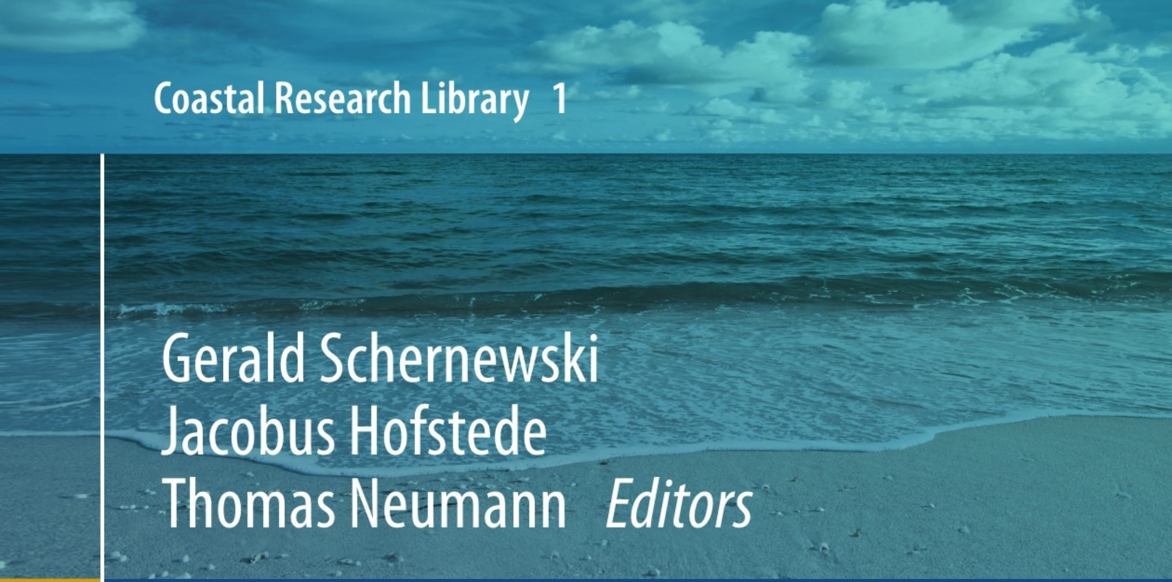

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Global Change and Baltic Coastal Zones

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Global Change and Baltic Coastal Zones

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Preface

According to the United Nations Framework Convention on Climate Change (UNFCCC), the term Climate Change means a climatic change attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. According to IPCC (2007), eleven of the last 12 years (1995–2006) rank among the twelve warmest years since 1850. Observations of increases in global average air and ocean temperatures as well as widespread melting of snow and ice provide clear evidence of an ongoing global warming.

The impacts of Climate Change vary regionally. In Europe, especially the Mediterranean will be significantly affected. In this region, Climate Change is projected to increase heat waves and droughts during summer, reduce water availability and decrease crop productivity. The negative consequences in the Mediterranean are overwhelming and Climate Change is regarded as a major threat for the future. In the North Sea region, rising mean sea levels and storm surge water levels are seen as a major challenge resulting from Climate Change. In the Baltic Sea region, the effects as well as the perception and evaluation of the consequences are different. Here, people tend to look – as well – at the opportunities of Climate Change.

A changing climate is not the only challenge for the future. At the same time political, social, economic and agricultural transformation processes are ongoing in the world. These developments interact with Climate Change and both can be summarized under the label ‘Global Change’. The strong geographical variability in Global Change calls for a regional focus, in this case the Baltic Sea region.

In the Baltic Sea region, Climate Change and ongoing transformation processes in economy and agriculture will have strong and multiple impacts. Numerous investigations on these topics have been conducted. During the last years the focus of activities shifted from analysis and evaluation of consequences via mitigation strategies towards adaptation approaches. This is well reflected in national initiatives and projects. The German ‘KLIMZUG’ funding activity, initiated in 2009, is one example. Background was the perception that an urgent demand for society, economy and politics exists to develop new and improved methods for adaptation. This initiative particularly stresses the regional aspect of adaptation by funding seven large regional projects. One of them is RADOST (Regional Adaptation Strategies for the German Baltic Coast). Similar large international projects, like BaltCICA

(Climate Change: Costs, Impacts and Adaptation in the Baltic Sea Region) or BALTADAPT (Baltic Sea Region Climate Change Adaptation Strategy) have their focus on pan-Baltic cooperation.

Adaptation strategies and measures are urgently needed but require a thorough and spatially differentiated understanding of underlying ecological, economic and social processes. The book addresses these changes, their consequences, practical challenges as well as adaptation options with a clear focus on the coastal zones of the Baltic Sea region.

Regardless of the strong spatial variability of Global Change, the resulting problems, challenges and, thus, possible solutions may show similarities for different regions in the world. In awareness of the fact that concrete adaptation measures and their implementation have to be tailor-made and fitted to the special situation

of a locality, an exchange of experiences in dealing with Global Change seems appropriate. Closer co-operation between scientific, administrative and political actors as well as different regions is required. Learning how the problems are addressed in different parts of the world, how different strategies and solutions look like and how basic approaches can be transferred to other regions are important educational issues today.

Against this background, the international summer-school ‘Climate Change in the Baltic – From global problems to local adaptation’ took place at the Leibniz-Institute for Baltic Sea Research between 6th and 17th of September 2010. 19 students and young scientists from 13 countries had the opportunity to exchange experiences and get an insight into activities in the Baltic Sea Region. Several lectures served as a basis for the articles of this book.

The participants of the summer-school ‘Climate Change in the Baltic – From global problems to local adaptation’ at Warnemünde beach

This book has been funded by the Federal Ministry for Education and Research within the KLIMZUG-project RADOST (Regional Adaptation Strategies for the German Baltic Coast; 01LR0807B). It received additional support from EUCC-The Coastal Union Germany and the European Regional Development Fund within the Baltic Sea Region Programme project BaltCICA (Climate Change: Costs, Impacts and Adaptation in the Baltic Sea Region) and BALTADAPT (Baltic Sea Region Climate Change Adaptation Strategy).

Rostock	Gerald Schernewski
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KLIMZUG
climate change in regions

RA:dOst
Regional Adaptation Strategies for the German Baltic Sea Coast

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Part I
Global Change – The Scientific Background

Chapter 1
Regionalisation of Climate Scenarios for the Western Baltic Sea

Ulf Gräwe and Hans Burchard

Abstract Global coupled climate models are generally capable of reproducing the observed trends in the globally averaged atmospheric temperature. However, the global models do not perform as well on regional scales. Here, we present results from two 140-year, high-resolution regional ocean model experiments for the Western Baltic Sea. The forcing is taken from a regional atmospheric model and a medium scale ocean model. The model runs with two greenhouse gas emission scenarios (each for 100 years), A1B and B1, for the period 2000–2100. A control run (C20) from 1960 to 2000 is used for validation. For both scenarios, the results show the expected warming, with an increase of 0.5–2.5 K at the sea surface and 0.7–2.8 K below 40 m. The simulations further indicate a decrease in salinity, a change in stratification, and an increase of the return period of storm surges.

1.1 Introduction

Climate Change and variability affect the coastal zone, the marine ecosystem, and fisheries in several ways. First temperature has a direct influence on metabolism and growth; see for example, Jobling (1996). Climate may also have secondary effects, affecting a species by changes in food availability, competitors, or predators. For the North Sea and Baltic Sea, there are several recent studies on the effects of Climate Change on the fish stock and plankton (Clark et al. 2003, Isla et al. 2008, Neumann 2010). Temperature and salinity changes may also act as proxies for other climate mechanisms such as circulation changes and changes in vertical mixing and stratification. For the Baltic Sea the episodic inflow of saline, oxygen rich North Sea water is an important climate variable (Omstedt et al. 2004, Meier 2007). In

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addition to the influence on the salinity, these inflows are also a source of nutrients and zooplankton (Feistel and Nausch 2008). Due to this highly variable environment, life in the Baltic Sea is highly adapted and often reaches its physiological limits (e.g. Feistel and Nausch 2008). Moreover, large scale variability in the atmospheric variables, and hence changes in local climate, might lead to significant changes in coastal erosion (Zhang et al. 2010, Meyer et al. 2008).

The Climate Changes projected to occur within the next 100 years, will have a considerable impact on the physical conditions of the Baltic Sea (BACC 2008). The projected warming is between 3 and 5 K, with a tendency towards a reduced salinity. To study the projected implications of Climate Change (Meier et al. 2004, Meier et al. 2006, Sanchez et al. 2004, Wang et al. 2008, Somot et al. 2008, van Roosmalen et al. 2010), a consistent scenario of future climate is needed. Such scenarios are produced by global coupled atmosphere-ocean circulation models. However, for shallow seas like the Western Baltic Sea, the present generation of such global models do not have the necessary resolution to properly resolve the complex topography. Typically, they also lack important shelf sea physical processes like turbulent mixing, overflows and fronts and a realistic description of the bathymetry and the coastline. Hence, there is an increasing need to use regional ocean model to provide valuable, high-resolution information to governments, stakeholders and coastal engineers (Holt et al. 2010, Brown et al. 2010, Melsom et al. 2009, Adlandsvik and Bentsen 2007).

This modelling study is embedded into a general framework for adaptation strategies for the German Baltic Coast, RAdOst (2009). The objective of RAdOst is the development of adaptation strategies for the Baltic Sea coastline of Germany through a dialogue between science, economists, policy-makers, and the public. Other important goals are to minimise the economic, social, and environmental harm and to capitalise on development opportunities brought about by Climate Change.

This paper uses dynamical downscaling to regionalise future global climate scenarios for the Western Baltic Sea. This is done by forcing a high-resolution regional ocean model with atmospheric forcing and open ocean lateral boundary description from a regionalised atmospheric and large-scale ocean model. The final spatial resolution of the model is approx. 1 km, which allows for a realistic description of topographic features like sills, sounds and coastlines. The forcing used in the present study are two greenhouse gas emission scenarios proposed by the Intergovernmental Panel on Climate Change (IPCC 2007), A1B and B1. The latter is the more optimistic of the two scenarios, with less greenhouse gas emissions. Because the simulations range from 1960 to 2100, no care has to be taken for the additional spinup in time slice experiments. These transient simulations are a novel feature in regionalised ocean climate modelling, because they do not rely on the assumption, that the underlying system has reached a steady state. This was also pointed out by Neumann (2010).

In this paper we are analysing the following model output data: 3-hourly sea level data, daily mean fields of temperature/salinity and weekly averaged potential energy anomaly.

1.2 Methods

1.2.1 The Forcing Scenarios

From the IPCC IPCC07, simulations of 20 Atmospheric-Ocean General Circulation Models (AOGCMs) are available. Ideally, these 20 AOGCMs are used to force 10 regional climate models (RCM) (Christensen and Christensen 2007, Jacob et al. 2007). This would give a total number of 200 possibilities for one realisation of one forcing scenario to span a sufficiently large ensemble of regional simulations. However, this is not yet feasible for a single working group. Therefore, only one combination of AOGCM and RCM is chosen to force the high-resolution ocean model.

The meteorological forcing chosen for our simulations was provided by the dynamic downscaling carried out with the CLM (CLM 2008), the climate version of the operational weather forecast model of the German Weather Service, used as the RCM for downscaling. The horizontal resolution of the CLM is about 18 km (this is high enough to capture the effect of land/sea transition) and the time resolution is taken as 3 h for all necessary meteorological variables (10 m wind, air temperature, dew point temperature, cloud cover, air pressure and precipitation). The global climate model is ECHAM5/MPI-OM of the Max-Planck-Institute for Meteorology in Hamburg, Germany (MPI 2008). The forcing data set covers the period from 1960 to 2100. It is splitted into the reference period (C20) covering the years 1960–1999 and the two greenhouse gas emission scenarios, A1B and B1 (2000–2100).

The oceanic boundary conditions are taken from the transient Modular Ocean Model, MOM-3.1 (Griffies et al. 2001) simulations of Neumann (2010). The model covers the entire Baltic Sea and parts of the North Sea and has a horizontal resolution of 3 nm and 77 vertical (geopotential) grid layers, with a near-surface resolution of 2 m, increasing with depth (Neumann 2010). For a validation of Baltic Sea simulations see Neumann (2000) and Janssen et al. (2004). The boundary conditions are provided with a temporal resolution of 4 h. At the boundaries, profiles of temperature and salinity are prescribed. Additionally, the sea surface elevation and the depth-averaged currents are given at the boundary points. Because the simulations of Neumann (2010) do not include the effect of sea level rise, it has to be added explicitly. Here we follow the projections of the IPCC, where the possible range for the A1B scenario is given as 21–50 cm and for the B1 scenario as 18–38 cm. In our experiments, we have chosen a sea level rise of 50 cm for the A1B scenario and of 25 cm for the B1 run. These values are linearly interpolated between 2000 and 2100.

1.2.2 The Regional Ocean Model

The General Estuarine Transport Model (GETM) (Burchard and Bolding 2002, Burchard et al. 2004), which has been used for the present numerical study, combines the advantages of a bottom-following coordinates with the turbulence module of the General Ocean Turbulence Model (GOTM) (Umlauf et al. 2006). GETM has been successfully applied to several coastal, shelf sea and limnic scenarios, for turbulent flows in the Wadden Sea (Stanev et al. 2007, Lettmann et al. 2009), for dynamics in the North Sea (Staneva et al. 2009), for estimating exchange and residence times the Willapa Bay in Washington State (Banas and Hickey 2005) and for a basin-exchange study in the Lake of Geneva (Umlauf and Lemmin 2005). Furthermore, GETM has recently shown its capabilities to simulate inflow events into the Baltic Sea (Burchard et al. 2005, 2009).

GETM is a three-dimensional free-surface primitive equation model using the Boussinesq and boundary layer approximations. Vertical mixing is parameterised by means of a two-equation $k-\varepsilon$ turbulence model coupled to an algebraic second-moment closure (Canuto et al. 2001) (see also Burchard and Bolding 2001) explicit horizontal mixing is neglected. For the discretisation, a high-resolution bathymetry (0.5 nm resolution) has been used as well as bottom- and surface-fitted vertical coordinates with 35 vertical layers and a horizontally homogeneous bottom layer thickness of 0.4 m, such that the flow can smoothly advect along the bed. Details of the model setup are explained in detail in Burchard et al. (2009). In contrast to the original settings, the time step was 15 s for the barotropic and 375 s for the baroclinic mode. These settings are close to the stability criterion, but allow for a fast time stepping. Additional, the Odra Lagoon (Fig. 1.1) was added to the computational domain.

To properly simulate the river discharge, five rivers are included in the model domain. The time series of river discharge are also taken from the simulations of Neumann (2010). The most important is the Odra (mean discharge 600 m^3s^{-1}), which directly discharges into the Odra lagoon (Fig. 1.1). For consistency, both ocean models use the same CLM atmospheric forcing on the same spatial grid. Due to the two open boundaries at which sea levels from the MOM Baltic Sea model Neumann (2010), were prescribed, the net flow through the Western Baltic Sea had to be fitted. This was done by adjusting the barotropic pressure difference between both open boundaries. Furthermore, to keep the water exchange through the Great Belt realistic, the bathymetry was deepened in the narrow channels (Fig. 1.1). The adjustment procedure, the changes in the bathymetry and more details of the model setup are explained in detail in Burchard et al. (2009). Although we used an ocean model with a wetting and drying algorithm, no changes in the coastline are considered. Especially the loss of land due to flooding is not taken into account. To keep the simulation computationally feasible, the whole domain ($426 \times 469 \times 35$ grid-points) was decomposed into 251 active sub domains ($21 \times 22 \times 35$ grid-points). The calculations were performed at one of the German supercomputers (22,000 cpu's (HLRN 2007)). At the supercomputing facility, 1 year of simulation took about 120 min of wallclock time.

1.2.3 Statistical Comparison

To validate climate simulations it is not possible to compare time series. Therefore, climate projections cannot reproduce single events rather than reproducing the

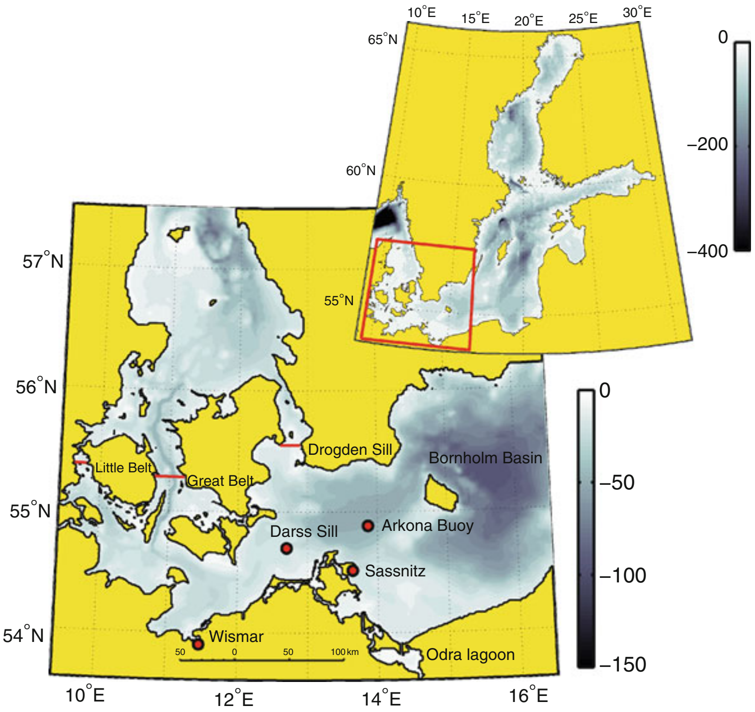

Fig. 1.1 Model domain and location of the Western Baltic Sea. The *grey shading* indicates the depth below mean sea level in m. *Upper panel*: a map of whole Baltic Sea showing the location of the model domain. The location of observation stations are denoted by the *dots*

long-term statistic. It is common to use 30 years to compute the appropriate statistics (Christensen et al. 1997). Because the observations of high-resolution time series of atmospheric forcing and temperature/salinity in the water only cover 14 years (Table 1.1), we have compared the statistic of 14-year slices and the full reference period. For both case no significant difference were visible. Thus, the limited lengths of observations are still challenging, but allow for a validation. Table 1.1 summarises the available observation data. The hourly sea level gauge data of Sassnitz and Wismar are converted to 3-hourly data by sampling every third point. Temperature/salinity and atmospheric forcing is measured hourly but for comparison with the control run, a daily average is computed.

Table 1.1 Summary of available observations stations (see also Fig. 1.1)

Station	Atmos. forcing	Gauge	Temperature/salinity
Wismar	–	1978–2004	–
Darss Sill buoy	1995–2009	–	1995–2009
Sassnitz	–	1978–2004	–

1.3 Validation

In the following section a validation of the atmospheric forcing and the simulation of the reference run (1970–2000) is given.

1.3.1 Atmospheric Forcing

In Fig. 1.2a, the comparison of the 2 m air temperature is shown, for which we have chosen the Darss Sill buoy (Fig. 1.1) for validation. At first, it is central in the model domain and quite representative for the whole German coast. Second this observation station offers time series spanning from 1995 to 2009. It is clearly visible that the CLM data show a cold bias of 1.3 K. However, the atmospheric model is able to reproduce the bimodal temperature distribution. Nevertheless, one has to keep the cold bias in mind to judge the outcome of the climate projection, especially if the GETM output is used in further impact studies.

In Fig. 1.2b, the probability density function (pdf) of the measured wind speed and the CLM wind speed is shown. The CLM dataset shows a slight overestimation of wind speed above 12 m s^{-1} and below 2 m s^{-1}. Because the CLM dataset tends to overestimate the extremes (low and high wind speed), there is an underestimation of moderate wind speeds of 5–12 m s^{-1}. However, one can conclude that the atmospheric model can reproduce the reference wind statistic.

For a detailed comparison of the CLM data and an inter-comparison of different RCA, the interested reader is referred to Jacobs et al. (2007).

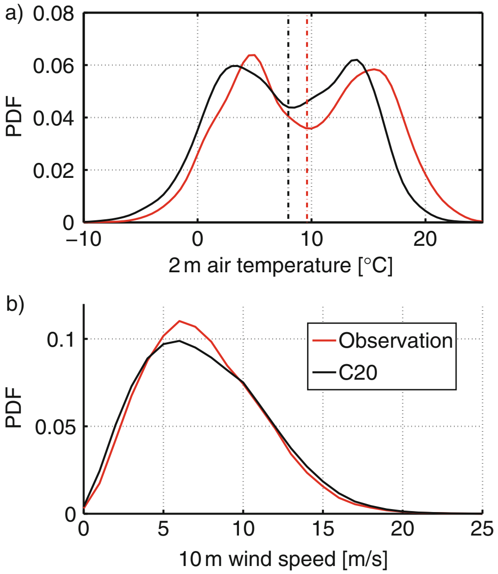

Fig. 1.2 Validation of CLM forcing at Darss Sill buoy, (**a**) pdf of 2 m air temperature. The *dashed lines* indicate the mean. (**b**) pdf of wind speed

1.3.2 Temperature and Salinity

To show that GETM can represent the present day statistic, Fig. 1.3a shows the pdf of bottom salinity at Darss Sill buoy. This station is quite important, because approx. 70% of the water exchange between the North Sea and the Baltic Sea goes over Darss Sill (Matthäus and Franck 1992). The comparison indicates that GETM can quite well estimate the salinity pdf. The occurrence of high salinities is only slightly overestimated. For the low salinity events, this is just reversed. Because the salinity within the Western Baltic Sea is mainly controlled by the boundaries, these minor deviations might be caused by the boundary conditions.

Looking on the statistics of the bottom temperature (Fig. 1.3b) reveals the impact of the cold bias in the CLM air temperature. The simulations show a cold bias of 0.9 K, which is slightly lower than for the air temperature (1.3 K). Having the cold bias in mind, it is difficult to judge the quality of the results.

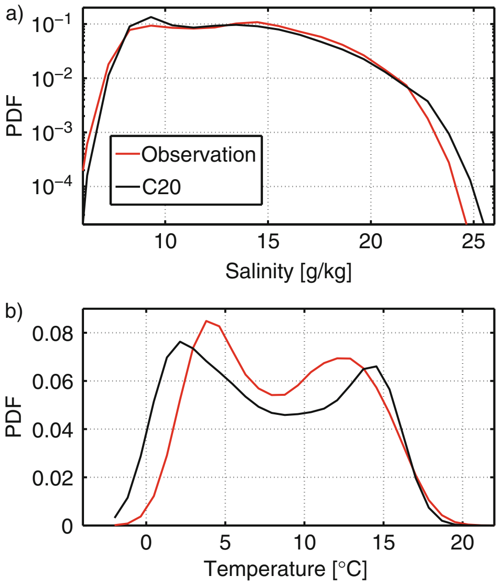

Fig. 1.3 Validation of the pdf of daily averaged (**a**) bottom salinity and (**b**) bottom temperature at Darss Sill buoy (19 m depth)

1.3.3 Sea Surface Elevation

A quantity, which is of great interest for coastal engineers and port authorities, is the occurrence of storm surges. Based on the return period of 10-year, 30-year, etc. surges, dykes and coastal protections have to be designed. In Fig. 1.4 we show the comparison of the pdf of sea surface elevation at two gauge stations Sassnitz and Wismar (Fig. 1.1). One has to note that Wismar is the more challenging, because topographic feature and local wind stress are modifying the surge. Looking onto the statistic of surges higher than 1 m, GETM slightly underestimates the probability of

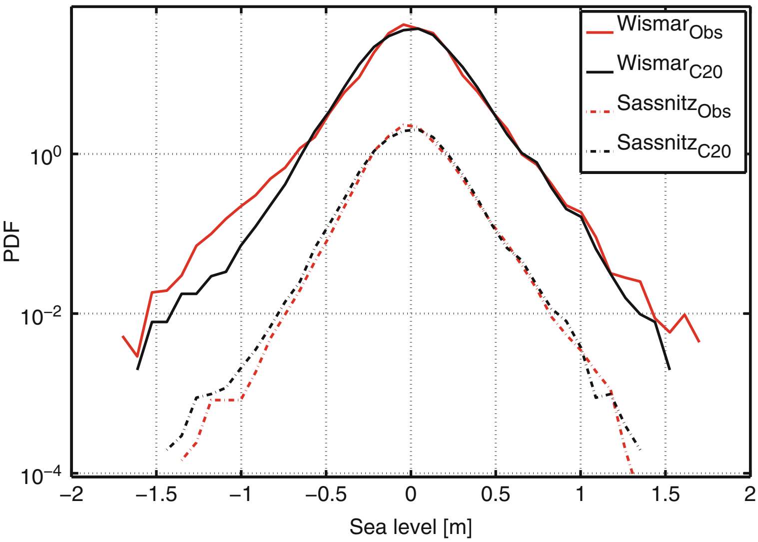

Fig. 1.4 Validation of the pdf of sea surface elevation at Wismar and Sassnitz. For better comparison, the Wismar gauge pdf is shifted upward

extremes. Further, GETM misses some of the extremes. This can be caused by the atmospheric forcing. The 18 km resolution of CLM is reasonably high; it still can be too coarse to reproduce the proper extreme wind statistic. Anyhow, GETM can reproduce the right side of the pdf of sea surface elevations for Wismar and Sassnitz. For extreme low water, GETM deviates from the observation. This might be caused by bathymetry and by the wetting/dry algorithm in GETM. Because Wismar is surrounded by much shallower water than Sassnitz, this effect is more pronounced. However, these low waters might be of interest for ship routing and fairways, but of minor importance in the context of Climate Change.

To have better comparison than by visual inspection, we performed a Wilcoxon rank sum test (Gibbons 1985). This test compares two time series and test the hypothesis if both do not have the same underlying distribution. As significance level, we have chosen the 5% level. Because we are interested in the high waters, only the distributions of the tails are compared. As tail, we define sea surface elevations greater than the 99 percentile of the observation time series (1978–2004). The 99 percentile for Sassnitz are 0.56 cm and 0.68 cm for Wismar (Table 1.4). The P-value of the Wilcoxon rank sum test indicates that the observed and simulated time series are drawn from the same distribution at the 5% significance level (37% for Sassnitz and 31% for Wismar).

1.4 Climate Projections for the Western Baltic Sea

In the following section, the impact of the projected climate-change on the Western Baltic Sea hydrodynamics is discussed. For visualising the results, some of the model state variables are used.

1.4.1 Atmospheric Forcing

To set the stage for showing the impact of Climate Change on the Baltic Sea in Fig. 1.5a annual mean time series of projected 2 m air temperature and standard deviation for the model domain (only above water points) is given. Here the increase by 2–3.5 K at the end of the century is visible. The standard deviation indicates a slight decrease in variability. Doing the same exercise for the wind speed revealed that the annual mean wind speed stays nearly constant in the next 100 years (not shown). More interestingly is, that the 99% quantile of the wind speed (strong wind events) (Fig. 1.5b) will slightly increase in the future. This might have implications on the occurrence of storm surges. The standard deviation does not indicate any significant trend.

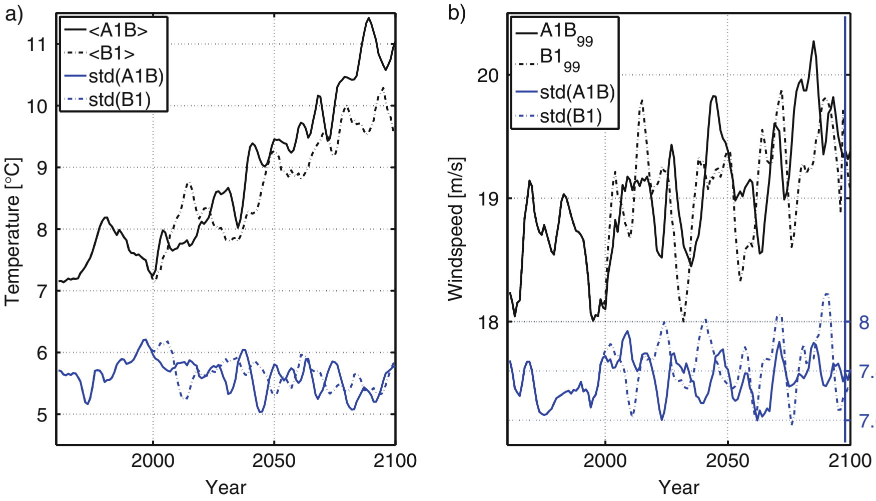

Fig. 1.5 (**a**) Projected annual 2 m air temperature over the western Baltic Sea and annual standard deviation and (**b**) projected annual 99% quantile of the wind speed and standard deviation of the annual wind speed. The data are smoothed by using a 5-year running mean

1.4.2 Sea Surface Temperature

Figure 1.6a shows the annual mean sea surface temperature (SST) for the control run (1970–2000). The average sea surface temperature along the German coast is approx. 8.5°C. Peak values of 9°C are reached in the Odra lagoon and around Wismar. The cooler water in the northeast of the domain is caused by coastal upwelling due to the prevailing westerly winds. The A1B scenario, Fig. 1.6b indicates an average increase of 0.9 K for the period 2020–2050 and 2.5 K for the period 2070–2100 (Fig. 1.6c). The highest warming can be seen in the Bornholm Sea and in the Arkona Basin. For the B1 scenario, the average increase for the period 2020–2050 is 0.5 K (Fig. 1.6d) and for the period 2070–2100 on average 1.7 K (Fig. 1.6d). In almost the same manner warming can be seen in the Bornholm Sea and in the

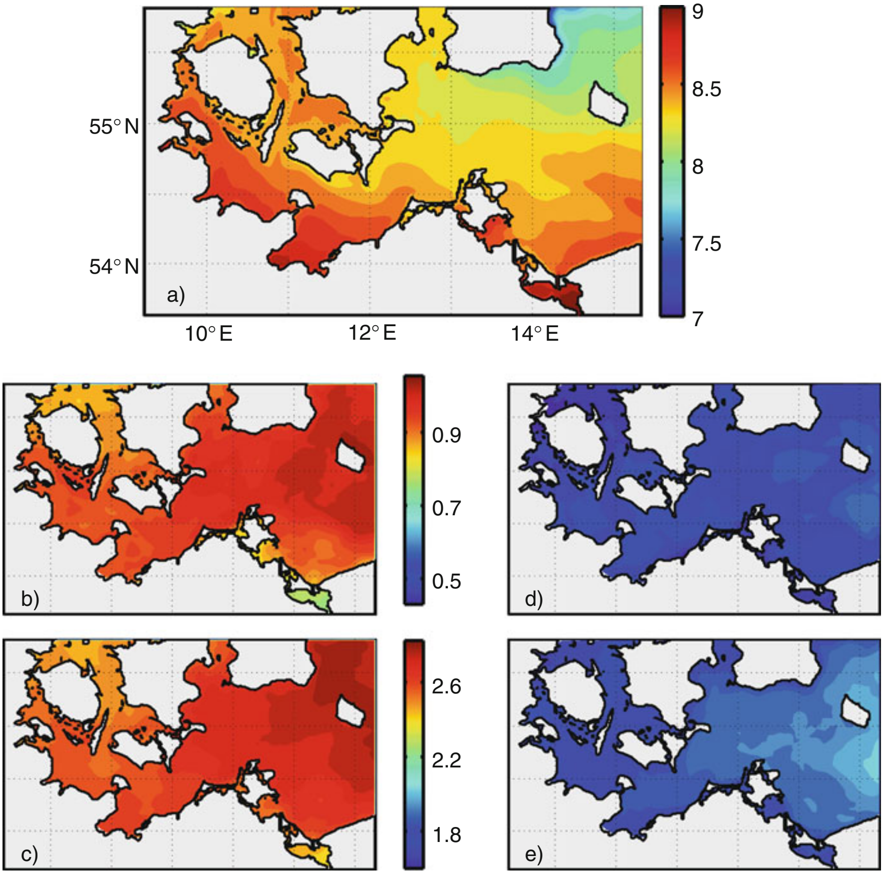

Fig. 1.6 (**a**) Annual mean sea surface temperature for the period 1970–2000. Projected changes in the annual mean sea surface temperature for (**b**) A1B 2020–2050, (**c**) A1B 2070–2100, (**d**) B1 2020–2050 and (**e**) B1 2070–2100. Note the different scales for 2020–2050 (**b**, **d**) and 2070–2100 (**c**, **e**)

Arkona Basin. A detailed description of the warming in relation to C20 is given in Table 1.2. The warming at the bottom (depth >40 m) is the strongest; however the values indicate that the whole water column is shifted towards higher temperatures.

Table 1.2 Summary of temperature changes for the SST, bottom temperature (depth > 40 m) and the whole water body

Station	A1B		B1	
	2020–2050	2070–2100	2020–2050	2070–2100
SST	+0.9 K	+2.5 K	+0.5 K	+1.7 K
Bottom temperature	+1.0 K	+2.8 K	+0.7 K	+2.0 K
Whole water body	+0.9 K	+2.7 K	+0.5 K	+1.8 K

1.4.3 Water Exchange

To compute the water exchange with the North Sea, the water transport Q_W through the cross-sections in the Little Belt, Great Belt and at Drogden Sill (Fig. 1.1) is calculated:

$$Q_W(t) = \int_A v(x, z, t)dA, \tag{1}$$

where A is the area of the cross section and v the meridional velocity. To quantify the overall residual mass flow, the advective salt flux Q_S into the Baltic Sea has been calculated explicitly:

$$Q_S(t) = \int_A v(x, z, t)S(x, z, t)dA, \tag{2}$$

Where S is the salinity. It is obvious, that $Q_S$should sum up to zero (if the salinity remains constant in the Baltic Sea), because there are no salt sources or sinks in the Baltic Sea. Therefore, to give Q_S a meaning, we compute the salt flux only for salinities exceeding a certain threshold. Thus, it is possible to quantify the inflow of saline North Sea water into the Baltic Sea.

The results are summarised in Table 1.3. The mean outflow Q_W during the reference period is approx. 15,000 $\text{m}^3\ \text{s}^{-1}$, which is similar to the observed climatological one Feistel08. The values indicate a slight increase for the B1 scenario. However, this is caused by the increase in freshwater supply (Meier and Kauker 2003) and agrees with the decrease in salinity (Fig. 1.7). Moreover, an increase in variability in the second part of the century is visible.

A second quantity of interest is the salt flux Q_S into the Baltic Sea. This can be decomposed into two parts: first, the contribution due to the salinity difference,

Table 1.3 Summary of water exchange through the Little Belt, Great Belt and over Drogden Sill (Fig. 1.1). Positive values indicate a flux out of the Baltic Sea

	Period	A1B	B1
Q_W	1970–2000	14,900 ± 5,700 $\text{m}^3\ \text{s}^{-1}$	14,900 ± 5,760 $\text{m}^3\ \text{s}^{-1}$
Q_W	2020–2050	14,300 ± 5,000 $\text{m}^3\ \text{s}^{-1}$	16,600 ± 5,710 $\text{m}^3\ \text{s}^{-1}$
Q_W	2070–2100	14,800 ± 6,900 $\text{m}^3\ \text{s}^{-1}$	17,300 ± 6,490 $\text{m}^3\ \text{s}^{-1}$
$Q_{S>15}$	1970–2000	–355 ± 90 t s^{-1}	–355 ± 90 t s^{-1}
$Q_{S>15}$	2020–2050	–340 ± 75 t s^{-1}	–380 ± 70 t s^{-1}
$Q_{S>15}$	2070–2100	–360 ± 105 t s^{-1}	–380 ± 80 t s^{-1}
$Q_{S>20}$	1970–2000	–240 ± 100 t s^{-1}	–240 ± 100 t s^{-1}
$Q_{S>20}$	2020–2050	–180 ± 105 t s^{-1}	–310 ± 75 t s^{-1}
$Q_{S>20}$	2070–2100	–130 ± 80 t s^{-1}	–280 ± 85 t s^{-1}
$Q_{S>25}$	1970–2000	–10 ± 25 t s^{-1}	–10 ± 25 t s^{-1}
$Q_{S>25}$	2020–2050	–5 ± 10 t s^{-1}	–35 ± 30 t s^{-1}
$Q_{S>25}$	2070–2100	–0 ± 10 t s^{-1}	–29 ± 30 t s^{-1}

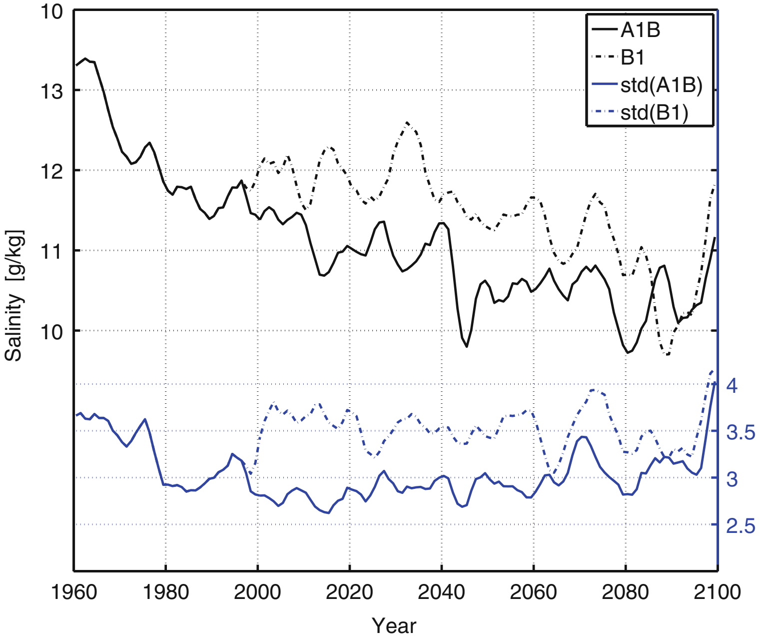

Fig. 1.7 Projected changes in annual mean bottom salinity and standard deviation for Darss Sill buoy. The data are smoothed by using a 5-year running mean

hence the baroclinic pressure gradient and the barotropic part, which is caused by sea level difference, between the North Sea and the Baltic Sea. Especially the later one is important for the deep-water exchange in the Baltic Sea. To characterise such inflow events, Matthäus and Franck (1992) used as indicator the bottom salinity at Darss Sill buoy. Salinities above 17 g kg^{-1}, during more than 5 days, define a major inflow event. It is not the intention of this paper to verify the findings of Matthäus and Franck (1992), rather than to give a broad description of the residual salt flux. Because we have the simulation data available, the flux is computed at Little Belt, Great Belt and at Drogden Sill transects (Fig. 1.1) for 3 thresholds, 15, 20, and 25 g kg^{-1}. For the calculation of Q_S we used transects of daily mean salinity and meridional velocity.

The results in Table 1.3 indicate, that there is an increase in Q_S into the Baltic Sea by medium inflow events, but also during major events (S >25 g kg^{-1}) for the B1 emission scenario. This would also explain the higher variability in the stratification in the Arkona Basin. The opposite is true for the A1B scenario. Here a decrease in salt flux for salinities >20 g kg^{-1} is visible, which again explains the lower variability at the Arkona buoy.

1.4.4 Bottom Salinity

The projected changes in the bottom salinity at Darss Sill buoy are given in Fig. 1.7.

For both scenarios, a decrease in salinity is visible, mainly caused by the increase in freshwater supply (Meier and Kauker 2003). These findings are in agreement with the results of Neumann (2010), with a decrease of approx 1.5 g kg^{-1} for the B1 scenario and 2 g kg^{-1} for the A1B scenario. In the time series of the standard deviation, no significant trend is visible, except that the B1 run shows a somewhat higher variability. Figure 1.7 further indicates that there are differences before and after 2000. At first the salinity is significant higher and second, the variability before 2000 is lower (especially 1980–2000). Here, a second control run might clarify these differences.

1.4.5 Stratification

Potential energy arguments have been found to be an excellent measure to study the competition of stratification and mixing. To quantify stratification, Simpson et al. 1977, considered changes in potential energy relative to the mixed condition and defined a scalar parameter ϕ, the potential energy anomaly,

$$\phi = \frac{1}{D}\int_{-H}^{\eta} (\overline{\rho} - \rho)\, gz dz \tag{3}$$

where D is the total water depth $D = \eta + H$, η the sea surface elevation, H the mean water level, $\overline{\rho}$ the depth averaged density, p is the vertical density profile over the water column, g the gravitational acceleration and z the vertical coordinate. For a given density profile, ϕ (J m^{-3}) represents the amount of work required to bring about complete vertical mixing per unit of volume and thus a measure to quantify the strength of the stratification. In Fig. 1.8a, the potential energy anomaly and standard deviation for the Arkona buoy (Fig. 1.1) is shown. For both scenarios, no significant trend is visible for the mean. Only the variability in the B1 run is slightly increased. Further, the stratification in the B1 scenario is on average stronger than under the A1B emission scenario. This seems surprising; since the stronger decrease in surface salinity for A1B (Fig. 1.7) would lead to a strengthening of the stratification. On the other hand, due to the increase in temperature, stratification is weakened. Therefore, both effects cancel each other. More interesting are the time series of annual minimum and maximum of ϕ (Fig. 1.8b). The spread between the annual maximum and minimum in the B1 run is higher than for the A1B run. The higher variability in the B1 emission scenario (Fig. 1.5) supports these findings. In addition, both model runs show lower annual minima than in the control run. This can be caused by the increase in highly energetic strong wind events. Thus, the occurrence of a less stratified Arkona basin is much more probable in the near future.

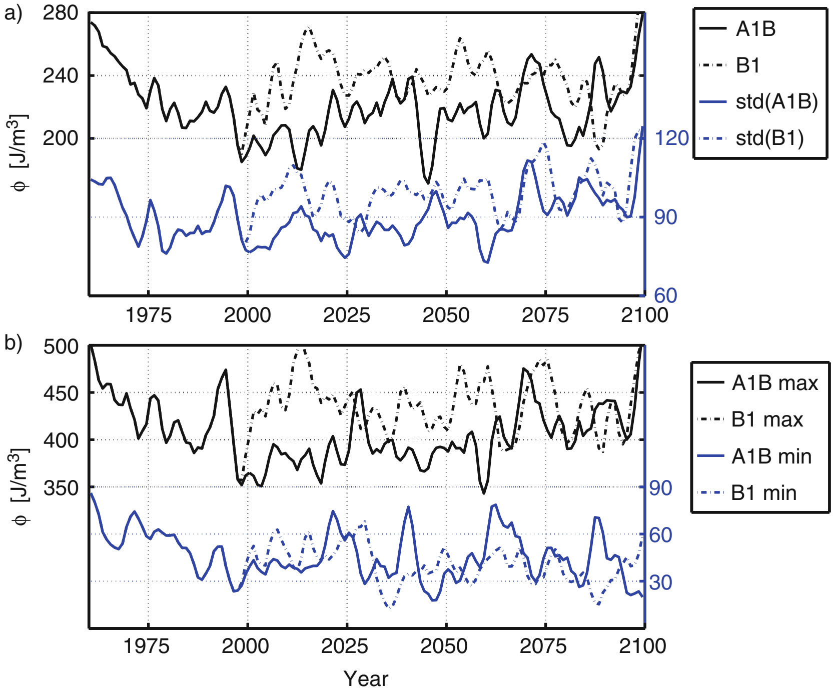

Fig. 1.8 Projected changes in potential energy anomaly in the Arkona Basin. (**a**) Annual mean and standard deviation and (**b**) annual maximum and minimum. The data are smoothed by using a 5-year running mean

1.4.6 Storm Surges

Changes in the return period and thus the occurrence of severe storm surges are of great practical interest. Depending on the return period of a 30 or 50-year surge, dykes and coastal protections will be designed. In Fig. 1.9 the projected changes for Sassnitz (Fig. 1.9a) and Wismar (Fig. 1.9b) are given. For comparison, also the return period, estimated from the observations, is shown. In this plot, the effect of sea level rise is included. For Sassnitz, there is a significant increase of surges with a return period of over 20 years. These changes hold for both scenarios. For Wismar, similar effects are visible, but not as pronounced as for Sassnitz.

To understand, if the changes in the return period are caused by the sea level rise or due to changed atmospheric conditions (Fig. 1.5), we again performed a Wilcoxon rank sum test with the tail distribution, based on the 99 percentile (Table 1.4). For the test the sea level rise was subtracted from the time series, thus all distributions have a vanishing mean. This enables us to directly compare the distribution functions. The results of this test are given in Table 1.4. The P-values indicate that due to the changed atmospheric forcing, there will be a significant change

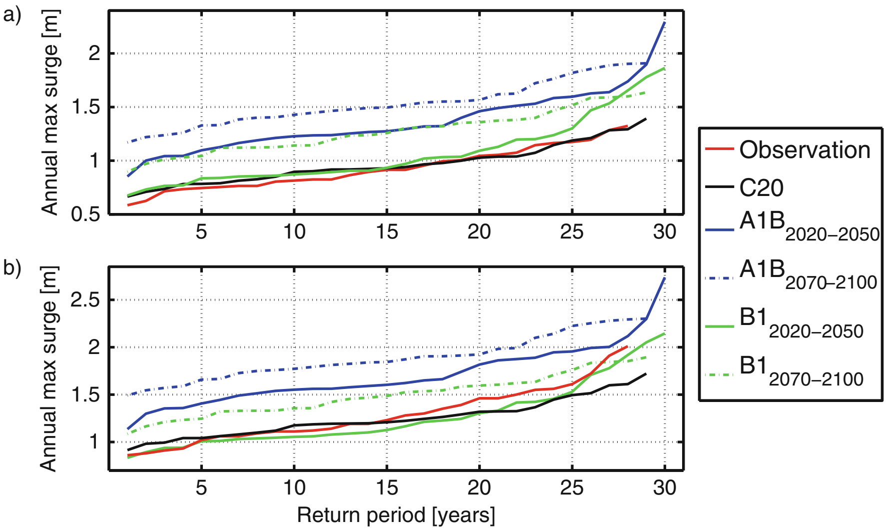

Fig. 1.9 Projected changes in return period for annual storm surge for (**a**) Sassnitz and (**b**) Wismar

Table 1.4 Statistical analysis of storm surges for the gauge stations Sassnitz and Wismar (Fig. 1.1). Given are the P-values of the Wilcoxon rank sum test for the tail distribution (sea surface elevation > 99 Percentile). The mean surface elevation is removed from all pdfs

Station	Scenario	99 Percentile (cm)	1970–2000	2020–2050	2070–2100
Sassnitz	A1B	0.56	0.37	< 0.05	< 0.05
Sassnitz	B1	0.56	0.37	< 0.05	< 0.05
Wismar	A1B	0.68	0.31	< 0.05	< 0.05
Wismar	B1	0.68	0.31	0.44	< 0.05

(at the 5% significance level) in the return period of storm surges. The only exception is Wismar in the period 2020–2050; here the changes are not significant.

To illustrate the change in sea level distribution in Fig. 1.10 the right side of the distribution is shown. To have a better visual comparison, the mean is removed. A widening of the distribution of sea level elevations is visible, to allow more extremes.

