014 and as of September 2014 the new law for maritime spatial planning is being implemented. The new law allows the state to develop spatial plans for Swedish sea areas starting 1 nautical mile from the base line and extends to the outermost limit of the EEZ. It is the Swedish Agency for Marine and Water Management that has the overall responsibility to develop the plans but it will be done in close cooperation with coastal municipalities and the County Administrative Boards. Three plans will be developed for the Swedish sea area; one for the Bay of Bothnia, one for the Baltic Sea and one for the west coast. Accordingly three county Administrative Boards have been commissioned with the task to lead and coordinate the work in each of these areas i.e. Three County Administrative Boards (West Norrland, Kalmar and West Götaland) have been commissioned to take on a coordinating role for the development of the plans. All three plans will depart from an ecosystem approach, that is the plans should strive to conserve natural values and see to that natural resources are not over exploited.

Coastal areas has in Sweden are regulated through the shoreline protection premises that were established in the 1950s. The purpose of this regulation was to safeguard public access to coastal areas but also to conserve healthy living conditions for animals and plants on land as well as in the water. The shoreline protection extends 100 meters from the shoreline into the water but also on to land 100 meters.

This distance can however be extended by the County Administrative Board to 300 meters in both directions (Strandskydd, 2010). Within the shoreline protection area it is prohibited to carry out certain types of activities such as construction of buildings or excavate in preparation for construction. This general rule is however connected with at range of exceptions for which one can apply for exemption. Until July 2009 the County Administrative Board was responsible for approving and deciding on approval of exemptions. It then changed and it is now the responsibility of the municipalities. In certain cases, when the area within which the exception is applied for in addition to the shoreline protection also is protected by other regulations e.g. Natura 2000, then it is still the responsibility of the County Administrative Board to decide on approval for exemptions. Worth mentioning is that even if exemption is given for construction within an area of shoreline protection a free passage route of at least ten metres must always be kept between the construction and the shore to allow open access for the public to the shore.

Institutional framework for resource extraction

Germany

The administrative structure of the mining authorities in Mecklenburg-Western Pomerania is organised at two different political levels. The Ministry of Energy, Infrastructure and State Development of Mecklenburg-West-

Political Level	Administrative bodies	Laws and formal competencies
State/ Land	State Ministry of Energy, Infrastructure and State Development of Mecklenburg-Western Pomerania [Highest regional mining authority]	Federal Mining Law (BBergG) German Energy Act (EnWG)
	Mining authority Stralsund [High regional mining authority]	

Mining authorities at different political levels in Mecklenburg–Western Pomerania/Germany

ern Pomerania is the highest regional mining authority, whereas the mining authority in Stralsund is the high mining authority. The former acts according to the Federal Mining Law, whereas the latter executes supervision and control of all the mining activities in terrestrial areas of Mecklenburg–Western Pomerania as well as in the Baltic Sea. At the same time, the Stralsund mining authority is the appeals authority and authority responsible for planning approvals related to mining or energy generation. It handles all mining authorisations and technical working procedure plans. In the southwest of the GWB, near the island of Koos, there is a marine priority area for resource extraction. This deposit of sand and gravel is used for commercial exploitation. But the technical working procedure plan has still not been submitted to the mining authority of Stralsund by the investor who has expressed an interest.

Marine resource extraction may have serious impacts on spawning and nursery grounds in the GWB, as extraction or dumping cause turbidity and changes in underlying sediment layers. Even if there are environmental reports that are obligatory for planning approval procedures, herring spawning areas in the GWB are quite often overlooked as the focus is solely on FFH species and FFH habitats. According to an expert of the Stralsund mining authority, statements from public bodies concerning spawning and nursery grounds have not been submitted to the planning approval authority. The importance of these areas as spawning and nursery grounds does not appear to have been acknowledged. Consequently, explicit protection of herring spawning areas is not part of any legislation.

Poland

The Vistula Lagoon basin is not rich in mineral deposits, and no extraction activities are performed in this region. Consequently, there is no threat of contamination from petroleum substances. The one example of an activity that borders on extraction and which can impact the aquatic ecosystem of the Vistula Lagoon and potentially herring spawning grounds is the harvesting of common reed (*Phragmites australis* (Cav.) Trin. ex Steud) in the coastal zone in winter. Permits for reed harvesting are only issued for the southern coast of the Vistula Lagoon near the towns of Suchacz, Tolkmicko, and Frombork. The northwest shore of the lagoon is located within the Mierzeja Wiślana Landscape Park, and harvesting reeds is strictly prohibited.

Reed harvesting is permitted after obtaining a water permit issued by the respective district office in accordance with the law of 18 July 2001 on water (Journal of Laws 2001 no. 115, item 1229). In certain instances, it is also necessary to have an expert assessment of the impact the undertaking will have on Natura 2000 areas pursuant to the law of 16 April 2004 on environmental protection (Journal of Laws of 2004 no. 92, item 880) and the law of 3 October 2008 on disseminating information about the environment and its conservation, public participation in environmental conservation and environmental impact assessments (Journal of Laws 2008 no. 199, item 1227 with amendments). Based on these documents, the director of the Maritime Office in Gdynia, pursuant to the law of 21 March 1991 on the maritime areas of the Republic of Poland and maritime administration (Journal of Laws of 2003 no. 153, item 1502, with amendments) and the law of 21 August 1997 on real estate management



Reed meadows in Vistula lagoon can be harvested provided that a water permit is obtained
 Source: Anetta Ameryk

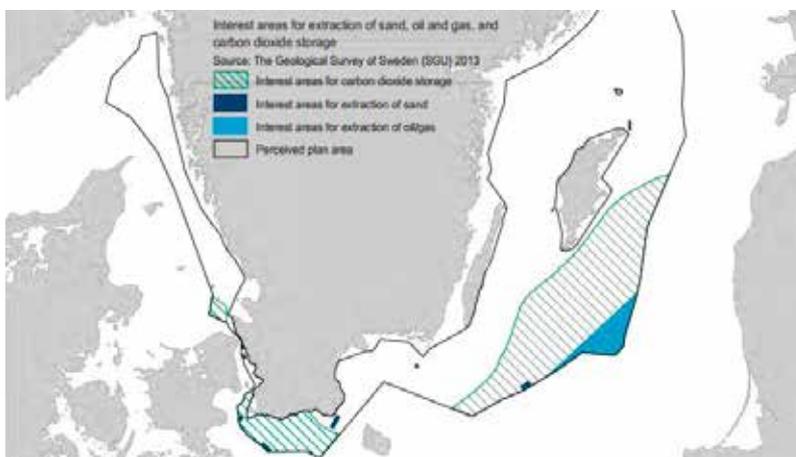
(Journal of Laws 1997 no. 115, item 741) states the conditions for making a given plot accessible (leasing) in the coastal zone.

Sweden

Extraction of sand and gravel from the sea-floor is carried out for a variety of purposes including beach nourishment, construction and land reclamation. Although more expensive per tonne, sand extracted from the sea bottom has a rounder and smoother shape than sand

extracted from land. Due to this, less cement and water is needed when producing concrete, which in turn, helps keeping the price of the concrete at a similar level to that produced with sand extracted from the land.

In Sweden extraction of sand and gravel from the sea has been carried out to a very limited extent during the past 20 years. A national authority, the Geological Survey of Sweden, is responsible for the administration and licensing of the extraction of marine aggregates in territorial waters. They must however, according to the Act of the Continental Shelf, consult any authorities that may be affected before granting any licences. It includes inter alia the Swedish Agency for Marine and Water Management and the Environmental Protection Agency. Beyond the territorial waters, in the exclusive economic zone, it is the responsibility of the government to grant licences for sand and gravel extraction. Since 1992 the Swedish Act of the Continental Shelf requires an environmental impact assessment to be made in connection with any application for extraction of marine aggregates (Lauwaert, B. 2009).



Interest areas for extraction of sand, oil and gas, and carbon dioxide storage in Swedish territorial sea and EEZ in the south Baltic Sea, Kattegat and Skagerrak.
 Source: Geological Survey of Sweden and Swedish Agency for Marine and Water Management.

One ongoing example of sand and gravel extraction is currently taking place off the south coast of Skåne, in the marine waters of the municipality of Ystad. The municipality has been

granted a licence from the Geological Survey of Sweden to extract 340,000 m³ sand and gravel from the sea floor over a period of ten years (SGU 440- 1632/2010). The material will be used for beach nourishment in the areas of Löderups strandbad and Ystad Sandskog.

Institutional framework for water and shipping administration

Germany

The water and shipping administration is organised into three different political levels. The Water and Shipping Office in Stralsund has the responsibility for maintaining all shipping and transport routes in the coastal waters of the Baltic Sea up to 12 nautical miles from



Shipyard in Stralsund. Source: Conny Deiter

Kühlungsborn to the German-Polish border. This also includes the shipping routes in the GWB that are especially important for the supply of the shipyard in Stralsund and the industrial ports of Wolgast, Greifswald, Ladebow, Vierow and Lauterbach. Additionally, a growing number of shipping companies offer tourist boat trips along the coastline or in the harbour. The trips around the islands Vilm, Ruden and Oie especially are attracting more and more people who want to watch recently settled grey seals. Furthermore, there are many bigger and smaller marinas serving as ports for sailors. The Water and Shipping Office is responsible for maintaining the federal shipping routes. This involves regular dredging of the shipping routes. This operation may have impacts on herring roe and spawning habitats due to resuspension of sediments. Federal waterway legislation specifies in Article 5 that the traffic on federal shipping routes in nature protection areas and national parks, that are protected through Articles 23 and 24 of federal nature conservation legislation, may be regulated, restricted or forbidden in consultation between the Federal Ministry of Transport, Building and Urban Development and the Federal Agency for Nature Conservation. The construction, reconstruction or removal of shipping routes requires planning approval. This procedure must consider public and private concerns as well as environmental compatibility (BMJV 2013 : §13 and §14). The approval authority responsible is the Water and Shipping Directorate.

Political Level	Administrative bodies	Laws and formal competencies
Federal government of Germany	Ministry of Transport, Building and Urban Development with the Federal Office of Civil Engineering and Spatial Planning	Federal Water Way Law (WaStrG) Federal Maritime Responsibilities Act (See-AufG)
	Federal Office for Shipping and Hydrography (BSH)	
State/ Land	Water and Shipping Directorate Nord in Kiel (there are 7 in Germany)	
Region	Water and Shipping Office Stralsund (WSA) (there are 39 in Germany)	

Water and shipping administration at different political levels in Mecklenburg-Western Pomerania/ Germany

Poland

The administrator of the Vistula Lagoon is the director of the Maritime Office in Gdynia, whose rights and obligations to supervise the proper use of lagoon waters are authorised by legislation. The Maritime Office in Gdynia was established under the regulations of the Minister of Transport and Maritime Economy on October 7, 1991 (Journal of Laws no. 98, item 438 with amendments). Simultaneously, these regulations provided for establishing maritime offices on the Polish coast in Słupsk and Szczecin. Additionally, since 1999, a branch of the Maritime Office in Gdynia has been operating in Elbląg. Maritime Offices are the field maritime administrations of the Republic of Poland and are subordinate to the Ministry of Infrastructure and Development.

The director of the Maritime Office in Gdynia acts within the jurisdiction set forth in the statute of the Maritime Office in Gdynia, which is an annex to enactment no. 13 of the Minister of the Interior of 21 March 2011 (Journal of Laws no. 3, item 17) and the Organisational Rules of the Maritime Office in Gdynia introduced with internal decree no. 17 of the Director of the Maritime Office in Gdynia of 8 July 2011. Within the scope of the director's jurisdiction, monetary penalties can be imposed for violations of regulations in the law of 24 August 2001 – code of procedures for misdemeanours (Journal of Laws of 2008 no. 133, item 848, with amendments).

The law of 21 March 1991 on the maritime areas of the Republic of Poland and maritime administration (Journal of Laws of 2003 no. 153, item 1502, with amendments) specifies territorial scopes of activity, and for the Maritime Office in Gdynia this includes internal marine waters, territorial seas, the exclusive economic zone, marine ports and harbours, and the seashore zone from the eastern Polish border to longitude 17° 40' 30" east. The harbour offices in the ports of Gdynia, Gdańsk, Hel, and Władysławowo are under this authority.

The Director of Maritime Office in Gdynia has legislative powers. As an organisational unit, independent decisions and regulations can be issued within the jurisdiction of this office;



*Ferryboat crossing the Nogat river
Source: Piotr Margonski*



*Tourist ferry in
Frombork harbour
Source: Iwona Psuty*

these are published in the voivodeship journals of laws to the territorial scope of the enactment, i.e., in the Journal of Laws of the Pomerania Voivodeship or the Journal of Laws of the Warmia and Mazury Voivodeship.