1.5 Discussion and Conclusion

In this paper, transient climate simulations, covering the period 1960–2100, were carried out using a high resolution ocean model (GETM) for the Western Baltic Sea. These simulations are based on the IPCC scenarios A1B and B1. Despite the

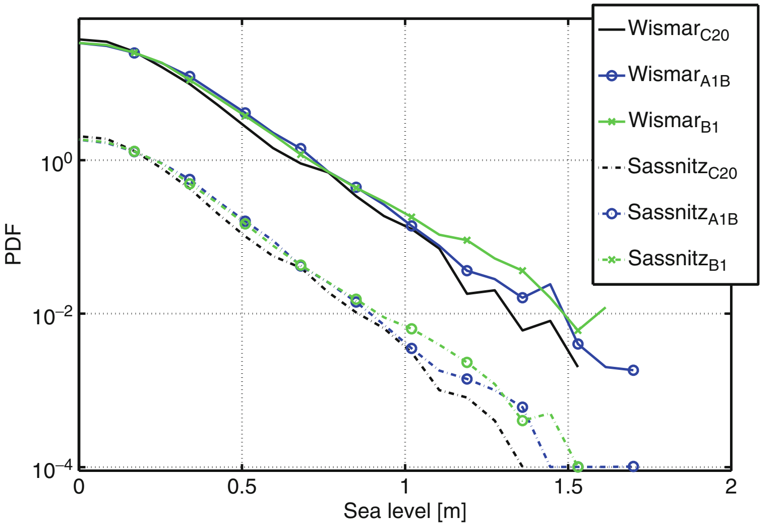

Fig. 1.10 Projected changes of the right side of the sea level distribution for Wismar and Sassnitz. Shown are the distributions for C20 (1960–2000) and the projected distributions for A1B and B1 (2060–2100). To compare the shape of the distribution, the mean is removed. For better comparison, the Wismar gauge pdf is shifted upward

fact, that this study is only based on boundary conditions from one regional atmospheric model (CLM) and one medium scale ocean model (MOM) and not a full ensemble, this analysis can offer valuable information of a changing environment. Due to restrictions in computing power, only one realisation for each scenario could be computed. Therefore, uncertainty estimates, based on ensemble prediction (Jacob et al. 2007) cannot be given.

A validation of the forcing time series revealed a cold bias of 1.3 K for the air temperature, which is known in the literature (Jacob et al. 2007), but the Climate Change signal is robust in the ensemble mean of different RCAs. Although there is an ongoing debate on bias correction of data sets (Piani et al. 2010, Seguí et al. 2010, Leander and Buishand 2007), we do not apply a statistical bias correction to the CLM data. At first, we have to be consistent with the large-scale driving model (Neumann 2010) and secondly the underlying assumptions on such a correction are uncertain. As a result, the ocean temperature shows a cold bias of 0.9 K. This is lower than the atmospheric bias, but still in the range of the Climate Change signal up to 2050. The authors believe that this cold bias will not significantly alter the physics (the water exchange in the Western Baltic Sea is mainly triggered by salinity (Meier 2007, Feistel and Nausch 2008, Matthäus and Franck 1992), but will have some implication on possible projections for biology and geochemistry. However, the used boundary conditions are currently the best available data and any correction are at first uncertain (Trenberth et al. 2003, Piani et al. 2010) and secondly not fully consistent (a change in temperature would cause a change in moisture, which would also effect the cloud cover). A second approach to circumvent the cold bias is to use the Δ -approach (Meier 2006). Although it is by definition bias free, it can only reproduce the present day statistic with a shifted mean prescribed by the Climate Change Δ Thus completely new atmospheric conditions or extremes (long lasting heat waves, changes in annual cycle, extreme winds) cannot be modelled by this approach. Without a further careful investigation of the cold bias in the RCA and in the reference run, the GETM output (especially the temperature fields) might be of limited use for impact studies. However, one could use the change signal. Here sensitivity studies have to clarify, how this cold bias propagate through the models. Nevertheless, for the hydrodynamic part of the modelling, the authors believe that this bias will not significantly influence the transport processes and physics of the Western Baltic Sea and that the results offer valuable insights into possible future scenarios.

The simulations indicate that the Western Baltic Sea will experience a decrease in salinity of up to 2 g kg^{-1} to the end of the century. This is consistent with the findings of Meier and Kauker (2003) and Neumann (2010). This decrease is mainly caused by an increase in freshwater supply (direct precipitation and river discharge). Figure 1.7 indicated a different behaviour of the bottom salinity at Darss Sill before and past 2000. Because the salinity within the model domain is mainly controlled by the boundary conditions, this change can only be caused by the driving model. But the results of Neumann (2010) show a similar transition for the Eastern Gotland Basin.

The climate projections show also the expected warming of the water column. Here, the increase of temperature in the surface layer ranges from 0.9 to 2.5 K for the A1B scenario and 0.5–1.7 K for the B1 scenario. The greatest changes are seen in the Arkona Basin and Bornholm Basin. This pronounced warming is consistent with the findings of simulations of the entire Baltic Sea (Meier 2006, Neumann 2010). The decrease in salinity and increase in temperature does not change the mean stratification in the deeper basins. No trend is visible, except that the B1 scenario shows slightly stronger stratification. Additionally, the variability in the B1 run is higher, which can be caused by an increase in salt flux into the Western Baltic Sea. The higher salt flux in the B1 run, lead to a stable dense water pool in the Arkona Basin, higher potential energy anomalies but also to a higher variability. The decrease in salt flux for the A1B emission scenario is causing the slightly lower stratification and lowered variability. Currently it is not fully clear, what is causing the change in salt flux for the A1B scenario. A possible explanation might be that changes in large scale weather pattern (changes in easterly-westerly winds). Moreover, both runs show lower annual minimum stratification, which is partially caused by an increase in strong wind events (Fig. 1.5b). However, Fig. 1.8 indicates that during both scenarios no complete mixing of the Arkona Basin occurred (the minimum potential energy is still greater than 25–30 J m^{-3}).

The analysis of the sea surface elevation indicates an increase in storm surges to the end of this century. The scenarios project an increase of the 25-year return period of 20–65 cm for Wismar and 30–55 cm for Sassnitz. The increase is caused by the sea level rise but also due to changes in atmospheric conditions. A widening of the distribution of sea level elevations is visible, to allow more extremes. Due to the sea level rise the whole distributions is shifted to the right.

Finally, we have again to state that this paper is only one downscaling of two IPCC scenarios from one regional atmospheric model and one medium scale ocean model. Therefore, the results cannot be regarded as 'truth' and should be used carefully. Moreover, the cold bias in the atmospheric forcing and in the ocean needs special attention. A broader ensemble of regionalised scenarios is necessary to give a more reliable assessment of the future state of the Western Baltic Sea and the uncertainties involved.

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Chapter 2
Climate Change Impacts on the Baltic Sea

Thomas Neumann and René Friedland

Abstract Climate impact research is of increasing importance because politicians, local decision makers, and the society require guidance regarding the environmental effects of global warming. This information is needed on a regional scale which cannot be provided by global climate models. Therefore, tools are needed to translate global climate trends into a regional scale. Regional climate models are used to scale global climate simulations with coarser resolution to a finer grid. Beside the knowledge about atmospheric variables further information of the marine environment, especially for coastal regions, is important. Regional ocean models driven by regional climate models can provide scenarios for the future development of the marine environment. A Baltic Sea ecosystem model is used for scenario simulations to assess the potential development of the Baltic Sea within the next 100 years. The simulations show an increasing water temperature in the range of 2–3.5 K and a decrease in salinity by 1.5–2 g kg^{-1}. Events with large suboxic areas are likely to increase in the western Baltic Sea. However, the uncertainties in the climate projections are high and for robust results more scenario simulations are needed.

2.1 The Baltic Sea and Climate Change

The climate trend of the last century and future projections suggest a global warming and its consequences like an accelerated water cycle, a rising sea level etc. Comprehensive assessments of Climate Change and its impact are published in the IPCC reports (Intergovernmental Panel on Climate Change http://www.ipcc.ch/). This trend is mainly caused by anthropogenic emissions of greenhouse gases and their increasing concentration in the atmosphere (Intergovernmental Panel on Climate Change 2007). However, for the assessment of regional Climate Change effects, projections from global models have to be transferred into a regional scale.

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Recent global climate models used for scenario simulations support a horizontal resolution of about 250 km. This coarse resolution cannot resolve many regional features and therefore trends observed in global models will not necessarily scale with regional trends (Christensen and Christensen 2003). Thus, regional climate models (RCM) are used to transfer results from global simulations to a regional scale to cover a certain region like Europe. For more information about RCMs see Rummukainen 2010. At their boundaries regional models are forced by global models and in the interior dynamics on a higher resolved spatial scale can develop. Recent regional models resolve the spatial domain with less than 20 km (ENSEMBLES 2009). This method is called dynamical downscaling.

The development and implementation of regional adaptation strategies for Climate Change require a sound basis of projections. Regional data sets have to fulfil diverse requirements of different stakeholders from policy, economy and science. The requirements are demanding and therefore at this stage several questions cannot be answered on the basis of recent regional climate projections. Despite the great scientific effort and improvements in climate modelling there are still some uncertainties. The main source of uncertainties is the future development of anthropogenic drivers like greenhouse gas emissions, land use changes, agriculture, and population patterns. The variety of uncertainties has to be taken into account when climate projections are used in decision making processes and the development of adaptation strategies. Regional climate simulations have been supported largely by funding agencies in recent years. An example is the ENSEMBLES project supported by the European Commission's 6th Framework Programme. Details of the project, reports, and data access are available under the ENSEMBLES (2009) web page.

For the Baltic Sea area a comprehensive compilation of the recent knowledge about Climate Change can be found in the book of the BACC Author Team 2008. In the last century an increase in air temperature of 0.7 K has been observed. Climate projections suggest a warming of 3–5 K for the next 100 years. However, depending on greenhouse gas emission scenarios and used global climate models the variations between the simulations and therefore the uncertainty of the projections are large. Increasing air temperature in the Baltic Sea basin would lead to a reduced sea ice cover and probably prolong the growing season in the Baltic Sea.

Precipitation projections largely depend on the used greenhouse gas emission scenarios and climate models. The general trend is an increasing precipitation during the winter season while the opposite is the case during the summer season, especially in southern areas. On an annual basis precipitation and fresh water supply to the Baltic Sea is likely to increase. Increasing fresh water supply has the potential to decrease the salinity in the Baltic Sea.

Projections for wind are uncertain and give no robust results so far. However, some of the simulations show a tendency towards increasing wind speeds.

Changes in the meteorological forcing will change the hydrographic conditions in the Baltic Sea accordingly. Most serious impacts will be increasing water temperature, decreasing salinity and a prolongation of the ice-free season in the northern parts. Therefore, habitat conditions for many species may change. Vegetation period may start earlier in the season and will affect several species in the food chain. For Baltic cod reproduction conditions may worsen due to decreasing salinity.

2.2 A Case Study with Transient Simulations

2.2.1 Introduction

The Baltic Sea has a great economic value as well as recreation potential and is of increasing focus of climate impact research. This research is based on regional climate projections and scenario simulations for the marine ecosystem of the Baltic Sea. One of the first approaches using a regional climate to force a Baltic Sea ocean model was done by Meier (2006). He applied a time slice for 2070–2100 to assess the effects of a changing climate on the Baltic Sea at the end of this century. A time slice experiment was necessary because regional climate data were only available for this short time period. In the following, Climate Change scenarios for the Baltic Sea ecosystem relying on transient regional climate forcing are presented. Transient (1960–2100) regional climate data sets have become available recently. Transient simulations show a number of advantages compared to time slice experiments. *Inter alia* transient simulations do not require artificial initial conditions (e.g. for year 2070), simulations show the time development of change, and the timing of abrupt changes can be determined more precisely.

2.2.2 Methods

Regional climate forcing used in this study is the CLM (local model of the German weather service in Climate mode) Community Runs (2008). The CLM model covers Europe with a horizontal resolution of 18 km. Boundary conditions for the CLM model were derived from the global model ECHAM5/MPI-O (ECHAM5 2008) of the Max-Planck-Institute for Meteorology in Hamburg-Germany. Details of the CLM Community Runs as model domain, resolution, forcing etc. are described in Hollweg et al. (2008). Global and regional simulations are based on the greenhouse gas emission scenarios A1B and B1 proposed by the IPCC (Intergovernmental Panel on Climate Change 2007). The quality of the CLM data is discussed in Hollweg et al. (2008) and Jaeger et al. (2008). However, using climate scenarios for a specific region requires a sound analysis of the data's properties. In particular these are biases and variability compared to observations. For the Baltic Sea region this was done by Neumann 2010. The CLM data shows a temperature bias of about –1 K. It is especially pronounced in the summer season. We have to note that the CLM Community Runs show a bias in other variables too like precipitation and humidity. The biases are introduced already by the forcing, global model and may be modified by CLM internal biases.

Furthermore, from CLM data freshwater runoff entering the Baltic Sea was derived for the projection period 2000–2100. Both scenarios A1B and B1 show an increase in runoff of about 20% by the end of the century. Owing to the warming the annual runoff cycle will change towards higher runoff in winter and a reduced peak-runoff in spring. For riverine and airborne nutrient loads we applied observed values for the period 1960–1999. In the projection period 2000–2100 a ‘business as usual’ was implemented which is based on mean loads of 1990–1999.

The meteorological forcing from CLM and the derived freshwater supply were used to force the Baltic Sea ecosystem model ERGOM (Neumann 2008). This ecosystem model consists of a 3-dimensional circulation model (modular ocean model MOM3.1, Pacanowski et al. (2000)), an integrated biogeochemical model and a thermodynamic sea-ice model. The horizontal resolution of the model grid is 3 nm, while vertically the model is resolved into 77 layers, with a layer thickness of 2–3 m for the upper 100 m and a constant thickness of 6 m at greater depths. The model domain and bathymetry is shown in Fig. 2.1.

The biogeochemical model consists of nine state variables. The nutrient variables are dissolved ammonium, nitrate, and phosphate. Primary production is provided by three functional phytoplankton groups: large cells, small cells, and cyanobacteria. A dynamically developing bulk zooplankton variable provides grazing pressure on the phytoplankton. Accumulated dead particles are represented by a detritus state variable. In the process of sedimentation a portion of the detritus is mineralized into dissolved ammonium and phosphate. Another portion reaches the sea bottom,

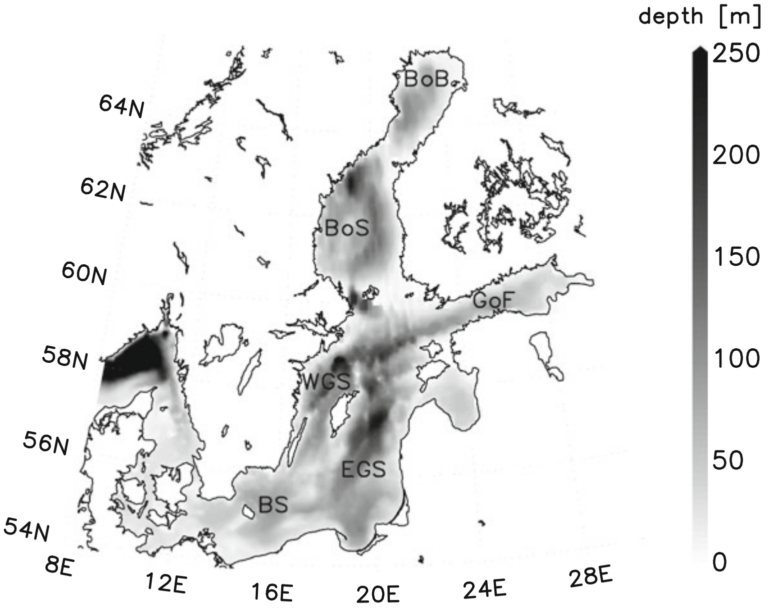

Fig. 2.1 Model bathymetry of the Baltic Sea with some geographic annotations for later reference. BS: Bornholm Sea, EGS: Eastern Gotland Sea, WGS: Western Gotland Sea, GoF: Gulf of Finland, BoS: Bothnian Sea, BoB: Bothnian Bay

where it accumulates as sedimentary detritus and subsequently buried, mineralized or resuspended in the water column, depending on the speed of near-bottom currents.

The study here is focused on changes in physical variables. For a more detailed analysis of the state variables from the biogeochemical model we refer to Neumann (2010).

2.2.3 Results and Discussion

Simulations with the ecosystem model cover the period 1960–2100. While the first 40 years are used to compare the model results with instrumental data (temperature, salinity, nutrient concentrations), simulations from 2000 to 2100 represent the impact of the greenhouse gas emission scenarios.

Biases of sea surface temperature (SST) and sea surface salinity (SSS) are shown in Fig. 2.2. The cold bias of CLM data directly impacts the SST. The strongest SST bias is found in summer, while in autumn and winter the SST bias is small. The sea ice extent is reproduced very well (not shown). SSS bias is negative and relatively small. Together, the CLM forced ecosystem model of the Baltic Sea reproduces the contemporary period reasonable well.

The projected SST warming at the end of the twenty-first century (Fig. 2.3) is in the order of 2–3.5 K and hence in the range of air temperature warming of the

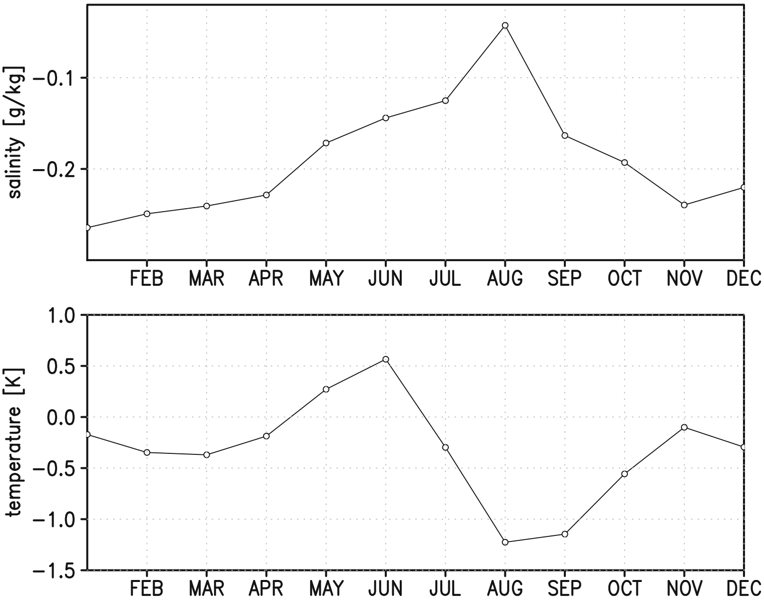

Fig. 2.2 Biases of sea surface temperature and sea surface salinity in the Eastern Gotland Sea (Fig. 2.1) for the year 1960–1999

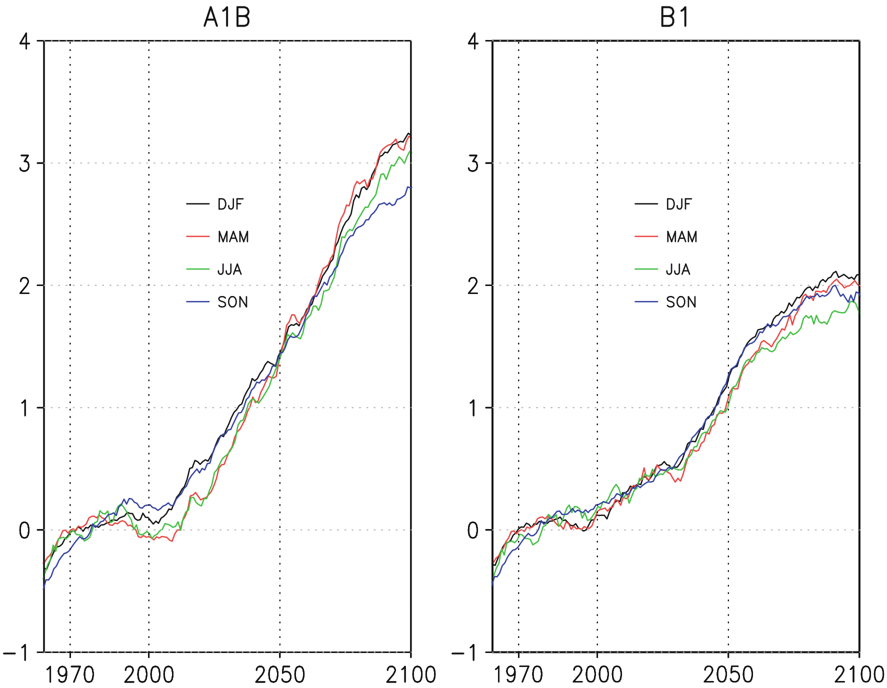

Fig. 2.3 Sea surface temperature (SST) warming [K] in the Baltic Sea for emission scenarios A1B and B1 compared to the period 1960–1999. Horizontally averaged SST for seasons winter (DJF), spring (MAM), summer (JJA) and fall (SON) are shown, smoothed by a 30 years running mean

forcing data. The warming in the B1 scenario is less pronounced and seems to stabilize by the end of the century. Differences between the seasons are small; however, the effect on winter SST tends to be more pronounced.

Changes in sea surface salinity (SSS) are shown in Fig. 2.4. Both scenarios show a clear trend towards a decrease in SSS in the range of 1.5–2 g kg^{-1}. A main reason for salinity decrease lies in the increasing freshwater supply (e.g. Meier and Kauker 2003). To a minor degree increased wind speed can contributes to decreasing salinity as well (Meier 2005). The CLM projections show increasing wind speeds for winter time. Differences between emission scenarios A1B and B1 are small due similar freshwater changes. The winter season shows a stronger signal caused by an enhanced runoff in winter in a warmer climate.

Owing to the warming sea ice extent will decrease. The simulated sea ice extent for scenarios A1B and B1 is shown in Fig. 2.5. By the end of the century the Baltic Sea is supposed to be covered by about one third of the recent coverage and the sea ice season will end earlier. Most affected will probably be the northern parts of the Baltic Sea, the Bothnian Bay, the Bothnian Sea, and the Gulf of Finland. The vegetation period will begin earlier because light will not be damped

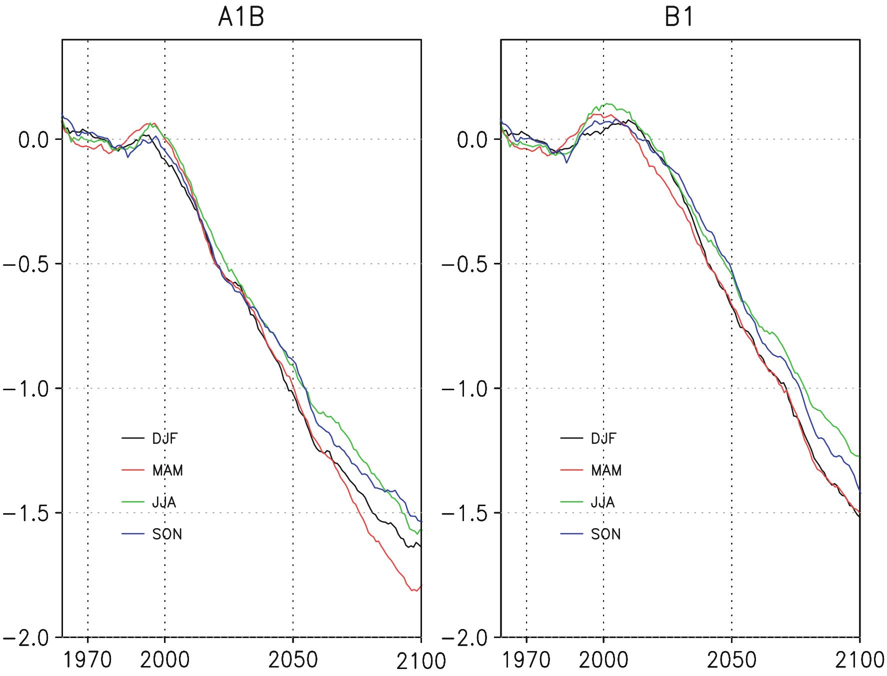

Fig. 2.4 Sea surface salinity (SSS) change [g kg^{-1}] in the Baltic Sea for emission scenarios A1B and B1 compared to the period 1960–1999. Horizontally averaged SSS for seasons winter (DJF), spring (MAM), summer (JJA) and fall (SON) are shown, smoothed by a 30 years running mean

by sea ice and the warming of water in spring can start as soon as the sea ice cover is melted down. However, a totally ice-free winter could not be observed in the simulations.

In Fig. 2.6 the 90th annual percentiles of the suboxic area (oxygen concentration less than 2 ml l^{-1}) in the Mecklenburg Bight and the Arkona Sea for emission scenarios A1B and B1 are shown.

This data are based on six-hourly means which ensures that also short events are taken into account. In 1960–2000 a strong increase occurs due to the eutrophication of the Baltic Sea. During the projection period with nearly constant nutrient loads, the suboxic areas will increase. In emission scenario A1B the signal is even stronger. At this point it is unsure which factor contributes to what extend to increasing suboxic conditions.

However, the temperature effect on oxygen solubility is likely to be the main impact for decreasing oxygen conditions in this area. A temperature increase of 3 K (increase 18°C to 21°C) will roughly decrease the oxygen solubility by 0.36 ml l^{-1} (about 6% of the saturation solubility). In a low oxygen environment this may have a strong impact.

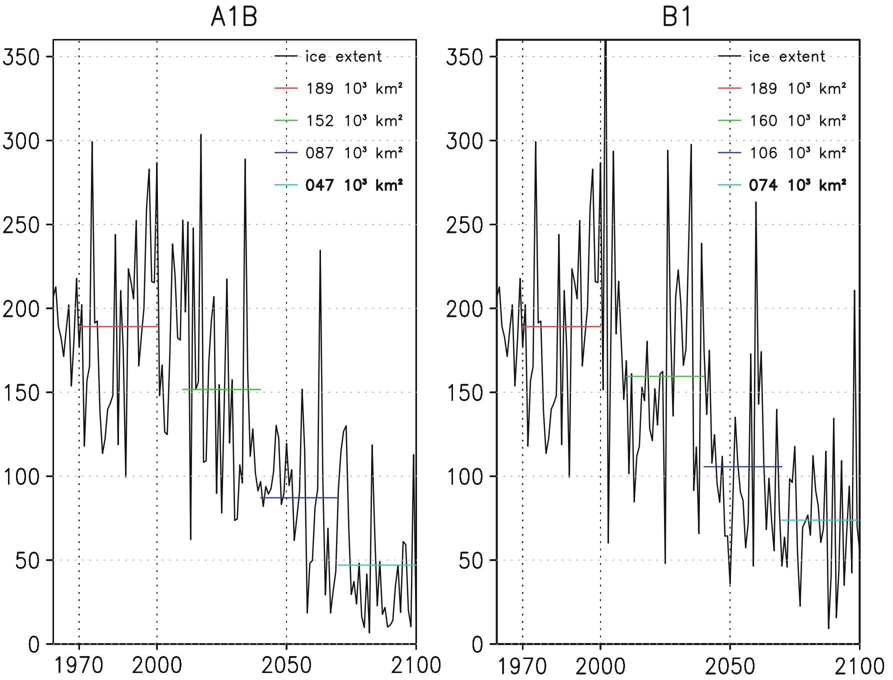

Fig. 2.5 Maximum sea ice extend [10^3 km^2] in the Baltic Sea for emission scenarios A1B and B1. The annual maximum sea ice extent (*black line*) and respective 30 year means are shown

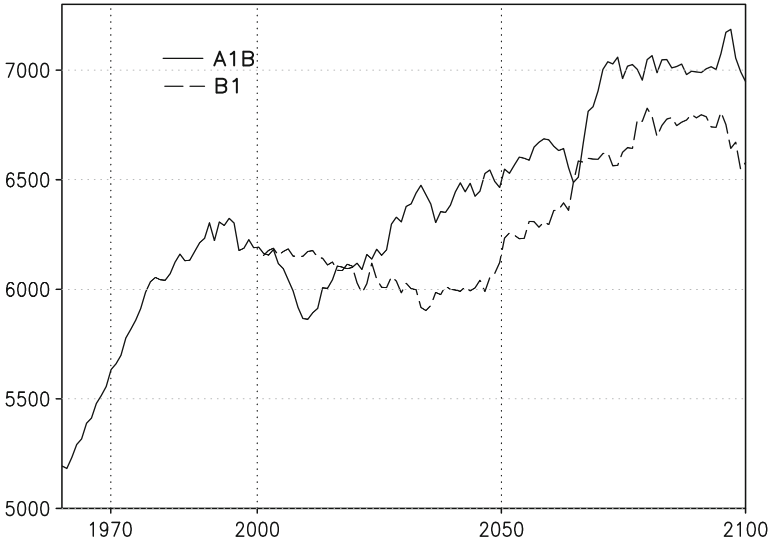

Fig. 2.6 90th annual percentiles of the suboxic area [km^2] (oxygen concentration below 2 ml l^{-1}) in the Mecklenburg Bight and Arkona Sea for emission scenarios A1B and B1, smoothed by a 30 years running mean

2.3 Summary

The long time scales that characterize the Baltic Sea are such that it will never be in steady state. Consequently, to derive initial conditions from a quasi-steady state for a certain period without the possibility to verify them with observations implies a persisting high degree of uncertainty. For this reason, transient simulations will increase the reliability of Climate Change projections. Another advantage of the transient simulation approach is its ability to cover the full time period – in this case the time period 1960–2100. This is important in order to distinguish between long-term variability of the Baltic Sea system and Climate Change signals. Finally, transient simulations provide consistent time series of changes. As an example, the SST warming begins to stabilize in 2060 in the B1 scenario.

The most serious impact on the Baltic Sea ecosystem will probably occur due to temperature and salinity changes. The increase in water temperature for intermediate and deep water are similar to the change in SST (1–3.5 K, not shown), while a salinity change for the entire water column of the central Baltic Sea can be expected to be about –2 g kg^{-1}. The changes in these physical parameters may totally alter the habitat conditions and distribution patterns of many species.

Both emission scenarios show an increase in the number of events with large suboxic areas in the western Baltic Sea. Oxygen conditions in the Baltic Sea are essential for many species, especially for those living close or at the sea floor. There are many factors controlling oxygen conditions in the sea water. Physical parameters like vertical mixing and lateral transport control the transport of oxygen, and temperature controls solubility of oxygen in water. Furthermore, consumption due to heterotrophic forms of live depletes the oxygen concentration particularly in deeper water. The amount of consumption is mainly determined by supply of organic matter due to primary production. All these parameter might change in a future climate.

In the presented simulations changes in the catchment which will impact the nutrient loads for the Baltic Sea are not considered. Moreover, the nutrient scenario is based on contemporary nutrient loading levels. Changing nutrient loads will in particular affect oxygen conditions and primary production.

Two greenhouse gas emission scenarios have been used in this study and highlighted the impact on the Baltic Sea ecosystem. Nevertheless, more simulations with different scenarios including different global and regional climate models are necessary to obtain more robust results and realize a probabilistic approach.

Furthermore, biases in global climate models and RCMs are evident. Processes scaling nonlinearly with biased variables have to be considered carefully whether change signals are still reasonable.

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Chapter 3
The CO_2 System of the Baltic Sea: Biogeochemical Control and Impact of Anthropogenic CO_2

Bernd Schneider

Abstract The marine CO_2 system is controlled by chemical equilibria between the dissolved CO_2 species (CO_2 (pCO_2), H_2CO_3, HCO_3^-, CO_3^{2-}) and the hydrogen ion concentration (pH). By gas exchange the system interacts with the atmospheric CO_2 and by dissolution/precipitation with solid $CaCO_3$. A major variable of the system is the alkalinity which determines the large scale distribution of the background total CO_2 concentration. The background concentrations are modulated by the consumption/production of CO_2 by biological production/decomposition of organic matter. The biological production is reflected in the seasonality of the surface water CO_2 partial pressure, pCO_2. Two pCO_2 minima are observed in the central Baltic Sea which are due to the CO_2 uptake during the spring bloom and during the mid-summer production fuelled by nitrogen fixation. The pH is closely related to the pCO_2 and shows two maxima which are coinciding with the pCO_2 minima. Due to the increasing atmospheric CO_2 the mean pH in the central Baltic Sea will decrease from currently 8.07 to 7.91 during the next approximately 100 years. The ecological consequences are not yet foreseeable, but may be severe since many biochemical reactions are controlled by the pH. At the same time the $CaCO_3$ saturation will decrease by a factor of almost two and the Baltic Sea surface water will be below saturation for aragonite almost throughout the year. This may affect the abundance of calcifying organisms because their growth is impeded at low $CaCO_3$ saturation.

3.1 Introduction

Although the CO_2 content of the atmosphere amounts only to about 0.04% and is thus lower than that of the noble gas argon (0.93%), it has a tremendous importance for both the physical and biogeochemical conditions on our earth. Next to water vapour it is the most important greenhouse gas and keeps the temperature on the earth at a moderate level. CO_2 is also the matrix for photosynthesis and thus

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constitutes the basis for highly developed life-forms. A major control for the atmospheric CO_2 are the oceans which are interacting with the atmosphere by CO_2 gas exchange. The total CO_2 inventory of the oceans which includes hydrogen carbonate (HCO_3^-) and carbonate ions (CO_3^{2-}) is roughly 50 times larger than the amount of CO_2 in the atmosphere. Hence, small relative changes in the ocean CO_2 may have a large impact on the atmospheric CO_2. Vice versa, the oceans are a buffer for perturbations of the atmospheric CO_2 and have the capacity to absorb almost the entire anthropogenic CO_2 emissions. However, due to the sluggish ocean circulation this will take many 1000 years.

The total CO_2 in the oceans is derived approximately in equal shares from atmospheric CO_2 and from the release of CO_3^{2-} by weathering of limestone on the continents. Most of this CO_2 and CO_3^{2-} form HCO_3^- which constitutes about 90% of the total CO_2 in the ocean. The relationship between HCO_3^-, CO_3^{2-} and CO_2 is controlled by acid/base equilibria and thus includes hydrogen ions.

It was the Baltic Sea area where pioneering experimental and theoretical work on the marine CO_2 system started in the beginning of the last century. Lab experiments were used to determine equilibrium constants and extensive field measurements were performed in the northern Baltic to characterize the physically and biologically driven variability of the CO_2 system. A boost in oceanic CO_2 research occurred about 30 years ago in conjunction with the growing awareness of the prospective climate change due to anthropogenic CO_2 emissions. The investigations aimed mainly at the determination of the oceanic uptake of anthropogenic CO_2 because this significantly attenuates the CO_2 increase in the atmosphere. Only since a few years the biogeochemical consequences of the enhanced dissolution of CO_2 in the ocean have attracted notice and are commonly subsumed by the term ‘ocean acidification’. This term is used for both the decrease of the ocean pH and the decline of the calcium carbonate saturation. Due to the steadily increasing atmospheric CO_2 it is expected that these effects will be augmented in the course of the next century. Hence, anthropogenic CO_2 emissions are not only changing the global climate but have also adverse effects on the life in marine systems. Therefore, many studies and international projects have been initiated to assess the consequences of ocean acidification for marine ecosystems. Here we address the physical-chemical aspects of ocean acidification in the context of a description of the Baltic Sea CO_2 cycle.

3.2 Basic Principles of the Marine CO_2 System

3.2.1 Chemical Equilibria

3.2.1.1 Equilibria in Seawater

In contrast to other atmospheric gases, CO_2 reacts with water and forms carbonic acid:

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \tag{1}$$

The two hydrogen ions (protons) of the carbonic acid may partly dissociate in two steps:

$$H_2CO_3 \Leftrightarrow HCO_3^- + H^+ \tag{2}$$

$$HCO_3^- \Leftrightarrow CO_3^{2-} + H^+ \tag{3}$$

As a result $HCO_3{}^-$ and $CO_3{}^{2-}$ are generated. The reactions (1)–(3) are typical equilibrium reactions and the relationship between the concentrations of the reaction products and those of the reactants can be described by equilibrium constants. For the first dissociation step, the reactions (1) and (2) are combined and the first dissociation constant, k_1, is given by:

$$\frac{[HCO_3^-] \cdot [H^+]}{[CO_2^*]} = k_1 \tag{4}$$

(at T = 10°C, S = 35, p = 0: $k_1 = 1.00{*}10^{-6}$ mol/kg)

For reasons of practicability, the variable $CO_2{}^*$ is used which represents the sum of CO_2 and H_2CO_3 where the contribution of H_2CO_3 is less than 0.5%.

Accordingly, the second dissociation constant, k_2, is derived from reaction (3):

$$\frac{[CO_3^{2-}] \cdot [H^+]}{[HCO_3^-]} = k_2 \tag{5}$$

(at T = 10°C, S = 35, p = 0: $k_2 = 6.11{*}10^{-10}$ mol/kg)

The constants k_1 and k_2 are a function of temperature (T), salinity (S) and pressure (p) (water depth) and control the CO_2 system in seawater. Many investigations have been performed to describe k_1 and k_2 as a function of T, S and p. Most of the functions were confined to oceanic salinities and only recently constants were reported that covered the whole salinity range from fresh water to oceanic values and are thus suitable for the Baltic Sea (Millero et al. 2006). Both k_1 and k_2 increase with increasing T, S and p.

Chemical species involved in the seawater acid/base system and constants/variables controlling the CO_2 system

CO_2 – molecular CO_2
H_2CO_3 – carbonic acid
$HCO_3{}^-$ – hydrogen carbonate
$CO_3{}^{2-}$ – carbonate
H^+ – hydrogen ions
OH^- – hydroxide ions
$CaCO_3$ – calcium carbonate
$HSO_4{}^-$ – hydrogen sulphate
$B(OH)_4{}^-$ – borate
H_2S – hydrogen sulphide
HS^- – hydrogen sulphide ions
$S_2{}^-$ – sulphide
k_o – CO_2 solubility constant
$k_{1,2}$ – 1. and 2. dissociation constant
k_{sp} – solubility product
pCO_2 – CO_2 partial pressure
pH – acidity
C_T(DIC, TC) – total CO_2
A_T(TA) – alkalinity

3.2.1.2 Equilibrium Between Dissolved and Gaseous CO_2

At equilibrium between CO_2 in water and CO_2 in the gas phase, the CO_2 concentration in water is proportional to the CO_2 partial pressure, pCO_2, in the gas phase. The proportionality constant is called solubility constant, k_o, which decreases with increasing T and S (Weiss 1974). In order to maintain consistency with the definition of the first dissociation equilibrium (Eq. 4), the solubility is not related to the dissolved CO_2, but to $CO_2{}^*$:

$$[CO_2^*] = k_o \cdot pCO_2 \tag{6}$$

(at T = 10° C, S = 35: $k_o = 0.044$ (mol/kg)/atm)

The equilibrium pCO_2 of seawater can be considered as a property of the seawater and depends on the state of the CO_2 system. In general, the seawater pCO_2 deviates from the atmospheric pCO_2. As a consequence of this disequilibrium gas exchange occurs because the system has the tendency to equilibrate. The almost permanent disequilibrium is caused by physical and biological processes which change the seawater equilibrium pCO_2 and which are faster than re-equilibration by gas exchange.

3.2.1.3 Equilibrium Between Solid and Dissolved Calcium Carbonate

Many marine organisms form $CaCO_3$ shells which may be dissolved after sinking into deeper water layers. These processes are controlled by the solubility product, k_{sp}:

$$k_{sp} = ([Ca^{2+}] \cdot [CO_3^{2-}]\,)_{\text{at equilibrium}} \tag{7}$$

(at T = 10° C, S = 35, p = 0: k_{sp}(aragonite) = $7.87 \cdot 10^{-7}$ mol/kg)

The solubility product describes the conditions at which $CaCO_3$ is at equilibrium with Ca^{2+} and $CO_3{}^{2-}$ ions. Hence, if the product of the actual concentrations of these ions are larger or smaller than k_{sp}, the seawater is above or below saturation and $CaCO_3$ may be formed or dissolved, respectively. The degree of saturation is thus defined as:

$$\Omega = \frac{[Ca^{2+}] \cdot [CO_3^{2-}]}{k_{sp}} \tag{8}$$

Most ocean surface waters are highly oversaturated with regard to $CaCO_3$ ($\Omega >> 1$) and provide favourable conditions for the biogenic formation of $CaCO_3$ whereas the abiotic precipitation of $CaCO_3$ is inhibited due to the presence of large amounts of magnesium. Two different modifications of $CaCO_3$, calcite and aragonite, are produced by marine organisms. The solubility (k_{sp}) of aragonite is by a factor of about 1.8 higher than that of calcite. Whereas the temperature dependency of k_{sp} is low, k_{sp} increases strongly with increasing salinity and pressure.

3.2.2 Characteristic Variables of the CO_2 System

Four variables, pH, alkalinity, total CO_2 and the CO_2 partial pressure, exist that may be used to characterize the CO_2 system and which are accessible by measurements (Dickson et al. 2007). Two of these variables together with the equilibrium constants (k_o, k_1, k_2) are necessary to calculate the remaining variables and the concentrations of all CO_2 species.

pH: The CO_2 system is part of the seawater acid/ base balance and thus includes hydrogen ions as a central property (Eqs. 2 and 3). The hydrogen ion concentrations are conventionally described by the pH which in dependence on the calibration procedure is defined in different ways. For many decades pH electrodes were calibrated with NBS (National Bureau of Standards) standards which imply that the pH is a measure for the H^+ ion activity. The activity represents the thermodynamic H^+ efficiency and deviates considerably from the hydrogen ion concentration in seawater. Since several years calibration buffer solutions prepared in a seawater-like medium have become widely accepted which provide pH values based on concentration units. Due to the procedure for assigning a pH to these buffers, the concentration of hydrogen sulphate ions which act as strong acids, are included in the definition of the pH on the 'total scale':

$$pH = -\log([H^+] + [HSO_4^-]) \tag{9}$$

Pure water at equilibrium with the atmospheric CO_2 has a pH of 5.58 (10°C) and is slightly acidic. At the same conditions ocean surface water shows a pH of 8.08 and is thus slightly basic. This difference is due to the effect of the alkalinity.

Alkalinity: The alkalinity, A_T, is defined as the excess of proton acceptors over proton donors and can be determined by titration with hydrochloric acid. Proton acceptors are the anions of weak acids which in oxic seawater are mainly hydrogen carbonate, carbonate, borate and hydroxide ions. Proton donors are strong acids such as hydrogen ions associated with a water molecule and hydrogen sulphate ions:

$$A_T = [HCO_3^-] + 2[CO_3^{2-}] + [B(OH)_4^-] + [OH^-] - ([H_3O^+] + [HSO_4^-]) \quad (10)$$

The major contributions to A_T are HCO_3^- and CO_3^{2-} (carbonate alkalinity) which are generated when groundwater or river water gets in contact with calcium carbonate (limestone) in the catchment area. According to the solubility product (Eq. 7) a dissolution process starts during which most of the released CO_3^{2-} ions are immediately forming HCO_3^- by reaction with CO_2 (Eq. 11, buffer reaction) that originates from the atmosphere or from the mineralization of organic matter:

$$CO_3^{2-} + CO_2 + H_2O \rightarrow 2HCO_3^- \quad (11)$$

Additionally, some of the CO_3^{2-} ions are taking up hydrogen ions and are thus shifting the pH into the basic range:

$$CO_3^{2-} + H^+ \rightarrow HCO_3^- \quad (12)$$

These processes continue until equilibrium between the dissolved species of the CO_2 system and also with $CaCO_3$ is established. The water conditioned in this way ends up in the oceans and constitutes the major contribution to the ocean alkalinity. Typical A_T values for ocean surface water are around 2,350 μmol kg^{-1}. The A_T in the Baltic Sea is in general much lower and depends on the limestone abundance in the different catchment areas.

Total CO_2, C_T (the symbols 'TC' and 'DIC', Dissolved Inorganic Carbon are also used): The total CO_2 is defined as the sum of all CO_2 species dissolved in water:

$$C_T = [CO_2^*] + [HCO_3^-] + [CO_3^{2-}] \quad (13)$$

The most accurate and precise method for the determination of C_T is based on coulometry. Large differences exist between the C_T in pure water and in ocean water (Table 3.1). At equilibrium with the atmosphere ocean surface water contains about one hundred times more C_T than pure water. Even more pronounced are the differences in the relative contributions of the individual species to C_T. In pure water CO_2* prevails whereas CO_3^{2-} ions are virtually absent. In contrast, ocean water C_T consists mainly of HCO_3^- and of a significant CO_3^{2-} fraction. These differences between pure water and ocean water are again a consequence of the high ocean water alkalinity that has been generated by the dissolution of $CaCO_3$ and subsequent uptake of CO_2 (Eq. 11).

CO_2 partial pressure, pCO_2: Measurements of the pCO_2 are mainly confined to surface waters and are based on infrared spectrometry of air that has been equilibrated with seawater. The data are used to characterize the CO_2 system and to calculate the air/sea CO_2 gas exchange. In most areas biological production and

Table 3.1 Total CO_2 concentrations and relative contributions of the different CO_2 species in pure water ($T = 10°C$) and ocean water ($T = 10°C$; $S = 35$, $A_T = 2{,}350\ \mu mol\ kg^{-1}$)

	$C_T [\mu mol\ kg^{-1}]$	CO_2^* [%]	HCO_3^- [%]	CO_3^{2-} [%]
Fresh water	23	88.5	11.5	0.0001
Ocean water	2,152	0.8	92.5	6.7

decomposition of organic matter are the major control for the pCO_2 and cause strong deviations from the pCO_2 in the atmosphere. These disequilibria are extreme in the Baltic Sea where the seawater pCO_2 may vary between about 100 µatm and 600 µatm, whereas the current atmospheric pCO_2 is in the range of 380 µatm.

3.3 The Baltic Sea CO_2 System

3.3.1 Large Scale Distribution of Total CO_2 and Alkalinity

The vertical distributions of total CO_2 in the major basins of the Baltic Sea were determined during a cruise with r/v Maria S. Merian in 2008 (Beldowski et al. 2010). The data from a transect between the Kattegat, the western Gotland Sea and the Gulf of Bothnia are shown in Fig. 3.1.

The C_T covered a wide range from more than 2,000 µmol kg^{-1} in the deep water of the Kattegat to about 600 µmol kg^{-1} in the northern part of the Gulf of Bothnia. The large scale spatial C_T distribution is widely controlled by the alkalinity distribution which at a given CO_2 partial pressure determines C_T. An approximately constant ratio between A_T and salinity exists in ocean surface waters because the variability of both is mainly caused by evaporation and precipitation which have no intrinsic effect A_T. The situation is quite different in the Baltic

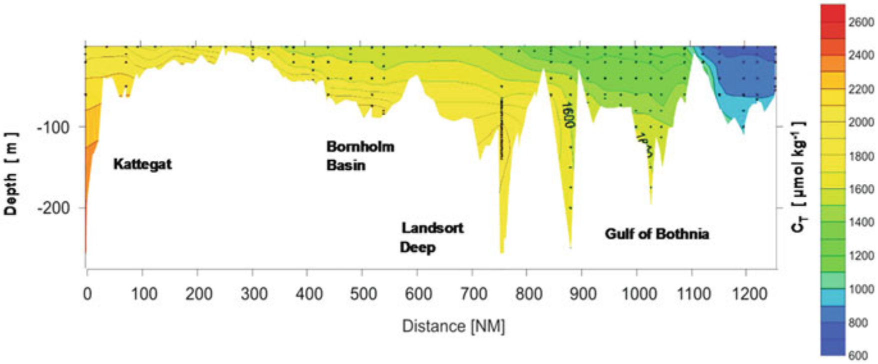

Fig. 3.1 The distribution of total CO_2 between the Kattegat and the Gulf of Bothnia (adopted from Beldowski et al. 2010)

Sea where the salinity is controlled by the mixing of river water with ocean water. Since river water contains A_T and since the A_T concentrations may vary extremely between different rivers, a simple relationship between A_T and salinity does not exist. This is indicated by Fig. 3.2 which shows A_T data from various regions of the Baltic Sea as a function of salinity (Beldowski et al. 2010). For individual regions linear relationships are observed which by extrapolation to zero salinity yield the A_T in the rivers discharging into the corresponding region. A mean A_T of more than 3,000 μmol kg^{-1} is obtained for river Daugava that flows into the Gulf of Riga. This high A_T is typical for rivers in the southern/eastern catchment area where limestone-rich soils are abundant. In contrast, the rivers discharging into the Gulf of Bothnia and the Gulf of Finland carry low A_T because the geology of the Scandinavian catchment is characterized igneous rocks which have a low potential for the release of A_T by weathering.

The straight lines that describe the different relationships between A_T and salinity are intercepting at a salinity of 7.0 +/– 0.5. This salinity range is typical for large areas of the central Baltic Sea which can be considered as a mixing chamber for water from the adjacent basins. Finally, mixing of the central Baltic Sea water with North Sea water leads to a linear A_T increase at salinities between about 7 and 35.

The complex relationship between A_T and salinity together with the large salinity gradients in the Baltic Sea control the spatial distribution of A_T and thus the background C_T, which would exist in an abiotic Baltic Sea at equilibrium with the atmosphere.

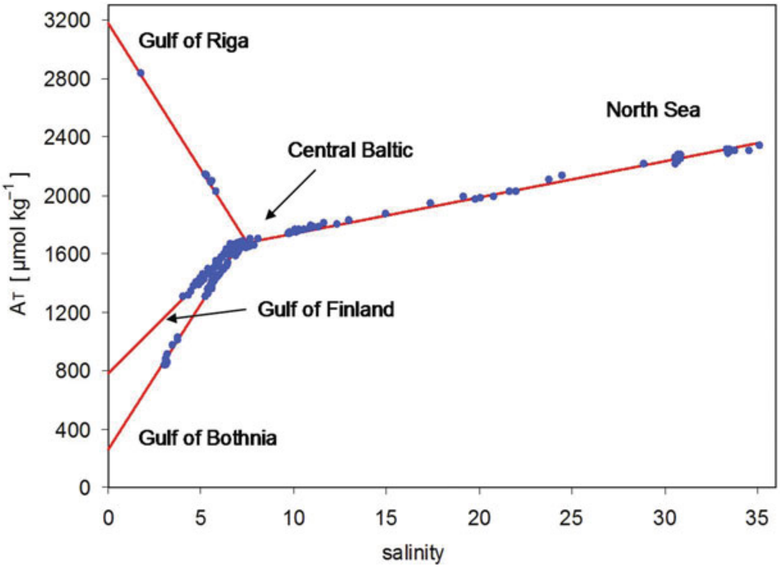

Fig. 3.2 Alkalinity/salinity relationships in different regions of the Baltic Sea. Extrapolations to zero salinity yield the mean alkalinity in rivers discharging into the corresponding region (adopted from Beldowski et al. 2010)

3.3.2 Biological Processes and the Surface Water CO_2 System

During photosynthesis the formation of organic carbon consumes an equivalent amount of CO_2 and, vice versa, microbial decomposition of organic matter produces CO_2. These processes modulate the large scale distribution of the total CO_2 and generate pronounced seasonal signals which are especially strong for the CO_2 partial pressure. Hence, biological processes in the surface water can be traced by measurements of the pCO_2. Therefore, a fully automated pCO_2 measurement system (Fig. 3.3) was deployed on a cargo ship (Schneider et al. 2006, Schneider et al. 2009) that commutes regularly at 2–3 day intervals between Lübeck in the southwest of the Baltic Sea and Helsinki in the Gulf of Finland (Fig. 3.4).

The seasonality of the surface water pCO_2 and of the atmospheric pCO_2 ($^{atm}pCO_2$) observed in 2005 at the entrance of the Gulf of Finland are presented in Fig. 3.5a. The pCO_2 shows two minima which are typical for the northern and central Baltic Sea. Due to the spring plankton bloom, the pCO_2 starts to decrease rapidly in the beginning of March and reaches a minimum far below the atmospheric level in the beginning of May. After this period no net organic matter production occurs and the pCO_2 is increasing slightly because of the increasing temperature.

Fig. 3.3 The pCO_2 measurement system on cargo ship FINNMAID. On the table to the *left*: The 'wet' unit where air is circulated in a closed loop through surface water that is pumped continuously into an equilibrator. *Right side* of the table: The 'dry' unit which contains the electronics and an IR spectrometer for the determination of the equilibrium CO_2 concentration (pCO_2) of the air circulating through the surface water in the equilibrator

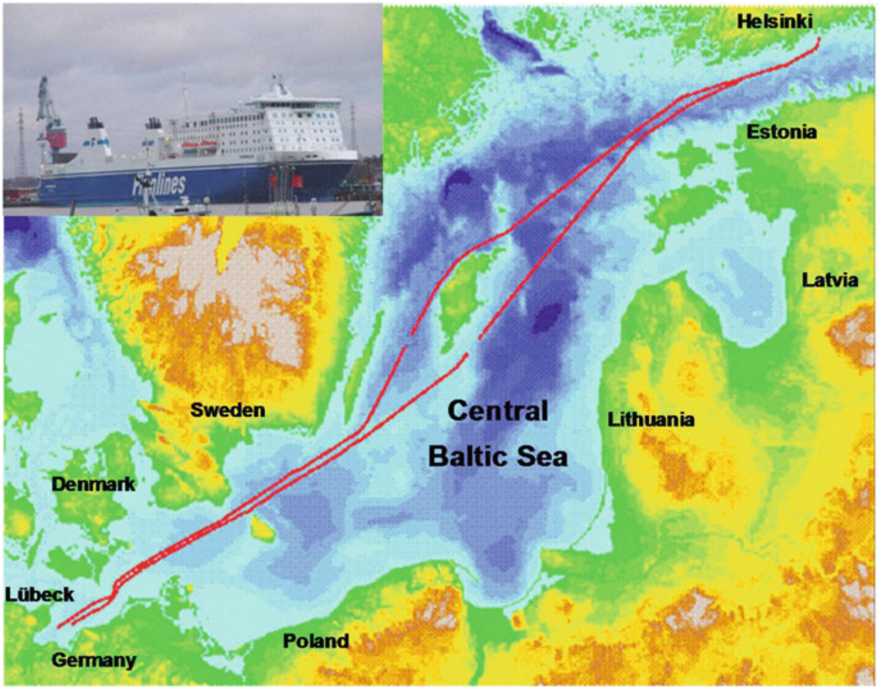

Fig. 3.4 The route of cargo ship FINNMAID where a fully automated system for the continuous recording of the surface water CO_2 partial pressure was deployed

However, by mid-June production fuelled by nitrogen fixation starts to develop and causes a second pronounced minimum in mid-July. During the following months the pCO_2 is increasing steadily until the end of the year because the summer stratification of the water column is gradually eroded. Hence, water from below the thermocline which due to organic matter decomposition is enriched in CO_2, is mixed into the surface layer. The pattern of the seasonal pCO_2 cycle is thus mainly controlled by biological processes and changes in temperature are less important. This refers also to the pH which is closely related to the pCO_2. The pCO_2 minimum and maximum shown in Fig. 3.5a correspond to pH values of 8.5 and 7.9, respectively.

To determine quantitatively biological production rates, the total CO_2 concentrations are calculated from the pCO_2 data (Schneider et al. 2009) using the mean alkalinity in the corresponding area, temperature and salinity together with the equilibrium constants of the CO_2 system. The decrease of the C_T during the spring bloom and the nitrogen fixation period are readily identifiable (Fig. 3.5b) and yield the net biomass production after accounting for the effect of the CO_2 gas exchange on C_T. This way to estimate quantitatively net production rates is considered to be more efficient and reliable than any other method.

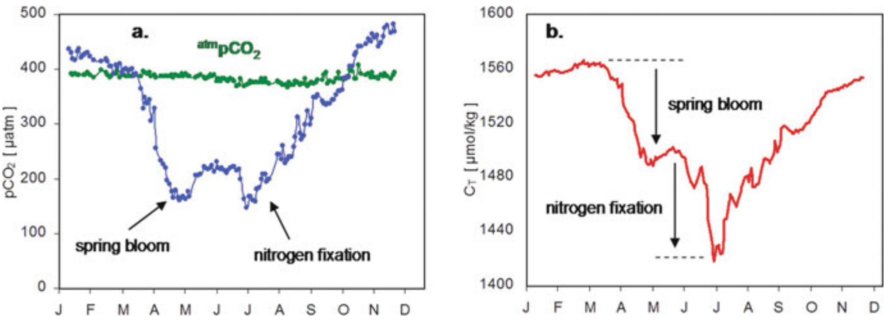

Fig. 3.5 The seasonal distribution of the surface water pCO_2 in 2005 and the atmospheric pCO_2 over the northern Baltic Sea (**a**) and the corresponding seasonal changes of the total CO_2 (**b**)

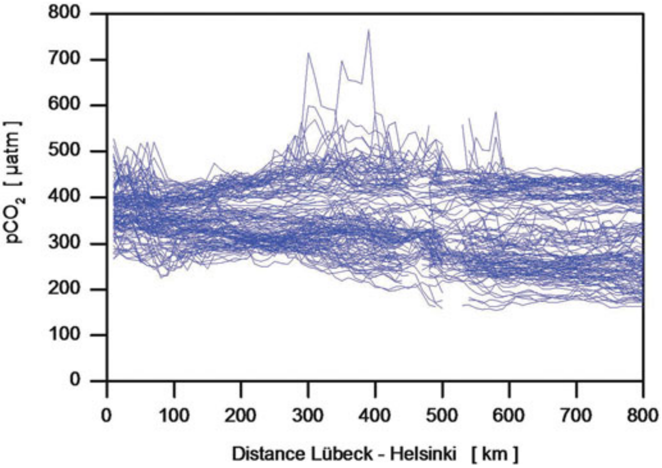

Fig. 3.6 The pCO_2 distribution between the southwest (Lübeck) and the northeast (Helsinki) of the Baltic Sea. About 150 transects are shown which were obtained from automated measurements on a cargo ship in 2005

A considerable large scale spatial variability in the biologically controlled pCO_2 distribution exists. This is illustrated by Fig. 3.6 which shows the pCO_2 data between the Mecklenburg Bight in the southwest and the Gulf of Finland in the northeast of the Baltic Sea for all transects recorded during 2005.

The vertical spread of the data represents the amplitude of the pCO_2 seasonality which is by a factor of about 2 larger in the north and central Baltic Sea than in the south-western regions. This is mainly caused by lower pCO_2 minima in the northern and central areas. The regional differences can partly be attributed to enhanced production rates in particular in the Gulf of Finland and adjacent regions where the nutrient loads are high. But the major causes are differences in the hydrographic conditions. A stable thermocline exists throughout the productive period in central and northern Baltic Sea and inhibits the input of re-mineralized CO_2 from deeper water layers into the surface. Therefore, the pCO_2 draw down by production is not damped by organic matter mineralization. The situation is different in the shallower and hydrographically more dynamic waters in the south-western Baltic Sea. Due to frequent full mixing of the water column down to the sediment surface even during spring and summer, production and decomposition of organic matter are not entirely separated by stratification of the water column and result in a less pronounced pCO_2 decrease during the productive period in spring and summer.

At a few occasions extremely high pCO_2 of almost 800 µatm were observed in late summer and autumn close to the Island of Gotland. These events could be attributed to coastal upwelling which occurs during strong winds from a particular direction and which transports highly CO_2-enriched deep water to the surface.

3.3.3 Organic Matter Decomposition and Deep Water CO_2 Accumulation

Particulate organic matter is sinking into deeper water layers and finally to the sediment surface where it is mineralized by bacteria. This process which reverses the photosynthesis, is chemically an oxidation of organic matter and thus consumes oxygen or other oxidants while producing CO_2. Since a permanent halocline separates the surface water from the deep water (Fig. 3.7a) and since the lateral water exchange may be inhibited for many years, mineralization products accumulate in the deep basins during such periods of stagnation (Schneider et al. 2010).

Because the oxygen pool is limited in the deep water, nitrate and finally sulphate are used as oxidants after O_2 is completely exhausted. This leads to the formation

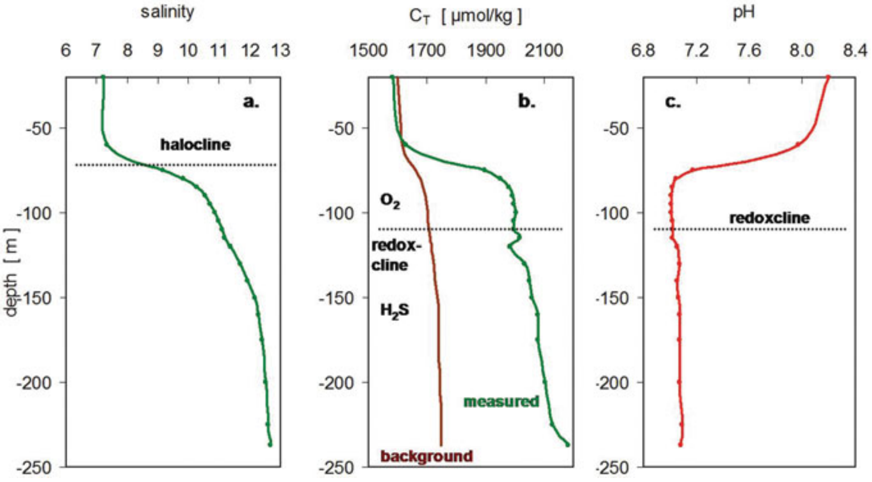

Fig. 3.7 Vertical profiles of salinity (**a**), background and measured total CO_2 (**b**) and pH (**c**) in the eastern Gotland Sea in 2008

of hydrogen sulphide and thus the establishment of anoxic conditions. This development starts at the sediment surface and the interface between oxic and anoxic conditions (redoxcline) propagates upwards (Fig. 3.7b) due to vertical mixing. The total CO_2 profile observed after a 2-year period of stagnation (2006–2008) in the eastern Gotland Sea and the background C_T that would exist at equilibrium with the atmosphere, are shown in Fig. 3.7b. The difference between the two lines represents the C_T increase caused by mineralization of organic matter. The highest C_T accumulation is observed in the bottom water where the C_T exceeds the background value by 440 μmol kg^{-1}. The C_T accumulation is limited by the fact that the permanent halocline is not a complete barrier for the exchange of seawater constituents. Although the mixing coefficients are small, the development of strong C_T gradients at the halocline (Fig. 3.7b) cause a flux across the halocline which partly compensates the biological C_T losses in the surface water. In the long run a steady state develops in the deep water at which C_T production by mineralization of organic matter is balanced by the C_T removal through mixing across the halocline.

The C_T enrichment in the deep water has also consequences for other variables of the CO_2 system. CO_2 partial pressures of up 4,500 μatm are observed (Beldowski et al. 2010) which exceed the atmospheric level by more than a factor of 10. Similarly, the deep water pH is by more than one unit lower than the mean value in surface waters and drops off to values below 7 (Fig. 3.7c). However, no further decrease of the pH is observed below the redoxcline despite the increase of C_T. In contrast, the pH is slightly increasing at the redoxcline and stays then approximately at a constant level. This is due to the formation of sulphide ions (S^{2-}) at anoxic conditions. S^{2-} contributes to the alkalinity because it is a strong proton acceptor and consequently takes up H^+ which are produced by the increasing C_T.

3.4 Anthropogenic Perturbations

The most obvious anthropogenic perturbation of the marine CO_2 system is caused by the increasing atmospheric CO_2. Due to the combustion of fossil fuels, cement production and intensification of agriculture, the atmospheric CO_2 has increased from the pre-industrial level of approximately 280 ppm to about 385 ppm in 2009 and a doubling of the pre-industrial atmospheric is expected within the next 100 years. The atmospheric CO_2 over the Baltic Sea was also determined in connection with the pCO_2 measurements on the cargo ship. The mean value is only 3 ppm higher than at the northern hemisphere background station Barrow in Alaska (Fig. 3.8). Furthermore, the seasonal cycles which are a consequence of the CO_2 consumption/production by the terrestrial biosphere, are quite similar. This indicates that the vicinity of the many CO_2 emission sources around the Baltic Sea have only a low impact on the atmospheric CO_2 over the Baltic Sea. This can be explained by the high CO_2 accumulation in the atmosphere (long residence time) and the fast atmospheric mixing.

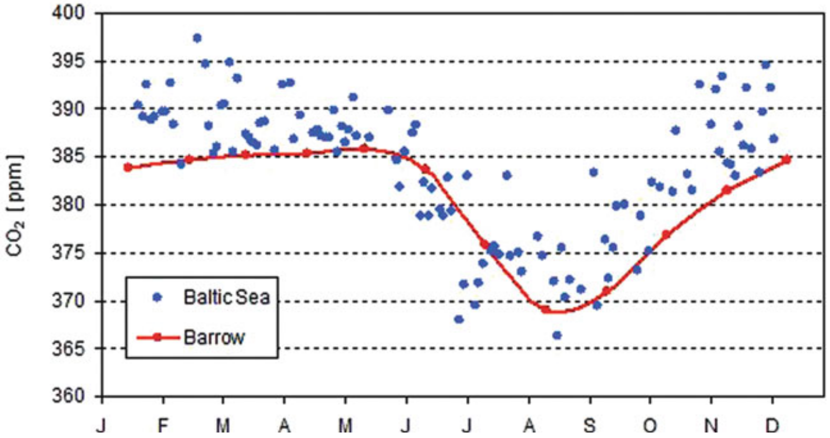

Fig. 3.8 The seasonality of the atmospheric CO_2 over the Baltic Sea and at the northern hemisphere background station Barrow in Alaska (data are from the Carbon Dioxide Information Analysis Center, http://cdiac.ornl.gov)

The increase of the atmospheric CO_2 causes elevated pCO_2 levels in the surface water. This may have a direct effect on the ocean productivity and many experiments have been performed to detect changes in either the production dynamics and/or the total biomass production at higher pCO_2 levels. However, the results are ambiguous and final conclusions cannot yet be drawn. Another effect of the increased dissolution of CO_2 is known as 'ocean acidification'. Although most the CO_2 excess is reacting with $CO_3{}^{2-}$ (Eq. 11) and producing $HCO_3{}^{-}$, a small fraction reacts with water and generates carbonic acid (Eq. 1) which then releases H^+. Assuming equilibrium between the atmosphere and the surface water (10°C), the effect on the mean pH of the Baltic Sea may be estimated. At the pre-industrial atmospheric CO_2 a pH of 8.19 is obtained whereas the present day pH amounts to 8.07 and will decrease to 7.91 after doubling of the pre-industrial CO_2. This decrease in pH may affect all kinds of biochemical reactions, however, the consequences for the ecosystem are entirely unclear. Attempts to detect trends in currently available pH data failed or produced results that were misleading because interfering biogeochemical and physical processes were not taken into account. The longest reliable pH time series in the Baltic Sea (Fig. 3.9) goes back to 1994 (Swedish National Monitoring Programme, SMHI), however, the predicted trend of 0.0016 units yr^{-1} is not yet detectable due to the large seasonal variability.

Another effect of the increased CO_2 dissolution is the loss of $CO_3{}^{2-}$ ions (Eq. 11) which causes a decrease of the aragonite/calcite saturation. The seasonality of the aragonite saturation in the central Baltic Sea in 2005 was calculated on the basis of the pCO_2 measurements on the cargo ship and is shown in Fig. 3.10 (blue line). The surface water is below saturation (saturation < 1) during October to April. This may explain the absence of coccolithophores (calcifying plankton) in the central Baltic Sea (Tyrrell et al. 2008) because this period includes the start

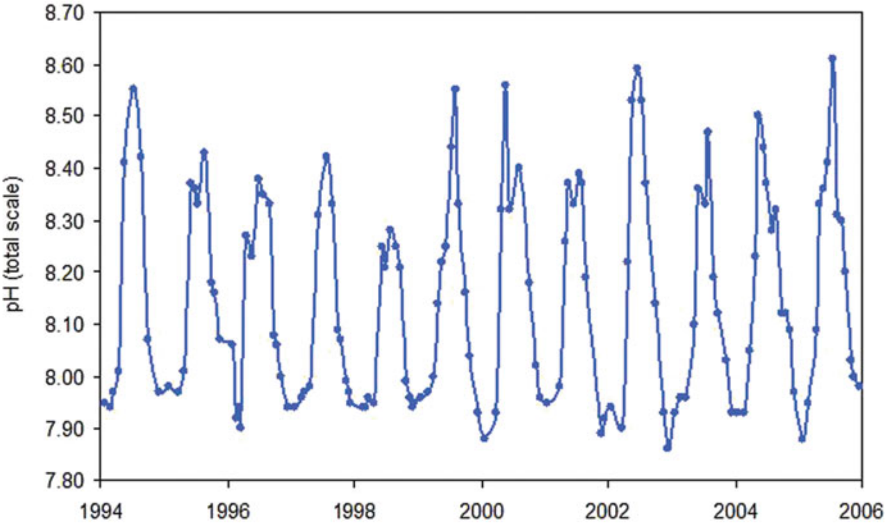

Fig. 3.9 Time series of the surface water pH in the central Baltic Sea (Swedish National Monitoring Programme, SMHI)

of the spring bloom. But higher CO_3^{2-} concentrations are generated during May to September by increasing temperatures and CO_2 consumption by biological production. Hence, aragonite saturation values of up to about 2.5 are observed and may favour the growth of $CaCO_3$-forming organisms. The aragonite saturation at the pre-industrial CO_2 and after doubling of the pre-industrial value was roughly estimated (Fig. 3.10, green and red lines, respectively) by changing accordingly the pCO_2 in the calculations, but ignoring possible long-term changes in temperature and biological production. Compared to the present situation, the spring/summer

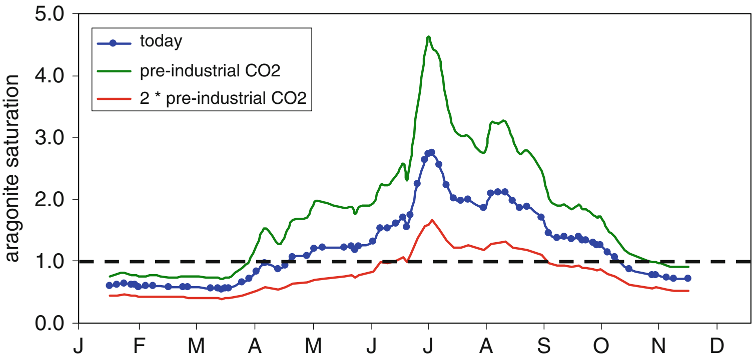

Fig. 3.10 Seasonality of the aragonite saturation in the central Baltic Sea: pre-industrial CO_2 (*green*), CO_2 in 2005 (*blue*) and after doubling the pre-industrial CO_2 (*red*)

period with saturation > 1 lasted somewhat longer in pre-industrial times and a maximum saturation of almost 5 was reached in midsummer. In contrast, the saturation will stay below 1 almost throughout the year after doubling the pre-industrial pCO_2 and only a slight oversaturation can be expected during summer. Many investigations concerning the consequences of the decreasing $CaCO_3$ saturation for the fate of calcifying organisms such as coccolithophores and corals have been initiated during recent years which indicate that serious adverse effects cannot be excluded.

An additional increase of the surface water pCO_2 and thus a reinforcement of the acidification and a further lowering of the $CaCO_3$ saturation may be caused by an enhanced input of dissolved organic carbon, DOC. The release of soil DOC in the catchment area and consequently the riverine DOC input into the Baltic Sea may increase in a warmer climate. The degradable fraction of the DOC will be mineralized by bacteria and the produced CO_2 will lower the pH and the $CaCO_3$ saturation. A quantitative estimate of this effect is currently not possible and complicated by the fact that counteracting processes such as an increase of the alkalinity may occur. The latter may be caused by the degradation of DOC in the soils of the catchment area which reduces the $CO_3{}^{2-}$ ion concentrations and thus favours the dissolution of $CaCO_3$. This results in an increase of the A_T which in turn increases the pH at a given CO_2 partial pressure (Omstedt et al. 2010).

3.5 Concluding Remarks

The marine CO_2 system is part of the complex acid/base equilibria in seawater. In addition to carbonic acid and its dissociation products, other ions such as borate and, at anoxic conditions, sulphide ions are affecting the pH. Nonetheless, the CO_2 system is the major control for the acid/base balance and mainly determines the pH. Therefore, any change in the ocean CO_2 either by increasing atmospheric CO_2 or indirectly by terrestrial organic carbon and subsequent mineralization will cause a shift in pH and related seawater properties such as the calcium carbonate saturation. Based on different scenarios for the future CO_2 emissions, the IPCC (Intergovernmental Panel for Climate Change) estimated the future development of the atmospheric CO_2. Despite large uncertainties in the different scenarios, there is no doubt that the CO_2 concentration in the atmosphere will exceed the pre-industrial level by a factor of about 2 within the next 100 years. Enhanced CO_2 concentrations in seawater by increasing mineralization of terrestrial organic matter will affect mainly coastal seas such as the Baltic Sea. The magnitude of this effect depends on the increase of the organic carbon release from soils in a warmer climate and is difficult to quantify. Whereas the reaction of the CO_2 system upon increasing CO_2 inputs depends on well-known fundamental physical-chemical laws, research needs exist with regard to the response of marine organisms to a decrease of the pH and the calcium carbonate saturation.

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Chapter 4
Climate Change Impacts on Coastal Waters of the Baltic Sea

Oda Störmer

Abstract Coastal regions are particular sensitive towards environmental changes. Climate Change is likely to cause changes in main determining environmental factors in coastal waters of the Baltic Sea. Several model studies indicate an increasing water temperature (in average about 3.0°C in sea surface temperature), a decrease in salinity (in the range of 2–3 g kg^{-1} in sea surface salinity) as well as changes in source and distribution of nutrient discharge via river runoff. Changes in the ecosystem of coastal waters in the southern Baltic Sea area occur mainly during the summer season due to decreased river runoff and hence, decreased nutrient input. This may result in reduced algae growth in coastal waters but also carries the risk of potentially toxic cyanobacteria blooms caused by N-Limitation. Cyanobacteria growth is also supported by higher water temperatures. Additionally, changes in species composition and distribution, the occurrence of pathogens as well as the introduction of non-indigenous species could be expected due to warmer water temperatures and/or a decrease in salinity. Those changes in the ecosystem are likely to have an effect on anthropogenic uses in coastal waters like bathing tourism (health problems) and fisheries (changes in coastal fish communities). On the other hand, the anthropogenic uses themselves affect the ecosystem considerably (e.g. pollution, overfishing, noise). The impact of Climate Change has to be seen as one of many interacting factors. Also changes in land use patterns and agricultural management will have a main influence on nutrient loads from the catchment area. Further, social developments like the increasing attractiveness of coastal regions in the southern Baltic Sea area for tourists and migrants will influence the impact on the local ecosystem of coastal waters. For coastal adaptation strategies knowledge about the regional vulnerability towards Climate Change is essential but lacking for Baltic coastal waters recently.

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4.1 Background

Climate Change is going to impact ecosystems worldwide. Coastal regions show a particular sensitivity towards environmental changes, especially when they are linked to large river systems (Schernewski et al. 2008). Being located in the transitional zone between river and sea, their main function lies in buffering and filtering (Schiewer 2008). The brackish water environment of the Baltic Sea already challenges the species which live in it. In areas with a comparatively high salinity content marine species can be found while freshwater species dominate in regions with lower salinity (HELCOM 2006). However, both are living outside their physiological optimum. Additionally, coastal waters are place of many human disturbances occurring in the framework of business (aquacultures, fisheries, bathing tourism), nature conservation, coastal protection, national defence and other uses (e.g. marine research) (Obenaus and Köhn 2002). Those affect the ecosystem and the species living in it in different ways. Main pressures on the ecosystem turn up in the form of overfishing, pollution and noise. Changes in main determining environmental factors due to Climate Change can be expected to challenge the coastal ecosystem further.

This chapter discusses the impact of Climate Change on the ecosystem of Baltic coastal waters and further on the anthropogenic uses. Given the recent projections, the question occurs, in which way exactly the ecosystem of the coastal waters interact with Climate Change. Based on this knowledge the impact of changes in the ecosystem on interactions between the ecosystem and anthropogenic uses can be shown. Which uses will be impacted? Will they be impacted in positive or negative ways? Hereby, the regional extent of Climate Change needs to be considered. The development of adaptation strategies to Climate Change is of main importance. In Germany a study in the framework of the project MORO investigated future consequences for spatial planning processes due to Climate Change (BBR 2008). This knowledge about regional impacts builds the basis for effective adaptation strategies. For coastal waters this knowledge is mainly lacking. The understanding of the interactions between Climate Change, ecosystem and human environment is the base for further investigations on regional scale.

The Baltic Sea is an unsteady system which is not easy to predict in its reaction towards Climate Change. Several approaches have been done by using various dynamical models of regional climate systems projecting future Climate Change (BACC 2008, HELCOM 2007). Climate Change impacts on the ecosystem of coastal waters can be seen as an additional challenge for a system which is already under intense pressure. Although climate-related changes are not likely to be the largest ‘threat’ to the Baltic coastal ecosystem, they may become a serious issue in combination with other stresses (Bijlsma et al. 1996).

Several model studies indicate an increasing water temperature (Graham et al. 2008, Döscher and Meier 2004), a decrease in salinity (Meier 2006, Neumann 2010) as well as changes in source and distribution of nutrient discharge via river runoff for the Baltic Sea by the end of the century (Graham 2004, Graham et al. 2008). Changes in wind conditions are likely but still uncertain (Graham et al. 2008). The water exchange with the North Sea could be affected as well. Current results of projected changing environmental factors due to Climate Change indicate further a rising sea level (Meier et al. 2004b) as well as a decrease in sea ice extent and season (Meier et al. 2004a, Neumann 2010). Consequences for the ecosystem occur in various ways, are highly dependent on the regional requirements and vary in space and time. All projected environmental changes are likely to cause decoupling effects in the ecosystem both in space and time (UBA 2009). Climatic changes may lead to changes in the timing of food requirement and availability (match-mismatch hypothesis, cf Cushing 1990), e.g. the shift in the timing of the blooms is likely to affect the 'match' between phytoplankton and zooplankton (Ottersen et al. 2004).

Baltic coastal waters differ a lot in their typology. Lampe (1996) grouped the Baltic coasts into several basic types: (1) Archipelago, (2) Fjärd, (3) Fjord, (4) seabed, (5) cliff, (6) mainland, (7) Bodden, (8) Haff, (9) compensational and (10) Delta coasts as well as (11) long narrow inlets (Förden). In southern regions moraine material is dominant while hard bottom and rocky shores are common in northern regions (Schiewer 2008). Lagoons and inner coastal waters like Bodden (wide and shallow coastal bays) and Haffe (former bights separated by a sand barrier starting from the mainland) are a common structure along the southern Baltic coast. Archipelagos as well as fjärd and fjord coasts can be found mainly in northern regions. The impact of Climate Change on Baltic coastal waters is likely to vary on regional scale depending on the local preconditions. Rocky shores are e.g. much less affected by erosion than coastlines consisting of soft glacial material.

Furthermore, the ecology of coastal waters crucially depends on their typology. Climate Change impacts are likely to affect those ecosystems to different degrees. Shallow coastal lagoons with high freshwater inflow (e.g. Odra Lagoon) and thus, low salinity content and long water residence time will react more sensitive to variations in the amount river runoff and water temperature than coastal waters with high water exchange with the open Baltic Sea.

4.2 Controlling Parameters in the Baltic Sea

The Baltic Sea is influenced mainly by water exchange with the North Sea (Fig. 4.1), direct influences like water temperature (Fig. 4.2) and indirect influences via the river basin (Figs. 4.3 and 4.4). The impact of Climate Change on those controlling parameters is shown in the following. The projected environmental changes due to Climate Change in the ecosystem are likely to have an impact on biota and biological processes in the Baltic Sea ecosystem (HELCOM 2007). Ecological responses to climate variability have already been shown by Ottersen et al. (2004). The effect on biota occurs directly via physiology and indirectly via changes in the biological environment. In addition, the physical parameters influence the competitive success of one species over another. Warmer water temperatures and a decreased salinity are likely to have a direct effect on species distribution and composition as well as their interactions (Dippner et al. 2008). Furthermore, nutrient availability plays an

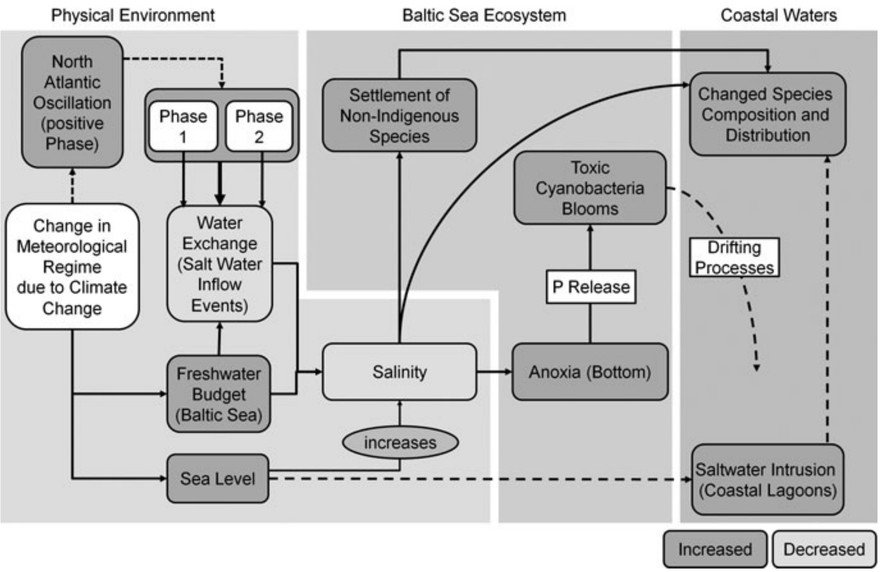

Fig. 4.1 Overview over the potential influence of projected changes in water exchange with the North Sea by the end of the century on the Baltic Sea ecosystem and further on the ecosystem of coastal waters. 'Phase 1' = high pressure with easterly winds; 'Phase 2' = strong zonal winds (over several weeks) and pressure fields over the North Atlantic and Europe (Matthäus et al. 2008). Each phase alone causes minor inflows while in combination very strong inflow events occur. The projected increase in the overall freshwater budget (+20% by 2100, Neumann 2010) and thus the outflow of water masses into the North Sea might counteract major inflow events. Despite the increasing effect due to sea level rise salinity is projected to show an overall decrease. Predictions about the future development of water exchange remain, however, very uncertain

important role. The seasonal input of nutrients via river runoff into coastal waters might change due to changed precipitation patterns. Nutrient cycling and mineralization will also be affected by increased water temperatures (Dippner et al. 2008) and might therefore have an additional influence on primary production. Altered species distribution and timing of the blooms may lead to changes in the food web structure. As a result, higher trophic levels might be affected, too, due to the bottom-up controlling effect.

4.2.1 Water Exchange with the North Sea

Water exchange with the North Sea is restricted by the narrow streets of the Little Belt, Great Belt, the Sound and by the shallow Darss Sill and Drogen Sill. The water exchange influences the Baltic Sea in different ways. The inflow of high saline water affects the salinity content and therefore the settlement of non-indigenous species (Table 4.1). The transport of deep saline water depends additionally on the

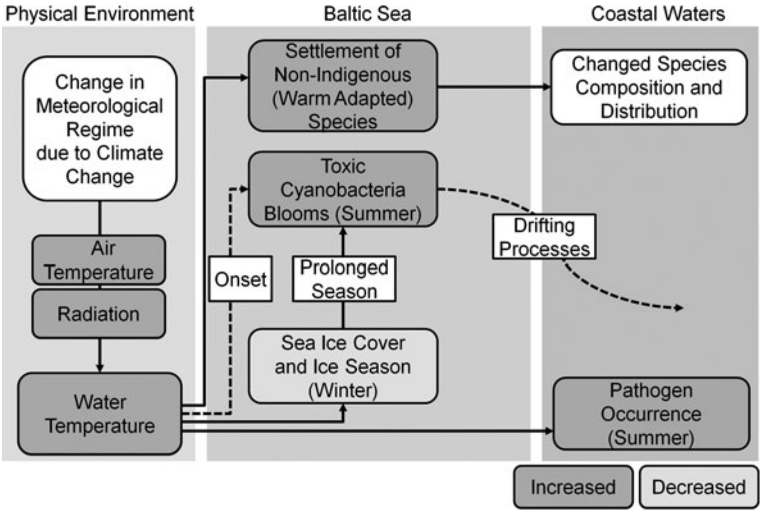

Fig. 4.2 Simplified figure showing Climate Change impact on environmental factors directly influencing the Baltic Sea (for the southern Baltic Sea Area during the summer period by the end of the century) and potential generalized ecosystem responses. Changes in biodiversity and biochemical processes are more complex in reality than shown in the figure. An increasing water temperature exceeding 16°C supports the onset of toxic cyanobacteria blooms (Wasmund 1997). Furthermore, the season for cyanobacteria blooms is prolonged

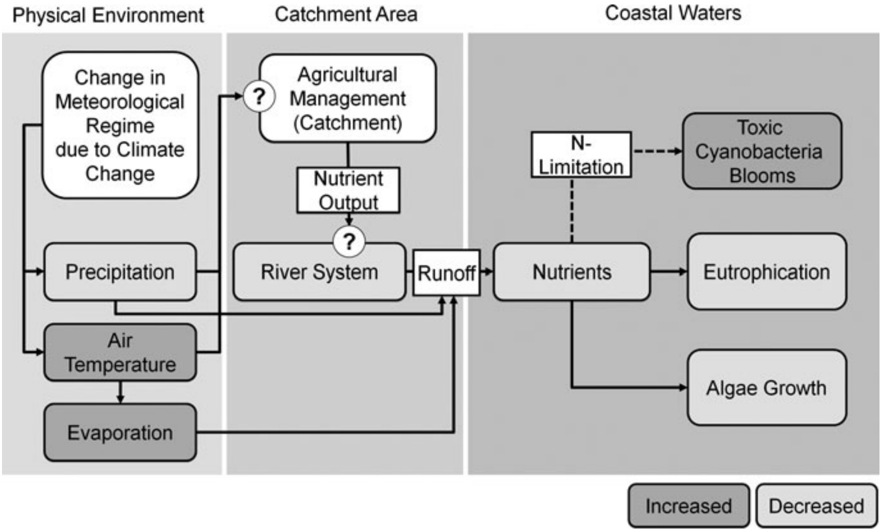

Fig. 4.3 Simplified figure showing the impact of Climate Change induced environmental changes on the interactions on the land-coast-sea interface (for the southern Baltic Sea area during the summer season by the end of the century). A reduced river runoff and hence nutrient loads into coastal waters may result in reduced algae growth but enhances the risk for harmful algae blooms due to N-Limitation

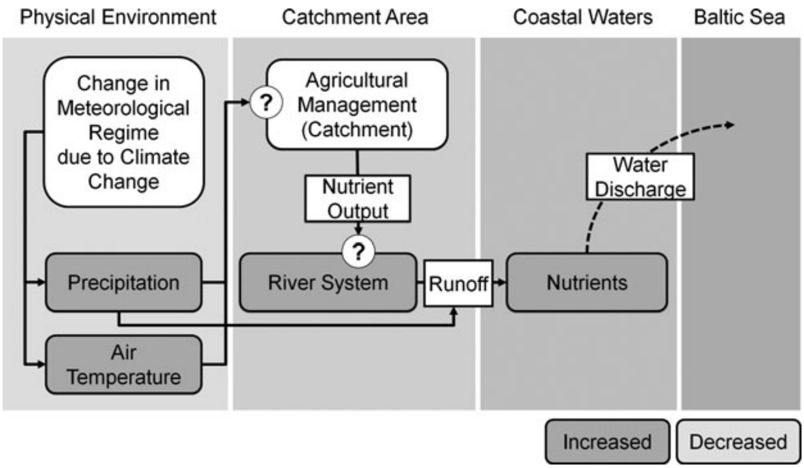

Fig. 4.4 Simplified figure showing impact of Climate Change induced environmental changes on the interactions on the land-coast-sea interface (for the southern Baltic Sea area during the summer season by the end of the century). Due to the winter season no considerable effects on the ecosystem of coastal waters can be expected

Table 4.1 Climate Change effects on the water exchange with the North Sea and potential ecosystem responses

		Effect on. . .			
	Projections by the end of the twenty-first century	Anoxia	Harmful algae blooms	Changes in species composition and distribution	Settlement of non-indigenous species
Salinity	–	+	+	+	+
Sea level	+	o	o	(+)	o
MBIs	?	o	o	o	o

+ = increase; o = neutral; – = decrease. Brakes indicate indirect effects. MBI = major Baltic inflow.

submarine sills in the Baltic Sea (HELCOM 2010). Furthermore, the sea level height in the Baltic Sea is connected to the North Sea.

Hänninen et al. (2000) suggest that salinity in the Baltic Sea is hypothetically controlled by westerly winds, freshwater runoff and the Northern Atlantic Oscillation (NAO). The NAO is a climatic phenomenon in the North Atlantic Ocean. Underlying climatic conditions are fluctuation differences in atmospheric pressure at sea level between the Icelandic Low and the Azores High (Jung 2000). The NAO is responsible for the climatic situation in the North Atlantic and the occurrence of westerly winds. In years with a high NAO index winters in the Baltic Sea region are mild accompanied by higher rainfall. On the opposite, a low NAO index leads to very cold winters while the precipitation is reduced. Since the late 1970s the NAO has been predominantly positive and was connected to the absence of major inflow events from the North Sea in the last decades (Hänninen et al. 2000).

Schinke and Matthäus (2003) studied the influence of sea-level pressure fields over the North Atlantic and Europe on major Baltic inflows (MBI). They found no close connections between MIBs and the variations of the meridional circulation over the North Atlantic. Instead favourable conditions seem to develop in the transition area and the Baltic Sea area itself. Therefore, mean atmospheric circulation patterns can be considered as a large-scale, potentially favourable, condition but the local dynamics represent the causal factors for MIBs.

Local preconditions can be divided into two phases (Matthäus et al. 2008). During the first phase, high pressure with easterly winds leads to a Baltic Sea level below normal accompanied by reduced river runoff and precipitation. In the following phase strong MIBs are caused by strong zonal winds (over several weeks) and pressure fields over the North Atlantic and Europe. As a consequence Baltic Sea level rises considerably. For weaker inflow events only one of the two phases needs to be well developed (Matthäus et al. 2008).

The inflow of saltwater into the Baltic Sea means at the same time the inflow of oxygenated water. During periods when major inflow events are absent, the bottom layers show a tendency to become anoxic resulting from biochemical oxygen consumption (Kahru et al. 2000). Anoxic conditions leading to a massive release of phosphorus from the sediment (Gunnars and Blomquist 1997) might favour (toxic) cyanobacteria blooms. Those blooms also potentially affect coastal waters due to drifting processes.

A rising sea level rise has an increasing effect on salinity in the Baltic Sea. However, according to the model studies (Meier 2006, Neumann 2010) salinity is predicted to show a considerable decrease. In general, a tendency towards lower salinity is projected for the whole Baltic Sea and all seasons by the end of the twenty-first century. In average salinity is projected to decrease by about 2–3 g kg^{-1} in sea surface salinity (Neumann 2010). Meier (2006) showed an averaged decrease in sea surface salinity of 1.8 psu (–28%). Considering only wind changes, average salinity changes vary between –31% and +9%, instead of –45% and +4% when freshwater inflow is included in the simulations (Meier et al. 2006).

In regard to the salinity controlled biodiversity in the Baltic Sea, the projected decrease will have a main impact on species composition. The composition and distribution of coastal fish communities might be affected, freshwater species favoured. Attril and Power (2002) investigated the climate influence on marine fish assemblage and found a significant relationship between NAOI (North Atlantic Oscillation Index) and fish population abundance. In the past regime shifts towards small pelagic swarm fishes like sprat have been connected with a positive NAO index (Alheit and Bakun 2010) and thus the absence of major inflow events. Besides, successful recruitment depends often on specific environmental conditions and might be affected as well. The influence of temperature and salinity on the embryonic development of fish was already described by Westernhagen (1970). He connected the occurrence of anomalies on embryonic and larval stages as well as a reduced survival rate with non-optimal salinity and temperature conditions. Fish nursery grounds like the Greifswalder Bodden (Germany) as a local breeding area for the herring could be seen as especially sensitive towards environmental changes.

A rising sea level is suggested by various studies on global scale (e.g. IPCC 2007, Rahmsdorf 2007) and in the Baltic Sea (Meier et al. 2004b). This may cause an enhanced threat for coastal zones. On a global scale the IPCC (2007) projected a mean global sea level rise in the range between 18 and 38 cm (B1) and 26–59 cm (A1F1) until the end of the century compared to 1990. Rahmsdorf (2007) raised the projected global sea level rise up to 50–140 cm. The regional extent of sea level rise is uncertain for the Baltic Sea Area. The model results from Meier et al. (2004b) show a high regional variability of sea level rise in the Baltic Sea due to isostatic compensation processes.