The maritime administration bodies are responsible for implementing assignments related to the exploitation of the sea in the maritime areas of the Republic of Poland, i.e., internal marine waters, territorial seas, the exclusive economic zone, marine ports and harbours, and the seashore zone. They are also responsible for the following: ensuring maritime safety; sea-port protection; the designation, construction, and exploitation of maritime routes; implementing measures to ensure safety during the study, exploration, and exploitation of seabed mineral resources; marine environmental protection. They can also create local spatial management plans for internal marine waters, territorial seas, and the exclusive economic zone. In the execution of their duties, the maritime administration bodies cooperate with other bodies and institutions such as local government, the Polish Navy and the Polish Border Guard, the Ministry of Internal Affairs, the National Labour Inspectorate, the Office of Electronic Communications, Polish Customs, the Police, and the Maritime Search and Rescue Service (SAR). Simultaneously, they are responsible for developing international cooperation in the fields of maritime safety, the use of sea routes and ports, as well as protection of the marine environment.

The institution responsible for managing internal waters is the National Water Management Authority in Warsaw was established on 1 July 2006 pursuant to the legislation of 18 July 2001 on water (Journal of Laws 2001 no. 115, item 1229). It is headed by the president of the national board of directors and operates pursuant to the regulation of the President of the Council of Ministers of 27 June 2006 on granting institutional status to the National Council of Water Management (Journal of Laws no. 108, item 774). The institution reports directly to the Minister of the Environment of Poland. The President of the National Water Management Authority is the central body of government administration responsible for water management and use. This authority is responsible for, among other things, imple-

menting tasks related to water management, developing a national water and waste water plan, developing proposals for the management of river basins, developing proposals for flood control and to counteract the effects of drought on Polish territory.

The National of Water Management Authority supervises seven field offices in Gdańsk, Poznań, Wrocław, Kraków, Gliwicy, Szczecin, and Warsaw, which covers activities throughout Poland. The Regional Water Management Authority (RWMA) in Gdańsk is a governmental administrative body that is independently subordinate to the National Council of Water Management in matters pertaining to water management. It acts pursuant to the regulation of the President of the Council of Ministers of 27 June 2006 on the borders of river catchments and water regions (Journal of Laws no. 126, item 878) and to the statute granted by the Minister of the Environment in decree no. 86 of 22 December 2006 as amended by decree no. 24 of 9 May 2012 (ME Journal of Laws, item 24) in the form of a legal state budgetary unit subordinate to the President of the National Water Management Authority. The area administered by the RWMA in Gdańsk comprises the water regions of the lower Vistula River including the Vistula Lagoon and the rivers supplying it.

The main task of the RWMA in Gdańsk is to manage the waters within the catchment area it is responsible for to ensure that the public drinking water supply is of sufficient quantity and quality, to protect waters from pollution, to protect against floods and droughts, to provide water for industry, navigation and hydropower, and to administer rivers and channels on behalf of the Polish Treasury. It is also charged with monitoring the status of plans and programmes related to water management and water use, enforcing compliance with the terms of contracts, providing maintenance for waters and water facilities, enforcing compliance with conditions applicable to protected zones and areas and those for levees and in areas of imminent flooding.

The Provincial Land Melioration and Water Units Board of the Pomeranian Voivodeship in Gdańsk operates pursuant to the law of 18 July 2001 on water (Journal of Laws 2001 no. 115, item 1229) and to resolution no. 90/LX/99 of

Political level	Administrative bodies	Laws and formal competencies
National	Sejm and Senate (Two Houses of Polish Parliament)	<p>Law of 21 March 1991 on the maritime areas of the Republic of Poland and maritime administration (Journal of Laws of 2003 no. 153, item 1502, with amendments)</p> <p>Law of 12 October 1990 on the protection of national borders (Journal of Laws of 2009 no. 12, item 67 with amendments)</p> <p>Law of 20 December 1996 on ports and fishing harbors (Journal of Laws 1997 no. 9, item 44)</p> <p>Law of 18 July 2001 on water (Journal of Laws 2001 no. 115, item 1229)</p>
Governmental	Ministry of Transport, Construction, and Maritime Economy	Regulation of the Minister of Transport and Maritime Economy of 7 October 1991 on establishing maritime offices, designating headquarter location, and regional scope of duties for directors of maritime offices (Journal of Laws no. 98, item 438 with amendments)
	Ministry of Infrastructure	Decree no. 13 of the Minister of Infrastructure of 21 March 2011 on granting institutional status to the Maritime Office in Gdynia (MO Journal of Laws 29.03.2011 no. 3, item 17)
	Ministry of Environment	Decree of the Minister of the Environment no. 24 of 9 May 2012 changing the decree on granting institutional status to the Regional Water Management Authority in Gdańsk. (ME Journal of Laws, item 24)
	Council of Ministers	<p>Regulation of the Council of Ministers of 23 December 2002 on the borders between inland waters, surface waters, and internal marine waters and territorial seas (Journal of Laws of 2002 no. 239, item 2035)</p> <p>Regulation of the President of the Council of Ministers of 27 June 2006 on the borders of river catchments and water regions (Journal of Laws no. 126, item 878)</p>
Regional	Maritime Office in Gdynia	<p>Statute of the Maritime Office in Gdynia, which is an annex do enactment no. 13 of the Minister of Infrastructure of 21 March 2011 (MO Journal of Laws 29 March 2011 no. 3, item 17)</p> <p>Organizational Regulation of the Maritime Office in Gdynia introducing internal decree no. 17 of the Director of the Maritime Office in Gdynia of 8 July 2011</p>
	Regional Water Management Authority in Gdańsk	<p>Statute of the Regional Water Management Authority in Gdańsk which is an annex to the decree of the Minister of the Environment no. 24 of 9 May 2012 changing the decree on granting institutional status to the Regional Water Management Authority in Gdańsk. (ME Journal of Laws, item 24)</p> <p>Water Management Planning</p> <p>Polish Water and Environmental Programme</p>
Local governmental / Marshal level of Pomeranian Voivodeship	Provincial Land Melioration and Water Units Board of Pomeranian Voivodeship	Statute of Provincial Land Melioration and Water Units Board of Pomeranian Voivodeship – Annex no. 1 to Resolution no. 595/XXIV/08 of the Sejmik of the Pomeranian Voivodeship of 28 July 2008
Local governmental / Marshal level of Warmia and Mazury Voivodeship	Provincial Land Melioration and Water Units Board in Olsztyn	Statute of Provincial Land Melioration and Water Units Board in Olsztyn – Annex to the Resolution no. XLIV/855/10 of the Sejmik of the Warmia and Mazury Voivodeship of 26 October 2010 r
	Provincial Land Melioration and Water Units Board Żuławy	Statute of Provincial Land Melioration and Water Units Board Żuławy – Annex to the Resolution Resolution no. XLIV/854/10 of the Sejmik of the Warmia and Mazury Voivodeship of 26 October 2010 r
Community level	Communes	Law of 20 December 1996 on ports and fishing harbors (Journal of Laws 1997 no. 9, item 44)
	Port Authority in Elbląg Sp. z o.o [Ltd.]	Regulations for waterfronts administered by the Port Authority