Additionally, sea level extremes will increase significantly which has to be taken into account in the framework of spatial planning (e.g. for coastal protection measures). Downscaling experiments showed further wind induced seasonal sea level changes for the Baltic Sea (Graham et al. 2008). Meier (2006) compared three different global average sea level rise scenarios: 9, 48 and 88 cm. For the highest scenario his model results suggest for several parts of the southern coastline of the Gulf of Finland and the Gulf of Riga an annual maximum sea level higher than 160 cm by the end of the century compared to the present climate (mean global sea level 1903–1998) for most winter periods. Extreme sea levels will increase considerably more than the mean sea level. The 100-year flood at the Gulf of Gdánsk shows an increase up to 114 cm above the present mean sea level (up to 97 cm) (Meier et al. 2004b).

A rising sea level rise may have an impact on the biota in coastal waters. Enforced erosion and sea level rise may cause problems for coastal lagoons like the Vistula Lagoon in Poland if their land bridge which separates them from the open sea is endangered. Along the Polish coast the soft glacial material could easily be eroded. Furthermore, due to the vertical movement of the earth crust the area of the Gulf of Gdánsk is sinking (Furmanczyk and Musielak 2002). Inflow of saline sea water into a coastal lagoon characterised by high freshwater inflow may result in regime shifts of the local ecosystem. Petersen et al. (2008) showed that a sudden increase in salinity was able to cause a bottom-up controlled turbid state into a top-down controlled clear-water state in a coastal lagoon in Denmark. Therefore, coastal lagoons can be seen as especially sensitive towards changes due to their comparatively fast reaction.

Introduction of non-indigenous species into the Baltic Sea occurs via intentional introductions of species, transportation in ballast water and active or passive intracontinental dispersal via canals between the rivers (Leppäkoski and Olenin 2000). The introduction of potentially harmful non-native species due to transportation processes during water exchange might influence the aquatic ecosystem in the Baltic Sea as well. However, with regard to coastal waters it plays a subordinate role compared to the other ways of introduction. Additionally, taken into account that the occurrence of major inflow events might stay low or even decrease in the future this way of introduction into the Baltic Sea does not seem very likely.

Projections for future major inflow events until the end of the twenty-first century are hardly possible especially due to the high uncertainty of future development of local preconditions for MIBs. Therefore, the impact of Climate Change on the water exchange with the North Sea and, thus, the impact on the ecosystem of coastal waters remain currently unclear.

4.2.2 Direct Influences

Radiation respectively the amount of solar energy reaching the surface varies due to natural variations like cloudiness (Russak 1994). Döscher and Meier (2004) showed in their simulations only minor changes in the overall heat budget. However, the flux components shift considerably, e.g. solar radiation to the sea surface is increased in a future climate. The heat transfer from the atmosphere to the Baltic Sea leading to an increase in water temperature shows seasonal changes.

Combined results of global climate models and downscaling studies show an overall increase in annual mean sea temperature of about 3–5°C for the whole Baltic Sea basin by the end of the twenty-first century (Graham et al. 2008). The warming will occur strongest in the northern regions in winter and in the southern regions during the summer months. Specific humidity and air temperature on time scales less than a year are mainly responsible for the water temperature; furthermore, wind speed and freshwater inflow may have an effect on long time scales (Meier 2006). Stigebrandt and Gustafsson (2003) suggested that a Climate Change related increase of temperature would be seen first in the sea surface temperature (SST) of the Baltic Sea as a result of the intense sea-air heat exchange. For the period 1990–2005, including seven of the warmest summers (concerning air temperature) of the past 60 years, a slight increase of the SST in the entire Baltic Sea of about 0.97 K could already be observed (Siegel et al. 2008). Future simulations of water temperature continue the past and recent warming trend. Meier (2006) showed an increase of SST of the regional ocean climate model scenario simulations lying in the range of +2.1 and +3.7°C until 2100. Similar results were found by Döscher and Meier (2004) who described an average mean SST increase in the range of +2.4 and +3.4°C in 2071–2100 compared to 1961–1990. In all cases, the warming is strongest during the summer season (May–September) and in the southern and central Baltic Sea.

Besides salinity, temperature is one of the main determining environmental factors of the Baltic Sea. The projected increase of water temperature is expected to cause changes in species composition (HELCOM 2007). Concerning primary production, the direct effect of temperature on phytoplankton is low. Regardless of individual preferences of the species, phytoplankton growth starts already at low temperatures. On the other hand, the indirect effect via stratification plays a role concerning algae species occurrence as some prefer stable conditions, others instable conditions (Dippner et al. 2008). The expected warming during the winter period is likely to reduce diatom spring blooms and favour the occurrence of dinoflagellates (Wasmund et al. 1998). Furthermore, higher water temperatures favour the occurrence of pathogens like Vibrio-related diseases (e.g. Cholera) (Muijsken and Menger

Table 4.2 The impact of directly by Climate Change influenced environmental factors on potential ecosystem responses. This is shown for the southern Baltic Sea area during the summer season

		Effect on. . .			
	Projections by the end of the twenty-first century	Anoxia	Harmful algae blooms	Changes in species composition and distribution	Settlement of non-indigenous species
Water temperature	+	o	+	+	+
Sea Ice cover	–	o	(+)	+	o
Radiation	+	o	(+)	o	o

The + indicates an increase, the o neutral behaviour and the – a decrease. Brakes indicate indirect effects

2007) which is of high importance in coastal waters where bathing tourism is taking place.

Overall, an increase in water temperature in combination with other environmental changes (decrease in salinity, changes in nutrient availability) due to Climate Change can be expected to change species composition and distribution considerably (HELCOM 2007, Dippner et al. 2008) and may enhance the risk of the settlement of potentially harmful non-indigenous species (Stachowicz et al. 2002) (Table 4.2).

Due to warmer water temperatures in winter the sea ice cover will be reduced down to 30% of the recent ice extent by the end of the twenty-first century (Neumann 2010). Meier et al. (2004a) showed in their model results a similar decrease in the range of 57–71%. Additionally, the length of the ice season will decrease between 1 and 3 months depending on the region. The reduced ice-cover in the northern part in combination with a prolonged growing season enables an earlier spring bloom for about 1 month (Neumann 2010). The season for cyanobacteria growth is prolonged as well in the future. Due to Climate Change the primary production might intensify and warm-adapted species like the toxic cyanobacteria *Nodularia spumigena* favoured (Dippner et al. 2008). Wasmund (1997) discovered that the development of strong blooms begins when water temperature exceeds 16°C. The forming depends further on wind speed ($< 6\ m^{-2}$) and radiation ($>120\ W\ m^{-2}$). An increase in wind speed might counteract those bloom forming processes.

4.2.3 *Indirect Influences from the River Basin*

Coastal waters linked to large rivers have to be seen as an interacting system (Schernewski et al. 2008). Climate Change will cause changes in the interactions in the land-coast-sea interface in the future and thus have an effect on the ecosystem of coastal waters. The river transports pollutants and nutrients to coastal waters which can result in eutrophication (Nixon 1995). The amount of river runoff depends on precipitation and evaporation in the catchment area. Precipitation is projected to change in amount, space and time until 2100 due to Climate Change. The freshwater budget of the Baltic Sea is predicted to increase about 20% by the end of the century compared to the reference period 1960–2000 (Neumann 2010, Meier 2006). The projected changes in precipitation are likely to alter seasonal river flow. Major changes in seasonal and sub-regional variations of river flow can be expected in comparison to the conditions in the recent climate (Graham 2004). The main annual river runoff in the northern parts is projected to increase until 2100 whereas runoff situation in summer in the southern regions is strikingly decreasing (Graham et al. 2008). Seasonally, the northern part projections show a change of about –5% – +25%, the southern regions a decrease down to –4% during the summer period. During the winter period a similar increase in precipitation is projected for northern (+25% – +75%) and southern (+20% – +70%) regions.

Water discharge and nutrient loads via river runoff affect the water quality of coastal waters (Schernewski et al. 2008). Parts of the nutrients which enter the river system get lost in processes of transformation and retention before being discharged into coastal waters (Behrendt and Opitz 2000). Transformation processes also occur within the coastal ecosystem. Nitrogen and phosphorus partly get lost by sediment burial due to coastal biochemical cycles (Richardson and Jørgensen 1996). Nutrient pollution can result in eutrophication which is a main problem for water quality. HELCOM (2005) described eutrophication as ‘a condition in an aquatic ecosystem where high nutrient concentrations stimulate growth of algae which leads to imbalanced functioning of the system’. Besides anthropogenic caused nutrient pollution natural processes like upwelling can result in eutrophication as well (Richardson and Jørgensen 1996).

Eutrophication in coastal waters is caused by high loads of growth-limiting nutrients like nitrogen (HELCOM 2010). HELCOM (2005) describes the eutrophication process as follows. In the first phase intense algal growth (filamentous algae and phytoplankton) takes place due to the higher availability of growth-limiting nutrients. The higher water turbidity leads to a deterioration of light availability for macroalgae. Filamentous algae become dominant. As a primary response an increased zooplankton feeding activity is acting as a buffer in the coastal system. Planktonic communities are likely to shift towards a microbial food web.

With ongoing eutrophication, the production of excess organic matter leads to a higher oxygen consumption rate. Anoxic conditions in the sediment lead to massive release of phosphate (Mortimer 1971) resulting in a shift towards an N-limitation. Nitrogen-fixating cyanobacteria and thus the development of (harmful) foam forming blooms might be favoured (Wasmund 2001).

Overall, eutrophication leads to structural and functional changes in the system, significantly affecting organisms like zoobenthos and fish (Bonsdorff et al. 1997). Coastal fish biomass is expected to increase during the first phase of eutrophication due to the increased food availability (Schiewer 2008). In contrast to the general theories of temperate lakes Lappalainen (2002) concluded in his study that ‘an increased primary production does not necessarily lead to a high (adult) fish biomass’.

The impact of Climate Change on the interactions in the land-coast-sea interface is shown in the Figs. 4.3 and 4.4. Eutrophication is mainly influenced by riverine nutrient loads.

Furthermore, airborne inputs play an important role. In the year 2000 25% of the nitrogen (1–5% of the phosphorus) entered the Baltic Sea as airborne input (HELCOM 2005). A reduced nutrient input during summer in the southern regions due to Climate Change may be considered to counteract eutrophication in coastal waters and reduce algae biomass (Schernewski et al. 2006). On the other hand, the limitation of nitrogen during the summer period in the southern regions may result in a higher risk for (toxic) cyanobacteria blooms (Neumann et al. 2002, Schernewski et al. 2008). Besides river runoff itself as a way of nutrient transport the land use patterns in the catchment area are highly responsible for the nutrient input into the river system and thus into coastal waters (Nixon 1995, Bonsdorff et al. 1997). Therefore, adaptations in agricultural management due to Climate Change are likely to have an effect on the nutrient output from the catchment. Retention of nutrients within the catchment area derives from point, diffuse and natural background sources as well as atmospheric deposition (HELCOM 2005). Climate Change can be expected to affect the agricultural management directly because changed precipitation patterns and higher air temperatures will probably lead to adaptations in the cultivation of different crop species combined with a potential increase in the need for plant protection and a higher risk of nutrient leaching (Olesen and Bindi 2002). Thus, the sort and amount of fertilizers is likely to change in future and influence the riverine nutrient load.

In regard to the complexity of interactions between catchment, river and coastal waters, a management of nutrients in coastal waters needs to include the management of the activities in the catchment area (Schernewski et al. 2008). Additionally, Climate Change affects those environmental conditions in coastal waters which play an important role in eutrophication processes.

A direct impact occurs in form of an increase in water temperature in the future. Water temperatures exceeding 16°C in combination with stable water conditions favour the forming of toxic cyanobacteria blooms (Wasmund 1997). However, an increase in wind speed due to Climate Change – which is more likely than a decrease in future projections – could counteract these processes (Dippner et al. 2008). Overall, the reaction of phytoplankton biomass and species composition is highly dependent on the strongest climatic factor.

4.3 Interactions Between Ecosystem and Anthropogenic Uses

Baltic coastal waters are used by humans in various ways. Economic relevant anthropogenic uses are ship traffic, harbours, fisheries, aquacultures, mining of marine resources and bathing tourism. Non-economic uses of coastal waters include coastal protection, nature conservation and military uses (Obenaus and Köhn 2002). Additionally, benefits for humankind occur via ecosystem services. Constanza et al.

(1997) defined that ‘ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits for human population derived, directly or indirectly, from ecosystem functions’. Both biological and physical changes interact with anthropogenic uses and ecosystem services.

Besides Climate Change related impacts, Baltic coastal waters are influenced by anthropogenic pressures which occur via pollution, changes in the natural environment (e.g. buildings), noise and overfishing. Main impacted factors by Climate Change are temperature, salinity and nutrient availability. This may lead to changes in species composition and distribution. Changes in the ecosystem are likely to influence ecosystem functions and hence ecosystem goods and services.

The impact of Climate Change on coastal waters varies strongly on regional scale. Projections show differences in space and time. Therefore, the focus is set on the coastal waters of the southern Baltic Sea to have a closer look on the interactions between Climate Change effects on the ecosystem and the human environment. In German coastal waters bathing tourism is the main economical factor along the German Baltic coastline. Fisheries are in decline but also play an economical role. Other relevant uses are coastal protection, the mining of marine resources and nature conservation. Minor roles play aquacultures, military uses and uses in the framework of marine research.

Several ecosystem responses seem likely for coastal waters in the southern regions. A decreased riverine nutrient load during summer due to a projected decrease in precipitation by the end of the twenty-first century may reduce algae growth in coastal waters in future. On the other hand, this might lead to nitrogen limitation which favours potentially toxic cyanobacteria blooms (Schernewski et al. 2008). Nutrient availability in combination with the effects of a decreased salinity and higher water temperatures may result in the introduction of (harmful) non-native species, better conditions for pathogens via warmer water temperatures and changes in coastal fish communities. If main ecosystem functions are changing, this can be expected to impact ecosystem services considerably.

4.4 Consequences for Anthropogenic Uses

Consequences for anthropogenic uses due to Climate Change induced changes in the ecosystem of coastal waters may occur in various ways (Fig. 4.5). The effect of possible relevant ecosystem responses due to Climate Change on anthropogenic uses is shown in Table 4.3 for the southern parts of the Baltic Sea during the summer season.

Biological changes in the ecosystem affect several anthropogenic uses. Bathing tourism depends on a good water quality (Schernewski et al. 2008) and is affected by various changes. In public perception clear and clean water is considered as a good quality (Dolch 2004). A high water transparency is generally regarded as desirable for touristic concerns (Dolch 2004). Thus, high water turbidity has a negative effect on public perception. Nutrient enrichment in coastal waters causes an increase in

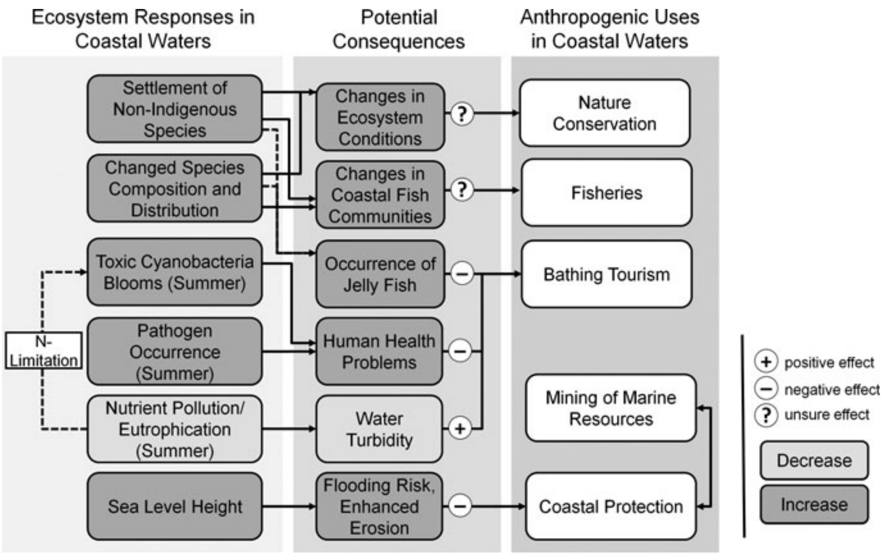

Fig. 4.5 Simplified figure showing interactions between potential ecosystem responses in the southern Baltic area and anthropogenic uses during the summer season by the end of the century

water turbidity due to an enhanced algal growth. For the southern Baltic Sea area river runoff is projected to decrease in the future during the summer months until 2100. Hence, the nutrient input to coastal waters is reduced and may counteract algae growth but enhances the risk for harmful cyanobacteria blooms (Schernewski

Table 4.3 Effected anthropogenic uses in coastal waters by ecosystem responses towards Climate Change in southern regions during summer by the end of the century

	Anthropogenic uses in coastal waters				
	Bathing tourism	Coastal fisheries	Mining of marine resources	Coastal protection	Nature conservation
Harmful algae blooms	–	o	o	o	(–)
Anoxia	(–)	(–)	o	o	–
Settlement of non-indigenous species	(–)	±	o	(–)	–
Changes in species composition and distribution	o	±	o	o	±
Occurrence of pathogens	–	o	o	o	o
Reduced water turbidity	+	o	o	o	(+)

– = negative; o = neutral; + = positive; ± = positive and negative effects possible. Brakes indicate indirect effects.

et al. 2008). A better knowledge about future nutrient discharge and local sensitivity of the ecosystem towards eutrophication processes is necessary for adaptive nutrient management and spatial planning.

Further, jelly fish occurrence might be favoured by Climate Change (higher survival rates due to warmer temperatures). A high occurrence of jelly fish is often regarded as a potential threat by bathing tourists due to a lack of information (Baumann 2010). In this case, information of bathing tourists can lead to higher acceptance in public.

Besides public perception of the water quality of coastal waters, factors which affect human health directly play an important role concerning hygienic water quality. This includes the occurrence of pathogens and toxic cyanobacteria blooms. Both are favoured by a prolonged growing season and warmer water conditions and are likely to have a negative effect on the tourism sector. On the other hand, increasing water temperatures may have positive effects as well due to a higher attractiveness for tourists during the summer period. For the southern regions, warmer and drier summers can also be seen as potentially supportive. Overall, the potential increase in the occurrence of pathogens and hence the negative impact on the tourism sector might be outweighed by the expected shift from Mediterranean tourist centers towards northern countries (Roijeckers and Lürling 2007). In the case of fisheries changes in coastal fish stocks are of main economical importance. Sprat, cod and herring are the main economical relevant species in the Baltic Sea (MLUV 2010). The coastal fish community consists of a mixture of marine and freshwater species adapted to the brackish conditions and their distribution (HELCOM 2006). Changes in salinity and water temperature are likely to have a direct effect on the distribution and composition of coastal fish communities as well as fish recruitment (HELCOM 2006). Furthermore, Climate Change induced indirect effects on eutrophication processes via the river basin may lead to changes in coastal fish communities as well. In eutrophic shallow coastal waters macroalgal blooms can have a negative effect on juveniles of marine fishes in nursery grounds (Pihl et al. 2005). Events like anoxia caused by eutrophication and supported by warmer water temperatures may cause fish death. This could be considered as especially important in the case of fish nursery grounds. On the other hand, changes in species communities and distribution could also mean a new potential for economical relevant fish species. According to the projections towards warmer water temperatures and decreased salinity warm-adapted freshwater species might be favoured.

In regard of cod and herring high commercial losses may occur in future if no adaptation strategies will be implemented in time. The problem is intensified by the fact that fishing pressures on selected fish species like cod have already caused changes in the ecosystem (HELCOM 2006). Besides fish-catch quota and other regulative measures a satisfactory result could not be achieved yet. For fisheries management future changes caused by Climate Change mean an additional challenge.

The main effects of erosion and sea level rise apply particularly to coastal protection and other marine buildings (harbours, marinas). Coastal protection measures often require resources like marine sands. Nowadays, resources for the mining of this material are often already intensive exploited. Projected future developments are likely to challenge coastal protection measures and adaptation strategies.

Non-economical uses like nature conservation might be affected by a changed ecosystem situation as the ecological value why it had been protected in the first place possibly no longer exists. On the other hand new valuable local ecosystems may develop in regions where no protection measures are implemented nowadays.

Overall, adaptation strategies for Baltic coastal waters will be necessary to face future challenges. This was already done e.g. for the terrestrial area of Germany (BBR 2008) but is lacking for coastal waters recently. Future spatial planning requires good knowledge about the regional impacts of Climate Change. Actually there is only little knowledge about the intensity of Climate Change in a spatial dimension and the sensitivity of local coastal ecosystems towards those changes. Therefore, consequences for anthropogenic uses on regional level are difficult to predict due to the uncertainty of the ecosystem response. Further investigations have to focus on the regional vulnerability. This knowledge gives valuable support for decision-making processes and enables an effective adaptive management for Baltic coastal waters.

One has to take into account that Climate Change is not solely going to impact the coastal waters of the Baltic Sea directly. It also will have consequences for agricultural management in the catchment areas. Changes in crop species and utilization of fertilizers are likely to have an effect on nutrient loads via the river system. Climate Change can be seen as an additional pressure for the ecosystem and hence anthropogenic uses. For the future management of coastal waters of the Baltic Sea Climate Change related changes have to be taken into account. This necessarily includes other sectors like agricultural management in the catchment as well as a near-coast land uses (tourism) which will have an effect on coastal waters. The management of the anthropogenic uses will be a challenge as well.

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Chapter 5
Global Change Impacts on Agricultural Land Use in the German Baltic Sea Catchment Area

Claudia Heidecke, Peter Kreins, Roger Stonner, and Horst Gömann

Abstract Global and Climate Change influence agricultural land use and production and, therefore, nutrient emissions into the Baltic Sea. The past development of agricultural land use and nutrient balances in German counties of the German Baltic Sea catchment are discussed. Crop yield estimations for winter wheat are made depending on historical data and on climatic parameters of Climate Change projections. Simulations with the agricultural sector model RAUMIS (Regional Agricultural and Environmental Information System for Germany) are conducted for the year 2020 to estimate the effects of differences in crop yields, as well as effects of the European Common Agricultural Policy and national regulations on agricultural land use. Results show that crop yields will increase on average until 2020, whereas under Climate Change yields increase less strongly with the exception of maize yields. Energy crops will be increasingly cultivated due to the current promotion of renewable energies. Altogether, decreasing nitrogen surpluses from agriculture can be expected. However, Climate Change and the cultivation of energy crops will lead to a less strong decline of nitrogen surpluses in the German Baltic Sea catchment area.

5.1 Introduction

Agricultural production in the German Baltic Sea catchment area is facing several challenges that need to be addressed in the coming years to maintain a sustainable development of land and water use. These challenges include global changes which refer to all human influences such as market effects, prices and policies, as well as Climate Change effects which are important when looking at the overall climatic conditions and its impact on land use as well as climate impacts on crop yields. As

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agriculture is contributing to a large extend to nutrient emissions into groundwater and surface waters it is important to evaluate the changes in water quality and eutrophication that might occur due to global and Climate Change. A decisive factor for the evaluation of nutrient emissions by agriculture is nitrogen surplus, also as an input into hydrological nutrient emission and transport models.

Global change effects on agriculture are mainly reflected by changes on the world food market, on the energy market, on changes in land use and consumption patterns, and of course climatic changes that influence crop yields and therefore production quantities and market competition. Global change effects in agriculture, especially Climate Change effects, have been increasingly discussed with the results and data available from the Intergovernmental Panel on Climate Change (IPCC 2007). A global analysis of the impact of Climate Change on land use has been conducted by Rosenzweig and Parry (1994) who concentrate on the linkage between Climate Change and crop yields worldwide by introducing changes in yields into a general equilibrium model, or by Rosegrant and Cline (2003) who focus on future global land and water use using the IMPACT model. For Germany global impacts on land use changes have been analysed for different possible future development paths with the model Land Use Scanner by Hoymann (2010). Gömann et al. (2010) discuss the impacts of global change on German agriculture using the agricultural sector model RAUMIS and analyse different scenarios for the German Elbe River Basin until 2020.

For the Baltic Sea region, agricultural land use changes have been discussed, e.g. by Granstedt et al. (2004). Economic analysis of nutrient emissions and possible measures has been conducted by Gren et al. (1997) who investigated the costs and benefits of measures in agriculture and other sectors to reduce nutrient input into the Baltic Sea for Sweden. Stochastic analysis of different reduction measures for nutrient surpluses has been conducted by Elofsson (2003) for all countries surrounding the Baltic Sea. Mewes (2006) concentrates on nutrient emissions and agricultural measures in the German Baltic Sea area using results of the hydrological model MONERIS.

This chapter focuses on the German part of the Baltic coastal zone by applying an agricultural sector model to analyze the impact of global and Climate Change on agricultural production. Climate Change effects on crop yields are estimated with regression analysis. These results are then introduced into an agricultural sector model. The development of nutrient surpluses from agriculture are evaluated on the basis of land use changes induced by price, market and policy developments. The development of agricultural production and land use in the Baltic coastal zone are analyzed in this chapter with the agricultural sector model RAUMIS (Regional Agricultural and Environmental Information System).

5.2 Agricultural Land Use in the Baltic Coastal Zone of Germany

The Baltic Sea catchment of Germany comprises around 29,000 km^2, which is around 2% of the total Baltic Sea catchment. The boundaries of the catchment area are the Baltic Sea to the North and to the South-west the major continental water divide, which is made up to the west by the Eastern hilly regions of Schleswig-Holstein, the land ridge of Mecklenburg-Vorpommern and the glacial valley of the rivers Oder and Neiße (Umweltbundesamt 2010a). Around 60% of the catchment area is located in Mecklenburg-Vorpommern, around 18% in Schleswig Holstein, and the rest is located in the federal states of Brandenburg and Saxony.

A total of 19 administrative counties (which is equivalent to the RAUMIS model regions) partially or fully constitute the German catchment of the Baltic Sea. Of these 11 are in Mecklenburg-Vorpommern, 7 in Schleswig-Holstein and only 1 in Brandenburg. These counties represent the majority of counties in the states of Mecklenburg-Vorpommern and Schleswig-Holstein.

The total population in the German Baltic Sea catchment is currently around 3.3 million inhabitants with the majority of the population living in the larger cities Rostock, Wismar, Kiel, Lübeck, Flensburg und Schleswig.

The region comprises around 2 million ha of utilized agricultural area (UAA). 80% of the total area of Schleswig Holstein and 70% of the total area of Mecklenburg-Vorpommern are used for agricultural production. Lakes, forest and urban areas make up only a small share.

Structural change in agriculture has been observed all over Europe in the last two centuries. In Germany average farm size has been slightly increasing in the last century. Especially small farms with less than 40 ha abandon agriculture to the benefit of larger farms. The same phenomenon can be observed in Schleswig-Holstein where the average farm size has been increasing from 41 ha on average in 1992 to 57 ha on average in 2007. In Mecklenburg-Vorpommern, the situation is reversed. 95% of farms cultivate more than 100 ha on average. Average farm size has, however, decreased in Mecklenburg-Vorpommern from 320 ha per farm in 1992 to 250 ha in 2007 (Fig. 5.1).

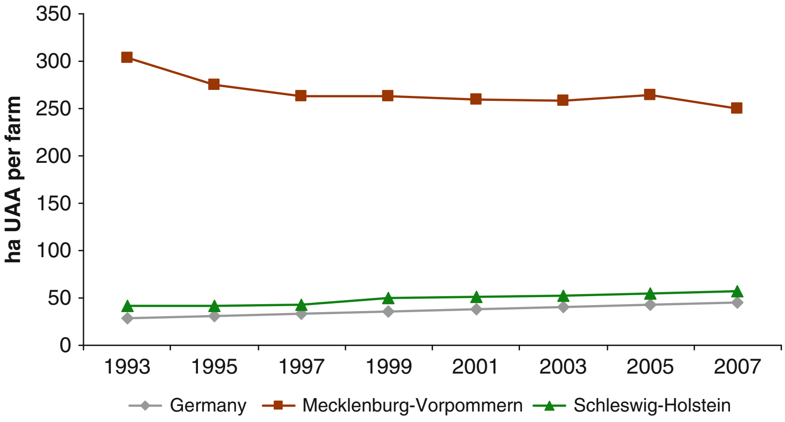

Fig. 5.1 Development of average farm sizes in Germany, and in Mecklenburg-Vorpommern and Schleswig-Holstein from 1992 until 2007

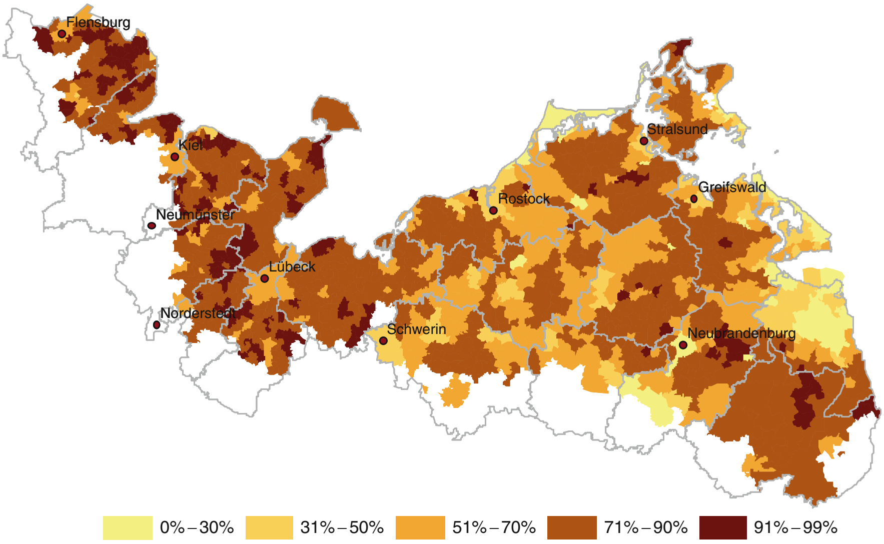

Fig. 5.2 Share of crop land on total used agricultural area (UAA) in the German Baltic Sea catchment area in % in 2003 (ATKIS 2003)

Agricultural production in the Baltic Sea catchment of Germany is characterized by highly intensive farming. Only 22% of total farm land is classified as grassland of which only around 1% is cultivated extensively.

Figure 5.2 shows the share of average farmland on total UAA for municipalities in the Baltic coastal zone. Especially in Schleswig-Holstein, some municipalities cultivate over 80% of farm land with crops. Around 44% of the UAA is cultivated with cereals, mainly wheat and barley; oilseeds take up 25% and corn and fodder maize took up only 6% in 2003.

Energy crops were hardly cultivated in 2003. With the modification of the Renewable Energy Law in 2004, and with its revision in 2008, farmers have shifted cropping patterns to grow more energy crops for biomass production and for utilization in biogas plants. As can be seen in Fig. 5.3, while the land set aside was reduced during the last year, more maize was grown. This includes, however, all kinds of maize grown as no reliable data has been available up to now to distinguish maize production into fodder and energy maize on the county scale. Altogether, cultivation shifted to more intensified farming by also increasing the area cultivated with cereals, especially with wheat.

If the trend to cultivate more energy crops on farm land is holding up, the question arises what impacts result on land use, crop yields and input use. Which price developments can be expected in the next decade and how do national and EU-wide policies affect land use in the German Baltic Sea catchment? Furthermore, it is important to evaluate how Climate Change might influence agricultural production in the future and what environmental impacts result from these developments. Some of these questions shall be answered in the following analysis.

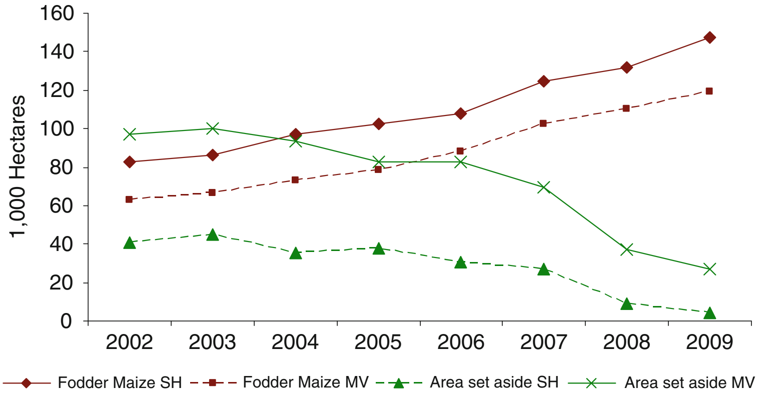

Fig. 5.3 Development of maize area and area set-aside from 2002 to 2009 in Schleswig-Holstein (SH) and Mecklenburg-Vorpommern (MV) (Statistisches Bundesamt 2008)

5.3 Climate Change Effects on Crop Yields

5.3.1 Crop Yield Estimation

Various methods for estimating crop yields have been applied for different purposes. A precondition for the development of crop yield estimation models is the availability of crop yield data and information on location characteristics from the past to estimate and quantify the dependencies between crop yields and local characteristics. Generally, the local characteristics are described with the help of soil and climate data. Climatic conditions, as well as soil characteristics, can be both, to a greater or lesser extent, limiting to crop yield (Hanus 1997).

Here, estimation of crop yields are based on winter wheat only, as winter wheat is the crop where most data is available and which is best represented in Germany. The changes of crop yield of winter wheat are ex post transferred to other crops which are included in the RAUMIS model.

On the basis of the available data for winter wheat and for the integration of crop yield and Climate Change effects into the RAUMIS model, the total cropping area of Germany was divided into 30 relatively homogenous regions. The regionalisation criteria were depicted on the municipality level using the agricultural land grade (Bodenzahl), the soil moisture as well as the average altitude. The regionalization was conducted by means of clustering using SAS software (SAS 1985) and the technique of SAS PROC CLUSTER and the WARD technique. A standardization of the variables beforehand assured the comparison of the different scale levels, and an equal weighting of variables. A linear regression model was estimated for each of the 30 resulting homogenous regions using the SAS PROC REG technique and the backward exclusion of variables. Accordingly, 30 different crop yield estimation models for wheat were derived for the whole of Germany.[1]

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[1] Estimations are based on results from the LandCaRe project described in Köstner et al. (2009).

The basis for the regression analysis are crop yields and production data of the Farm accountancy data network (FADN), climate data of Germany's National Meteorological Service and of the Climate and Environment Consulting Potsdam GmbH (CEC) as well as soil data of the German soil overview map (BüK5000). All data are available on the municipality level, whereas the data of the Farm accountancy data network is not available on an area-wide coverage due to its sample approach. However, the regression analysis allows estimates of the yields of municipalities where no crop yield data was available. The climatic parameters used in this analysis to present the specific local micro climates (Hall et al. 2003) are average temperature, minimum and maximum temperature, precipitation, the climatic water balance as well as the days without precipitation.

5.3.2 Climate Data

Climatic data need special data processing that allows both the presentation of the different phenological stages of plant development and their climatic requirements (Rust 2006). Correspondingly, climate variables have been selected to explain the variation in wheat crop yields in the 30 clusters.

The variables set up for winter wheat are:

- Length of maximum temperature above 25°C during ripening (in weeks)
- Duration of water deficit during the vegetation period (in weeks)
- Number of days without rain from November until April (in days)
- Number of days without rain from May until July (in days)
- Number of days without rain from August until October (in days)
- Number of frost days from November until April (in days)
- Precipitation in sum from November until April (mm)
- Precipitation in sum from August until October (mm)

The influence of these climatic variables varies between the municipalities of the German Baltic coastal zone. For example the calculations based on data from the Germany's National Meteorological Service for 2003 did not show any significant difference from water deficiency for plants along the coast of Schleswig-Holstein (Fig. 5.4), but the calculations for the Baltic coastal regions of Mecklenburg-Vorpommern and Brandenburg, in contrast, show the great differences of water deficiency which might impact on wheat crop yields.

5.3.3 Projections for 2021–2040 and 2041–2060

Climatic induced changes of crop yields were assessed with the help of the estimated regression coefficients and climatic data of a STAR2 (CEC) realisation of the A1B Scenario of the scenarios of the Intergovernmental Panel on Climate Change

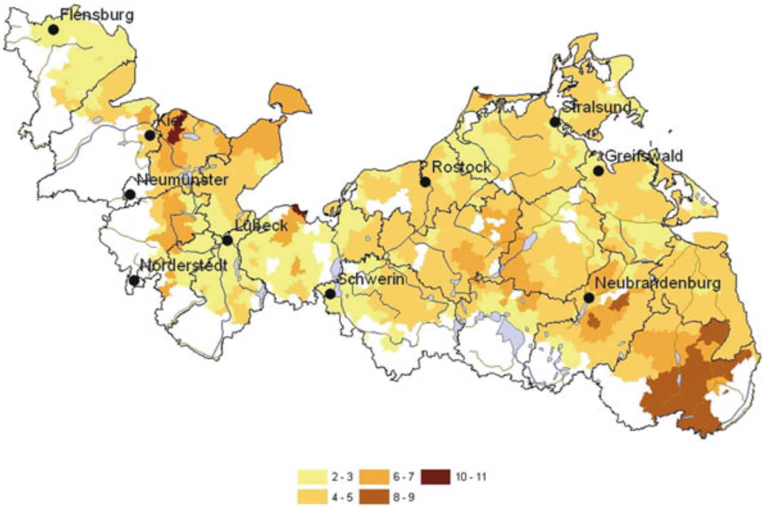

Fig. 5.4 Duration of water deficiency in successive weeks in 2003 in the Baltic coastal zone. Note: Water deficiency or yield depressing water deficit is defined here as the amount of successive weeks that the available water capacity is below 40%

(IPCC 2007). Data was available for the years 2007–2060. Along the lines of the application and interpretation of climatic data, the estimation and the analysis is based on longer time intervals (20 years) rather than analysing crop yields of single years. Therefore, the estimations are made for two time periods, first for the time period of 2021–2040 and, second, for 2041–2060. As no STAR data was available for current years, we estimate and integrate the differences in crop yields on the basis of future scenarios only. In the following, relative crop yield changes are presented for winter wheat. These changes are later on transferred to other crops and introduced into the RAUMIS model.

Figure 5.5 only shows positive crop yield developments for a few municipalities in the German Baltic coastal zone, ranging between 0 and 2.5%. The majority of the municipalities have decreasing crop yields between 0 and 2.5%, estimated especially in major parts of Schleswig-Holstein and Mecklenburg-Vorpommern. In some rare cases crop yield losses of up to 8% have been calculated. Especially the eastern parts of Mecklenburg Vorpommern are affected. In Brandenburg results show a decrease in crop yields of 2% on average.

For an evaluation of the impact of climatic influences, not only absolute crop yields are relevant but also the expected variation of crop yields needs to be investigated. The variation represents the changes in variation of winter wheat crop yield between the time periods 2041–2060 to 2021–2040.

Figure 5.6 shows that some regions have decreasing variations in crop yields, whereas other regions sometimes have strong increases in variations. Especially in the hilly areas of Schleswig-Holstein, the variations in crop yields will decrease by 20% or sometimes even by up to 40%. In some regions south of Lübeck

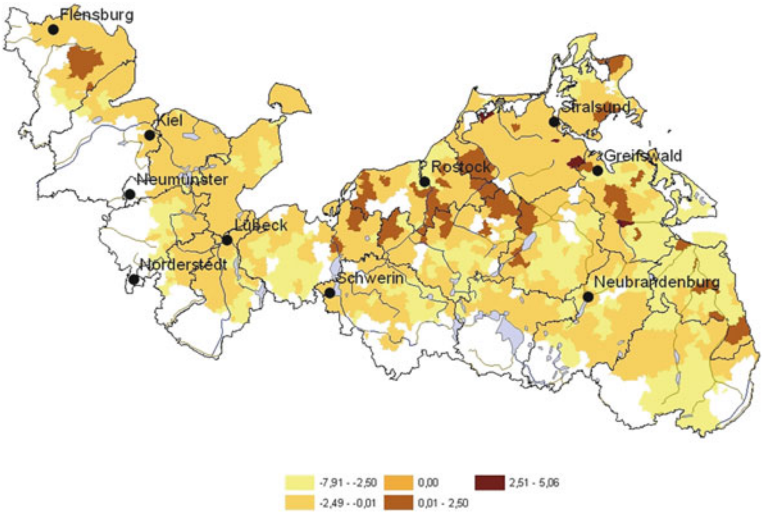

Fig. 5.5 Relative changes of winter wheat crop yields in the period 2041–2060 compared to 2021–2040

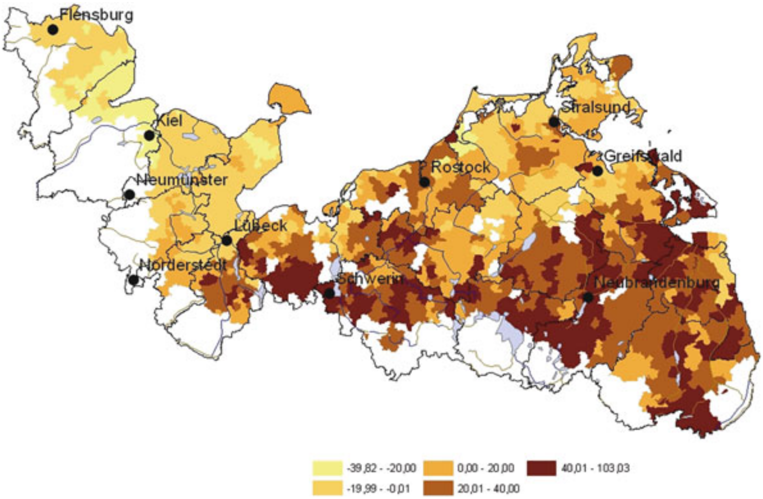

Fig. 5.6 Relative changes of the variations of winter wheat crop yield in the period 2041–2060 compared to 2021–2040

increasing variations in crop yields are expected. For Mecklenburg-Vorpommern and Brandenburg only some regions show a decrease in crop yield variations. For large parts of the Baltic Sea catchment area estimations show an increase in crop yield variations of 20% and above, in some regions even over 40%. Whereas in Schleswig-Holstein a decrease of 7% is estimated on average, for the states of Mecklenburg-Vorpommern and Brandenburg an increase of 25 and 31%, respectively, is estimated.

The estimations above have been made for winter wheat crop yield. To allow an analysis of Climate Change with RAUMIS for different crops, the changes derived for winter wheat crop yield under Climate Change scenario A1B of the STAR scenario are transferred to other crop yields with the approach by Gömann et al. (2003). They use crop yield simulations of the hydrological model SWIM for six selected crops and Climate Change projections for the Elbe river basin in Germany and transfer these with the help of correlations to the RAUMIS activities.

The crop yield changes of the simulations 2050/2030 are introduced into the agricultural sector model RAUMIS for the simulations of agricultural production in the year 2020. This means that we assume that the Climate Change effects between the years 2030–2050 will already be noticeable in 2020. This is a strong and disputable assumption in this paper and has to be kept in mind when analysing the results. On the other hand, economic simulations beyond 2020 are not possible as no reliable information exist of market and price developments as well as policy effects beyond this period.

5.4 Modelling Global Change Impacts on Agricultural Land Use in Germany

The following section introduces the methodology used to analyse the influences on the development of agricultural production and land use in 2020. We describe the agricultural sector model and its application to the Baltic coastal zone.

One reference scenario called baseline for the year 2020 is set up that includes and carries on all known observed trends as well as all policies that are already implemented or passed. Secondly, a scenario is simulated that introduces the effects of the Climate Change scenario A1B on crop yields into the baseline.

5.4.1 Structure of the Model RAUMIS

In this paper regional adjustments of agricultural land use, production and nutrient surpluses in the Baltic coastal zone region are calculated with the Regionalised Agricultural and Environmental Information System (RAUMIS). RAUMIS has been developed by Henrichsmeyer et al. (1996) and since then been applied to various questions regarding agricultural production and land use in Germany. For example, the effects of agricultural policies have been evaluated by Kreins and Gömann (2008) with a focus on the impact of the European Health Check on German agriculture; water and nutrient management have been analysed by Kreins et al. (2007) for the Weser river basin and by Gömann et al. (2004) for the Rhine river basin.

In RAUMIS, agricultural production and its necessary inputs are presented by 40 activities and more than 50 products on the basis of a process analysis approach. The model is closely related to the national accounts of agriculture which are based on the rules and definitions of the European National Accounting Systems.

326 so-called ‘model regions’ are defined on the basis of a closed and consistent data base for the whole of Germany; the Baltic coastal zone comprises 19 RAUMIS model regions as described above. Each model county is represented in an activity differentiated matrix, which differentiates analytical activities in accordance with the consistency framework of the national accounts of agriculture. For the base year an average over 3 years is used in order to avoid exceptional variations thus including 1998–2000 to represent the base year 1999. The sectoral production and input quantities are divided among the model regions and classified into different production activities making extensive information and statistics on the extent of production of the described activities available at the country level, but not at the regionally implemented input levels. The calculated average input use of individual production alternatives in each of the model regions bases on calculation data. Both, trend based functions and yield dependent need functions are used. A technology module is used to derive machine costs, reinvestment costs as well as labour requirements. This module describes various technologies that permit a flexible definition and specification of production processes. Since the technologies are each formulated in consistent packages, labour needs, average investment costs and variable machine and energy costs are adjusted to each other.

Profit maximization represents the supply behaviour of agriculture, whereby optimal production structures are determined in the model regions in the framework of a Positive Mathematical Programming approach (PMP) (Howitt 1995). This non-linear formulation leads to ‘soft’ model adjustment reactions. The PMP cost terms result from the calibration of the base year and represent non explicit model effects, such as for example, non linear production functions, further crop sequence effects, heterogeneity of the locations conditions within a model considered to be homogeneous and risk aversion (Cypris 2000).

The nitrogen balance calculated with RAUMIS is based on the national sectoral mineral balance and the complete national mineral balance as described in PARCOM (1993). In addition to the national basic mineral balance other intrasectoral flows can be included such as the utilization of manure. On the other hand, other inputs such as seeds and biosolids as well as mineral fodder cannot be differentiated (Kreins et al. 2010). The model RAUMIS calculates balances for nitrogen, phosphorus and potassium; this paper focuses on the results of the nitrogen balance.

For the application of RAUMIS to the German Baltic coastal zone the RAUMIS model for the whole of Germany is solved first to assure consistency with all other model counties. Then, the counties located within the Baltic coastal zone are evaluated in detail with a special focus on crop yields, land use and nitrogen surpluses. Two model simulations are compared. First, the baseline which includes all potential impacts induced by policy changes and market effects but which does not include the yield changes of the Climate Change scenario described above. Second, a scenario is set up which includes all assumptions of the baseline but incorporates the yield changes of scenario A1B to the yields estimated for the baseline.

5.4.2 Baseline Definitions

The formulation of the baseline is adopted from the general baseline assumptions for the year 2019 by the modelling group of the Johann Heinrich von Thünen-Institute (Offermann et al. 2010) that are the basis for the RAUMIS model simulations. The baseline defines price and market developments and European and German national policy influences.

The price developments on the world agricultural markets that are introduced into RAUMIS rely on calculations of the AGMEMOD model, a partial equilibrium model covering the European Member States (Salamon et al. 2008; Chantreuil et al. 2005). Price projections from AGMEMOD are based on the 2009 FAPRI outlook (FAPRI 2009). Prices are formed by the interrelation of supply and demand whereas demand for food is closely related to global demographic developments.

In general, demand for agricultural products is expected to increase due to population growth and promotion and thus rising demand of bio-energy products. However, this increase is lower than previously expected due to the 2008/2009 economic crises (Offermann et al. 2010).

Price projections also differ between the different products. With the increased competition over land use, prices for cereals and oilseeds are expected to increase, whereas prices for oil meals are expected to increase less strongly. Although, since 2008 prices for cereals have decreased, due to economic recovery and the influence of ethanol policies on wheat demand prices for cereals are expected to rise again in the coming years.

Since 1992 the European Agricultural Policy has been continuously reformed, first, with the Mac Sharry reform of 1992, then with the Agenda 2000 signed in 1999 in Berlin, and the MidTerm Review of 2002. Lately the Common Agricultural Policy (CAP) was continued to be revised with the European Agreements of Luxembourg in 2003 (European Commission 2003a, b, c) and the EU Sugar Market Reform of 2006. Animal and area premiums were successively decoupled from production and coupled to the maintenance of certain basic requirements (Cross Compliance).

By law famers in Germany are obliged to obey the guidelines of the good agricultural practice. Additional laws and regulations are set up to promote an environmental friendly and sustainable cultivation. On the European level the Nitrate Directive (EU Commission 1991) was put in place in 1991 to assure improvements in water quality in Europe. The Nitrate Directive is also contributing to the European Water Framework Directive (EU Commission 2000) that aims to ameliorate ground and surface waters in Europe. In Germany, the Nitrate Directive is implemented amongst others with the Fertilizer Regulation revised in 2006. Its aim is to regulate fertilizer and pesticides application. Two restrictions apply: First, organic fertilizer is only allowed up to a limit of 170 kg ha^{-1} on cropping and grassland, whereas under certain exceptions 230 kg ha^{-1} are possible on grassland only, and second, each farm is obliged to report a nitrogen balance which is not allowed to exceed a nitrogen surplus of 60 kg ha^{-1} on a 3-year average.

Due to rising energy prices and the debate about Climate Change emissions, renewable energies are promoted in European energy policies. In Germany, the Renewable Energy Law was amended in 2004 and revised in 2008. It promotes the cultivation of renewable energies on cropland as biogas facility owners paid around 22–24 € t^{-1} for energy maize during the period of 2003–2006 (free silage plate with 30% dry matter in the fresh matter). This price level and the good integration ability in the crop rotation make energy maize crops very competitive. As a result energy maize has been increasingly cultivated in the German coastal zone of the Baltic Sea.

5.5 Results

5.5.1 Crop Yields and Land Use

Due to technical progress such as better fertilizer exploitation, crop yields are expected to increase in the German Baltic Sea region. Compared to German average, crop yields in the Baltic coastal zone are slightly higher. This is especially due to above average crop yields in Schleswig-Holstein. Regarding the difference between the baseline scenario and scenario A1B with climate effects on crop yields, wheat crop yield decreases on average under Climate Change projections. Crop yields of winter barley and corn maize are expected to increase, whereas the majority of the other crops decrease in yield on average. However, it has to be noticed that crop yields vary according to municipalities and local characteristics and thus also vary in the RAUMIS model calculations on the county scale (compare Table 5.1).

The changes of crop yield, policies and prices also influence land use. Area of cereals declines, whereas area of oilseed, pulse and root crop as well as maize area increases. Outstanding is the cultivation of energy maize in 2020 which was not cultivated in 1999 as the Renewable Energy Law was not amended before 2004. With the cultivation of energy maize competition for land use has increased. Area set-aside which was still obligatory in 1999 was phased out as of 2007 and in 2020 it is expected that under the currently known conditions and more competition for land use hardly any area set aside will be practised. Furthermore, the cultivation of energy maize leads to a decline in the area cultivated with cereals, especially barley. As crop yield of wheat is slightly smaller in the Climate Change scenario, less area is cultivated with wheat in this scenario compared to the baseline.

The cultivation of energy maize varies regionally in the German Baltic Sea catchment. Figure 5.7 shows the share of energy maize cultivation to total agriculturally used area which ranges from 1 to 15%. Including Climate Change effects and thus

Table 5.1 Results of crop yields, land use and nitrogen surplus for 1999 and for the baseline 2020 and scenario A1B in year 2020 for the German Baltic Sea catchment area. Source: RAUMIS model results (2010)

	Unit	Baseyear (1999)	Baseline (2020)	Scenario A1B with climate crop yields	
Crop yield					Percentage of baseline
Winter wheat	t/ha	7.98	9.27	9.14	–1
Summer wheat	t/ha	5.90	6.86	6.56	–4
Rye	t/ha	6.54	7.29	6.98	–4
Winter barley	t/ha	7.51	8.32	8.39	0.8
Summer barley	t/ha	5.23	5.79	5.55	–4
Oats	t/ha	5.40	6.64	6.54	–2
Corn maize	t/ha	6.63	8.55	9.44	10
Other cereals	t/ha	6.38	7.08	6.79	–4
Pulses	t/ha	3.32	3.68	3.53	–4
Rape seeds	t/ha	3.87	4.63	4.68	1
Fodder Maize	t/ha	36.86	43.58	47.94	10
Energy Maize	t/ha	–	51.45	56.62	10
Area aggregated					
Cereals	1,000 ha	880	776	735	–5
Wheat	1,000 ha	443	441	420	–5
Barley	1,000 ha	234	117	163	39
Oilseeds	1,000 ha	317	375	365	–3
Pulses and roots	1,000 ha	38	44	43	–2
Fodder crops	1,000 ha	183	69	63	–9
Maize total	1,000 ha	127	257	316	23
Energy Maize	1,000 ha	–	167	228	37
Area set aside	1,000 ha	110	3.0	2.8	–7
Net value added					
Net value added total	Mio. Euro	1,037	1,315	1,372	4
Net value added per ha	Euro /ha	527	662	688	4
Nitrogen surplus					
Nitrogen surplus	Kg N/ha	78.5	65	67	3

higher yields of maize, the area of energy maize even increases up to 18% in the Uckermark in Brandenburg. In general, counties in Mecklenburg-Vorpommern will have a higher share of energy maize of UAA than in Schleswig-Holstein due to less competition with other land use possibilities.

The net-value-added to factor prices is rising to 1315 million € between 1999 and 2020 in total for the Baltic Sea catchment area. Although crop yields are slightly smaller under Climate Change expectations for most crops, net value added to factor prices increases to 1372 million € due to the increasing cultivation of energy maize. This also leads to higher net value added per ha in the Climate Change scenario.

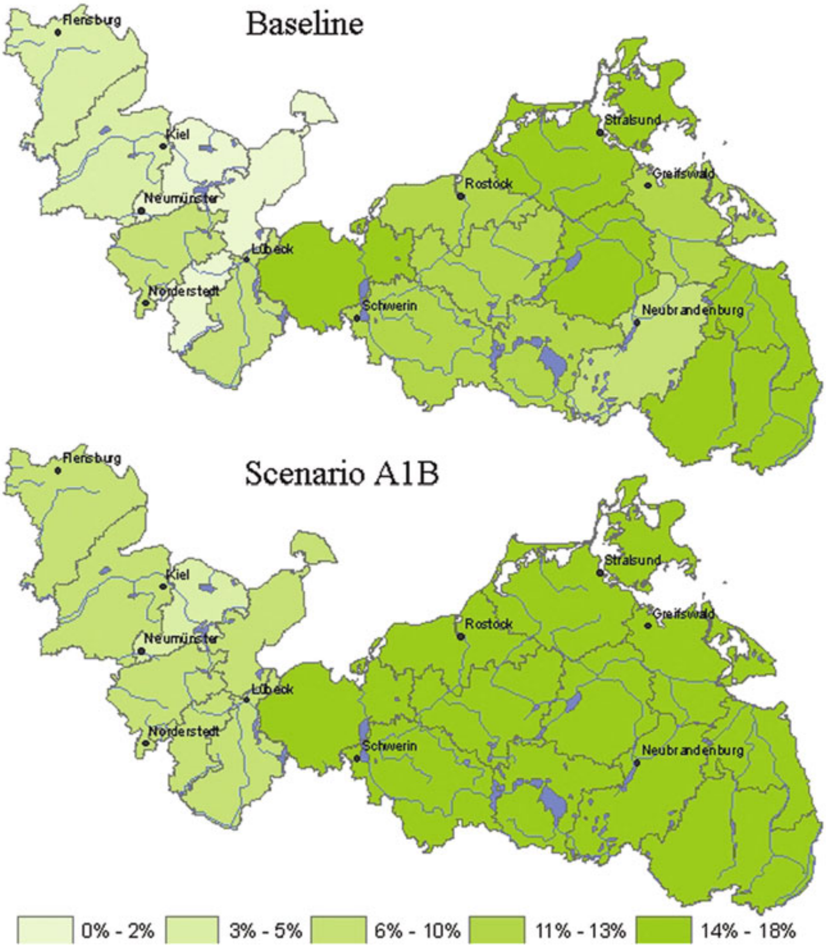

Fig. 5.7 Share of energy maize to total agriculturally used area in the German Baltic Sea catchment area in 2020 in the baseline and in scenario A1B with Climate Change effects on crop yields. Source: RAUMIS model simulations 2020

5.5.2 Nitrogen Surplus

Nitrogen surplus in the Baltic coastal zone is expected to decrease to 65.3 kg ha^{-1} on average in 2020 in the baseline scenario compared to a nitrogen surplus of 78.5 kg ha^{-1} in 1999 calculated on the balancing equation described above. This is mainly due to a decrease in animal numbers from 0.6 animal units per ha to 0.4 animal units per ha, and therefore a decline in organic fertilizer use. However, regional N surpluses vary across counties as can be seen in Fig. 5.8.

In 1999, counties located in Schleswig-Holstein had an average N surplus of 89 kg ha^{-1} and counties in Mecklenburg-Vorpommern an average surplus of

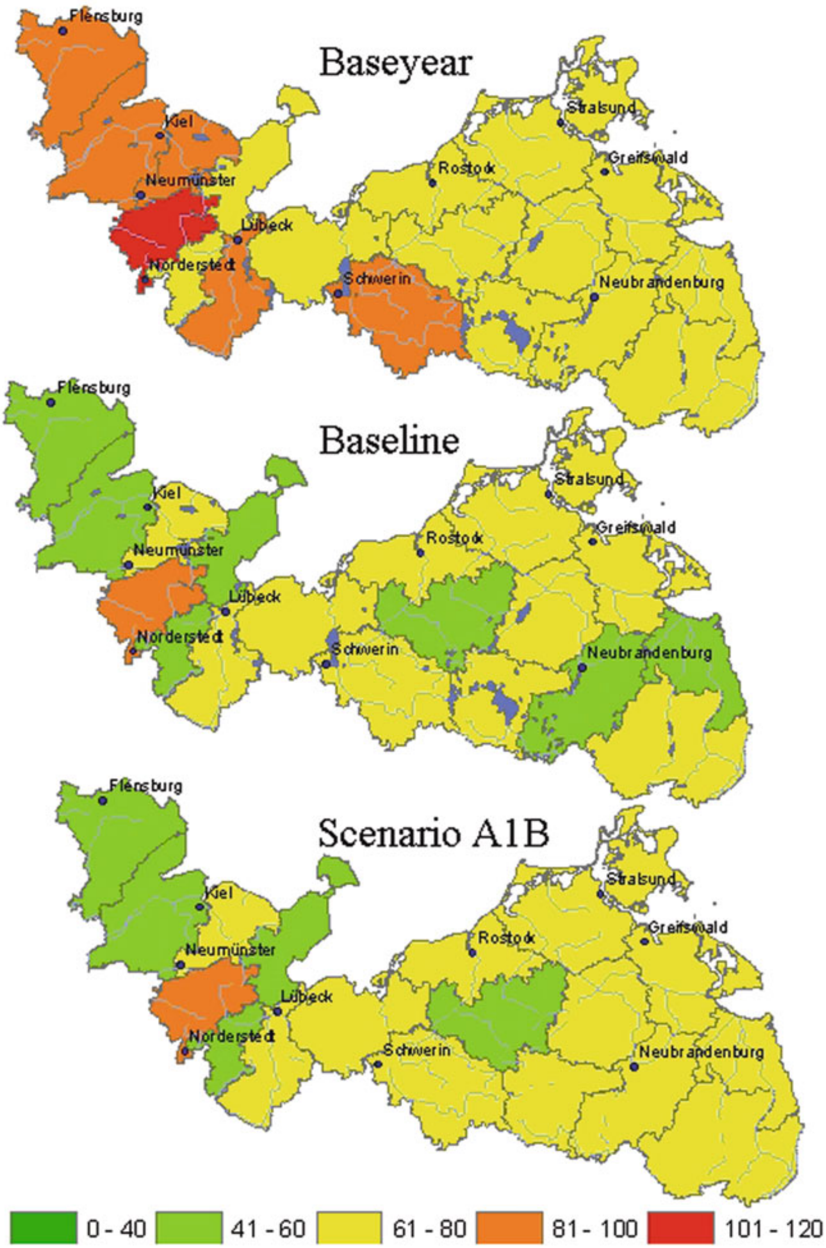

Fig. 5.8 Nitrogen surplus in the German Baltic Sea catchment area in kg nitrogen surplus per ha in 1999, in the baseline and in scenario A1B for 2020. Source: RAUMIS model results (2010)

73 kg ha^{-1}. In 2020 calculations indicate average N surpluses of 62 kg ha^{-1} in Schleswig Holstein and 68 kg in Mecklenburg-Vorpommern, respectively. In the Uckermark, the only county located in Brandenburg, N surpluses stay more or less stable in 2020 (Fig. 5.8).

Introducing climatic effects of crop yields into the calculations, average N surpluses in the Baltic coastal zone are slightly higher with 67.3 kg ha^{-1} compared to 65.3 kg without climate effects. This is due to the increase in energy maize yields and thus an increase in the cultivation of energy maize as described above. With more intensified agricultural area higher nitrogen surplus can be expected. Furthermore, in the case of energy maize the digestate from bioenergy production which contains nutrient and which is redistributed onto the field is included in the calculation of the nitrogen balance. Results again differ between counties as the crop yield effect can be positive or negative depending on local characteristics as described above.

To separate the impact of energy maize on nitrogen surplus we conduct a simulation of the baseline without the possibility to cultivate energy maize. Without energy maize the overall N surplus in the year 2020 is lower at an average of 62.5 kg ha^{-1}. Thus it can be concluded that the promotion and cultivation of energy maize in the Baltic coastal zone contributes to an additional nitrogen surplus of 3 kg ha^{-1} on average. In simulations for the whole of Germany and for the Weser river basin similar impacts on nutrient surpluses due to energy maize were found (Kreins et al. 2010).

5.6 Conclusions for the Baltic Coastal Zone of Germany

The Baltic Sea Region in Germany is facing new challenges in the twenty-first century. Up to now high uncertainty exists regarding the extent of Climate Change, and therefore development of temperatures and sea level rise. On the basis of currently available climatic projections based on one scenario of the IPCC, estimations for crop yields of winter wheat where made for the Baltic Sea region to evaluate the climatic influence on agricultural crop yields. Results show that the impact of Climate Change on crop yields will vary regionally in the Baltic Coastal zone depending on local characteristics and climatic projections. Introducing the projected crop yields into the agricultural sector model RAUMIS revealed that changes in crop yields will affect agricultural land use, production, farm income and nutrient surpluses. However, other changes such as for example changes in prices and policies will probably have an even greater influence. Agricultural price developments have a great influence due to its direct relation to profits. National and EU-wide agricultural policies are further expected to influence land use and nutrient surpluses. It was already stated that energy crops have gained importance in the German Baltic Sea region. This development is expected to further proceed under the current regulation for renewable energies. Energy crops will more and more substitute fallow land and other crops such as cereals or root crops.

The trend of decreasing nitrogen surpluses from agriculture is likely to continue due to technological progress, a better utilization of mineral fertilizer and the help of national regulations such as the fertilizer regulation. Nevertheless, the German Environmental Agency advises further changes in cropping patterns to achieve the objectives of the European Water Framework Directive and to regulate nutrient emissions into the oceans. Agricultural measures can include intertillage, more efficient use of fertilizer and a reduction of erosion and nutrient leakage (Umweltbundesamt 2010b).

However, more scenario analysis and sensitivity analysis are needed to assure a greater viability of the results. Due to data availability the estimations of wheat crop yields are based on only one scenario (A1B) of the IPCC scenarios available. Different scenarios should be tested in the future including different Climate Change scenarios as well as different climate models. It was also discussed that variations in winter wheat crop yields play a decisive role for the stability of crop yields within a county. The variation of crop yields and thus the uncertainty of crop yields have not been incorporated into the RAUMIS simulations. This would be crucial to analyse farmers risk in the future. Furthermore, different scenarios of policy changes assure a broader perspective of agricultural development. One important aspect is the adaptation possibility of farmers to Climate Change. Different crop varieties and cropping techniques should be evaluated in future research to provide a more comprehensive picture of future land use in the Baltic Sea region.

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Part II

Sea-Level Rise and Coastal Protection

Chapter 6
Climate Change and the Need for Integrated Coastal Risk Management in the Baltic Sea

Jacobus Hofstede

Abstract Climate Change and its consequences will significantly impact sandy coasts and coastal lowlands in the Baltic Sea region. The risks of flooding and coastal erosion will probably rise due to higher storm surge water levels. Further, it must be accounted for that long-term coastal retreat will increase if sea level rise accelerates. Traditionally, adaptation strategies focus on technical measures like sea dikes, revetments or beach replenishments. After the introduction, this chapter starts with a discussion of sea level rise scenarios. Next, it is argued that a sustainable adaptation strategy implies a holistic coastal risk management consisting of the elements prevention, protection, preparedness, emergency response, recovery and review. These integral components are described as parts of a control loop. The chapter ends with an outlook, including a reflection of the EU-Flood Directive.

6.1 Introduction

Storm surges may cause temporal flooding of coastal lowlands as well as erosion along sandy shores. When the flooding or erosion is perceived by society as a threat to life and property, it becomes a hazard that needs consideration or, rather, risk management. Risk may be defined as a function of the occurrence probability of a hazard and its harmfulness for society, i.e. its damage expectations. Hence, coastal risk management (CRM) may be implemented by controlling the occurrence probability of flooding and erosion through technical means and/or by controlling the damage expectations (Fig. 6.1).

Implementing CRM by controlling the damage expectations in coastal lowlands is only hesitantly getting more attention in politics and administration (e.g. CPSL 2005, 2010). In contrast to technical defences, these solutions may have several

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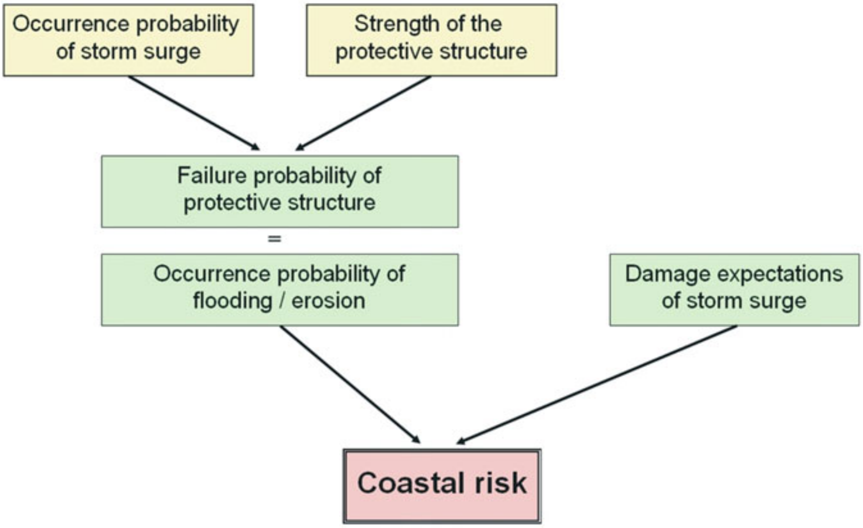

Fig. 6.1 Schematic presentation of coastal risk

'unpopular' consequences. That is, they may cause development constraints along the coasts and may result in more personal responsibilities and higher efforts for the affected population. However, with respect to the possible consequences of Climate Change, the evaluation of alternative and complementary options for CRM seems justified.

6.1.1 Regional Overview

The coastline of the Baltic Sea region has a total length in the order of 40,000 km; of which about 70% belong to Finland and Sweden. Whereas the Gulf of Bothnia is characterized by emerging rocky coasts, the southern coastlines as well as parts of the south coast of Sweden consist of sandy shores. Along the sandy coasts, erosion during storm surges is a common phenomenon. According to EUROSION (2004), about 2,300 km of sandy coastlines in the Baltic Sea region suffer from long-term coastal erosion. In Denmark, Germany and Poland and, on a local scale, in the Baltic States, technical adaptation measures like beach replenishments and the construction of revetments are being conducted to avoid coastal erosion and retreat. In all, about one quarter of the eroding coastlines are artificially stabilized in the Baltic Sea region (EUROSION 2004).

Larger flood-prone coastal lowlands exist in Denmark, Germany and Poland. Along the Baltic Sea coast of Germany, for example, almost 1,400 km^2 of coastal lowlands are situated less than three meters above mean sea level. In this area, more than 235,000 people live. During extreme storm surges, the lowlands could become

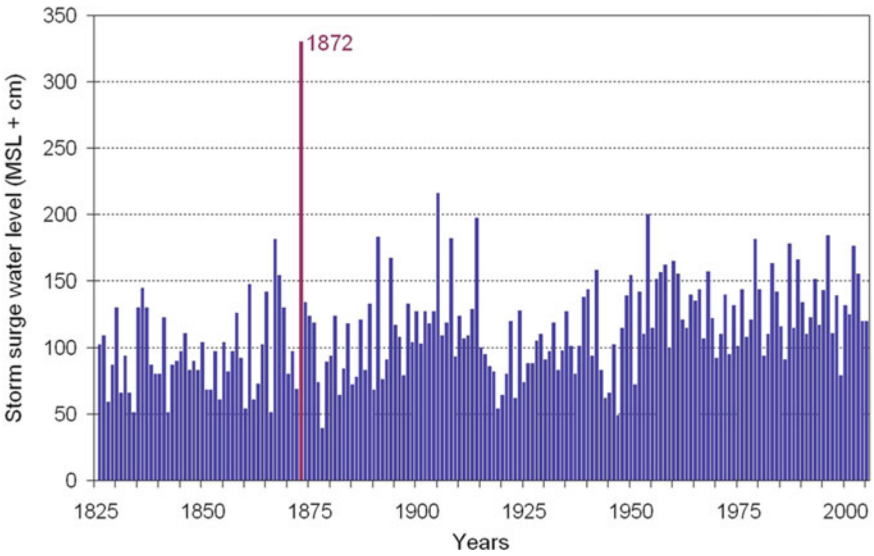

Fig. 6.2 Yearly highest (storm surge) water levels in Travemünde (Germany) since 1825

inundated without adequate flood defence (Hofstede et al. 2009). In the year 1872, before proper flood defences were in place, a catastrophic storm surge struck the western Baltic Sea region. With water levels of up to 3.3 m above mean sea level, it was by far the highest storm surge ever experienced in the area (Fig. 6.2). Most of the coastal lowlands were inundated. In Germany and Denmark, 271 people lost their lives (Kiecksee 1972).

In Poland, the large cities Gdansk and Gdynia are situated in flood-prone coastal lowlands. A further 'hot spot' is St. Petersburg in Russia. According to Alenius et al. (1998), this city has been flooded more than 280 times since 1703. The highest storm surge with a water level of with 4.21 m above mean sea level occurred in 1824. Most coastal lowlands in the Baltic Sea region are protected from flooding by sea defences like dikes and flood walls. For example, in front of St. Petersburg, a new sea dike with two sluices is being constructed through the bight. It extends for 25.4 km and stands eight metres above mean sea level. Along the Baltic Sea coast of Germany, 340 km of sea dikes protect the low-lying areas from flooding.

6.2 Sea Level Rise Scenarios

It is generally accepted that global mean sea level rise (SLR) will increase in the coming decades as a result of human activities. The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2007) delivered a range of global SLR scenarios. Depending on the models and emission scenarios, the values vary among 0.19 and 0.58 m of SLR between 1990 and 2100. According to IPCC, accelerated melting of the Greenland icecap may contribute up to 0.2 m of extra SLR to these values.

Newer publications suggest that the SLR-projections of IPCC may be too low. Rahmstorf (2007) published a semi-empirical approach to estimate SLR among 1990 and 2100. His relationship connects observed global SLR to observed global mean surface temperature rise during the twentieth century. Applying this relationship for the IPCC temperature scenarios, Rahmstorf delivered SLR projections among 0.5 and 1.4 m. Horton et al. (2008) applied the semi-empirical relationship from Rahmstorf to the coupled global climate models that were used for the fourth IPCC report. With a mean of 0.71 m, the resulting global scenario values ranged among 0.54 and 0.89 m. Grinsted et al. (2009) used a physically plausible four parameter linear response equation to relate 2,000 years of global temperatures and sea level. Future sea level was projected from IPCC temperature scenarios and past sea level from multi-proxy reconstructions (assuming that the established relationship between temperature and sea level holds from 200 to 2100 AD). In result, SLR until 2100 was projected to be 0.9–1.3 m for the IPCC A1B scenario, with low probability of the rise being within IPCC confidence limits. Finally, Vermeer and Rahmstorf (2009) applied a simple relationship linking global sea-level variations on time scales of decades to centuries to global mean temperature. For different IPCC emission scenarios they came up with SLR-projections varying among 0.81 and 1.79 m, the model averages ranging among 1.04 and 1.43 m for the time period 1990–2100.

These publications indicate that SLR may turn out higher than the IPCC values; a range among 0.5 and 1.4 m may be more realistic. With respect to the starting date for most SLR projections (1990), it is interesting to note that, at least along the Dutch and German coasts, after about 20% of projection period, no indications of an accelerating SLR could be observed (Fig. 6.3; Hofstede 2007a).

Especially in the Gulf of Bothnia, SLR is and will be counteracted by glacio-isostatic land uplift. Meier et al. (2004) regionalized global SLR scenarios for the Baltic Sea region. For a global SLR scenario of 0.88 m, they calculated a local SLR (winter mean) of about one meter for the cities of Gdansk, Riga and St. Petersburg, and less than 0.1 m in northern Sweden.

According to Meier et al. (2004), it is unclear whether regional winds will change or not in the Baltic Sea region. If storm patterns and intensity would not change, storm surge water levels would rise correspondingly to mean SLR. However, Meier et al. (2004) state that, in areas where the sea ice disappears due to a warmer climate (e.g. in the Gulf of Bothnia), extremes of the wind speed will increase more than the mean wind speed. In consequence, at the ends of the gulfs, for example in St. Petersburg, Gdansk and Riga, extreme storm surge water levels would increase significantly more than mean sea level.

In conclusion, magnitude and range of mean and extreme SLR-scenarios call for flexible and sustainable adaptation measures and strategies.

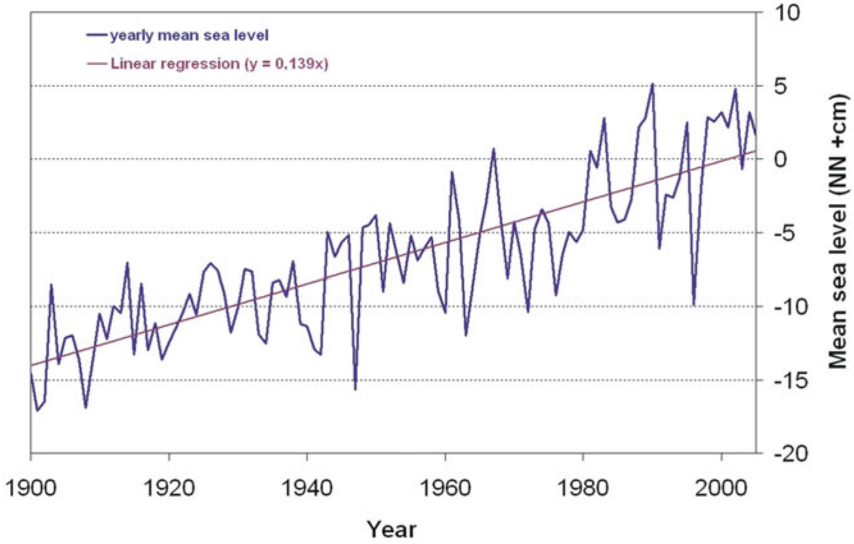

Fig. 6.3 Development of mean sea level since 1900 AD along the Baltic Sea and the North Sea coastlines of Germany and the Netherlands (averaged over 17 long-term tidal gauge stations)

6.3 Integrated Coastal Risk Management

Coastal risk management (CRM) traditionally focuses on technical defences. Due to high vulnerabilities (damage expectations) along sandy coasts and in coastal lowlands, maintaining and adapting these defences will remain a corner stone of CRM. However, with respect to Climate Change and its consequences, technical defences underlie a number of constraints (Hofstede 2007b).

Accelerated SLR and, in consequence, higher storm surge water levels may reveal the financial limits of technical defences. Above a certain threshold the necessary financial efforts to maintain safety standards could become unacceptable for society. In this case, alternative and additional (non-technical) CRM options become inevitable. It should be stated here that technical solutions to counteract a SLR of several meters in a long-term (centuries) perspective do exist. Further, technical defences interfere with nature and may reduce the natural resilience of sandy coasts with respect to SLR. Examples are the fixation of the coastline in an unfavourable location or the interruption of natural sand redistribution patterns. Hence, wherever possible, natural hydro morphological processes should be allowed or furthered. In this case, however, alternative measures to reduce the coastal risks may become necessary. Apart from these constraints, focussing on (ever higher) sea dikes has some inherent disadvantages. The higher the dike, the stronger the inundation processes (water depths and current velocities) after dike breach, and the more severe the consequences will be. Further, high and strong dikes may lead to the (false) impression of absolute safety. Hence, the dependence on one single measure or dike line makes society more vulnerable.

These considerations imply that a sectoral approach towards CRM that only focuses on technical measures is not sustainable. The challenges arising from Climate Change imply that classical defence schemes should be an integral part of a holistic risk management that combines technical and non-structural methods (Hofstede et al. 2005a). Sustainable CRM may be defined as a cycle (control loop) that consists of six components: prevention, protection, preparedness, emergency response, recovery, and review (Fig. 6.4).

Prevention aims at avoiding or minimizing (controlling) damages from flooding and erosion. They become a hazard when society starts to utilize sandy coasts and coastal lowlands for infrastructure, housing, etc. For example, a natural salt marsh is regularly flooded. Due to failing damage expectations, however, no risk evolves (on the contrary, salt marshes depend on regular salt water inundations). Controlling the development along sandy coasts and in flood-prone coastal lowlands by spatial planning is, thus, the first step in the CRM cycle.

Spatial planning is realized at local, regional and national levels. At the local level, municipalities are normally responsible for building or town planning. Specific regulations for building areas like flood-proof housing (Fig. 6.5) may substantially reduce damage expectations due to coastal flooding and erosion. On a regional level, the identification of buffer zones and hazard zones in regional plans constitute promising non-structural measures to control coastal risks (CPSL 2005, 2010). Coastal buffer zones, demarcated by setback lines in regional plans may provide protected zones between the sea and the hinterland, where human utilization and development are strongly restricted. As the term 'buffer' already implies, this

Fig. 6.4 The coastal risk management cycle (CPSL 2010)

Fig. 6.5 Summerhouses on stilts in a flood-prone lowland on the Isle of Rømø (Denmark)

measure provides a zone that allows for natural hydro morphological processes or reserves space for necessary defence measures. In this way, the natural resilience of the coast with respect to Climate Change and SLR may be enhanced as well. In coastal hazard zones, human activities can be managed (regulated) in such a way that damage expectations in the area are reduced. The fact that hazard zones are depicted in regional plans already increases the awareness of the risk (see below).

Protection constitutes the second element of the CRM cycle. It becomes necessary, when sandy coasts and coastal lowlands are utilized. Thus, damages from flooding and erosion may occur. With respect to SLR, reserving space for strengthening campaigns by depicting buffer zones in regional plans is a sustainable measure. Necessary technical measures may be implemented in a more sustainable way that minimizes the impacts on ecology and the natural resilience of the coasts. CPSL (2005) lists a number of such solutions like performing beach nourishments (Fig. 6.6) to balance coastal erosion and retreat as well as dune management techniques to stabilize and sustain the dune systems as natural flood defences. Beach nourishments, especially, present a flexible no-regret approach to deal with Climate Change as they can easily be adapted to the actual rate of SLR. Necessary dike strengthening should be performed in a sustainable way that minimizes the ecological interferences, for example by strengthening to the landward side.

Preparedness, being the third component in the CRM cycle, has much to do with risk awareness. Aware people are prepared to personally undertake preventive and emergency actions. Further, they (are prepared to) accept the high costs for defences and other possible constraints of CRM like flood-proof housing and living in the upper floor, on stilts (Fig. 6.5) or behind a dike. In consequence, appropriate coastal risk awareness or, rather, a high level of preparedness may significantly reduce the damages resulting from flooding. The main tool to achieve coastal risk awareness is risk communication (Hofstede et al. 2005b).

Fig. 6.6 Sand replenishment on the beach of the Isle of Sylt (Germany)

Emergency response in the CRM cycle includes all measures related to impending or real coastal flooding. The aim is to prevent or reduce catastrophic consequences and, therewith, the risks. Emergency response includes measures like flood warnings (based on flood forecasts by hydrological services), evacuation, placing sand bags, and aftercare. During an emergency, the responsible disaster management authority may access the capacities of other authorities like health services, fire departments, flood defence administration, etc.

Recovery aims at restoring the flooded area to its previous state. It starts after immediate needs like closing the breaches or social and medical aftercare, are addressed. Recovery actions are primarily concerned with measures that involve repair of essential infrastructure and rebuilding of destroyed property. Hence, in a strict sense, recovery is not part of the CRM cycle as it does not directly control or reduce the risks. However, effective recovery should take advantage of a 'window of opportunity' for the implementation of preventive and protective measures that might otherwise be unpopular (Alexander 2002). Citizens of flooded areas are more likely to accept these measures when a recent disaster is in fresh memory. Implemented in this way recovery can contribute to the aims of CRM.

Review stands for monitoring and (scientific) evaluation of all integrated CRM components. In a broader sense, it also includes research on changes in SLR, storm surges and spatial development in coastal lowlands as these factors determine future coastal risks. Based on the outcomes of the evaluations and research, the next CRM cycle may be optimized.

From the above elaborations it becomes clear that all CRM elements complement one another. For example, depicting buffer zones in spatial plans facilitates the long-term implementation of coastal defence and protection. Raising awareness by effective information or ‘intelligent’ recovery increases the acceptance of necessary planning measures like living in the second floor. Vice versa, the depiction of flood hazard zones in spatial plans increases the awareness and preparedness. Finally, an appropriate reviewing process is prerequisite for developing optimal information tools like travel exhibitions. Hence, in combination, the six integral components present a holistic approach towards CRM.

6.4 Outlook

Anthropogenic Climate Change and, in consequence, strongly accelerating (mean and extreme) SLR will significantly impact sandy coasts and coastal lowlands in the Baltic Sea Region. The hazards of coastal flooding and erosion will probably rise due to higher storm surge water levels. Further, it must be accounted for that long-term retreat of sandy shores will increase due to accelerated SLR.

With respect to these challenges, holistic implementation of the CRM cycle seems a precondition to achieve sustainable development. This fact is acknowledged by the EU-Flood Directive (European Union 2007). Purpose of this Directive is to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community. Based upon a preliminary flood risk assessment, flood risk areas shall be delineated. For these areas, flood hazard and risk maps as well as flood risk management plans shall be established. Focussing on prevention, protection and preparedness, all aspects of the CRM cycle should be addressed in these plans. In order to achieve tailor-made solutions and to raise risk awareness, Member States shall make available to the public all products. Further, active involvement of interested parties in the production, review and updating of the flood risk management plans shall be encouraged. The implementation of the Flood Directive requires close coordination among the member states and the competent authorities (coastal defence, disaster management, spatial planning) as well as active involvement of the affected. As such, the Flood Directive is a chance for sustainable adaptation to Climate Change and its consequences in the coastal areas of the Baltic Sea region.

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Chapter 7
Climate Change and Coastal Protection: Adaptation Strategies for the German Baltic Sea Coast

Peter Fröhle, Christian Schlamkow, Norman Dreier, and Knut Sommermeier

Abstract Consequences resulting from future climate change may be one of the most severe threats for people and economies in many countries of the world. With respect to coastal Protection, the resulting changed hydrodynamic impacts are discussed globally. At present, IPCC (2007) is estimating a world-wide average sea level rise of less than 1 m within the twenty-first century. Other sources (e.g. Rahmstorff and Schellnhuber 2007) which are taking into account possible melting of the two main continental ice covers (Greenland and Antarctica), estimate significantly higher values especially over long periods. Besides the problem of sea level rise, also possible general changes in the frequency and intensity of storms as well as general changes in the average wind and wave field are discussed. With respect to the protection of the coast against flooding and erosion, possible adaptation strategies and measure are described in brief.

7.1 Introduction

Problems related to climate change and the predicted global warming are being discussed world-wide at present. Serious estimations assume that – depending on the selected scenario – a rise of the temperatures of at least 2°C during the next 100 years (Fig. 7.1) will be unavoidable. Despite the fact that politicians world-wide have agreed that the rise of the temperatures has to be limited to 2°C by 2100 and have also decided to implement measures accordingly, many climate change researchers still assume that the future rise of the global temperatures will be significantly higher. Moreover, the world-wide distribution of the temperature rise is extremely irregular distributed over the globe (Fig. 7.2).

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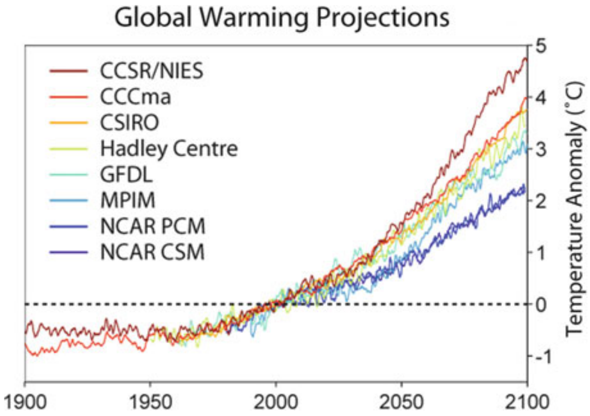

Fig. 7.1 Projections of global warming for the scenarion A2 (www.globalwarmingart.com)

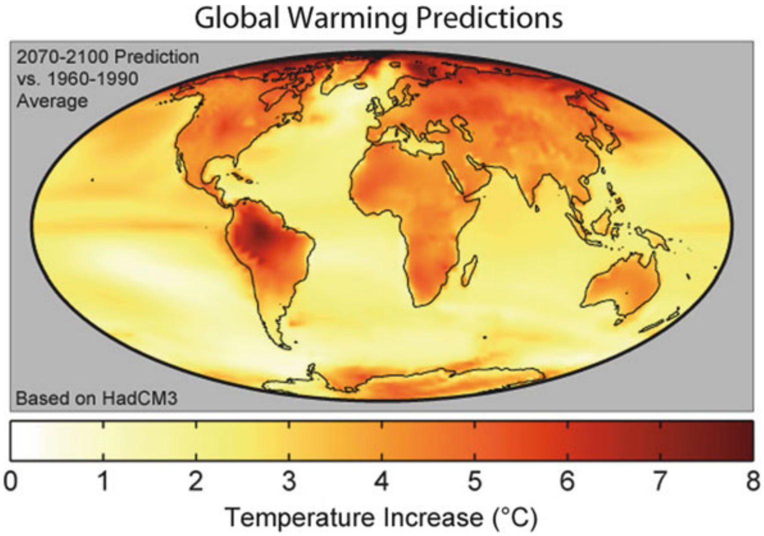

Fig. 7.2 Global distribution of temperature rise 2070–2100 related to 1960–1990 (www.globalwarmingart.com)

Consequences resulting from future climate change may be one of the most severe threats for people and economies in many countries of the world. At present, IPCC (2007) is estimating a world-wide average sea level rise of less than 1 m within the twenty-first century. Other sources (e.g. Rahmstorff and Schellnhuber 2007) which are taking into account possible melting of the two main continental ice covers (Greenland and Antarctica), estimate significantly higher values especially over long periods.

Small islands and low lying coastal regions are the most vulnerable areas against accelerated sea level rise. The main questions for these areas are, whether the natural morphological development of these low lying areas is fast enough to adapt to the sea level rise, or, whether coastal protection measures can protect the areas against flooding in the long-run.

The Baltic Sea Coasts of Mecklenburg-Vorpommern and Schleswig-Holstein are underlying ongoing erosion of coastal sediments along approx. 70% of their entire length. Hence, 70% of the coast-line is retreating permanently. The protection of the coast, i.e. the stabilization of the coast-line and the protection of the hinterland against flooding, already currently demands considerable financial means. Against the background of the predicted climate change with rising water levels and changed wave conditions it must be expected that the expenditures for coastal protection will rise if the level of protection shall remain constant in the future.

With rising water levels and changed hydrodynamic loads on the coast the question arises whether the actual coastal flood defence and protection constructions and the corresponding concepts are effective on medium term (decadal scale) and long-term (end of twenty-first century) engineering time scales. Within the context of the changed climatic conditions and the planning periods in coastal engineering, it is necessary to develop sustainable long-term strategies for coastal flood defence and protection based on the actual situation. In addition, it is also necessary to identify, as early as possible, future hot spot areas on the coast and sensitive and vulnerable as well as robust constructions and concepts. This includes the analysis and assessment of possible scopes of action and possible periods of action. The comparatively long planning periods make it necessary already now, to analyze the development of the safety standard of existing coastal flood defence and protection measures under changed hydrodynamic conditions.

7.2 Sea Level Rise

One of the most important expected effects resulting from the increase of the temperatures is the world-wide rise of the local water levels in the seas and oceans. With respect to the protection of coastal areas, the changes of the sea level are related to i) a rising of the mean sea level and/or ii) possible increase of storm induced extreme water levels (wind set-up).

7.2.1 Mean Sea Level

A (moderate) rise of the mean sea level (‘secular sea level rise’) is monitored since more than a century (Fig. 7.3) for nearly all water level gauges in the southern part of the Baltic Sea.

The long term rates of the local sea level rise are in the range between 1 and 2 mm yr^{-1} in this area. Altimeter data from Satellites has been analyzed as average over the complete Baltic Sea by NOAA (Fig. 7.4).

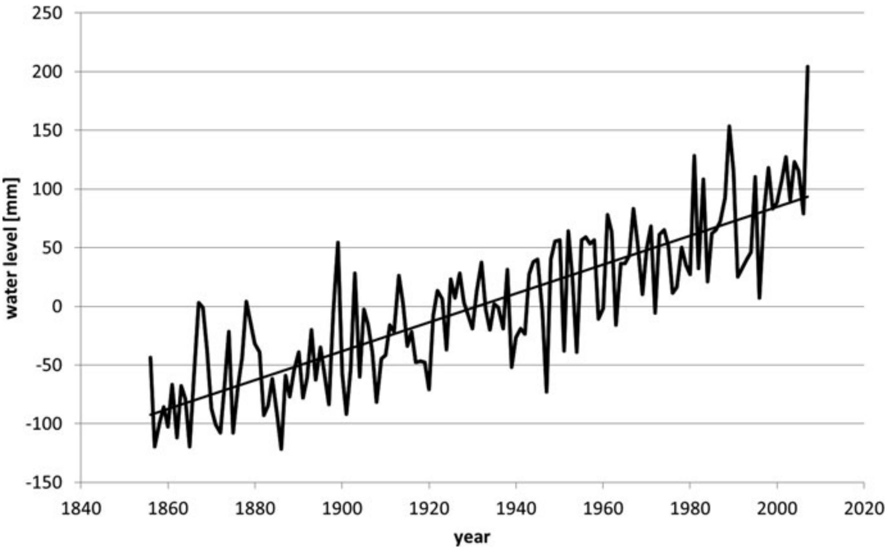

Fig. 7.3 Sea level changes gauge Warnemünde, Baltic Sea, (data source: PSMSL data, average sea level rise approx. 1.23 mm yr^{-1})

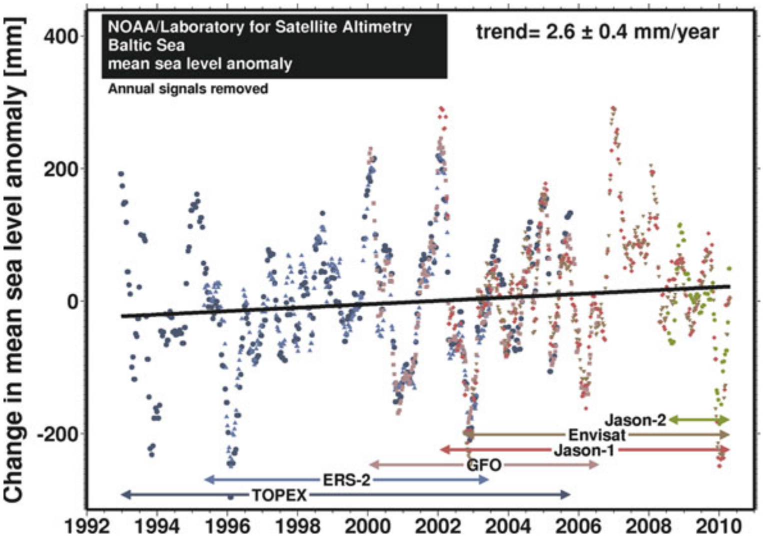

Fig. 7.4 Sea level time series for the Baltic Sea (annual signals removed) measured by altimeter Satellite (NOAA Laboratory for Satellite Altimetry)

NOAA calculated an average sea level rise of the Baltic Sea of 2.6 mm yr^{-1} for the last 20 years, which is significantly higher than the average rate of the past century.

Sea level rise at even higher rates is expected for the future and is partly already monitored, but the statistical uncertainties are still comparatively large.

Basically, the absolute changes of the mean sea level are divided into eustatic and isostatic changes, where isostatic changes in the Baltic area still result from the loading / unloading of the earth crust caused by the last ice age. The eustatic changes result mainly from the temperature effects of climate change and are therefore directly related to global warming. The relative changes, which are in the last consequence decisive for coastal protection, result from the addition of the local isostatic and eustatic changes.

The German part of the Baltic Sea coast is locally especially affected by the sea level rise, since coastal areas are sinking due to isostatic balance movements (Fig. 7.5).