Water and shipping administration at different political levels in relation to the Polish part of Vistula Lagoon.

28 June 1999 of the Sejmik of the Pomerania Voivodeship. It is a local government budgetary unit of the voivodeship, and is subordinate to the Board of the Pomerania Voivodeship. The Provincial Land Melioration and Water Units Board in Olsztyn also operates pursuant to the law of 18 July 2001 on water (Journal of Laws 2001 no. 115, item 1229) and resolution no. 576/02 of 27 August 2002 of the Sejmik of the Warmia and Mazury Voivodeship. The Provincial Land Melioration and Water Units Board Żuławy, headquartered in Elbląg, was created pursuant to resolution no. XL/575/02 of 7 August 2002 of the Sejmik of the Warmia and Mazury Voivodeship. The tasks of these bodies include maintaining inland surface waters, maintaining and operating water management facilities, such as pumps, canals, and levees throughout the Pomerania and the Warmia and Mazury voivodeships.

Sweden

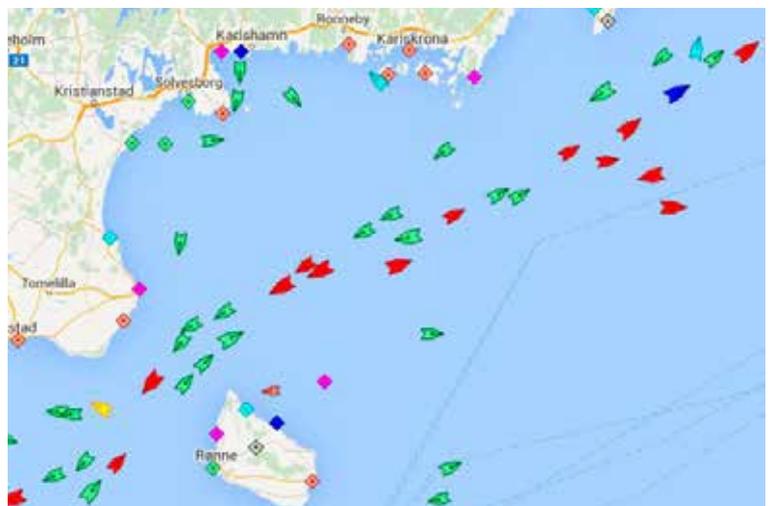
A fundamental right of states originating from international customary law is the freedom of navigation, defined in the LOSC Art. 90 as every state's right "to sail ships flying its flag on the high seas." Rooted in the principle of freedom of the high seas, it resonates throughout the history of maritime transport with the notion of freedom from regulation. If for many centuries, or even millennia this remained largely an uncontested and virtually absolute premise – to the extent of exempting all but the ship owner of responsibility for the fate of any maritime enterprise – the last two centuries have witnessed the progressive encroachment of this freedom by ever growing rights of appropriation over maritime territories by coastal states legitimised mainly by international treaty law. This "rise of the coastal state in the law of the sea" (Gold, 1979) has resulted in a current legal regime for maritime transportation that attempts to balance these two opposing rights: that of navigation by flag states, and that of appropriation by coastal states (Carneiro, G. 2013).

The two main bodies overlooking international regulations on shipping are the UN agencies International Maritime Organisation (IMO) and the International Labour Organisation (ILO). The IMO is a global standard-setting

authority for safety, security and environmental performance of international shipping. Its main objective is to develop a regulatory framework for shipping that is fair, effective and universally implemented. The work of ILO, with respect to the maritime industry, is mainly related to regulation of labour conditions for people working at sea in general and on board vessels in particular.

At the regional level the EU and HELCOM are two important regulatory organs for setting standards. Both have generally refrained from creating new rules different from those of the IMO, and instead focused their efforts on ensuring regional compliance with the international regulatory regime. A salient exception in recent years was the EU's imposition of an accelerated regime – relative to IMO's proposed calendar – for the phasing out of single-hulled tanker vessels following the Erika and Prestige accidents. Within its transport policy the EU is also active in the areas of multi-modal integration and the regulation of competition and state-aid to the shipping and port sectors.

On a national level, individual states have responsibilities both towards vessels flying their flag and towards vessel calling at national ports. One of the essential principles of freedom of the seas is that a ship must fly the flag of a single state and that it is subject to the jurisdiction of that state (Brown 1994 in Mansell 2009). Thus flag state control includes enforcing regulations on e.g. documentation of safety and pollution prevention documents on the vessels registered in the country. Port state control refers to in-



Snapshot of marine traffic outside Hanö bay. Green arrows refer to cargo vessels and red arrows to tankers. Source: Marinetraffic.com

spection of foreign ships in national ports to ensure that the condition of the ship and its equipment comply with the requirements of international regulations.

In Sweden three main national authorities are working with shipping administration; the Swedish Transport agency, the Swedish Transport administration and the Swedish Maritime Administration. The transport agency works to achieve safe and environmentally adapted transportations on railway, air, shipping and

roads. They are also commissioned to develop regulations, licence granting and enforcing transport regulations. The transport agency is also responsible for the Swedish ship register where all vessels and leisure boats larger than 12 meters need to be registered. The transport administration is responsible for the long term development of transportation on rail, air, road and at sea. They are also responsible for construction, operation and maintenance of national roads and railways. In addition the transport administration is also the authority in charge of examining national support to the Swedish shipping sector. The Maritime Administration is responsible for providing safe, environmentally friendly and effective transportation routes at sea and to give service to those who are using these. They are working both towards the shipping sector, the ports and the public.