The accelerated sea level rise (eustatic changes) increases the danger of flooding, especially in the low lying Bodden- and Haff-Areas and the wide bights and firths of the Baltic Sea. Analyses of water level measurements in Warnemünde (Fig. 7.6) indicate that –for the period 1992–2009 – the relative sea level rise is in the order of 5 mm yr^{-1}, which is significantly higher than the regional analyses using altimeter satellite data (approx. 2 mm yr^{-1}).

A trend in the same order of magnitude can be found for other gauges in the southern Baltic Sea. Again other gauges in the area do not show this accelerating trend (Hofstede 2007). This locally varying effect may be the result of local isostatic changes, meteorological changes and/or other local effects.

Analyses on the global scale indicate – for the future – an accelerated sea level rise. Global projections are in the order of approx. 0.2–0.8 m for the time period 1990–2100 (IPCC 2007), newer investigations result in even higher values (e.g.

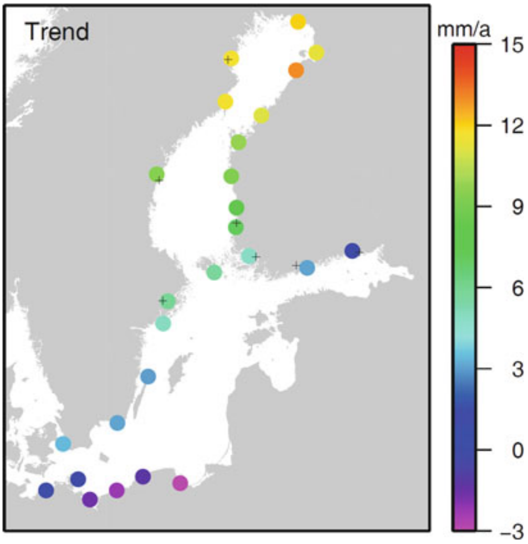

Fig. 7.5 Isostatic changes in the Baltic Sea (Novotny 2007)

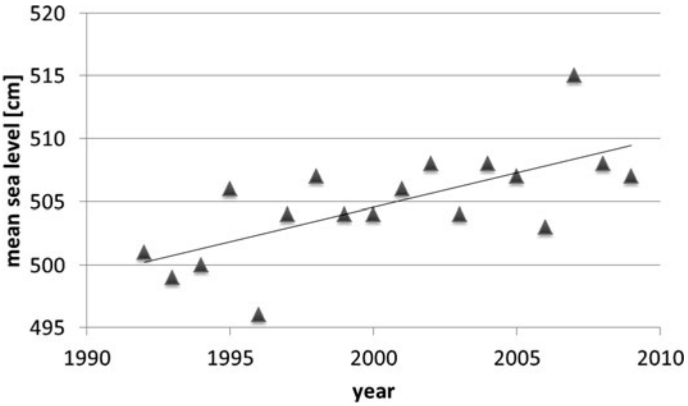

Fig. 7.6 Development of yearly average water levels in Warnemünde, Baltic Sea (Data Source: WSA Stralsund)

Vermeer and Rahmstorf 2009). Projections on local sea level rise in the southern part of the Baltic Sea are not available. According to BACC (2008) it can be expected that the water level changes in the Baltic Sea will not be equally distributed.

7.2.2 Storm Surge Water Levels

The changes of storm surge water levels for the gauge Warnemünde are compiled in Fig. 7.7. The linear trend of the storm surge water levels in the period 1855–2009 is higher (1.96 mm yr^{-1}) than the linear trend of the average water levels (1.23 mm yr^{-1}) for the gauge Warnemünde (Fig. 7.3), which may support the hypothesis that the storm intensity will increase or is already increasing. Nevertheless, the highest water levels at the gauge Warnemünde have been observed at the end of the nineteenth century and at the beginning of the twentieth century and the maximum water levels in the last 50 years are significantly lower than these extreme high water levels. Besides this, the linear trend of the storm surge levels in the period from 1900 to 2009 has nearly exactly the same value (1.20 mm yr^{-1}) as the linear trend of the average water levels. This may indicate that storm surge water levels in Warnemünde are increasing for ‘average’ storms, only, and are not increasing for extreme storm events.

Despite the fact that many people assume an increase in intensity and frequency of storm events and correspondingly an increase in the intensity and frequency of coastal flooding for the future, a direct scientific evidence for an increase of the storm intensity and frequency is at present not available (e.g. von Storch et al. 2009). According to the information distributed by the Northern German Climate Bureau (Norddeutsches Klimabüro, www.norddeutscher-klimaatlas.de) it is still unclear, whether or not the intensity of storms in average per year will increase up to the end of the twenty-first century (period 2071–2100) compared to the period between

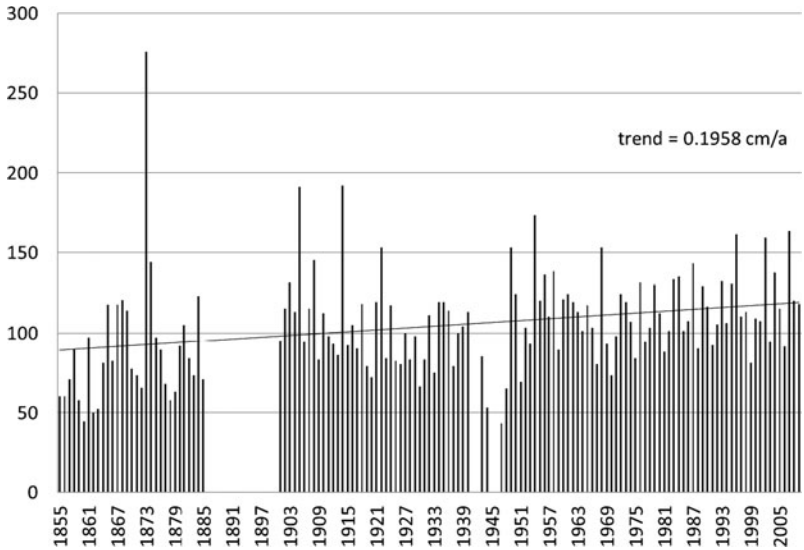

Fig. 7.7 Development of yearly maximum water levels in Warnemünde period 1855–2009, Baltic Sea (data source WSA Stralsund)

1961 and 1990 (Fig. 7.8a). There are some indications that in the winter period the storm intensity will increase even if the statistical significance of the simulation results is not very high at present (Fig. 7.8b). The values given in the BACC-report (2008) also indicate an increase of the storm intensity and resulting on the storm surge water levels, even if the order of magnitude of the water levels for a storm flood event with a return period of 1 per 100 years seem, especially for the German Baltic Sea coast, significantly too low.

The increase of the storm surge water levels will at least be in accordance with the increase of the mean sea level.

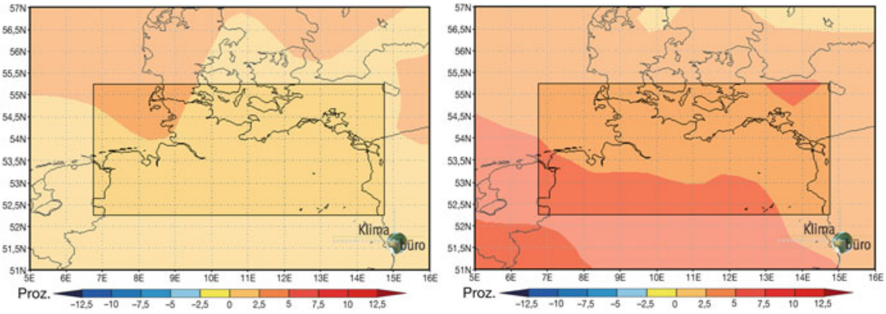

Fig. 7.8 Changes of storm intensity in the German Baltic Sea area, average scenario (**a**) yearly average 2070–2100 comp. 1960–1990 (ensemble range 0% to +4%), (**b**) winter season 2070–2100 comp. 1960–1990 (ensemble range 0% to +13%) (Source: www.norddeutscher-klimaatlas.de, Meinke & Gerstner, 2009)

7.3 Waves and Sea State

7.3.1 Average Sea State

The local average sea state (wave conditions) in the region of the German Baltic Sea coast is generated by the wind-field over the Baltic Sea. This means that changes in the wind-field (velocity and direction) are affecting the wave conditions directly. According to the analyses of the north German Climate Bureau (Norddeutsches Klimabüro) no significant changes of the wind-velocities have to be expected up to 2100 for the German Baltic Sea, if moderate scenarios are assumed in the scenario runs. Merely for the fall season within the year, the model results show a slight increase of the wind velocities. Correspondingly, the wave heights will also increase. Analyses of the BACC group (BACC 2008) indicate locally a maximum increase of the mean significant wave heights up to the end of the twenty-first century of up to 0.4 m.

Schlamkow et al. (2010) investigated possible future changes in the wave climate of the Baltic Sea on the basis of wind-wave correlations and wind information from climate change consortial runs using the CLM regional model in combination with the ECHAM5 global climate model. Figure 7.9 shows the calculated wave height distributions for the A1B and B1 scenarios for the periods 2030–2050 and 2070–2100 in comparison to the actual conditions calculated with the same model for a location in approx. 10 m water depth off Warnemünde. The differences are compiled in Fig. 7.10.

The analyses show a small increase of probabilities for higher wave and a small decrease of probabilities for lower wave heights. Hence, the model results indicate a small increase of the overall wave energy input for the future for all

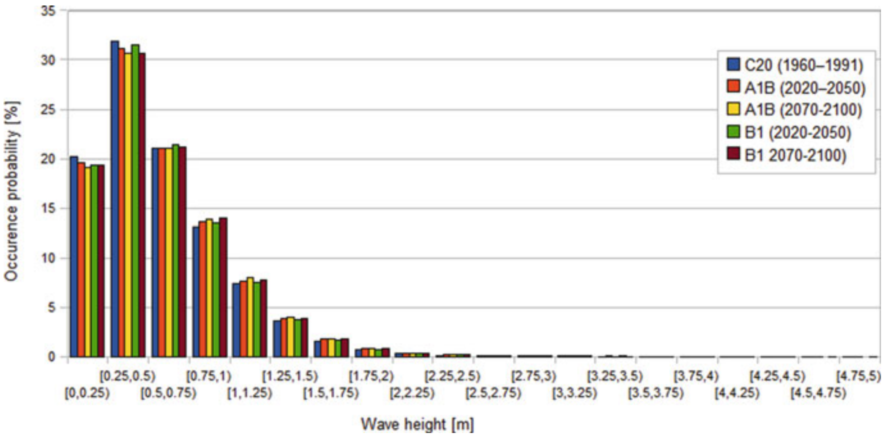

Fig. 7.9 Comparison of wave height distributions off Warnemünde for different climate change scenarios and different periods (Schlamkow et al. 2010)

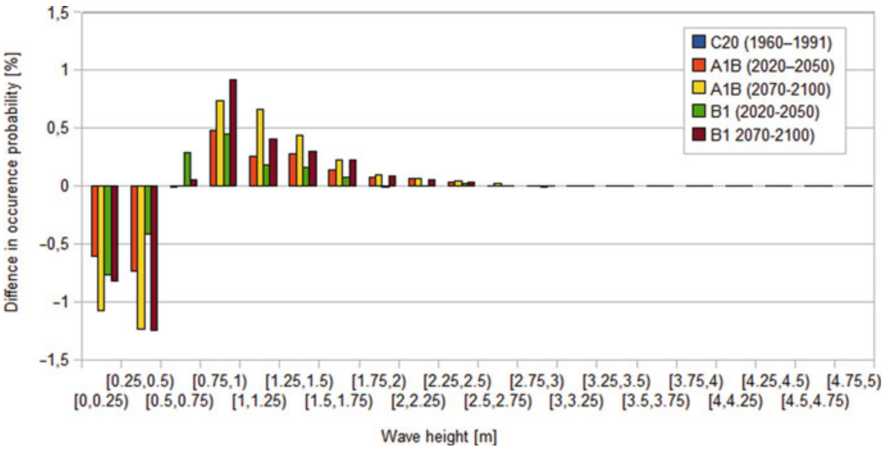

Fig. 7.10 Changes in the probability of occurrence of wave heights off Warnemünde for different climate change scenarios and different periods, compared to the period 1960–1991 (C20 run; Schlamkow et al. 2010)

selected climate change scenarios, respectively. However, the projected changes are all comparatively small and well below 1.5%.

Possible changes in the wind-directions over the Baltic Sea are as relevant as changes of the wind speed and corresponding wave height changes, especially, in connection with waves and the effects of waves on coasts. Information on possible changes of wind directions and also wave directions are not available from the literature at present. If the wind-directions are changing in future, the wave directions and storm surge heights will follow these changes correspondingly.

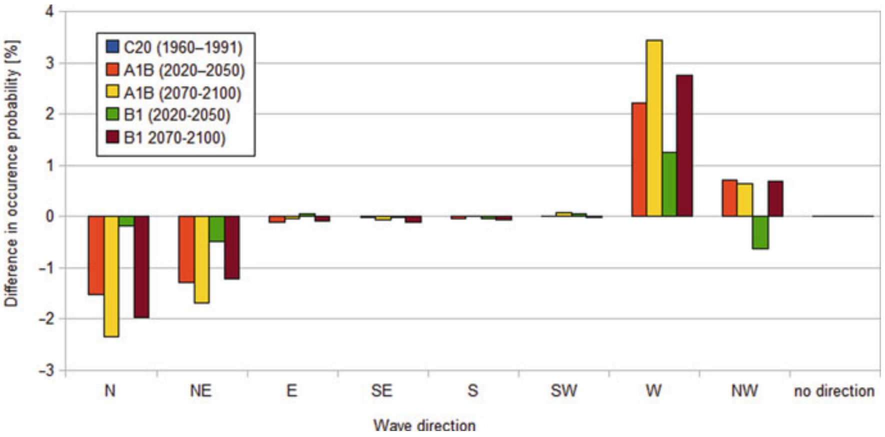

Fig. 7.11 Changes in the probability of occurrence of wave directions off Warnemünde for different climate change scenarios and different periods, compared to the period 1960–1991 (C20 run; Schlamkow et al. 2010)

Calculations based on possible future climate change scenarios indicate a change in the local wind directions at the German Baltic Sea Coast (Fig. 7.11). Westerly wave directions may increase by up to 3.5%, whereas easterly and north easterly directions may decrease by 1–2%.

7.3.2 Extreme Events

Detailed analyses of changes in extreme wave conditions are not available. According to the BACC group (BACC 2008), it could be possible that extreme wave conditions increase at least in a statistical sense. The BACC group states an increase of the 90% percentile of the significant wave heights of up to 0.5 m for the Baltic Sea.

7.4 Consequences for Coastal Flood and Erosion Protection

Normally, coastal flood defence and protection systems are supposed to have a life and operating time of approx. 50–100 years. Hence, also long-term gradual changes of the loads are of importance. Secular changes of the mean sea level in a range between 0.15 m 100 yr^{-1} (Baltic Sea) and 0.25 m 100 yr^{-1} (North Sea) have been taken into account for the design of coast and flood protection structures since several decades. Along the German North Sea coast, during the last years, a climate safety margin of 0.5 m 100 yr^{-1} is taken as a consequence of higher SLR projections (IPCC 2007, Vermeer and Rahmstorf 2009). Within the context of the accelerated sea level rise caused by the global climate change the question arises, which consequences have to be drawn for the methodology and design of future coastal protection concepts and constructions.

7.4.1 Flood Defence

In the context of this contribution, wave run-up and overtopping at dykes and revetments will be considered, exemplarily. Here, the wave conditions at the toe of the construction are the critical values used for the design. The wave conditions at the toe are normally depth limited. Hence, not the deep water conditions but the shallow water wave conditions are the applicable design values.

Under the assumption that the morphology of the coast in front of as dyke or a revetment can follow the sea level rise, solely the changes of the storm surge water level are the reason for higher waves at a construction and have to be taken into consideration. If the morphology cannot completely follow the sea level rise, consequently, the wave conditions at the toe of a construction will change i.e. increased wave heights and most probably also longer wave periods.

Figure 7.12 shows exemplarily the changes in the wave overtopping rates at a sloped construction for changed water levels at the toe of a construction.

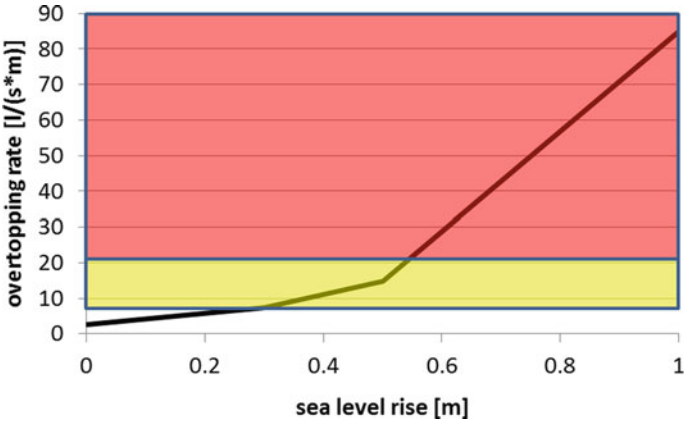

Fig. 7.12 Wave overtopping rates at a dyke as a function of the local sea level rise (*yellow*: unsafe conditions for persons on the dyke and first damages, *red*: dangerous conditions for persons on the dyke and significant damages)

The results indicate that without taking into consideration higher wind speeds and / or higher additional flood water levels the height of the constructions has to be increased to ensure comparable safety for the construction and, consequently, in the protected areas. Consequences of the accelerated sea level rise for the design of coastal flood protection constructions are manifold. In this context, the development of the overtopping discharge of an actual sea dyke with nearly no overtopping is used as an example (Fig. 7.12). The discharge rates are increasing with increasing sea level rise and the dyke is going to be unsafe from a sea level rise of approx. 0.3–0.5 m onwards.

7.4.2 Sediment Transport and Protection of Sandy Coasts

The amount of the *long-shore* sediment transport is depending mainly on the incoming wave energy. The direction of the long-shore sediment transport is depending on the direction of the incoming wave energy. Comparison calculations for the Island of Sylt (Witte et al. 2002) showed that, as long as the morphological changes of the coast are accepted and taken into consideration (see also cross-shore transport) and a moderate climate change is assumed, the amount of longshore-transported sediments is practically the same and that merely the directions of the sediment transport is changing. These changes are strongly depending on the actual location and have to be taken into consideration for practical applications, respectively.

For an assessment of the morphological development of a *cross-shore* coastal profile it is often assumed that a so called dynamic equilibrium profile, which is depending on the incoming waves, is developing at a coastal stretch. Based on this equilibrium profile a possible morphological reaction of the coast to hydrological changes has been calculated.

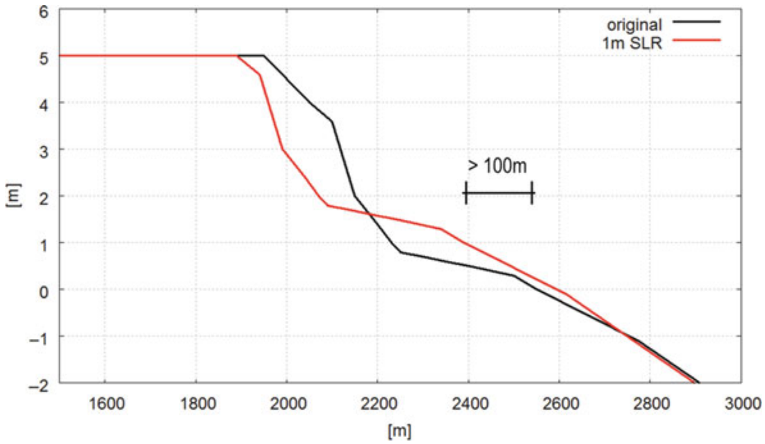

Fig. 7.13 Erosion rate of a selected coastal profile on a sea level rise of 1 m

For the calculation of the reaction of a coast to a changed mean sea level, it was assumed that the cross-shore profile of a coast is constant (dynamic equilibrium) and only based on the relative mean water level and that the necessary amount of sediment for the development of the profile is coming from the cross-shore sediment transport. Furthermore, it was assumed that the long-shore components of the sediment transport can be neglected. Under these assumptions the reaction of the coast was calculated by balancing the eroding and accumulating areas of the cross shore profile. For a freely chosen example cross-section the coast will retreat in an order of magnitude of approx. 100 m for a sea level rise of 1 m (Fig. 7.13). Other, comparative calculations with different assumed amounts of sea level rise from SLR = 0 m to SLR = 1.0 m showed that for the selected case the retreat of the coast is approx. 100-times the amount of the sea level rise. This retreat is high, compared to the actual rates of coastal retreat which is presently in average around 10–30 m per century at the German part of the Baltic Sea.

7.4.3 Consequences

The described changes of coastal flood protection and the local sediment transport as well as possible morphological development of coasts have a wide variety of consequences for the protection of sandy coasts. Examples are:

1. the future practical applicability of established coastal flood protection and erosion protection measures and constructions,
2. the functional and constructional design of measures and constructions for the protection of sandy coasts,
3. the future safety of protected areas and changed risks in coastal areas,
4. the development of adaptation strategies, measures and constructions

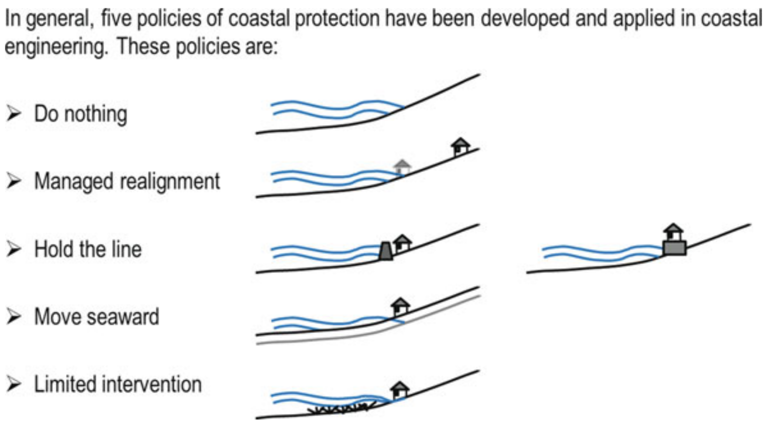
In general, five policies of coastal protection have been developed and applied in coastal engineering. These policies are:

Fig. 7.14 Coastal protection policies modified after IPCC (1990)

At present, especially the first point is under detailed investigation in the parts of the German southern Baltic Sea, since wide areas are protected using flood protection dunes, only.

In general, five policies / strategies of coastal flood protection and erosion protection are being applied in coastal flood defence (Fig. 7.14), where the term limited intervention means to influence the oceanographic and/or hydrodynamic conditions with structures with the aim to limit their effects on the coast. These policies / strategies are mainly based on century long experiences in coastal engineering. A similar division in strategies has been suggested by IPCC (1990) based on first analyses of possible sea level rise and consequences for the coasts. The possible three adaptation strategies to accelerated sea level rise are i) retreat, ii) accommodation and iii) protection. At present (Hofstede et al. 2009) nearly all strategies are being applied by the responsible authorities in German coastal areas. The selection of an actual strategy is mainly a political decision which has to take into account several technical and especially non-technical (societal) conditions.

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Chapter 8
Natural Development and Human Activities on Saaremaa Island (Estonia) in the Context of Climate Change and Integrated Coastal Zone Management

Are Kont, Jaak Jaagus, Kaarel Orviku, Valdeko Palginõmm, Urve Ratas, Reimo Rivis, Ülo Suursaar, and Hannes Tõnisson

Abstract The coastal zone is a crucial environment that is experiencing pressure from a wide variety of different agents and interests. Many sandy beaches high in recreation value are suffering from increasing erosion, and the shoreline is receding in these areas despite of tectonic land uplift. Sediment deficit is evident in many places. One key problem in recent decades has been a rapid increase in the number of holiday houses built as close as possible to the seashore. Unlike in the Nordic countries, where major coastal settlement expansion took place after WWII, almost the entire coast of Estonia was, until 1991, proclaimed a Soviet border zone in which activities were strongly restricted. A revival in coastal land use and a rapid increase in coastal settlement have occurred over the last 15–20 years. This paper focuses on Climate Change impacts, natural and artificial changes on the coast of Saaremaa Island associated with increasing pressure and conflicting interests. We also examine the advantages and disadvantages of existing legislation regulating land use within the Estonian coastal zone in the context of integrated coastal zone management. The paper ends with an outlook.

8.1 Introduction

Estonia's coastal zone – with its long shoreline (3,800 km), strongly indented by peninsulas and bays, and dotted with a multitude of islands – is an attractive environment for human settlements and economic activity. The seashores surrounding both the mainland and Estonia's islands are vulnerable and change quickly under the impact of different external factors (Orviku et al. 2003, Kont et al. 2003, 2008, etc.). Increasing activity in seashore dynamics in recent decades has been detected in many countries worldwide (Johansson et al. 2003, Langenberg et al. 1999, Lowe

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and Gregory 2005, Shaw et al. 1998, Furmanczyk and Dudzinska-Nowak 2009). Such changes are particularly active on depositional (i.e. sand, gravel, pebble, till, silt) shores.

Due to changes in atmospheric circulation and warmer winters, strong westerly storms associated with high sea levels in ice-free sea conditions have increased in frequency on the Estonian coast. The energy of strong storms and their impact on shore dynamics is exponentially larger than that of moderate storms (Orviku et al. 2009). Strong storms, such as the storm named ‘Gudrun’ which struck Estonia on 9 January 2005 may leave a lasting mark on the geomorphology of the shore or may change the trend of development of the existing shore formations (Tõnisson et al. 2007a, b).

The structure and development of coastal landscapes and ecosystems are affected by, and in some cases dependent on, the character and intensity of human activity (Ratas et al. 2003, Puurmann et al. 2004). Some types of coastal vegetation, such as seashore grasslands, are semi-natural plant communities, which exist and develop only where there is periodic mowing or crazing. Estonia’s history of settling the coastal zone has therefore shaped many of its coastal landscapes and ecosystems.

The current paper focuses on the main trends of both natural development and population changes in the coastal area of Saaremaa Island, Estonia in recent decades (the last 20–30 years). We also discuss the management and development of the coastal area in relation to the specific problems facing them. Finally, we examine the advantages and disadvantages of existing legislation regulating land use along the Estonian coast.

8.2 Study Area

The definition of ‘coast’ used in this article is the same one used by HELCOM and often used in coastal zone spatial planning and management. It describes an area ranging from 300 m seaward and 3 km landward of the shoreline. This is an area of matter and energy exchange between land and sea susceptible to global Climate Changes. As such, the area strongly influences local infrastructure and economic activity. It is worth noting that natural coastal processes are usually examined in narrower limits starting from the breaker zone in the sea and finishing with the upper limit of swash on land while human-related coastal topics are usually studied in a broader zone.

The principal results of the current paper are based on our investigation and analysis of data obtained primarily from Saaremaa Island. Saaremaa can be considered a small model of Estonia, where the shore types, development of coastal settlements and the history of human impact on the seashores are quite similar to the rest of the country.

Saaremaa is an island located in the West Estonian archipelago. It is 2,700 km^2 in area; has a population as of 34,700 (as of January 2009); and, has a population density of 13 inhabitants per km^2 (Fig. 8.1). It is the fourth largest island in the Baltic Sea after Sjaelland, Gotland and Fyn.

Fig. 8.1 Location of coastal geomorphic and landscape study sites in western Estonia, meteorological and hydrological stations, tide gauges

Saaremaa's geography is variable with different geomorphic types of coast exposed at different angles to the open sea. The main geomorphic features of the coastal zone here reflect the preglacial relief, the last glacial phase and postglacial isostatic uplift which is still going on. The northern coast of the island is characterized by its Silurian glint and by limestone cliffs, which tower over the tops of the island's many peninsulas. Many spits and beach ridges consisting of gravel and pebble have been formed beside the cliffs as a result of permanent strong erosion of the cliffs and longshore transport of sediment. Rocky shores made up of limestone alternating with accumulative sandy, gravel and pebble shores are predominant on the western coast of Saaremaa. Extensive sandy beaches are concentrated on the southern coast, west of Kuressaare which is the main urban centre of the island. The central and eastern part of the southern coast mainly consists of eroded till shores and silty shores covered with vegetation (Orviku 1974, Orviku et al. 2003).

About 40% of the population of Saaremaa lives in Kuressaare, the capital of the district. The rural settlements are small, and the permanent population in coastal villages is sparse. The number of temporary residents in coastal villages has increased dramatically over the last few decades as more people have begun to build summer cottages there (Statistics Estonia 2010).

8.3 Data and Methods

The current study is based on the results obtained during the fieldwork in the study sites in different parts of Saaremaa as well as on an analysis of existing maps and datasets. The analysis of the natural development of different geomorphic shore types with differing exposure to the open sea is based on the results of field studies carried out under various scientific research projects in Saaremaa (Orviku et al. 2003, Ratas et al. 2003, Ratas and Rivis 2005, Tõnisson et al. 2007a, b).

Climate Change trends during the last 60 years (1950–2009) in Estonia are analysed based on the datasets of the Estonian Meteorological and Hydrological Institute (EMHI). Monthly mean air temperature time series were obtained from six stations in different coastal regions of Estonia (Fig. 8.1). In addition to monthly data, annual and seasonal temperatures are analysed. Long-term changes in winter storminess are described by the use of data from Vilsandi station. A 'storm day' as used in this article, describes a day when mean wind speed was 15 m s^{-1} or higher during at least one synoptic time period during such day. Time series of a number of storm days during Dec–Feb in 1949/1950–2008/2009 were analysed. Sea ice conditions along the Estonian coast were described using three variables – the date of formation, the date of disappearance of sea ice and the sea ice duration, i.e. number of days with sea ice. Data are obtained from five coastal stations with continuous sea ice observations during 1949/1950–2008/2009 (Fig. 8.1).

Long-term sea-level measurements are available from seven coastal stations located at different parts of the Estonian coastline. In the present study, data from two tide gauge stations (Pärnu and Ristna; Fig. 8.1) offering the most extensive and reliable data, were considered. We have used the digitized database of the EMHI, which include both monthly mean and extreme sea levels updated through the end of 2009, as well as hourly data from Pärnu tide gauge for certain high sea level events. Monthly mean and maximum sea-level data measured in relation to the Kronstadt zero benchmark served as initial data during the observation period. At present, the mean sea level of Estonian tide gauges is roughly around Kronstadt zero (Suursaar and Sooäär 2007).

Linear regression analysis using least square error was applied for the trend analysis. The trends were considered statistically significant on $p < 0.05$ level.

Process-oriented field studies on hydrodynamic conditions were carried out near Harilaid Peninsula (Saaremaa Island). Altogether 154 days of measurements were obtained at Harilaid-Vilsandi mooring site (58º 27.6'N; 21º 49.2'E) in 20 December 2006–23 May 2007 (Suursaar et al. 2008). The site is about 1.5 km off the shore. The depth of the mooring was about 11 m, but it varied with sea level changes. The measurements of relative sea level variations, currents and waves were carried out by the oceanographic measuring complex RDCP-600. The Recording Doppler Current Profiler (RDCP, by AADI Aanderaa) data was used for studying hydrodynamic features in the study area, and they also served for calibration reference for a wave model (Suursaar and Kullas 2009).

The long-term calculations of wave parameters with the use of SMB model were performed. Our first effort was based on Vilsandi wind data and RDCP calibration data of waves near Harilaid Peninsula in winter 2006–2007.

The main trends in natural development of different shore types with differing exposure to the open sea described in the current paper are based on the results of specific coastal studies carried out in recent years in Saaremaa (Fig. 8.1) (Orviku et al. 2003, Tõnisson et al. 2007a, b). The dynamics of the shores are assessed by comparison of areal changes of the shore formations both in space and time. A comparison of geomorphic and topographic maps as well as aerial photographs (1955, 1981 and 1985) and ortophotos (1998, 2005) was conducted to analyse the geomorphology and character of shore processes in the study sites. We also took GPS-measurements to ascertain short-time changes in shoreline position, contours of beach ridges and the location of their crests over the last 10 years (i.e. 2000–2009). Topographic surveys were conducted to assess beach profiles in the study sites. In addition, maps and plans compiled among 1963–1989 were used. The collected data were processed using *MapInfo*. This programme was also used for calculating reductions and increments of the areas of the spits. The GPS measurement results taken before and after strong storms have made it possible to observe the storm results in both high and low sea level conditions.

Landscape analysis and historical-geographical interpretations were the main research methodologies used in assessing the changes in land cover pattern and their relationships with changed human impact. In order to analyze important geographical, cultural, and socio-economic factors contributing to the development of coastal landscapes and to estimate the rate and character of such changes, we applied the following methods. First, we analyzed landscape changes by comparing maps from different periods that show land cover. Maps identifying land cover are available back to the beginning of the twentieth century, and in some cases even earlier. The land cover units are based on the *Corine* system (Meiner 1999). Second, we analyzed the data obtained from the landscape transects compiled within the frameworks of the Estonian coastal zone monitoring program.

The problems of increasing human impact and recent developments in coastal zone utilization are examined not only on the basis of the above-mentioned scientific research results but also on the basis of a number of large-scale maps from different times. In the regard, we used the Russian 1 verst (1,067 km) maps from 1895 to 1917 in 1:42,000 scale and the Soviet General Staff topographic maps from 1935 to 1939 in 1:50,000 scale among the older ones. We also used the Estonian Basic Map (1:10,000 scale) in Lambert-EST projection and the Estonian Base Map (1: 50,000 scale) in TM BALTIC projection from the Estonian Land Board, which are the main sources of for the present-day digital datasets used in this article.

The analytical work with the datasets was carried out within the framework of the Interreg IIIB project ‘Developing Policies and Adaptation Strategies for Global Climate Change in the Baltic Sea Region’ (ASTRA), funded by the European Regional Development Foundation (ERDF) for the purpose of creating a detailed coastal zone management plan for Saaremaa Island. *MapInfo* software was used in the data processing. The results are presented using GIS technique. An overview of data layers is given in Palginõmm et al. 2007.

8.4 Results and Discussion

8.4.1 Observed Climate Change

Extraordinary climatic changes have occurred during the last about 30 years in Estonia and in the whole Baltic Sea region for which the driving force appears to be a change in atmospheric circulation. The intensity of zonal circulation has significantly increased, and the number of cyclones crossing the Baltic Sea in winter has also increased (Sepp et al. 2005). This has induced warmer winters and springs. The annual mean air temperature has increased by up to two degrees (Table 8.1).

The temperature increase is particularly evident from January to May. There is a difference between stations at the western coast of the West Estonian archipelago (Vilsandi, Ristna) and the other stations. Statistically significant trends were revealed at all stations in winter, spring and summer but not in autumn. During those periods, there is a decreasing tendency in sea-level pressure and an increase in precipitation, which are concurrent.

As a consequence, the snow cover duration and the extent of sea ice have significantly decreased (Jaagus 2006). Ice cover duration in the coastal sea of Estonia has decreased by 1–2 months over the last 60 years (Fig. 8.2).

Table 8.1 Changes of monthly, annual and seasonal air temperature among 1950–2009 (linear regressions, in degrees Celsius)

	Vilsandi	Ristna	Kihnu	Virtsu
January	3.5	3.1	3.9	3.9
February	3.4	3.0	3.2	3.2
March	3.1	2.7	3.9	3.7
April	2.4	2.0	2.9	2.9
May	2.1	1.7	1.9	1.9
June	1.0	0.5	0.7	0.6
July	2.2	1.8	1.9	1.8
August	1.8	1.4	0.5	1.4
September	1.0	0.6	0.7	0.4
October	0.3	0.2	0.3	0.1
November	0.9	0.7	0.6	0.6
December	1.4	1.4	1.3	1.1
Year	1.9	1.6	2.0	1.8
Spring	2.5	2.1	2.9	2.8
Summer	1.7	1.3	1.4	1.3
Autumn	0.7	0.5	0.5	0.3
Winter	2.8	2.5	2.8	2.7

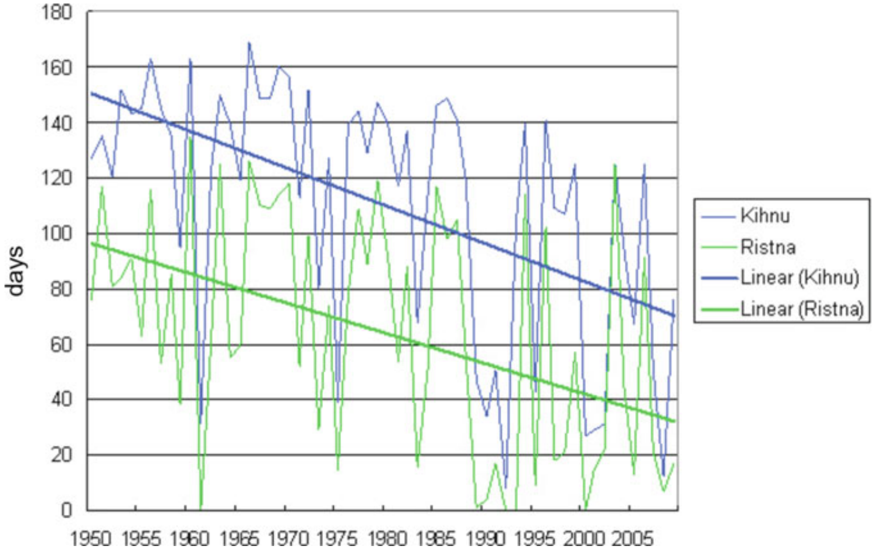

Fig. 8.2 Time series of the number of days with sea ice and their linear trends in Kihnu and Ristna during 1949/1950–2008/2009

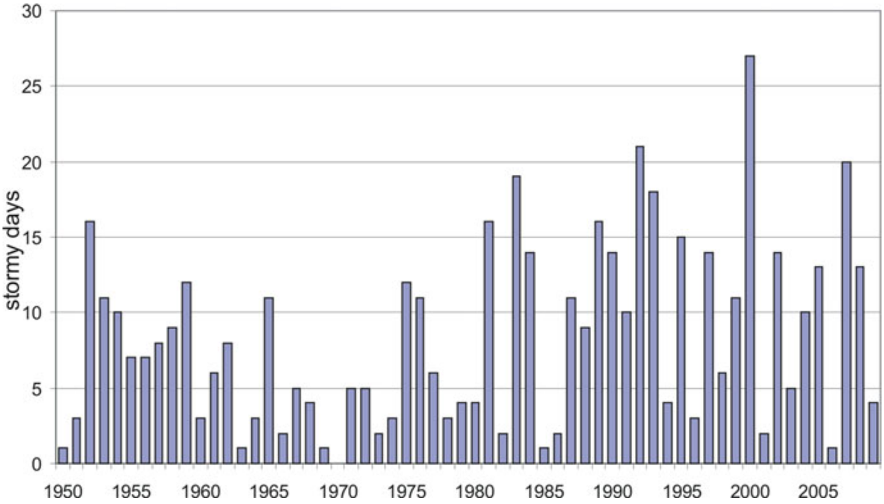

Fig. 8.3 Time series of winter storminess in Vilsandi from 1949/1950 to 2008/2009 (number of storm days per winter)

From Fig. 8.3, it becomes clear that storminess in winter has increased over the last decades. For the time period 1950–1969, the mean number of storm days per winter amounted to 6.4. For the time period 1990–2009, it increased to 11.3.

Stronger and more frequent storms in winter coincide with described climatic changes (Alexandersson et al. 2000, Pryor and Barthelmie 2003, Orviku et al. 2003). They constitute key factors shaping the coast of Saaremaa today.

8.4.2 Changes in Hydrodynamics

Tides, which are the most common source of sea level variability in the world's oceans, are negligible in the semi-enclosed Baltic Sea. The amplitudes of the main tidal wave constituents are around 1–5 cm in the Baltic Proper (Magaard and Krauss 1966). Short-term sea level variations on the Estonian coast are mainly caused by wind. Long-term trends in sea level variation at different stations are strongly dependent on different rates of land uplift.

The radial crustal movements in Estonia are mainly influenced by regional Fennoscandian postglacial rebound, and the uplift rates vary between 0.5 and 2.8 mm yr^{-1} along the Estonian coast (Vallner et al. 1988). The land uplift has been the highest in Ristna, NW Estonia, and it decreases towards south-east.

On the basis of hourly data from 1961 to 2009, some 90% of the data falls within the relatively narrow range from –40 to 50 cm at Pärnu. Still, the sea level variability range is up to 400 cm (Suursaar and Sooäär 2007). Both extreme high and low sea level events tend to occur in meteorologically more variable winter months. Strong east winds lower the sea level in the Estonian coastal waters and west winds raise it up. The high sea level events are mainly associated with North European cyclonic storms. The two highest sea levels off the Estonian coast were both registered at Pärnu: 253 cm on 19 October 1967 and 275 cm on 9 January 2005 (Fig. 8.4). The mean sea level rise for the western coast of Estonia (1.5–2.5 mm yr^{-1} according to linear trend), corrected for the land uplift rates, is roughly equal to the global estimates for the twentieth century (e.g. Church and White 2006, IPCC 2007). The crucial role of changes in wind climate is confirmed by large change rates in maximum sea levels, ranging in different gauges and different periods between 3.7 and 13 mm yr^{-1} (Fig. 8.4), while the rates in minima are only 0.5–3.4 mm yr^{-1} (Suursaar et al. 2006).

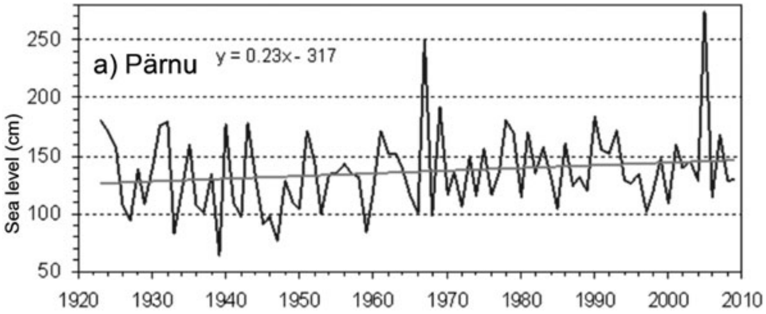

Fig. 8.4 Decadal variations in annual maximum sea levels at Pärnu and linear trend

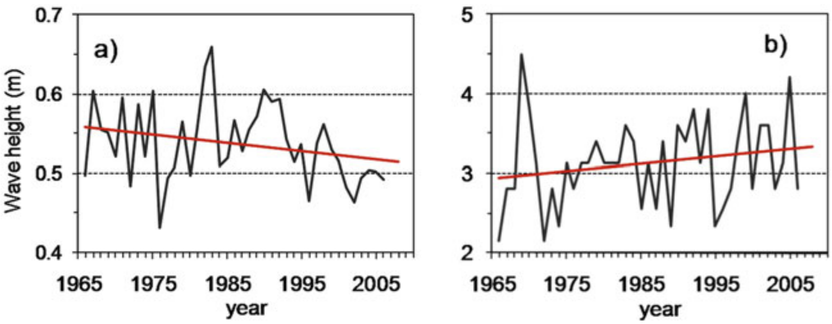

Fig. 8.5 Hindcasted decadal variations in annual mean (**a**) and maximum wave heights (**b**) at Harilaid Peninsula

Positive sea level trends in annual time series appear due to the steeply increasing (2–4 mm yr^{-1}) trends in winter (December to March) sea levels. The significantly higher mean sea level rise in winter correlates with increased local storminess during the same months and with the greater intensity of westerlies in winter (Suursaar and Sooäär 2007, Jaagus et al. 2008).

Currents in the coastal waters of Estonia are predominantly weak (5–20 cm s^{-1}) and non-persistent with relatively small geomorphic influence on the seashores (Suursaar et al. 2008).

Wave activity is the main hydrodynamic agent that affects the seashores and relocates the bottom sediments. Although wind is by far the primary force in wave production, the changes in wave climates are not always straightforward in bodies of water where the fetch is limited and the shape of the basin is complex. The mean properties of wave heights and wave periods show quasi-periodic cycles. Changes in the yearly mean and yearly maximum wave heights near Harilaid study site among 1965 and 2006 are depicted in Fig. 8.5. The mean wave heights show a falling tendency, whereas the maximum wave heights, in general, seem to rise. Over the last decades, the frequency and strength of storm events have increased on the western coast of the West Estonian archipelago (Broman et al. 2006, Jaagus et al. 2008, BACC 2008).

8.4.3 Shore Evolution

The Estonian coasts are considered regressive at present, and even the effect of the average ocean-level rise (1.5–2.0 mm yr^{-1}; Church et al. 2001) is insignificant on their evolution. The rate of the annual land uplift in Saaremaa ranges from 1.5 to 2.5 mm (Vallner et al. 1988). The most important factors influencing the formation and development of seashores in Estonia including Saaremaa are wave activity and sea-level fluctuation caused by surges arising from westerly storms.

Some parts of the accumulative coast in Saaremaa are well exposed to the waves and westerly prevailing winds. These are geologically active and the most rapidly changing coasts. The most significant processes shaping the shores there today are erosion and the accumulation of sediments caused by wave activity. Rapid coastal change expressed in both shoreline displacement and in the structure of coastal formations usually results from powerful storms (mean wind speed > 25 m s^{-1}) or from stormy periods of a long duration accompanied by high sea level conditions (Orviku et al. 2003).

An acceleration of shore processes, which are presumed to be associated with warmer winters, has been observed in Saaremaa in the last 20–30 years. In many places the shores have been severely eroded by frequent storm surges. Sandy shores, which are preferred as recreational areas, are particularly vulnerable to erosion. Strong erosion by storm waves combined with a lack of sediment has often resulted in shoreline retreat and reduction of sandy beach areas notwithstanding the land uplift (Orviku et al. 2003, Kont et al. 2008, Tõnisson et al. 2007b).

Good examples are the Järve study site, S coast, and Kiipsaare study site on Harilaid Peninsula, NW coast of Saaremaa. Both areas are made up of sandy beaches with foredunes and dunes. The principal change in the Järve study site consists of the recession of the seaward scarp, particularly the edge of it, in the dune range. Periodic measurements of the beach profile in Järve evidence a steady recession trend over the whole study period. A nearly 4 m high scarp receded by 6 m over the period from 1990 to 2005, 4 m of which were the direct result of Gudrun in January 2005 (Fig. 8.6). This confirms the hypothesis that the impact of a major storm can be exponentially greater the cumulative impact of a number of ordinary storms over the preceding years or even decades (Zenkovitch 1975).

Shore processes during the last century have caused the north-westernmost point of Harilaid Peninsula, Cape Kiipssare to migrate over 300 m to the north-east and to become longer and narrower (Fig. 8.7a). Erosion on the western coast

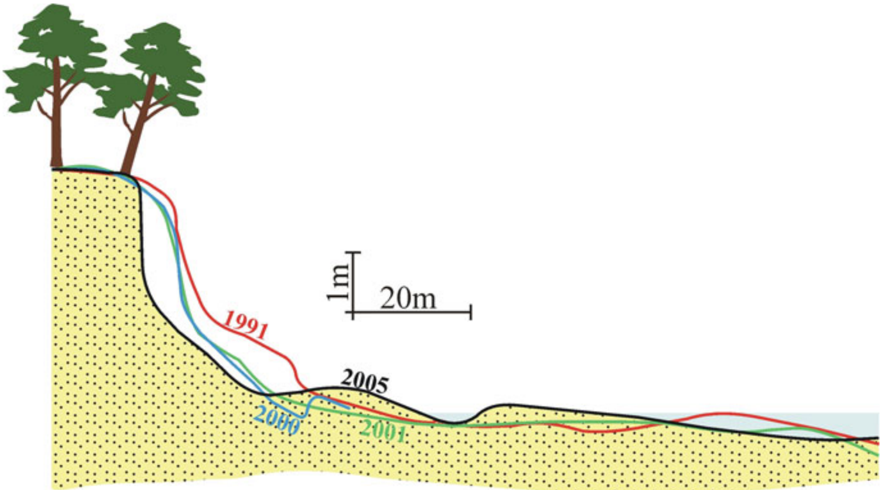

Fig. 8.6 Scarp recession at Järve

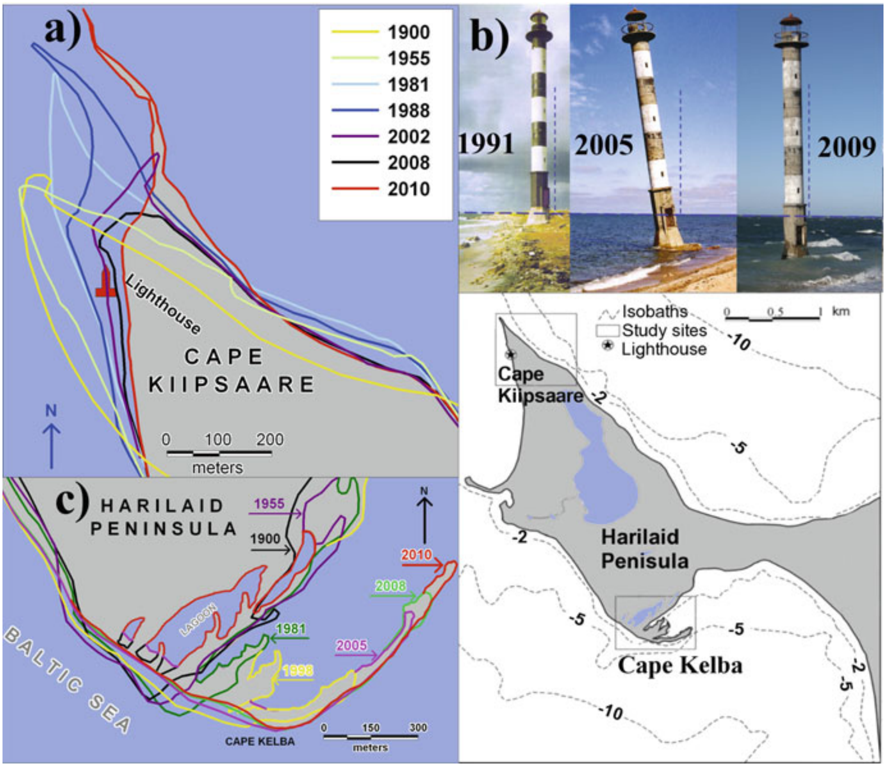

Fig. 8.7 Shoreline changes on (**a**) Cape Kiipsaare, (**b**) location of Kiipsaare lighthouse in 1991, 2005 and 2009 (photos K. Orviku), (**c**) Cape Kelba

and re-deposition of sand on the north-eastern and eastern coast of the cape are confirmed by a retreating scarp. As the scarp has retreated, ancient fishing boats have been uncovered. More dramatically, Kiipsaare lighthouse, originally built in the middle of the cape, is today positioned in the sea, 35 m from the shoreline (Fig. 8.7b).

Cape Kelba, a spit consisting of beach ridges of gravel and pebble in south-eastern Harilaid, shows the clear relationship between storm events and shore dynamics. Continuous accumulation of new beach ridges elongates the spit. The increment of the spit is clearly delineated by the ridges and their positions, and is well correlated with storm data (Fig. 8.7c). The growth rate of the Kelba spit over the last 30 years is about four to five times as high compared to the growth rates at the beginning of the twentieth century until the end of the 1970s (Orviku et al. 2003). The gravel-pebble beach ridges that were formed during Gudrun are likely to remain there unchanged for a long time. They are positioned far inland from the mean shoreline and located at high elevations due to the very high storm surge water level during Gudrun. The unique confluence of factors that produced Gudrun and its resulting shoreline processes are unlikely to reoccur soon (Tõnisson et al. 2007a).

8.5 Historical Background of Coastal Population and Land Use: Changes in Coastal Land Cover Pattern

Centuries-old human land use has played an important role in the formation of the present-day coastal landscape of Saaremaa. According to archaeological findings, the territory of Saaremaa has been inhabited for at least 5000 years.

The land surrounding the villages was not divided among households until the middle of the nineteenth century in Saaremaa. The coastal areas have been in common use by local communities over the entire history of Estonia. These areas were generally too brackish for land cultivation, and thus were not used by the villages and small farmsteads as crop fields. Instead, they were used in accordance with the laws of the local community. Even inland villages had opportunities to use the coastal areas for pasturing or fishing (Johansen 1964). Permanent settlements and cattle grazing were, in general, not permitted along the shoreline. However, fishermen were allowed to set up temporary campsites near the shoreline and could build small sheds for nets and boats. The harbours too were in common use by the local communities.

Due to the scarcity of suitable land for cultivation, the fields were divided into parcels of different sizes and shapes. The village allocated a portion of each soil type to each household. The diverse land cover pattern consisting of numerous small parcels reflects the communal traditions of the village communities (Fig. 8.8). Such land use practices remained in effect in Saaremaa until the end of the eighteenth century, much longer than anywhere else in Estonia. Common use of the seashore grasslands and the forests remained in effect until WWI (Palginõmm et al. 2007).

In 1919, the manors were expropriated by law, and the land was allocated to the local peasants. Although private farmsteads became the dominant form of land ownership, the coastal areas still remained in common use for mowing, grazing and fishing. As fishing had been a collective activity since ancient times, the traditions were kept alive in Saaremaa until WWII. The sheds for nets were erected next to each other (often under the same roof) on sites most suitable for boats to come ashore.

Favourable climatic conditions and geographical isolation helped the island become one of the most densely populated areas in Estonia until the Soviet occupation. It was a typical agrarian region with about 10,000 farms. Due to the unavailability of new land naturally suitable for cultivation, the majority of the fields have been in the same place for centuries. Following the old traditions, seafaring, fishing and seal hunting were also important sources of income on the coast.

The events in the summer 1940 signalled an abrupt departure in how Saaremaa's coastal zone would be used over the next 50 years. In 1941–1947 the population of Saaremaa decreased by nearly 10% more than in other regions of Estonia.

Its location along the lengthy western border of the Soviet Union meant that all of Saaremaa was declared a restricted zone with strict limitations on sea-borne navigation and movement on land.

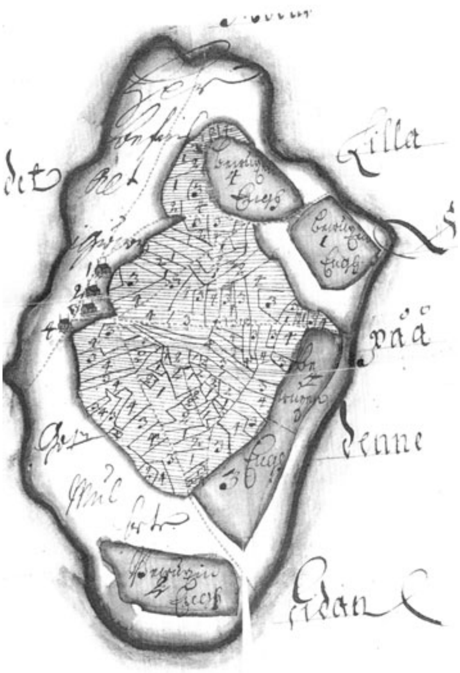

Fig. 8.8 Fields divided into parcels on Kõinastu Island in 1687/1688

After 1991, new land reforms were initiated to return the land back to the former landowners and their successors. For the first time in the island's history the seashores of Saaremaa, as well as the rest of Estonia, were privatised. Since that time, relatively low land prices have been attractive to foreign buyers, and particularly for Finns, who have acquired large tracts of coastal land. As a result, the towpath on the seashore has been closed for public access in many places.

The land cover pattern on the coast is a dynamic feature, showing a certain stage in the development of coastal landscape at a given moment of time.

The character and properties of its soils are the natural factors that influenced the development of Saaremaa's economy and the cultural heritage. Soils influence the size, location and fragmentation of cultivated land as well as the appearance of villages and households (Troska 2002). The cultivated areas tended to be smaller and less fragmented in the eastern part of Saaremaa with its relatively flat topography and highly productive soils, while in the western part of the island the areas under cultivation tended to be larger and more fragmented due to greater variability in topography and the presence of poorer soils.

Coastal wetland vegetation, including seashore meadows, in Saaremaa is mostly located in regressive coastal areas with wide and flat shores where wave activity is negligible even during strong storms. The characteristic feature of these areas is that they are temporarily flooded with seawater. The soil–vegetation complexes of seashore meadows have undergone a series of stages in their development from

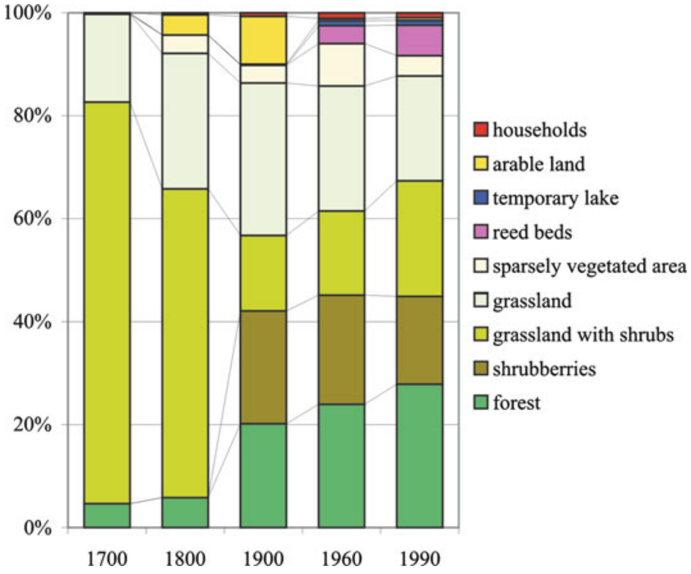

Fig. 8.9 Land cover changes on Vilsandi Island in 1700–1990

hydrolittoral to epilittoral as a result of land uplift. A constant replacement of one plant community by another in a certain site over a certain time interval supports this general process (Puurmann et al. 2004).

The period of most intensive exploitation of coastal meadows lasted from the middle of the 1850s up to the beginning of the 1940s. At that time the coastal landscapes were strongly influenced by human activity. Fields were interspersed with woods, wooded meadows, shrubberies and meadows. Farms, windmills and stone fences added to the diversity. Insular landscape structures became more varied.

A comparative analysis of land cover maps of agricultural coastal areas from different time periods suggests that the area of land used for agriculture has steadily decreased over the last 60 years. Reed beds, shrubberies or woodlands and overgrowth replace the former grasslands (Fig. 8.9). The expansion of reed beds is caused by a cessation of grazing and mowing. The main trends in the changes in coastal land cover pattern are as follows: natural seashore grasslands become shrubberies or reed beds; wooded meadows and small fields become forests; natural forests become managed forests; and, natural land cover generally becomes areas for summer cottages and dwellings (Ratas and Puurmann 1995).

8.6 Some Aspects of Coastal Zone Management

Integrated Coastal Zone Management (ICZM) as a land use approach designed to access, analyze, and balance the concerns of various coastal zone interest groups is missing today in Estonia. A patchwork of land use restrictions exist in various areas.

Some progress has been achieved on Hiiumaa Island, where, within the frameworks of the Estonian Pilot Project 'The Hiiumaa Island', a functioning ICZM model was tested at the county and municipal level. As a result of this project, the ICZM information centre was established in Kärdla, the main urban centre of Hiiumaa.

Moreover, a few local authorities in Saaremaa have managed to create a comprehensive land use plan for the municipalities and to establish regulations governing construction along the coast. Unfortunately, existing measures have often been undertaken more as a way to legally sanction existing activities than to regulate future coastal development. In some cases, spatial planning procedures are impeded by interest groups who argue that the coastal development regulations under consideration might adversely affect their businesses.

Estonia's current patchwork of laws and regulations regulating its coastal zone – while still evolving – remains incomplete and subject to numerous loopholes. The rapid socio-economic changes occurring today along Estonia's coasts present a major challenge. An example is the powerful storm (and subsequent flood) that struck Estonia in January 2005. The people whose properties suffered the most damage from the storm accused the local authorities of doing nothing to prevent or mitigate the disaster and protect their coastal property.

Existing laws governing Estonia's natural areas prohibits construction within a 100 m zone from the mean shoreline on mainland Estonia and within a 200 m zone in Saaremaa. However, the act gives the Minister of the Environment the right to make exceptions (loopholes see above) and to reduce the size of the protected zone. These loopholes in the statutory scheme have at times been exploited by landowners and developers.

Certain conflicts between the existing regulatory scheme and current land use needs and practices are evident. Regulations based solely on a uniform set of parameters (such as, regulations protecting forests or prohibiting construction or activities within 100 or 200 m of the mean shoreline, etc.) have caused misunderstandings and are usually insufficiently tailored to suit either the natural conditions or existing customs and practices. Indeed, strict adherence to such rules may occasionally give rise to undesirable or anomalous results. For instance, there are many coastal areas in Saaremaa where ancient roads and settlements are located less than 200 m from the mean shoreline and have never suffered from storm damages or floods so far. In many places, the old traditional settlements are located in zones currently restricted to any building, and, conversely, forests and cultivated fields, commonly used for many centuries but abandoned today, lie in the middle of a construction area (Palginõmm et al. 2007).

8.7 Outlook

The attitude of local authorities, landowners and developers but also of ordinary people towards the sea has not changed during Estonia's nearly 20 years of independence. The sea remains, in the minds of many Estonians, dangerous and off-limits. Nearly two generations of people have been living with the knowledge that going to the sea is forbidden and can be punished. This is one of the most enduring legacies of the Soviet occupation. Mismanagement of Estonia's coastal zone including Saaremaa is evident, and a common sense of responsibility in handling this precious resource is still missing.

An expected rise in the mean global sea-level, combined with more frequent cyclonic activity and increasing storminess, could significantly affect the Estonian coast over the next decades. Estonia is facing a serious challenge today: how to use the coast in sustainable manner and to preserve it for the next generation in a rapidly changing world. One option is to follow the practice of the Nordic countries, i.e. to rest Estonia's coastal zone management scheme on the principles of private ownership, the net effect of which will be to make the coast inaccessible to vast majority of the population. Another possibility is to keep alive Estonia's old traditions and to keep the shores open to public access and common use. A comprehensive coastal zone management scheme will allow the public to consider fully these approaches and others in order to determine the best way for Estonia to manage this important resource and to protect the coastal zone against the negative effects of both global Climate Change and increasing encroachment by development.

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Chapter 9
Coastal Erosion Along the Portuguese Northwest Coast Due to Changing Sediment Discharges from Rivers and Climate Change

Francisco Taveira-Pinto, Raquel Silva, and Joaquim Pais-Barbosa

Abstract Coastal erosion is a common problem along sandy shores in Europe, a result of the dynamic nature of its coastal zones, of anthropogenic influences and of the effects of Climate Change. A possible increase of extreme events, the weakening of river sediment supplies due to dams and embankments and the expected acceleration of sea level rise tend to aggravate coastal erosion on decadal time scales. To minimize negative effects it is necessary to understand the various processes causing erosion so as to assess possible prediction scenarios for coastal evolution on the medium to long terms. This paper deals with the erosion situation to which the Portuguese northwest coast has been subjected, in relation to known sedimentary changes and to potential impacts of Climate Change on coastal areas. The possibility of re-using sediments from Portuguese reservoirs to nourish eroded beaches is pointed out. Also, coastal response to Climate Change driven variations in the longshore sediment transport regime is considered.

Abbreviations

CD	Chart datum
ECMWF	European Centre for Medium-Range Weather Forecasts
FEUP	Faculty of Engineering of University of Porto
IGP	Portuguese Geographical Institute
IH	Hydrographical Institute
INAG	Water National Institute
SLR	Sea level rise
WAM	Wave analysis model

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9.1 Introduction

Coastal erosion is a common problem along sandy shores in Europe, as a result of the dynamic nature of its coastal zones, of anthropogenic influences such as coastal interventions and littoral occupation and of the effects of Climate Change. A possible increase of extreme events, the weakening of river sediment supplies and the expected acceleration of sea level rise tend to aggravate coastal erosion on decadal time scales. Describing vulnerability and risk patterns for environmental actions is of great importance to coastal planning and management in order to rationalize the decision making process. To minimize negative effects, it is necessary to understand the various processes causing erosion so as to assess possible prediction scenarios for coastal evolution on the medium to long terms. This paper deals with the erosion situation to which the Portuguese northwest coast has been subjected, in relation to the known sedimentary changes and to the potential impacts of Climate Change on coastal areas. The possibility of reusing sediments from Portuguese reservoirs to nourish eroded beaches is pointed out. Also, coastal response to Climate Change driven variations in the longshore sediment transport regime is considered.

Coastal zones are dynamic geomorphological regions that respond on different temporal and spatial scales to changes in natural and anthropogenic effects. Natural factors include wave action, winds, tides and surges, whereas man-made impacts occur through resource exploitation, construction and pollution (Fig. 9.1).

The assessment of beach evolution over time is complex. At any given moment a beach may be changing rapidly as a result of a short-term disturbance such as a winter storm, from which it can recover during calm wave conditions, thereby maintaining equilibrium. At the same time slight changes caused by sea level rise may be occurring in one or more of the several morphological states that are part of a dynamic equilibrium, cycling over time scales of years or even decades. Extreme events may also trigger abrupt irreversible changes.

A major challenge in understanding beach evolution is the ability to identify and separate processes beyond any given morphological change. A possible approach to this problem is to group the processes on a beach response scale: short, medium and long terms (Stive et al. 2002), Fig. 9.2.

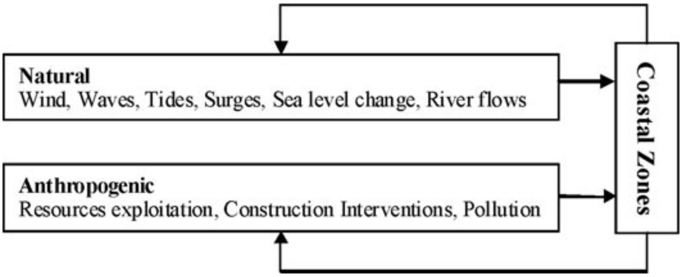

Fig. 9.1 Driving forces in the coastal zones

	hours	years	decades	centuries	millennia
10 m	Short Term				
1 km		Medium Term			
5 km					
10 km			Long Term		
100 km					
...				Longer Term	

Fig. 9.2 Spatial and temporal scales for beach change

The causes of medium-term changes are relatively well understood, because they are readily observed and have been studied for almost a century. Some of the processes and mechanisms behind the short-term changes are areas of active research (e.g. the relation between bed forms and cross-shore sediment transport in the surf zone (van Rijn et al. 2007)).

Processes and responses taking place at such small scales may not be observable under natural settings (e.g. the intensive sediment transport taking place in a thin boundary layer with a thickness of the order of some cm has only been measured in the laboratory (Nielsen 2006) and their importance may not be well recognized.

Long-term changes may also be difficult to identify because observational time-series are often not long enough to allow the identification of long-term cycles, and gaps are frequent. This is, as an example, the case for the wave data series (1993–2003) measured at the Leixões wave buoy (Portugal) where extreme conditions are often missed as a result of damage or breakdown during storms (Fig. 9.3).

The factors contributing to small scale changes in beach morphology (10 m – 1 km; hours – years) include the instantaneous response to the direct action of waves, winds, tides and surges, as well as seasonal changes in the surf zone between storms and calm periods (Komar 1998). On this scale, nearshore waves and currents induce spatial variations in sediment transport and are the most important natural factors contributing to beach change. Artificial replenishment and surf zone structures interfere with these patterns.

On medium scales (1 – 5 km; years – decades), surf zone bar cycles, inter-annual wave regime change, or recovery from a major storm event are important processes contributing to change in beach morphology. On this time scale coastline evolution is usually consistent with predictions obtained from estimates of sediment volume fluxes, based on knowledge of the alongshore transport in relation to wave height and angle at the breaking zone. The influence of large surf zone structures or

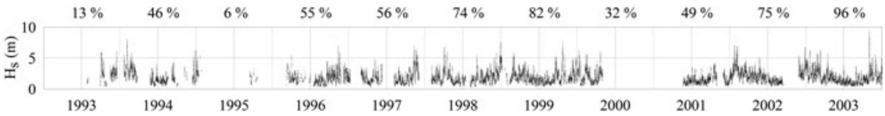

Fig. 9.3 Significant wave height time series, obtained from Leixões wave buoy observations and monthly percentage of valid registers from 3 to 3 h, between 1993 and 2003 (buoy station located offshore of the Portuguese northwest coast, owned and operated by Hydrographical Institute – IH)

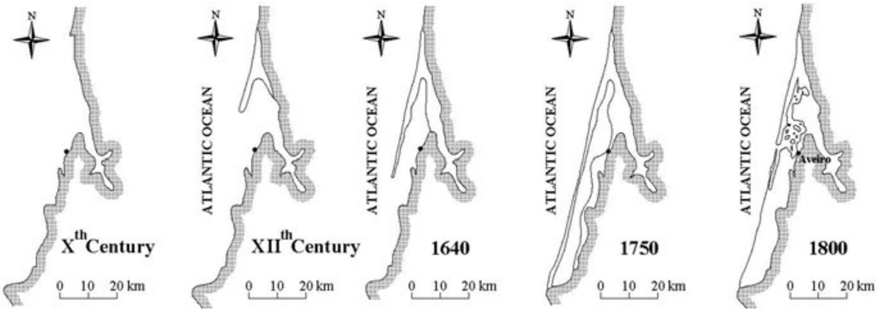

Fig. 9.4 Morphological states of the evolution of the Aveiro lagoon, located on the Portuguese northwest coast (after Delgado and Choffat, in INAG/FEUP 2001)

other coastal structures may also cause changes in beach configuration on this scale (Stive et al. 2002). Other medium-term responses are related to changes in the sediment availability, such as what could result from fluc-tuations in river input.

On larger scales (10 – 100 km; decades – centuries) changes often arise where spatial difference in alongshore transport occur (Horikawa 1988). An example is given in Fig. 9.4, where different morphological states in the formation of the Aveiro lagoon are presented.

The long-term changes also reveal the effects of sea level rise and of regional wave Climate Change, together with evidence of negative effects of erosion also as a result of a lack of coastal zone management. Possible effects of Climate Change could increase medium to long-term erosion of an already critical situation.

The causes of coastal erosion and their relative importance are site specific, changing from place to place. Measures to solve the problem must be incorporated in future coastal zone planning and management policies, at least at a medium term horizon. To help develop a hierarchy of action priorities, coastal zone risk assessments can be accomplished through the creation of risk maps (Coelho et al. 2006). Numerical models may be helpful tools in the analysis and projection of different anthropogenic and natural scenarios (Coelho et al. 2009).

9.2 The Portuguese Northwest Coast

Portugal is located on the Iberian Peninsula in south-western Europe, facing the Atlantic Coast. The northwest Portuguese coast, at latitudes 40–42° N, is a highly energetic region, as may be inferred from the average annual wave power obtained with data from the Wave Analysis Model (WAM) archive of the European Centre for Medium-range Weather Forecasts (ECMWF), Fig. 9.5 (Cruz 2008).

The Portuguese west coast is exposed to waves usually coming from the northwest, with an offshore mean significant wave height of 2–3 m and a mean wave period of 8–12 s. Storms generated in the North Atlantic are frequent in

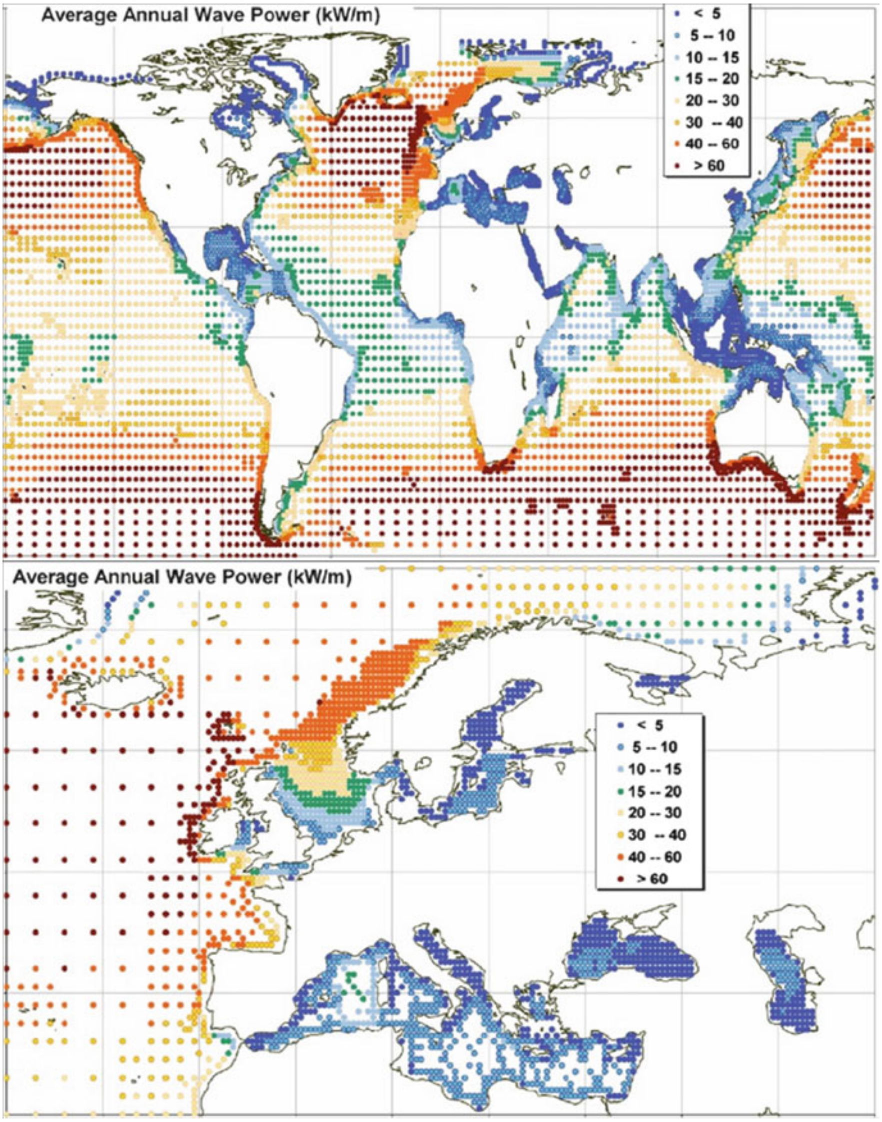

Fig. 9.5 Global mean annual wave power estimates in kW m^{-1} obtained with data from the WAM archive of the ECMWF calibrated and corrected with Fugro OCEANOR against a global buoy and Topex satellite altimeter database (after Cruz 2008)

winter, and can persist for up to 5 days with significant wave heights up to 8 m (Costa et al. 2001).

It is a high energetic coastal zone compared to that of the Baltic coast (Fig. 9.5), where the wave climate is much milder in general. For instance, wave data from the Northern Gotland Basin have shown that in 90% of the cases, significant wave height is less than 2 m (Leppäranta and Myrberg 2009).

The characteristic periods are also larger in the Portuguese west coast, since in the Baltic sea wave fields may be considered similar to those on large lakes, with long-period swell almost absent (Leppäranta and Myrberg 2009). In fact, wave conditions considered exceptional and associated with major storms in the Baltic coast occur every year in the Portuguese west coast.

In the Portuguese west coast, the tides are semi-diurnal ranging from 2 to 4 m during spring tides. Also, this type of tidal regime is quite different to that of the Baltic coast, where tide range is estimated to be about 10 cm (Zeidler et al. 1995).

The strong wave regime of the Portuguese west coast induces a southward alongshore transport of 1–2 million m^3 $year^{-1}$ (Oliveira 1997).

The Portuguese northwest coast may be divided in two main stretches, based on geomorphological characteristics (Fig. 9.6). The first stretch, from Caminha to Espinho is composed of low rocky formations.

The second stretch, from Ovar to Marinha Grande, is mostly a low-lying open sandy shore, vulnerable to wave action and backed by dunes which have already been destroyed in some places. The Douro river estuary and the Aveiro inlet are important morphological features. They are strongly influenced by anthropogenic effects from the cities of Porto and Aveiro (Fig. 9.6), as well as by the input of sediments. The pointed differences, between the Portuguese west coast and the Baltic coast, for the typical regimes of the hydrodynamical actions, necessarily result in

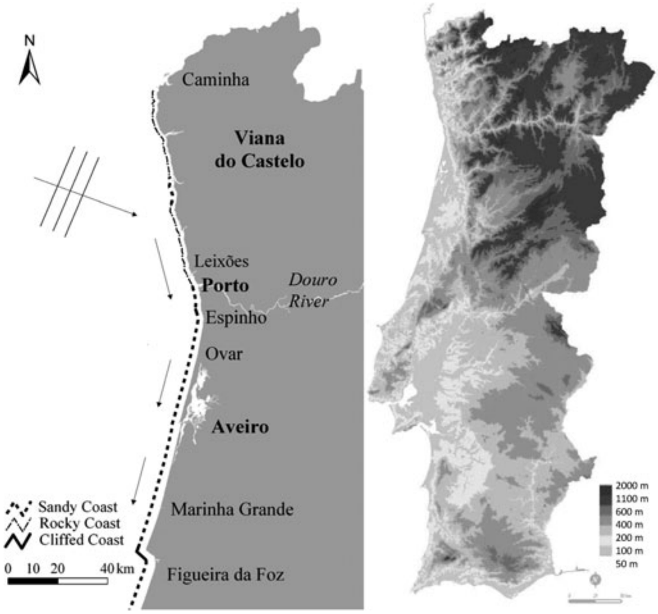

Fig. 9.6 Littoral drift and dominant incident wave direction on the Portuguese northwest coast (*left*); Topographic map of continental Portugal (*centre*, IGP – Portuguese Geographical Institute); Morphostructural scheme of continental Portugal (*right*, IGP)

different morphologies and sediment dynamics. The erosion problems have different magnitude orders, the coastal defense structures need to be stronger in the Portuguese west coast and nourishment volumes higher. Also higher are the costs of erosion mitigation.

9.3 Sedimentary Changes

9.3.1 Coastal Erosion

The main sources of sediments of the Ovar-Marinha Grande (Fig. 9.6) coastal stretch are the Douro river and coastal erosion. The Douro, in its natural regime, used to supply about 1.8 million m^3 $year^{-1}$. This amount decreased to about 0.25 million m^3 $year^{-1}$ (Oliveira 1997), causing coastal erosion to increase as alongshore transport has not significantly altered.

During the last two decades the rate of shoreline retreat has increased, reaching 7 m $year^{-1}$ in some stretches (Veloso-Gomes et al. 2006a). Several studies indicate different rates for this area (Table 9.1). These studies used different methodologies, base maps, sea levels, tides, different stretches and time series. In consequence, a comparison is difficult. However, a consensual conclusion is possible: the tendency for the major part of the shoreline is retreat (Veloso-Gomes et al. 2006a).

It is important to recall that in 1958 coastal defence structures weren't present. Their number has increased since then to protect various urban waterfronts. Recent studies performed to quantify the vegetation line retreat (Pais-Barbosa 2007, Taveira-Pinto et al. 2009), between Cortegaça and Furadouro settlements, shows that in some coastal points the vegetation line moved inland by up to 200 m from 1958 to 2002 (Fig. 9.7).

Harbors, which are essential for socio-economic development, introduce severe perturbations in the littoral drift system by changing wave propagation through the construction of long breakwaters and by changing the sedimentary dynamics through the dredging of navigation channels. Thus, the effects of refraction, diffraction and reflection of waves are transformed; currents are created that carry sediments offshore to depths where waves are not able to bring them back to the beach and the littoral drift is interrupted. In addition, development activities (e.g. sand removal from beaches, sand retention, and channel dredging without repositioning down-drift) in harbours (Viana do Castelo, Leixões, Aveiro and Figueira da Foz) tend to aggravate erosion.

Coastal erosion and inappropriate urban development too near the foreshore have caused narrowing of the beaches. The weakening or destruction of dune systems inhibits their function of tightening the active beach profile by limiting the landward extension of wave wash, as well as their ability to protect low-lying areas of the coast. Several coastal defence interventions have been needed along the Portuguese northwest coast. In the last 3 years, the Portuguese government investment in coastal defence works has been about 35–40 million € (Oliveira 2010).

Table 9.1 Erosion rates of some stretches of the Portuguese northwest coast (Veloso-Gomes et al. 2006a)

		Ferreira and Dias (1991)		Veloso Gomes et al. (2002)	Hidrotécnica Portuguesa (1980) in Teixeira (1994)			Bettencourt and Ângelo (1992)		Ferreira and Dias (1992) and Ferreira (1993)				Teixeira (1994)	
		1958/ 1980	1980/ 1989	1996/ 2001	1947/ 1958	1958/ 1973	1973/ 1978	1900/ 1958	1958/ 1985	1947/ 1958	1958/ 1970	1970/ 1980	1980/ 1990	1947/ 1973	1973/ 1989
Strech	Beach	m/year													
Costa Nova – Vagueira	Aveiro	–	–	3.3	8.2	5.2	4.0	1.7	2.2	4.6	4.3	4.4	–	4.0	0.3
	Costa Nova	–	–	–	0.4	2.9	2.4	1.7	2.2	1.5	6.3	3.8	3.7	0.2	–
	North Costa Nova/North Vagueira	–	–	6.6	–	–	–	–	–	–	–	–	–	–	–
Vagueira-Mira Beach	Vagueira Seafront	3.0	3.3	7.1	0.4	2.9	2.4	–	–	0.1	1.6	2.4	3.9	0.2	–
	Labrego	0.7	3.3	6.7	–	–	–	–	–	–	–	–	–	–	–
	Areão	0.7	3.3	5.7	0.4	2.9	2.4	–	–	–	1.3	1.4	1.8	0.2	–

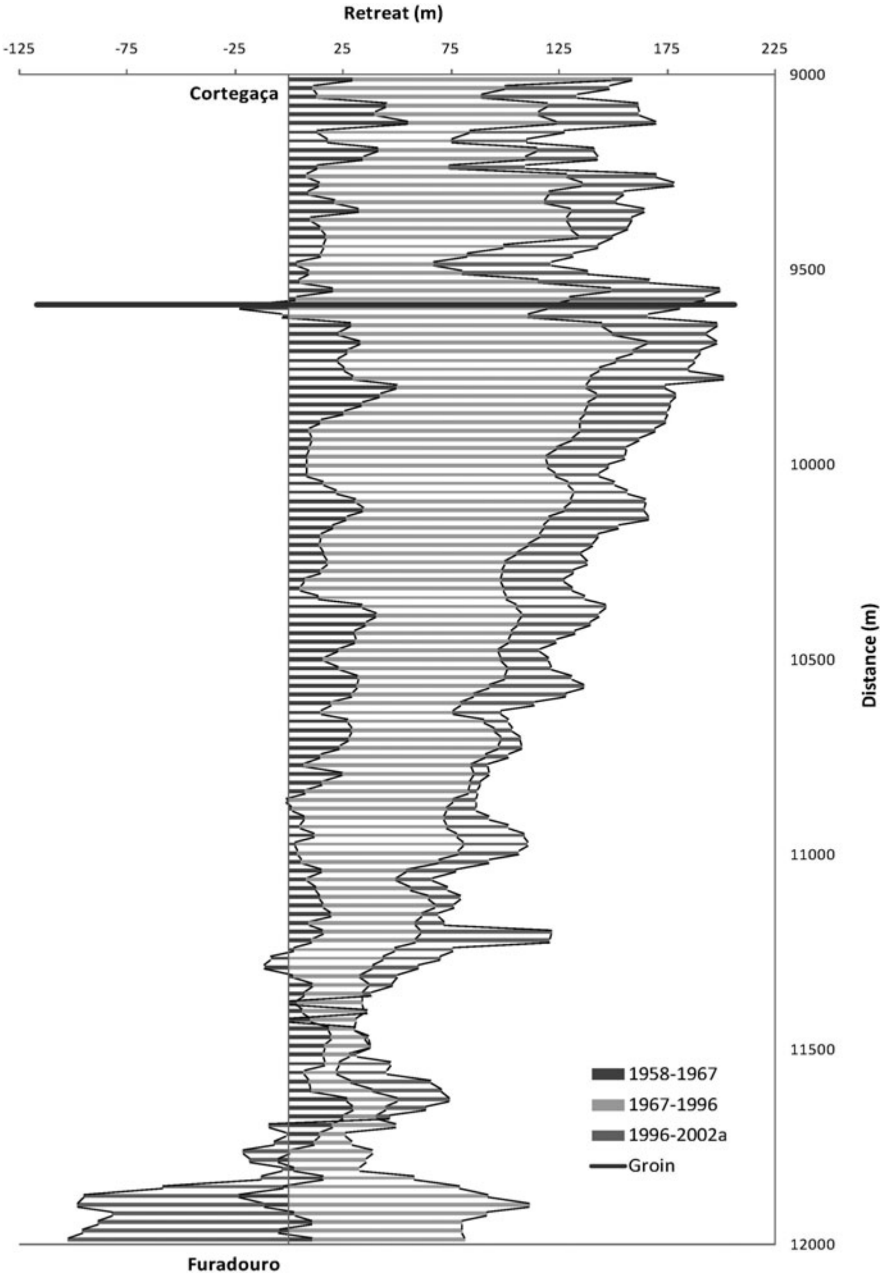

Fig. 9.7 Vegetation line retreat between Cortegaça and Furadouro (Pais-Barbosa 2007, Taveira-Pinto et al. 2009)

At the Portuguese northwest coast (Fig. 9.6) coastal erosion is mainly due to:

- the generalized sea level rise and other Climate Change effects,
- the misruled littoral occupation and use,
- the external works in harbours which result in perturbations to the littoral system,
- the reduction of sediments supply from natural sources with a cessation tendency.

Moreover the sediment supply reduction is considered as the main cause of the erosion problem felt in this coastal stretch (Silva et al. 2007).

9.3.2 River Sediment Supply Reduction

The river sediment supply reduction, estimated to ascend to 80% in Portugal (Fonseca 2002), may be the basic cause of the erosion process that has been affecting the Portuguese northwest coast. The reasons behind this reduction are mainly sand extraction in estuaries and along the river and dam construction (Fig. 9.8). In fact, sediments for the building industry are dredged from the river's bed in several places and in amounts beyond what would be sustainable (Veloso-Gomes et al. 2006b).

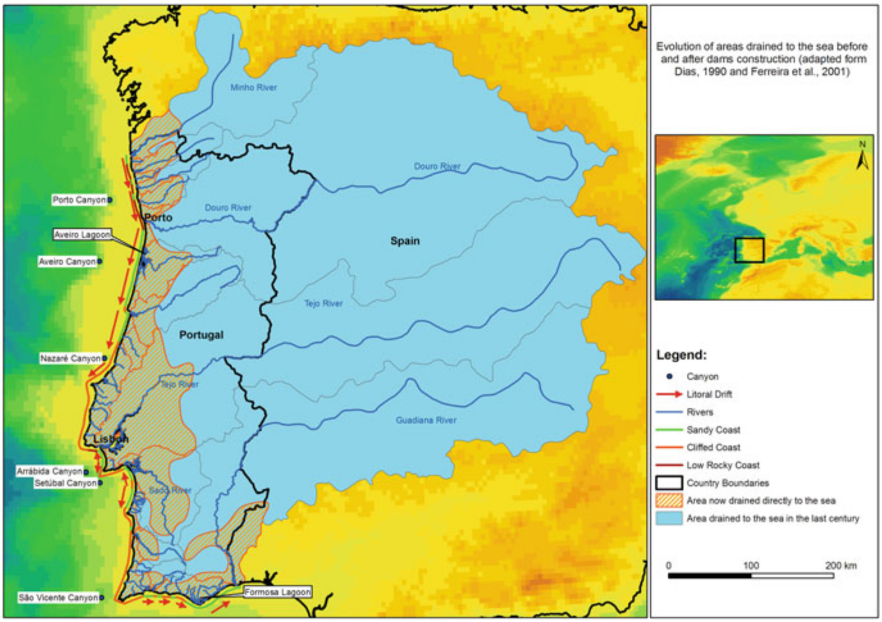

Fig. 9.8 Geological and littoral drift characteristics in the Portuguese coast. Evolution of areas drained to the sea without damming in the last century compared to the present (adapted from Veloso-Gomes et al. 2006a)

In 1930, previously to the construction of the dams the affluence of sediments from rivers to the Portuguese northwest coast was approximately 2 million m^3 yr^{-1}, with the Douro river assuring 90% of this value (National Water Plan 2002). Nowadays, as a result of the dams construction, this river only contributes with a small amount estimated in 0.25 million m^3 $year^{-1}$ (Fig. 9.8).

The dam construction induces sediment supply reduction in two ways: retention in reservoirs and changing the hydrological regime. Although dams are of extreme importance in the energy production sector, their construction triggers the upstream retention of a volume of sediments that otherwise would nourish coastal beaches. This way, dam construction contributes for the aggravation of the coastal erosion and for the reduction of the volume of water storage available for the regulation of the rivers.

9.3.3 Sediment Retention in Reservoirs

The construction of a dam modifies the sediment transport conditions (Fig. 9.9), typically representing a breach in the repetition of the usual sequence of erosion, transport and deposition, with the formation of deltas in the upstream border of the reservoir, silting of the mentioned border and causing erosion downstream of the restitution (Lysne et al. 2003).

In fact, when designing a reservoir it is mandatory to save some space for the sediments deposition, the dead volume, which is defined according to the river scheme of solids' transportation and to the probable working life of the structure (Lencastre and Franco 2006).

In the late 1960s and 1970s several evaluation campaigns where conducted for sediment transport and sedimentation in reservoirs in the main Portuguese

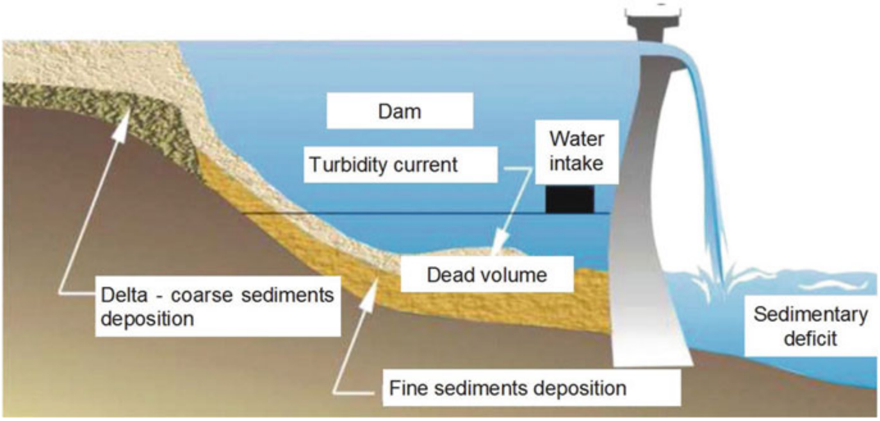

Fig. 9.9 Typical pattern of sediments' deposition in reservoirs (Taveira-Pinto and Lameiro 2010)

rivers (Douro, Mondego and Tagus), essentially to support the major hydraulic works then performed. A sedimentological monitoring network was established but subsequently, between 1990 and 1993, its maintenance was no longer justified.

In the National Water Plan (2002), the implementation of a sedimentological monitoring network is proposed, based on the historical network, but having the environmental concern as structuring motivation. Monitoring and supervision of sand extraction are also foreseen, through the conduction of bathymetric surveys, upstream and downstream of those sites, sediment transport measurements and bottom sediments grain size analysis. The main objectives of the proposed network are the assessment of sediments deposition in reservoirs, identification of deposition/erosion mechanisms and sediment transport characterization in water-courses. The proposed network is not yet operational.

9.3.4 Beach Nourishment with Sediments from Reservoirs

Taveira-Pinto and Lameiro (2010) have pointed the possibility of artificially nourish beaches with sediments deposited in dam's reservoirs. In a project of reuse of sediments from the reservoirs to nourish beaches some aspects must be considered, such as: the sediments availability in reservoirs, their extraction, treatment, transportation and a cost-benefit analysis of the process. Some of these aspects will be discussed in this section.

9.3.4.1 Sediments Availability in Portuguese Reservoirs

Due to the lack of information regarding sediment transport in Portugal, the amount of deposited sediments in Portuguese reservoirs remains unknown. Taveira-Pinto and Lameiro (2010) estimated the present level of sedimentation in 151 (out of 166) Portuguese reservoirs. As a basis for the evaluation, the authors used the National Water Institute's (INAG) inventory of the Portuguese dams, finding that in general they obey to the criteria of having more than 15 m high or having more than 1 million m^3 of total storage capacity. The values of current sedimentation in the reservoirs were estimated from the dead volumes, as they were defined in the project phase of the dam. The dead volume of the reservoir would correspond to the volume of sedimentation of the reservoir after 50 years or more of existence. This way for dams having more than 50 years the current volume of sedimentation was taken to be equal to their dead volume, whereas for under 50 years dams it was taken to be in proportion to its age. The authors found a global volume of current sedimentation of about 1.5 million m^3 and a total gross capacity for sedimentation of about 12.5 million m^3, representing 12.5% of the total gross capacity for water storage. Of the 151 dams about 66% have a volume of sedimentation below 10% of its gross capacity for sedimentation, 28% are between 10 and 50% and only 6% are above 50%.

Following a study in Spain (Sánchez 2008) the authors pre-selected 53 reservoirs of potential interest for a project of reuse of sediments for beach nourishment. The criteria for selection were the proximity to the shore and the current volume of sedimentation, in relation to the transportation of extracted sediments. These 53 reservoirs retain about 80% of the volume of current sedimentation in the 151 dams.