*Vessel outside south coast of Sweden
Photo: Peter Caputa*



*Ferry outside south coast of Sweden
Source: Peter Caputa*



Seagulls in Vistula Lagoon
Source: Iwona Psuty

SUMMARY AND CONCLUSIONS

This book is the result of a compilation of 6 different reports written by German, Polish and Swedish partners within the HERRING project. All reports are available in their full length on the project homepage <http://www.baltic-herring.eu/>. The book summarizes the reports and sets out to provide an analysis of herring spawning areas in the Greifswalder Bodden, Polish part of the Vistula Lagoon and Hanö Bight from two main perspectives – Ecological status and Governance structures.

Summary and conclusions of ecological situation

German case study area – Greifswald Bay

The German case study area Greifswald Bay (GWB) is a semi-enclosed inshore lagoon, formed by the mainland of Mecklenburg-Western Pomerania to the south and by the island of Rügen to the north.

GWB is considered a major spawning area for spring spawning herring of the western Baltic Sea. During spawning season herrings migrate into the coastal waters to attach demersal eggs to submerged macrophytes in the shallow, littoral zone.

Although spawning stock biomass levels have remained stable in recent years, recruitment levels have decreased in the last decade for reasons presently unknown.

The herring embryo is sensitive to all kinds of low-level environmental changes. In previous centuries, the increased anthropogenic utilization of coastal waters overloaded the natural potential of this ecosystem. Anthropogenic stressors are going to change the physical and biological environment temporarily or permanently and consequently affect spawning habitat and the success of egg development.

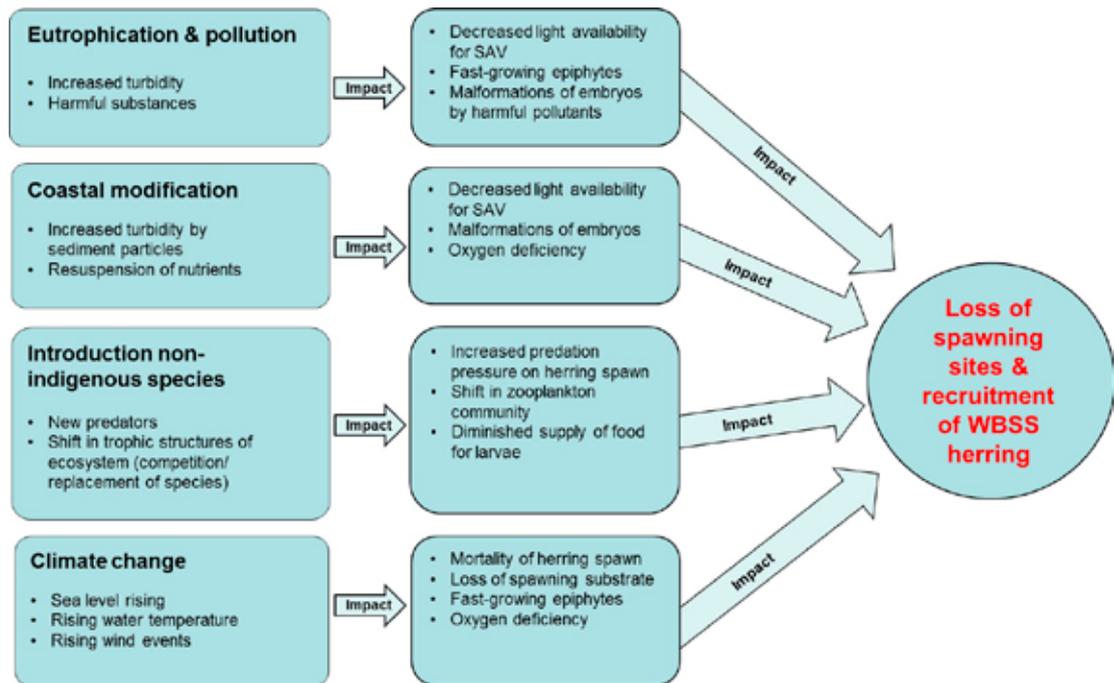
Eutrophication

GWB is a eutrophic ecosystem due to high nutrients loads from agriculture in neighboring regions.

The long-term development of total mean nitrogen and phosphor concentrations are marked by a strong decline until the early 1990's, after which the trend weakened but remained negative. According to the assessment of WRRL, nitrogen and phosphor concentrations in GWB have exceeded reference levels for the last 30 years.

High nutrients loads result in massive growths of phytoplankton and zooplankton. These organisms can cause increased water turbidity and therefore decreased light availability for submerged aquatic vegetation. The vegetative cover

Anthropogenic stressors influence natural ecosystem drivers
 Source: Dorothee Moll; symbols courtesy of ian.umces.edu/symbols/



in GWB dropped from 90% to 15% today, and macrophytes are currently mainly found in the shallow littoral zone. Eelgrass appears to live near its growth limits in the estuary and is distributed from 2.2 m down to a depth of 3.4 m sea level, whereas pondweed can be found in depths above 2 m.

Pollution

Pollutants are produced and emitted by human use of resources, infrastructure and industrial development, agricultural activities, and tourism. In coastal regions, concentrations of pollutants such as heavy metals and organic contaminants are much higher than in open waters, due to pollutant discharge into coastal waters. Pollutants accumulate in coastal sediments and have a high persistence.

Coastal modification

Coastal modification involves a mobilization of coastal sediments, and therefore increased turbidity and sedimentation. In addition, the mobilization of coastal sediments reintroduces formerly sequestered nutrients and pollutants that have been accumulating within the sediments for a long time.

Alien species

The introduction and establishment of alien species generally changes ecosystems. Non-indigenous species may potentially lead to an increased predation on herring spawn or larvae. Furthermore it may lead to competition for

food and the same ecological niche between native and non-native species.

Although there are extensive monitoring programs for the Baltic Sea, GWB is underrepresented. According to the present state of knowledge, a classification of the importance of single spawning grounds within GWB in relation to herring recruitment is impossible. It is assumed that small-scale spawning sites might have an important function on the population level.

The ecological status quo of the GWB is well assessed; however ongoing monitoring of important parameters is patchy. In particular, research on the potential effects of anthropogenic impacts on herring spawning success is scarce.

In general, water temperature, salinity, and oxygen supply are the main physical drivers for the successful development of herring eggs. However, these variables are highly influenced by human impacts. Although success has been made reducing nutrient inflows in the previous decades due to the reduction of point source discharges, e.g. installation of sewage systems with nitrogen elimination systems, there are still issues concerning nutrient inflows from diffuse sources.

Climate-change related risks from increasing water temperatures and salinity changing due to sea level rise and the inflow of Baltic Sea wa-

ter have the potential to jeopardize the WBSS herring stock by further reducing macrophyte coverage in GWB.

The State Agency of Environment, Nature Conservation and Geology of Mecklenburg-Western Pomerania has implemented a water quality assessment policy for coastal waters and controlled annual water quality since 1979. In this water quality report, abiotic parameters and the state of eutrophication and pollution are analyzed and assessed, as well as coastal monitoring of fauna and flora.

According to this source, eutrophication is one of the major remaining challenges of GWB.

An ecosystem is influenced by a multitude of factors and interactions. Caution is required to ensure that the right measures are taken. A holistic approach helps to understand the possible consequences of treating one symptom and thereby triggering other issues due to unknown ecological linkages.

An extensive ecological monitoring is necessary to describe the condition of these highly productive inner coastal ecosystems. However, currently extensive monitoring programs are limited to the outer coastal zone of the Baltic Sea. Monitoring the status of the Natura 2000 area GWB exists, but it is necessary to get more information concerning anthropogenic factors and their impact on spawning habitat of herring. A baseline should be established, including year-round monitoring of nutrient and pollutant concentrations in water and sediments on a suitable spatial scale. Additionally, detailed mapping of submerged aquatic vegetation should be initiated.

As a sound baseline for competent management, more research on herring spawning ecology is needed to further develop scientific insight into the interactions between abiotic parameters, anthropogenic factors, and their impact on the natural spawning habitat of herring and herrings' reproductive success.

It can be expected that the effects of anthropogenic stressors and the process of climate change will accumulate in the future and will negatively affect the spawning habitat of the WBSS herring stock and the success of reproduction.

Polish case study area ***– Vistula Lagoon***

The ecological analysis of Vistula Lagoon makes it possible to verify the importance of natural fluctuations related to climate change and human activities. Changes and fluctuations in the environment may be unfavorable for herring spawning in the Lagoon. Two categories are presented as outcomes of an unfavorable impact on herring spawning:

1. Spawning sites degradation effecting space suitable for spawning leading to significant decrease of recruitment which in consequence may impact the herring fisheries in the Lagoon.
2. Increased mortality of herring eggs and larvae, reducing spawning success and ultimately leading to lower contribution to the Central Baltic herring stock recruitment.

Climate change

Projected warming in the Baltic Sea area is expected to be higher than the global averages. This means that we should consider experiencing faster changes driven by climatic forcing in the region. Even a slight increase in temperature may significantly influence the period of the ice-cover in the lagoon. More pronounced warming may drastically change the functioning of the whole ecosystem, leading to increased riverine loads during winters, changes in community structure of phytoplankton and zooplankton as well as to shifts in their taxonomic dominance, increased primary production including the algal blooms intensity and even changes in fish communities.

However, the direct impact of increased temperature on herring spawning success in the Vistula Lagoon is expected to be positive. The increased frequency of milder winters with shorter ice-cover period or even entirely without ice-cover will extend the herring reproductive period. In consequence, considering the fact that higher water temperature and no-ice conditions may significantly influence the whole lagoon functioning, the longer herring spawning period will increase the probability of matching the best first feeding conditions for herring larvae. This, on average, should result in higher survival of the herring year-classes.

Human influences

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, if indeed, there is no need at present time to implement special protection for herring spawning grounds, such a cavalier approach could lead to overlooking potential risks to both effective spawning and egg and larva survival. Thus, it is very important to take some steps to significantly increase the awareness in regard to possible risks for successful spawning of herring in the Vistula Lagoon.

It is very often stated that most human activities bring a potential risk to the environment. This general statement must be however specified for an individual case. Therefore, it is concluded here that if a given human activity is to be considered as dangerous for the environment from the point of view of potential risks for herring spawning sites, it must bring a threat in one of the following categories:

- a. direct damage to spawning grounds,
- b. pollutants at levels that increase egg and/or larval mortality,
- c. eutrophication that results in low oxygen levels and/or changes in bottom structure from sandy to muddy accompanied by extinction of immersed plants.

When analyzing the possible effect of different types of human activities, geographical distribution of a given activity as well as the time within year of its occurrence should be also taken into account. From this point of view, equally important it is to have a knowledge about not only timing of the spawning but also about spawning sites distribution.

For sure one of the main factors affecting the level of interest in protection of a given species is its economic importance. This is why we consider it as an important issue to increase the profitability of herring fisheries and to promote herring products at the same time.

Most of the human activities that could be responsible for unfavorable changes in the envi-

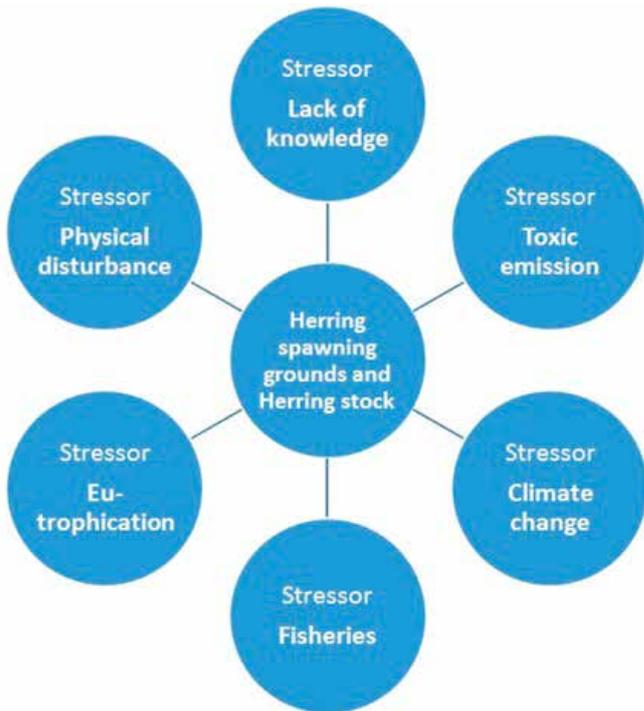
ronment and herring spawning grounds in the Vistula Lagoon area are currently practiced at either very low levels of intensity (e.g., fisheries, tourism, passenger and cargo transport, dredging, industry, urbanization) or are non-existent in this region (e.g., mining, energy extraction). The possibility of the increased intensity of such activities in the near future is the highest for tourism, especially if the plan for building a channel through the Vistula Spit is executed. Although increased tourism will probably not be intense enough to pose significant threats to the environment or herring spawning grounds, it should be kept in mind that potentially this is one of the most significant aspects to consider.

Currently, agriculture is the most significant factor of human activities impacting the lagoon. 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 in 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. Another main current danger for herring spawning grounds is related to dredging and sand extraction - appropriate dredging methods and extracted material handling should be employed.

The current information on herring spawning sites distribution is very weak. Therefore, implementation of three years research project providing accurate data for mapping of herring spawning grounds is strongly advised. It should be in fact treated as a priority if herring spawning grounds safety is to be considered during preparation of the land development plans in the Vistula Lagoon area (we may expect that the plan will be developed within 3-4 years, i.e. by 2017).

Swedish case study area – Hanö Bight

The coast of Hanö Bight is an ecologically variable area with a rapidly steeping seabed quickly reaching down to 20 to 30 m in the southern



Possible human activities inducing stress on herring spawning grounds and herring stock in Hanö Bight. Source: Lilitha Pongolini

part. The northern parts of the bay are characterized of the archipelago with shallower and more sheltered areas. From previous knowledge of preferable spawning environment and conducted field studies herring appears to spawn more frequent in the northern Hanö Bight.

The existence of good quality spawning areas for herring is not only important for the vitality of the herring stocks, but also for the marine ecosystem. Herring is an important part between lower and higher trophic levels as they mostly feed on phyto- and zooplankton and are preyed by larger fish as cod. The complicated interactions between herring, the physical environment and other biological organisms are tightly linked and changes in this interaction may cause consequences that may be hard to predict. An important part of a sustainable herring stock are spawning grounds of good condition making it essential identifying human activities that may disturb these areas as well as having a purpose to through management and measures reduce these negative stressors.

Lack of knowledge

It is of importance to conduct annual studies with the aim of mapping geographically the most important spawning grounds for herring.

As there is a lack of knowledge about the location, quality and importance of the spawning grounds in Hanö Bight, it complicates the ability to identify and evaluate the negative human impact and to have an efficient management approach.

Fisheries

It is of importance to regulate the fisheries with an ecosystem approach to be able to fish sustainably. Overfishing, in combination with only targeting large individuals, may lead to major shifts in species composition and abundance with the effect of changes in the ecosystem. One aspect is that large mature individuals have in general the ability to produce larger amount of reproductive cells. A decrease of the reproductive capacity and quantity of mature fish i.e. spawning stock biomass due to overfishing would therefore lead to a decreasing contribu-



Trawling for herring in Hanö Bight, 1969. Source: Stieg Eldh

tion of the amount of offspring that have the chance to survive and grow to mature individuals. The value and importance of herring as a food source and part of human recreational activities should not be neglected. Taking into account and adapt to the impact of fisheries combined with other human induced pressures is necessary for a development of healthy herring populations and the possibility of usage of herring as a natural resource.



Sorting of herring by hand in the harbour of Brantevik, 1969. Source: Stieg Eldh

Physical disturbance as a stressor

To avoid physical disturbance and destruction of herring spawning grounds, such as dredging and dumping, it is of importance to have the knowledge about the geographical area where the spawning grounds are situated. Establishing nature reserve and Natura 2000 areas would be a good approach to implement protection of the most important spawning grounds.

Toxic emission as a stressor

Many toxic substances are known to have a major negative impact on marine organisms.

The research and knowledge about the toxicity of different substances have a hard time to keep up since many new chemical substances emerge and are emitted to the environment without adequate tests. It is of importance to have knowledge about which different substances are emitted and their toxicity as well as what effect combinations and accumulation of these toxics have. Determining the legal limits of each chemical substance must take this in to consideration. It is essential to follow up known toxic emissions and monitor the environmental impact.

Eutrophication and turbidity

There are several rivers and streams having their outlet in Hanö Bight, and as these pass large

agricultural and forestry areas there is a substantial transport of nutrients and suspended particles to the sea, with the consequence of eutrophication and lower visibility and water quality. Preventive work that have been performed is improvement of sewage and treatment plants as well as establishment of wetlands and ponds that serve as barriers of excessive nutrients and suspended particles before they reach the sea. Due to preventive efforts the emission of nutrient from the industry and other anthropogenic activity had shown a significant decrease. Since the nutrient load of to the Baltic Sea is high, the effects of preventive measures may linger and it is essential to develop and continue these measures.



Seabed outside Ronneby in the archipelago of Blekinge with signs of eutrophication. Source Lilitha Pongolini

Climate change

The various effects of climate change with increasing temperatures, decreasing salinity, acidification, sea level rise and changes in weather conditions may impact the whole ecosystem in the Baltic Sea by altering the marine physical and chemical environment as well as species abundance and composition. How these changes will affect the population and spawning grounds of herring is hard to predict. An assumption is that climate change in combination with other anthropogenic stressors may decrease the resilience of herring populations and enhance the negative impact of the stressors induced to the marine environment. It is important that measures are taken at regional, national and global level to reduce greenhouse gas emissions.

Although there is an assumption that herring spawn in vast areas along the coast, it has to be taken into consideration that human impact

will increase in the coastal regions and potentially have a negative effect on herring spawning grounds. Due to lack of knowledge it is of importance to conduct monitoring and research during longer periods of time. Comparable data from multiple years provides the opportunity to learn about the natural variations or changes in the behavior of spawning herring. Having this knowledge would help to establish protection of the areas identified as especially important for spawning herring. Taking in to consideration would be the amount of herring that spawn, quality of substrate, water quality and other factors related to specific areas that may have significant impact on the success of spawning.

Summary and conclusions of governance structures

German case study area - Greifswald Bay

The German report on governance structures concludes the following for the Greifswald Bodden:

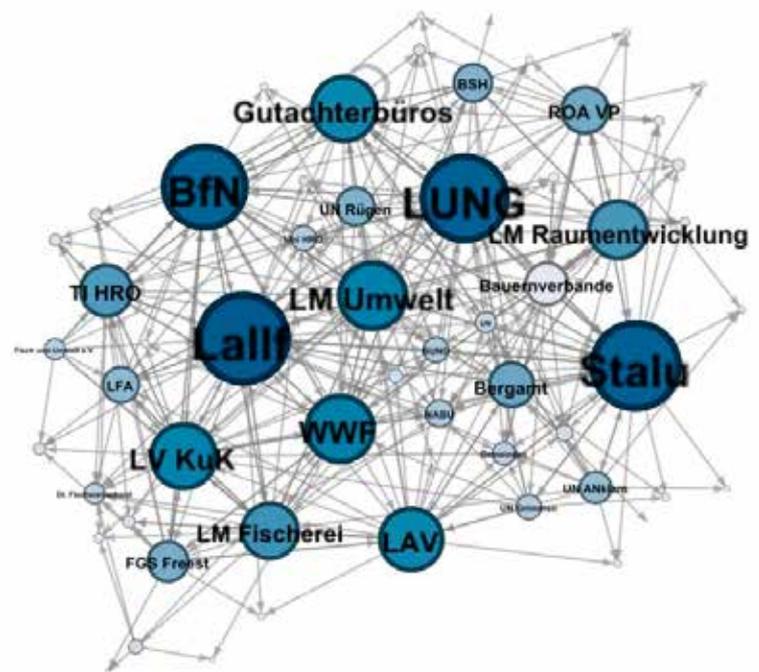
There are no regulations (fisheries, nature conservation, marine spatial planning) regarding and at the same time explicitly protecting herring spawning grounds in Greifswald Bay. Furthermore, different responsible stakeholders, with often contrasting values and interests, regulate the different usage claims. These stakeholders have very different expectations and interests concerning the sustainable use and protection of spawning sites.

The awareness of the importance of herring spawning areas in Greifswald Bay was different between and within stakeholder groups. While almost all representatives from the fishery acknowledged that the protection of spawning areas in Greifswald Bay were unnecessary, some representatives from nature conservation and fishery sciences emphasized the need to improve ecosystem health including further efforts in sustaining and improving spawning areas in Greifswald Bay. Our empirical analysis revealed that especially the awareness of central fishery stakeholders to improve spawning area quality and ecosystem health in Greifswald Bay

was relatively low. Thereby one major concern of the fishery was the fear of potential new restrictions, in particularly zero-use zones.

Semi-structured interviews with stakeholders were carried out in order to help understand their specific interests in regard to a sustainable spawning area management. Stakeholders mentioned a systematic assessment of spawning sites as a prerequisite for informed decision-making and sound planning processes. This included the expansion of the knowledge base to quantify natural and anthropogenic impacts. In most cases these data and information are still missing. The importance of basics research to further understand ecosystem interactions was emphasized.

A social network analysis was realized to learn about stakeholder interactions and communication in the policy process. The analysis revealed that there was a substantial science-policy gap. In particular political stakeholders criticized the restricted access to scientific data. Scientific institutions were peripheral in the governance network suggesting that there was no interface between politics and science. According to the social network analysis central and influential



Social network map from German Greifswald Bodden showing the relationship between different authorities influencing the management of spawning grounds in the area. For a more detailed description of the network analysis see the full report available on www.baltic-herring.eu

of information flow was observed regarding the spatial management plans of municipalities located adjacent to the Vistula Lagoon.

A positive aspect is the growing ecological awareness of local communities pertaining to the Vistula Lagoon. Residents are attempting to utilize newly acquired knowledge in accordance with European tendencies to earn income from pro-ecological ventures such as running agricultural tourism or organizing recreational activities for visitors like angling and sailing. To what degree this is benefitting the strategic development of the lagoon region depends on the local governments and the authorities of both voivodeships. Additionally, the question is raised whether or not the trends observed will be reflected directly in the improved material status of local area residents.

Increasing awareness is noted among local governments regarding the overall potential that lies in the waters of the Vistula Lagoon and adjacent areas both with regard to the development of aquatic tourism and in the promotion of the ecological heritage of the region. Simultaneously, the interviews indicated that the consciousness of local governments, institutions, and organizations regarding the significance of the Vistula Lagoon for herring spawning in the southern Baltic Sea is low.

It is recommended that the current environmental monitoring programme should include fish larvae (ichthyoplankton) among the biological parameters, in addition to phytoplankton, zooplankton, and benthos. Identification of herring, and other fish species, spawning areas is crucial for the efficient governance of the coastal environment.

Swedish case study area – *Hanö Bight*

The Swedish report on Governance structures of herring spawning areas in the Hanö bay concludes the following:

Sweden like any other EU country has through the marine strategy framework directive committed itself to reach a good environmental status in all its marine waters by 2020. Initial steps were taken in 2012 by making an assessment of the current state of the Swedish marine waters as well as a socio-economic analysis of the usage of the sea. The assessment states that the methodology used for monitoring of coastal fish populations is adequate but that the frequency and geographical coverage of the monitoring is too low to be able to apply the results to non-monitored areas. Particularly the Swedish seawaters in the south Baltic Sea lack monitoring of coastal fish stock and it is not possible to assess how alterations in coastal areas may affect species that use coastal waters for reproduction. Furthermore the assessment also states that a much needed complement to the current environmental monitoring would be monitoring of fish larvae as well as an inventory of important habitats for coastal fish species.



Fishingboat in Vitemölla harbour north of Kivik in Sweden 1972.
Source: Stieg Eldh

In the development of the Swedish marine spatial plans a report was recently released describing the current situation in Swedish marine waters (Swam, 2014). Also this assessment states that there is currently only sufficient knowledge to point out 12 spawning areas in Swedish marine waters. None of these are located in Hanö bay.

The lack of identification of herring spawning areas, a monitoring programme for spawning areas and an authority with the specific mandate to monitor spawning areas are probably the biggest challenges to be addressed to improve management of herring spawning areas. The first step, identification of the spawning areas, is suggested to be included in the new marine spatial plans that currently are being developed. Furthermore, a deeper understanding and awareness rising about the link between well managed coastal resources and socio-economic development in coastal communities is also likely to benefit the management of coastal spawning areas.

*Sandy shores along
Hanö Bight.
Source: Naomi
Images*



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*Back cover:
Small creek flowing into the Hanö Bight.
Source Naomi Images.*



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