9.3.4.2 Sediments Treatment

The process of treatment of the sediments removed from reservoirs, in order to prepare them for its several purposes, may be divided in two different stages: grain size separation and decontamination.

Sediments layers on the bottom of the reservoirs are known as preferential for organic deposits and mineral materials placement, namely, nutrients, heavy metals and bacteria, considered in its whole as pollutants. This leads to the need of decontaminate the sediments to be used. The evaluation of the heavy metals concentration is of most importance, while the content in organic matter may actually be considered positive if the sand is to be applied to dune reconstruction, since it will contribute to vegetation development. It has been accepted that polluted particles are concentrated in the softer fraction of the sediments deposited in the reservoirs. Nevertheless, recent studies show that the metals don't establish themselves to a specific fraction of sediments (Pétavy et al. 2009). Therefore, it will be convenient to always check the need for decontamination through chemical analysis before proceeding to the transportation of the sediments to apply on the beaches. Within a project of reuse of sediments to artificial beach nourishment, the need for sand decontamination will result in high costs, which may actually lead to the impracticability of the project. Nevertheless, normally, this process of decontamination may be dismissed in what concerns the coarser fraction.

The sediments separation by grain size is usually obtained through sieving. For beach nourishment the required fraction corresponds to the sand fraction (with grain sizes between 0.063 and 2 mm). The sediments grain sizes shall be as close as possible to the typical sizes on the beach to nourish. Typical values for the median grain sizes of the sand in the Portuguese northwest coast beaches are between 0.35 and 0.6 mm (Silva et al. 2009). The beaches nourished with coarser sand will be more stable but with steeper profiles, possibly having implications in the comfort for beach users and beach safety level. Beaches nourished with finer sediments are potentially more unstable, with placed volumes tending to be sooner washed away by the sea.

9.4 Climate Change

Human utilization of the coastal zone has increased rapidly in the twentieth century and is likely to continue to increase in the twenty-first century (Nicholls et al. 2007). Therefore, negative impacts of Climate Change on the coastal zone are certain to have massive socio-economic impacts worldwide. Climate Change processes can result in variations in some or all of the environmental phenomena that govern coastal zone processes. According to Nicholls et al. (2007) the range of potential drivers of physical Climate Change impacts in coastal areas may be summarized as in Table 9.2.

Changes in all of these drivers are subject to regional variations. In most cases any impacts will be the result of the interaction between these Climate Change drivers and other drivers of change. Increases of extreme sea levels due to rises in mean sea level and/or changes in storm characteristics are of widespread concern. The future wave climate is uncertain, although extreme wave heights will increase in those areas, where more intense storms will occur (Meehl et al. 2007). Andrade et al. (2007) have presented an assessment of projected wave Climate Changes affecting the western coast of Portugal by the end of the twenty-first century. The authors suggest there will be invariable mean wave heights in the region, but a clockwise rotation of approximately 6° in the mean wave direction. Changes in runoff driven by changes to the hydrological cycle appear likely, but the uncertainties are large.

Of the many impacts identified in Table 9.2, the one impact that has received most attention to date is coastline recession due to sea level rise (SLR), while little or no attention has been given to the other potential Climate Change impacts on coastlines (Nicholls et al. 2007). One potentially major Climate Change impact on the coastline is the coastal response to Climate Change driven variations in the longshore sediment transport regime. These variations could either be permanent due to changes in the average offshore wave conditions (mainly wave height and direction), or intense and episodic due to changes in storm characteristics (mainly storm surge, wave height, period and direction). Climate Change driven permanent variations in gross or net spatial gradients in longshore sediment transport are likely to lead to slow, systematic coastal changes, particularly at medium to long term (Cowell et al. 2003). These coastal changes may include slow coastline recession/progradation (over and above that resulting from SLR), slow inlet migration, and

Table 9.2 Main climate drivers for coastal systems, their trends due to Climate Change and their main physical effects (Trend: ↑ increase; ? uncertain) (adapted from Nicholls et al. 2007)

Climate driver (Trend)	Main physical effects on coastal systems
Sea surface temperature (↑)	Increased stratification/changed circulation; reduced incidence of sea ice at higher latitudes
Sea level (↑)	Inundation, flood and storm damage; erosion; saltwater intrusion; rising water tables/impeded drainage; wetland loss (and change)
Storm intensity (↑)	Increased extreme water levels and wave heights; increased episodic erosion, storm damage, risk of flooding and defence failure
Storm frequency (?) Storm track (?)	Altered surges and storm waves and hence risk of storm damage and flooding
Wave climate (?)	Altered wave conditions, including swell; altered patterns of erosion and accretion; re-orientation of beach plan form
Run-off	Altered flood risk in coastal lowlands; altered water quality/salinity; altered fluvial sediment supply; altered circulation and nutrient supply

gradual realignment of embayed beaches. Climate Change driven ephemeral variations in longshore transport rates and/or spatial gradients of longshore sediment transport rates can lead to episodic yet irreversible medium scale coastal changes including severe dune erosion or complete destruction of dunes and sudden inlet relocation/closure.

Coelho et al. (2009) have highlighted the possibility that other Climate Change impacts may in fact override or mask coastline recession in the Portuguese northwest coast due to SLR alone. The authors have applied a coastal (shoreline evolution) numerical model to a stretch of the Portuguese coast to determine the effects of various scenarios of wave action and SLR that might result from Climate Change over the next 25 years. They conclude that the effects of SLR might be less important than changes in wave action.

9.5 Concluding Remarks

The Portuguese northwest coast suffers from a continued high sedimentary deficit. Contributing to the problem, on the one hand are the dynamic nature of coastal zones and Climate Change, and on the other are the anthropogenic influences. To deal with the problem in an effective manner an adequate understanding of these causes is needed. However, expedient knowledge of coastal zones dynamics is limited, the effects of Climate Change over coastal zones are identified in a context of great uncertainty, and the effects of human interventions have not been systematically monitored.

Attention is called to the fact that of the many impacts of Climate Change identified in coastal areas, the one that has received most attention to date is coastline recession due to sea level rise, while little or no attention has been given to other potential Climate Change impacts on coastlines. One potentially major Climate Change impact on the coastline is the coastal response to Climate Change driven variations in the longshore sediment transport regime.

Nevertheless, although the causes are not clearly identified and understood, it is increasingly clear that people and assets in some littoral urban fronts are endangered and that serious damage and high costs should be expected. The situation calls for measures to be taken.

One feasible and sustainable solution to the erosion problem would be artificial sand nourishment. For this solution, however, in the Portuguese west coast, the amounts of sediments needed are enormous. The present strategy holds on the construction and maintenance of coastal defense structures to protect urban fronts and the passive acceptance of erosion in intermediate stretches.

In this article some ideas were raised, namely the need for a sediment management strategy, that could represent a major economical plus to the country. The current investment in the revitalization of the sedimentological networks in rivers could constitute an excellent opportunity for its implementation. The possibility of reusing sediments from Portuguese reservoirs to nourish beaches is pointed as an option.

This option may be extended to other coastal zones, which are in general less energetic, requiring lower sediments volumes for beach nourishment. For its implementation, sediment availability in reservoirs from which transportation is feasible is essential.

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Part III
Changes and Spatial Planning

Chapter 10
A Spatial Development Strategy for Climate Change – The Western Pomerania Example

Roland Wenk and Holger Janßen

Abstract The Regional Planning Association Western Pomerania conducts the research project 'Spatial Development Strategy for Climate Change in the Planning Region Western Pomerania'. This project is part of the action program 'Demonstration Projects of Spatial Planning' (MORO) of the German Federal Ministry of Transport, Building and Urban Affairs. The Strategy aims at a combination of adaptation measures and measures for climate protection, which can be effectively communicated to the public. Five fields of action that are geared towards the most important spatial factors and that are discussed by experts and other stakeholders ensure an integrated Adaptation Strategy. The fields of action 'biodiversity', 'agriculture, forestry and fishery', 'water management and water cycle', and 'settlement and urban development, mobility, tourism, power generation and energy distribution' build on one another and show a number of interactions. The fifth field of action addresses the regional measures for climate adaptation. Upon project completion in 2011, a coherent Strategy for regional development will be presented. The Strategy will also address the parameters precipitation and temperature and the indicator rise in sea level, which are influenced by Climate Change. The Strategy contains the planning direction in terms of protection of regional biodiversity, adaptation of agriculture and forestry, protection of ground- and drinking water, settlement and urban development and tourism as well as new mobility and power generation concepts. Measures for climate protection that offer development opportunities for local authorities, industry and private enterprise receive a supporting regional context. The Spatial Development Strategy will be politically binding by way of the resolutions of the Regional Planning Association Western Pomerania and will direct regional planning in the coming years.

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10.1 Introduction

For regional planning at federal level, demonstration projects are an important instrument for the implementation of plans. They are based on an understanding of planning and politics that is process-, action- and project-orientated. With the action program 'Demonstration Projects of Spatial Planning' (MORO) the Federal Ministry of Transport, Building and Urban Affairs (BMVBS) supports practical trials and the implementation of innovative regional planning approaches and instruments.

In 2008, Germany adopted the 'German Adaptation Strategy to Climate Change', which is to be followed by the 'Action Plan on Adaptation' in 2011. Within the Adaptation Strategy spatial planning was assigned a coordinating role in terms of the sustainable development of settlement-, transport- and open space structures, the protection of natural resources, as well as the identification of suitable actions. To achieve these objectives, a meaningful combination of mitigation and adaptation strategies, closely linked to the various departmental policy sectors, is viewed as an appropriate course of action. Within the demonstration project 'Spatial Development Strategies on Climate Change' ('KlimaMoro') regional strategies on climate protection and adaptation to Climate Change will be developed in eight German regions (Fig. 10.1) in an integrated and sector-specific manner. In 2009, the Regional Planning Association Western Pomerania (RPV VP), within the context of a nationwide competition initiated by the Federal Ministry for Transport, Building and Urban Affairs, successfully applied to take part in the demonstration project 'Spatial Development Strategies on Climate Change'.

The regional demonstration project is run by the Regional Planning Association Western Pomerania (RPV VP) with its rural districts Rügen, Nordvorpommern, Ostvorpommern and Uecker-Randow, and the Hanseatic Cities of Stralsund and Greifswald. Other important stakeholders and experts come from the towns and municipalities within the planning region, the University of Greifswald, the University of Applied Sciences in Stralsund, the Chambers of Commerce in Neubrandenburg and Rostock, the Western Pomerania Tourist Board, the Island Usedom Tourism Association, the Farmers Unions, the large conservation areas, the Leibniz Institute for Baltic Sea Research Warnemünde, the State Offices for the Environment and Nature Ueckermünde and Stralsund, the regional Offices for Agriculture and the regional forestry authorities. For implementation purposes, the RPV VP set up a standing 'Working Group Climate Change'. The working group meets regularly and discusses the strategic direction for the individual areas of action within the context of the overall Strategy. The working group has an advisory role for the RPV VP and prepares politically relevant documents in collaboration with the RPV VP head office.

The innovative approach of the Spatial Development Strategy is reflected in the linking of projected impacts of Climate Change with formal and informal measures of spatial planning.

It is the objective to identify an efficient transformation method which allows the transfer of the research findings with regard to Climate Change to spatial planning

Data: Continuous spatial monitoring by BBR
Geometric data: BKG, counties, 12/13/2007

Fig. 10.1 Eight model regions ‘spatial development strategies on climate change’

and policy making. The incremental deduction of climate scenarios right through to specific measures does not only allow the setting up of regular monitoring cycles, but also a step by step re-evaluation of initial approaches and the use of data that has been updated in the meantime. The methodological orientation of the approach is based on the chronological sequence of preparing regional climate scenarios, assessing the impacts of Climate Change for the region, ascertaining the resulting strategic orientation of spatial development policy and identifying first measures for the sectoral fields of action (Hilpert K, Mannke F, Schmidt-Thomé Ph 2006). The definition and differentiation of individual fields of action are guided by regional planning regulations, which are constitutive and climate sensitive in the interest of sustainable regional development.

10.2 Regional Description

Western Pomerania is Germany's northernmost planning region, on the border to Poland and in vicinity of the Baltic States. In four rural districts (Nordvorpommern, Ostvorpommern, Rügen and Uecker-Randow) and two independent cities (Greifswald and Stralsund) live 467,516 inhabitants (30/06/2009) in an area of 6,775 km^2 (RPV 2010). The municipal structure is, in parts, fragmented. Population density is low at ca. 70 inhabitants per km^2, and can be under 20 inhabitants per km^2 in areas distant from the coast. The spatial structure is characterized by the coastal and Bodden[1] landscape, and the agricultural hinterland.

Tourism is the most important economic sector in the coastal region. More than half of the accommodation capacity of the whole of the Land Mecklenburg-Western Pomerania is located within Western Pomerania, which results in 55% of yearly overnight stays spent here. Looking into the future, tourism will remain an important pillar of economic development within the region. This is facilitated by a stronger emphasis on wellness and health tourism, and by the opening of new markets, e.g. nature tourism.

Plasma physics, biotechnology, energy technologies and health sciences have the potential, through innovation, to bring about regional structural change. The maritime industries including shipbuilding, fishing, shipping and port industries, medical and environmental technology, as well as agriculture and food industries will remain important sectors of the local economy. The services sector generates the bulk of the economic output of the region, and employs ca. 75% of the workforce that is liable to statutory social insurance.

The landscape of the region is characterized by a diverse coastline with cliffs, beaches, islands, peninsulas, coves, Bodden and lagoons. The distinctive feature of this coastline is its extraordinary length of ca. 1,450 km with an area of ca. 356 km^2 in danger of flooding at 0.50 m above sea level (LM MV 2009). In the southern Baltic region, the interplay of peninsulas and coves, lowlands and hills, sandy beaches and cliffs is of unique scenic diversity. Especially noteworthy are the large-scale salt marshes and brackish water reedbeds. The eminent ecological value of Western Pomerania is reflected in the scale of protection afforded to critical areas.

The registered Areas under the Habitat Directive within the planning region Western Pomerania cover an area of ca. 2,400 km^2 (March 2008), the Areas under the European Bird Directive an area of ca. 5,000 km^2. A large scale federal nature conservation project in the Peene valley, undertaken within the last few years, ensured the protection of northern Germany's largest still unspoilt lowland river,

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[1] The regional term 'Bodden' refers to bays of the Baltic Sea.

including its associated fen (ZP 2009). Beside the remarkable coastal landscape the fens and river valleys contribute to water conservation within the ecosystem and the capture of CO_2 emissions (LM MV 2009). In Western Pomerania, an area of 17% (1,145 km^2) is covered by wetlands.

10.3 Regional Climate Change Scenarios and Consequences

Within the planning region, a noticeable drop in precipitation is expected, besides the general rise in temperature (MW MV 2008). It is further anticipated that the sea level will rise by 20–30 cm until the end of the century (Schmidt-Thomé 2006). The erosion of the shoreline will accelerate (at present on average ca. 35 cm $year^{-1}$) (MW MV 2008). The rise in surface water temperature of the Baltic Sea by 2–4°C will lead to a decrease in sea ice, the deterioration of water quality and a change in salinity.

A particular vulnerability of the region results from the unique natural assets of the coastline (Säwert 2010). The coastal landscape formed by Bodden and lagoons is unequally more vulnerable in terms of expected rise in sea level and more frequent and potentially more severe storm surges than other coastal regions of the North and Baltic Seas. A large scale protection through dikes and other measures within the hinterland appears unrealistic (LU MV 2009).

The inherited natural and cultural landscape is particularly affected by the rising sea level and the intensification of wind and water effects on flat coasts. Regional centers such as Stralsund and Greifswald, medium- and small-sized towns such as Ueckermünde, Barth and Anklam are especially vulnerable due to their low location in immediate vicinity to the sea and have to adapt their settlement and urban development strategies to the altered conditions in the medium term.

On cliff coasts, an increasing number of landslides are currently being recorded. These can have serious implications for affected settlements and urban areas, as became evident in Lohme on the island of Rügen in spring 2005. Whether Climate Change is the cause for increasing cliff erosion is still uncertain.

The projected rise in temperature will result in rising temperature of coastal waters, which may cause a deterioration of water quality. It is expected that the range of species as well as the feeding and reproduction behaviour of various species (e.g. cod, cyanobacteria and jellyfish) will be altered due to consequential changes in oxygen levels. This could result in a considerable damage to the regional tourism industry. In particular the water quality will influence whether the existing and newly developed tourism products are taken to or rejected by the tourists.

Furthermore, a considerable decrease in precipitation during the summer months in the hinterland area is expected, which cannot be compensated by an increase in winter precipitation. In terms of agriculture, summer droughts and heat damage can lead to yield losses or necessitate significant adaptation measures.

Changes in temperature and ecological water cycle cause a change in the species composition, genetic diversity and the structure of ecosystems. Safeguarding the regional biodiversity will become increasingly difficult. Species in wetlands (fens, wetland forests and wet grassland) and coastal regions (salt marshes) are affected in particular.

Regional Requirement for a Spatial Development Strategy: In an initial study by the BBSR the planning region Western Pomerania is viewed as relatively resistant towards the effects of Climate Change. However, in the RPV VP application it became clear that Climate Change and its impacts bear considerable risks for the regional development of Western Pomerania due to its demographic and economic situation. While a number of investigations identified economic opportunities, in particular for tourism and the maritime industries, the works necessary to tackle Climate Change and the measures for climate protection are likely to require significant investment by public and private sectors, which are in comparison to other regions in Germany of more limited capacity. To be able to better plan and coordinate the necessary restructuring, it is prudent to embed all important measures within a strategic spatial framework.

Preliminary Achievements: The RPV VP is dealing with the consequences of Climate Change and measures for climate protection at the latest since 2003 and after that with increasing intensity (Erben 2004, see also Fig. 10.2). A regional analysis of development potentials for agriculture delivered first points of reference. Within the analysis the dependency of agriculture on key climate indicators as well as the exploitation of renewable energies were assessed. In the following years

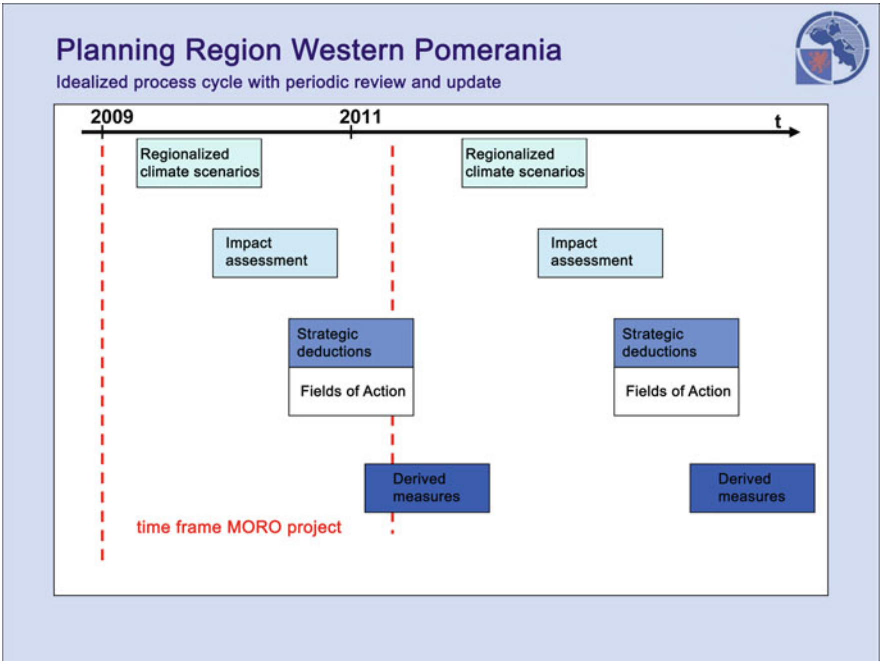


Fig. 10.2 Sequence of process and methodology

regional climate protection measures and municipal climate protection concepts for the independent cities and rural districts came more into focus. Increasingly, spatial planning dealt with problems that necessitate a number of adjustments due to rising sea levels at the southern Baltic Sea coast. The awareness of the apparent risks has noticeably grown in the meantime and resulted in an intensive search for possibilities of how to respond. At the same time, the development of regional opportunities to generate renewable energies was advanced further. In particular, on-shore and off-shore wind power generation, biogas generation and timber production have performed well, or even, in parts, have reached the limits of spatial compatibility.

Further previous strategic achievements are the continued restoration of fens since the end of the Nineties (UM MV 2000) and the strengthening of the central places system as a basis for an effective and climate sensitive transportation network.

Current Gaps in Knowledge: The most obvious and hindering gaps in knowledge for the development of a regional Spatial Development Strategy lie within the still uncertain transformation of climate development scenarios into sufficiently reliable forecasts. This pertains to the most important climate indicators for Western Pomerania, temperature pattern, distribution of precipitation, and in particular the rising sea level. The existing uncertainties not only have a direct influence on the content of the Spatial Development Strategy, but also on the process of drawing up the Strategy. In addition, they can compromise the political enforceability of such a Strategy.

10.4 General Objectives and Thematic Scope of the Regional Spatial Development Strategy

The main objectives of the Spatial Development Strategy are to distill the necessary adaptation measures in the context of the particular regional vulnerability and to design effective and applicable climate adaptation measures. Because of the complexity of Climate Change these measures will be drawn up in an informal planning process with participation of a wide range of experts and other stakeholders.

With respect to mitigation, the following issues can play a considerable role for Western Pomerania:

- Innovative and energy efficient settlement, transport, power generation, and energy supply structures
- Integrated municipal climate protection concepts (HGW 2009)
- Exploitation of wind energy (on-shore and off-shore)
- Wetland restoration (including tidal marshland), afforestation, forest conversion
- Sustainable land use practice in connection with regional economic cycles, preservation of permanent grassland

In comparison to other regions in Germany, especially the wetlands of Western Pomerania provide ample opportunities for climate mitigation. Owing to the fact that the wetlands in Western Pomerania cover an area of 17% of the total area in comparison to 5% national average, effective climate protection measures are possible with sustainable wetland conservation alone. Also the potential for afforestation by ca. 12–18% on average is remarkable.

The adaptation to the expected Climate Change needs to address the following issues in particular:

- Tackling rising sea levels at flat coasts.
- Steering the settlement and urban development at cliff coasts.
- Adjusting agriculture to the altered climatic conditions.
- Strengthening of forests as climatic sanctuaries and compensatory spaces with multi-functional effects.
- Developing the potentials to extend settlements and urban areas within the coastal region commensurate with the requirements of biodiversity and coastal protection.
- Exploiting regional opportunities for renewable energy generation in the interest of strengthening the labour market.

Mitigation and adaptation measures can be regionally structured through spatial planning. It is thus possible to co-ordinate the development of settlements and urban areas, open spaces and technical infrastructure systems within an interdisciplinary and intra-communal context. Spatial planning as an interdisciplinary and supra-local discipline has the task of weighting all spatially relevant matters and interests within a central steering and coordinating function. To this end, formal and informal planning and communication tools are required. Especially on regional level, spatial planning has appropriate tools for the development of effective adaptation measures at its disposal.

It is evident that tackling Climate Change and climate protection is a holistic planning task (Ritter 2007). In many fields of action within regional planning the issues of climate protection and the adaptation to Climate Change emerge as catalysts for new spatially relevant developments. In the course of this, the Spatial Development Strategy for Western Pomerania at first focuses on the key fields of action.

To continue the process and to set the terms for regional planning it was necessary to identify indicators and how they change over time. The following are viewed as suitable indicators: temperature, precipitation, wind, cloud coverage, humidity and changes in sea level. In terms of temperature, precipitation, wind, cloud coverage and humidity the initial values are derived from the reference period 1971–2000. The baseline for the mean water level of the sea level is taken from the latest topographical map scale 1:100 000 (TK 100) published by the Ordnance Survey Mecklenburg-Western Pomerania.

The following Table 10.1 summarizes the configuration and sources of the forecast values in terms of the chosen indicators.

The regionally important issues have been summarized into fields of action that show a causal interrelation to climate mitigation and adaptation measures. Five areas have been identified as fields of action:

Table 10.1 Climate change indicators and their projected values

Indicators	Forecast value	Time horizon	Data source
Sea level	+ 50 cm	2100	State offices for the environment and nature Ueckermünde and Stralsund (StAUN) Rostock
Temperature	(possible average change in °C) Spring + 2,3°C Summer + 3,1°C Autumn + 3,1°C Winter + 3,5°C per annum + 3°C	Reference period 2071–2100	German weather service (DWD)/climatolgical atlas for Northern Germany
Summer days	Yearly average number Possible average change +16,8 days	Reference period 2071–2100	DWD/climatological atlas for Northern Germany
Hot days	Yearly average number Possible average change +5,8 days	Reference period 2071–2100	DWD/climatological atlas for Northern Germany
Precipitation	(Average sum in mm) Spring: possible average change +9% (max. change −5 to +25%) Summer: possible average change −17% (max. change −50 to +10%) Autumn: possible average change+14% (max. change −25 to +20%) Winter: possible average change+30% (max. change +5 to +35%) Per annum: possible average change+ 7% (max. change −15 to +15%)	Reference period 2071–2100	DWD (maximum values) Climatological atlas for Northern Germany (mean values)

Table 10.1 (continued)

Indicators	Forecast value	Time horizon	Data source
Days with precipitation	Yearly average number days with min. 1 mm Possible average change −3 days Yearly average number days with min. 10 mm Possible average change −3 days	Reference period 2071–2100	Climatological atlas for Northern Germany
Days with snowfall	Yearly average number days with min. 1 cm: –3,1	Reference period 2071–2100	Climatological atlas for Northern Germany
Days with maximum temperature < 0°C	Yearly average number: –15,6	Reference period 2071–2100	Climatological atlas for Northern Germany
Days with minimum temperature < 0°C	Yearly average number: –34,5	Reference period 2071–2100	Climatological atlas for Northern Germany
Hours of sunshine	Average sum in hours for seasons and per annum	Forecast not yet available	–
Cloud coverage	Average sum for seasons and per annum (in eighth)	Forecast not yet available	–
Tropical nights	Yearly average number: + 8,9	Reference period 2071–2100	Climatological atlas for Northern Germany
Snow	Yearly average possible average change −82%	Reference period 2071–2100	Climatological atlas for Northern Germany
Climatological water balance	–	Forecast not yet available	–

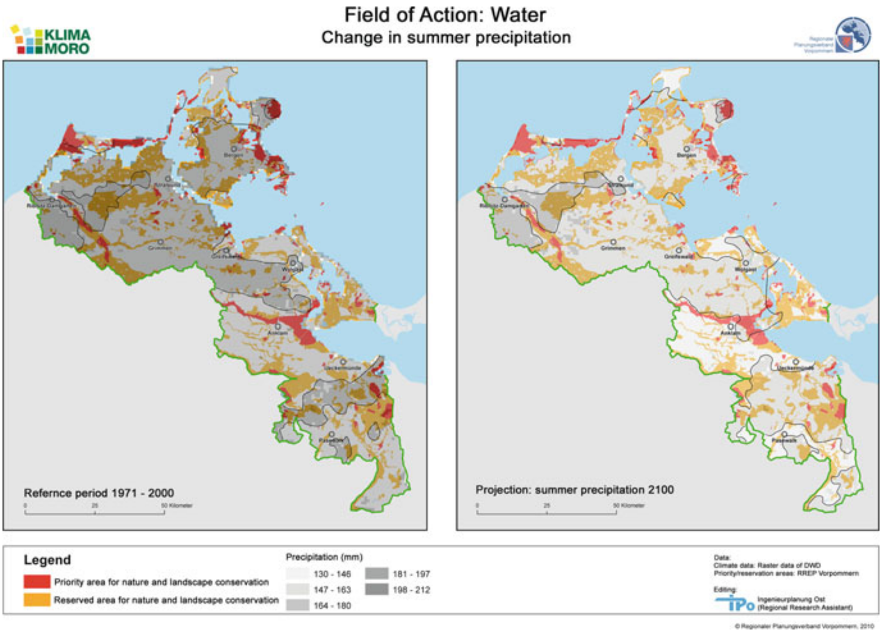


Fig. 10.3 Example for projecting forecast values onto the planning region

- Biodiversity and nature conservation (Fig. 10.3)
- Agriculture, forestry and fishery
- Water management and water cycle
- Settlement and urban development, mobility, tourism
- Energy and climate protection

The following sections present the strategic spatial approaches in relation to the three fields of action 'biodiversity', 'agriculture and forestry' and 'water management', which have been developed in the planning process until so far. Initially, the key development tendencies are identified in order to be able to determine the strategic direction, to illustrate the interactions with other fields of action and to highlight the respective contribution to climate protection.

10.5 Strategic Spatial Approaches for Protecting Regional Biodiversity

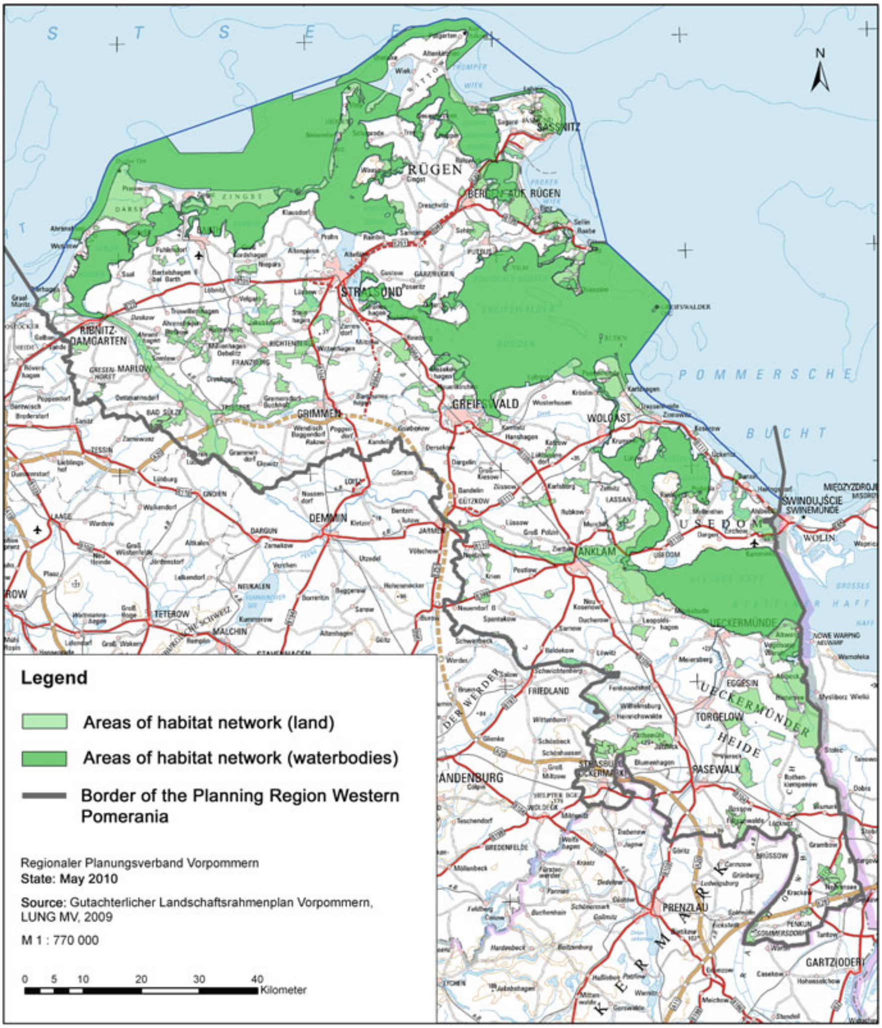
10.5.1 Adaptation to Climate Change

The following interrelations can be discerned as key development tendencies:

Habitat network: From a nature conservation point of view the conservation and expansion of the regional habitat network has priority. A coherent network of the ecologically most important habitats is capable of performing protection functions in terms of species preservation, the regional spectrum of species and the most important habitats (Fig. 10.4).

Coastal waters, fens, forests: Coastal waters, fens and forests are and will remain the most important large-scale elements within the regional habitat network. Their contribution to biodiversity is complemented by lakes, smaller waters, salt marshland and other types of habitats.

Continuous differentiated spatial modifications in the distribution of animal and plant species are also triggered by Climate Change. A defined habitat network is



Regionaler Planungsverband Vorpommern
State: May 2010

Source: Gutachterlicher Landschaftsrahmenplan Vorpommern, LUNG MV, 2009

M 1 : 770 000

Fig. 10.4 Regional habitat network

a relatively static planning tool for the safeguarding of sites and it is therefore not possible to meet these changes in species distribution in full.

The consequences of the anthropogenic changes in land use patterns within the landscape are considerably more significant than the effects of Climate Change. The summation of both effects can lead to significant negative impacts on the regional biodiversity.

10.5.2 Strategic Orientation of Spatial Planning to Protect Regional Biodiversity

Stabilize system of conservation areas: The existing conservation areas are the backbone of the habitat network. They are to be preserved and expanded in a spatially sensitive manner.

Speed up the habitat network planning process: Based on a systematic monitoring of endangered species and habitats the planning process with regard to the habitat network needs to be adapted to the requirements of biodiversity by shortening planning intervals.

Activate management: In order to actively influence the ecological conditions necessary for safeguarding biodiversity the management of conservation areas and species or habitats worthy of protection has to be enhanced.

Differentiate land use pattern: The change in land use patterns within the landscape has to be accompanied by the development of multifaceted use patterns. Large-scale monotonous industrial land uses do not offer sufficient conservation opportunities for regionally distributed species, which have manifold requirements. It is therefore necessary to create spaces with a tiered intensity of use through to zones without an ascribed land use. Extensification remains one of the main pillars for protecting regional biodiversity.

Strengthen compensation: The consequences of industrialization, technical infrastructures and the exploitation of renewable energies that are disadvantageous for biodiversity, have to be remedied by effective compensation measures. Above all, effective compensation can be ensured by developing the conservation area system, managing species and habitats, as well as by an extensive and differentiated land use pattern.

10.5.3 Interactions with Other Fields of Action

Water management: Coastal waters, lakes, flowing waters, smaller waters and wetlands belong to the most important elements of the regional habitat network. Their performance is influenced by chemical and ecological parameters of the water body. The implementation of the European Water Framework Directive in its entirety therefore renders indispensable services for maintaining the functions of the regional habitat network.

The protection of drinking water and groundwater resources is mainly supported by measures of extensifying land uses. Measures for the protection of biodiversity and for the protection of water resources therefore have to be geared towards supporting each other.

Coastal protection: In terms of safeguarding and improving biodiversity it would be advantageous to direct coastal protection measures exclusively towards the protection of settlements and urban areas. This approach however does not take regard to important and valid aspects in terms of the cultural landscape and settlement history.

In order to restore tidal flood marshes and other coastal areas, measures of embankment and flood management should receive high priority. In the process, it needs to be taken into consideration that rising sea levels can lead to sea water encroaching on private property, buildings, industrial plants or other assets and therefore to interference with their proper use and even to their economical devaluation. Coastal protection measures are therefore in continuous need of a meticulous weighting of aspects of biodiversity and economic effects.

Agriculture: A land use pattern that is sensitive to the location and responsive to Climate Change can facilitate a wide range of measures of landscape development that can be advantageous for regional biodiversity. Such measures predominantly include improvements to the water cycle, reduction of run-off and groundwater recharge as well as cultivation of timber outside of forests (‘Flurholz’)[2] for improving the local climatic conditions.

The expansion of extensive and wide ranging land use forms such as ecological farming, biomass production on grassland, sensitive wetland exploitation and pasture grazing with livestock and game can deliver important contributions to biodiversity. Particular attention should be afforded to biomass production for energy purposes. In this regard it is necessary for agricultural policy to develop control mechanisms to counteract an imbalanced and not sustainable land use pattern.

10.5.4 Qualitative Contributions of a Durably Safeguarded Biodiversity to Climate Protection

The contribution of *forest development*: A species rich and extensively utilized forest with high biodiversity is alongside fully functional wetlands the ecosystem in the planning region Western Pomerania with the best carbon dioxide binding performance.

By retaining water within the landscape and mesoclimatic compensation effects, the forests and afforestation serve important functions of buffering negative impacts of Climate Change. Furthermore, forests are an indispensable source of renewable resources, which can substitute fossil fuels.

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[2] Along roads, water courses, in urban parks, nature conservation areas etc.

The contribution of *fen restoration*: The implementation of the Fen Protection Program ('Moorschutzkonzept Mecklenburg-Vorpommern') is of significant importance in particular for Western Pomerania due to its extensive fen areas. By restoring fens important contributions are made in terms of binding greenhouse gases. Restored and extensively utilized fens are an important pillar of regional biodiversity (BM MV 1998). Because of these reasons it is necessary to further implement the Fen Protection Program.

10.6 Strategic Spatial Approaches for Protecting Agriculture, Forestry and Fishery

10.6.1 Adaptation to Climate Change

Identification of key development tendencies:

Site competition: The regionally utilized area for agriculture is continuously diminishing. This is due to agricultural land being converted to competing land uses. Economically more attractive and through legal regulations reinforced land uses lead to the continued loss of agricultural land (RPV 2003).

Profit orientation: An imbalanced orientation solely towards financial gain has a detrimental effect on the services agriculture should deliver in terms of public goods.

Internal competition: Agriculture and forestry are in an internal competition over suitable sites in particular with regard to the objective to further afforestation.

Innovative sectoral planning: The regional objectives of the agricultural and forestry sectors have to be better represented and justified. This can for instance promote their public perception as promising economic sectors.

Renewable energy: The exploitable potentials of agricultural production and land use in terms of renewable energies are to date inadequately realized. When increasing their exploitation spatial and environmental policy framework conditions need to be considered.

In order to support freshwater and in-shore fishing by means of spatial planning instruments, priority and reservation areas for fishery ('Vorrang- und Vorbehaltsgebiete Fischerei') can be considered. In terms of inland areas this issue is dealt with by regulations within the Regional Spatial Development Programme for Western Pomerania ('Regionaler Raumentwicklungsplan für Vorpommern', RREP VP 2010) (RPV 2010). For coastal waters and in terms of the Exclusive Economic Zone (EEZ)[3] further efforts are required, to spatially secure the important areas for fishery.

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[3] According to UN law an exclusive economic zone (EEZ) is a sea zone over which a state has special rights over the exploration and use of marine resources.

10.6.2 Strategic Orientation of Spatial Planning Towards Protecting Agriculture and Forestry

Preserve agricultural land: The agricultural land is the production basis of regional agriculture (Fig. 10.5).

Land loss has to be resisted and if need be compensated. The function of priority and reservation areas for agriculture (‘Vorrang- und Vorbehaltsgebiete Landwirtschaft’) has to be further developed.

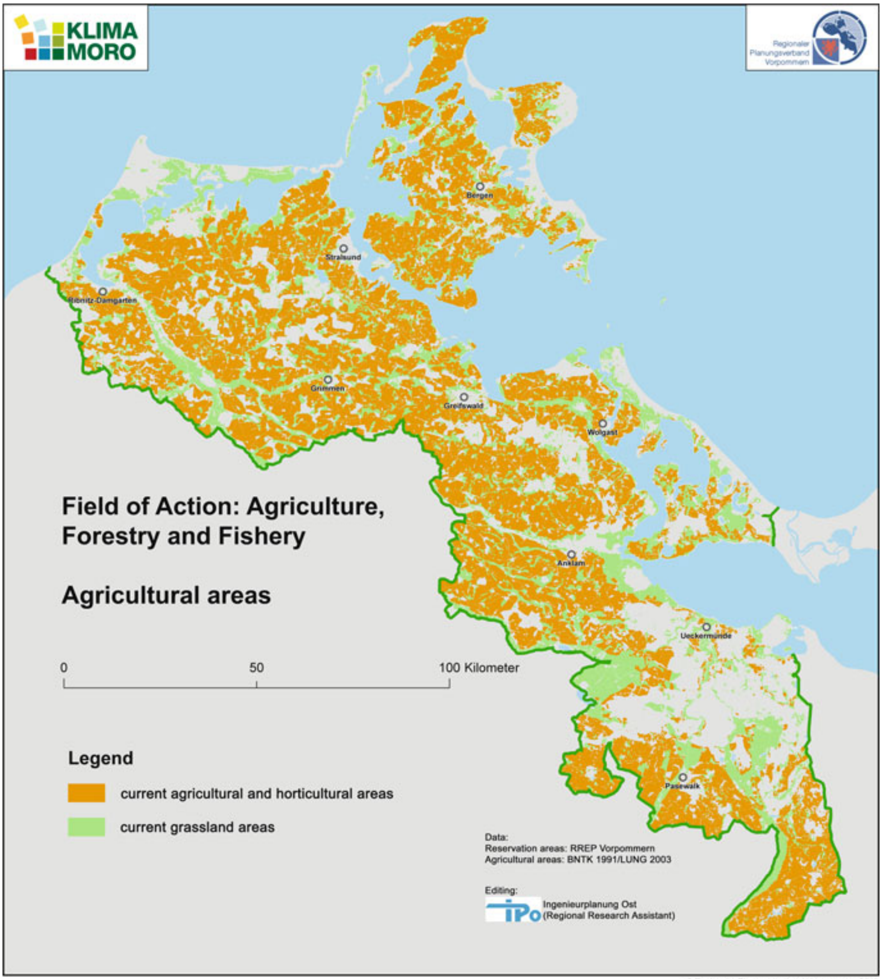

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Fig. 10.5 Agricultural areas

Use sustainably: The contributions of agriculture and forestry to the protection of drinking and groundwater, biodiversity, the ecological water cycle, air pollution control, climate protection and coastal protection have to be strengthened. A durable protection of natural resources has to be ensured by a land use practice that is sensitive to the location.

Generate synergies: Climate change will result in site characteristics being altered. Site competition between agriculture and forestry has to be resolved by applying sectoral planning tools in such a manner, that sustainable land management remains possible. It is the objective to further afforestation.

Utilize regional energies: The regional potentials of agriculture and forestry to generate renewable energy sources have to be activated for the benefit of economic development and climate protection. This process is to be supported by a regional concept for utilizing renewable energies.

10.6.3 Interactions with Other Important Fields of Action

Coastal protection: The Coastal Protection Strategy of Mecklenburg-Western Pomerania cannot, at present, ensure the protection of agricultural and forestry land. It is therefore necessary to regionally assess those areas affected by a rising sea level and to develop relocation strategies in order to identify alternative sites for the purpose of their change of use.

Biodiversity: A land use practice that is sensitive to the location can, in the context of Climate Change, facilitate the delivery of various measures of landscape development that can also be advantageous for regional biodiversity. Such measures include, above all, amelioration of the water cycle, reduction in run-off, groundwater recharge as well as the cultivation of timber outside of forests (‘Flurholz’) and the afforestation for the purpose of improving the local climatic conditions.

The expansion of extensive and wide ranging land use forms such as ecological farming, biomass production on grassland, sensitive wetland exploitation and pasture grazing with livestock and game can make important contributions to biodiversity. Particular attention should be afforded to biomass production for energy purposes. In this regard it is necessary for agricultural policy to develop control mechanisms to counteract an imbalanced and not sustainable land use pattern.

Settlement and urban development: Settlement and urban development and land consumption have to take account of the increasing importance of agricultural and forestry areas. The land consumption for urban areas and technical infrastructures as well as the increase in impervious surface coverage has to be reduced considerably. Urban and regional land use planning has to focus to an even larger degree on the inner development of settlements and urban areas in order to maintain regional open spaces. Suitable urban planning tools such as land recycling or landscape planning have to be applied rigorously.

10.6.4 Qualitative Contributions of a Durably Protected Agriculture and Forestry to Climate Protection

The contribution of *agriculture*: The orientation towards a modern agriculture offers numerous opportunities to actively contribute to climate protection. In this regard, the regional potentials for the generation of renewable energies take preference. Their contribution in replacing fossil fuels and thereby in reducing carbon dioxide emissions has to be expanded significantly (MW MV 2010). To utilize these potentials and ensure a spatially and environmentally sensitive exploitation sectoral concepts at regional and municipal level are needed.

The contribution of *forestry and afforestation*: forests and sustainable forest exploitation make important contributions to absorbing carbon dioxide from the atmosphere. Above and beyond, forests are an irreplaceable source of renewable energy resources, which facilitate the substitution of fossil fuels.

The contribution of sensitive *wetland exploitation*: An agricultural land use practice that is sensitive to the location ensures the conservation of fens and their multiple functions within the ecosystem. They make important contributions to binding greenhouse gases.

The contribution of an enhanced *water cycle*: The implementation of the European Water Framework Directive and the continued restoration of polluted water bodies are prerequisites for the preservation and improvement of forest ecosystems, wetlands and surface water bodies. The retention and storage of precipitation within the landscape is therefore in direct functional correlation to the most important carbon sinks imprinting on the landscape.

10.7 Strategic Spatial Approaches to Securing the Ecological Water Cycle

10.7.1 Adaptation to Climate Change

The projected considerable reduction in summer precipitation necessitates retaining winter precipitation within the landscape as long as possible. In particular the flowing waters of Recknitz, Peene, Trebel, Uecker, Randow, Ryck, Barthe, Zarow, Ziese, which are embedded within expansive river fens, as well as natural forests, ponded depressions, small waters and wetlands that are only drained to a small degree function as sponges within the ecological water cycle. It is therefore necessary to stabilize the water storage capacity of these spaces. The cultural landscape can be further developed through forms of extensive cultivation practices, e.g. sensitive ‘wet agriculture’ (paludiculture[4]) in fens. The conservation of groundwater

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[4] Cultivation of biomass on wet and rewetted peatland, e.g. reed cultivation for producing energy, sphagnum farming for horticultural substrates, cultivation of Black Alder for energy and timber production.

stores within the natural limits (ground water bodies) relies on the monitoring and influencing of groundwater recharge. The prerequisite for a sustainable exploitation of water resources lies within their systematic management.

Identification of key development tendencies:

Groundwater recharge – quantity, quality: Groundwater recharge does not appear to be in danger in terms of quantity (Tab 1). However, the regional storage situation with regard to ground- and drinking water needs to be urgently reassessed.

Quality of drinking water: The quality of recharged groundwater in particular below agricultural areas is, in parts, problematic. Weak or insufficiently formed surface layers of the aquifer lead to increasing risks of contamination.

Drinking water supply: The regional drinking water supply is increasingly subject to seasonal fluctuations and regional differences.

10.7.2 Initial Strategic Considerations on the Adaptation Requirements of Water Management

The following strategic considerations have been derived to date:

Efficient management of resources: The regional drinking and groundwater resources have to be efficiently managed also in the future, due to the demand, the demand structure and various risk factors. The water management authorities in charge of water catchment areas require robust projections in terms of the future demand for water.

Provisions, consumption management: The protection of drinking water has to be improved by making provisions for the future and by managing the consumption and the development of the consumption within the drinking water protection areas (‘Trinkwasserschutzgebiete’). In particular, afforestation should be directed to the drinking water protection areas.

Spatial protection: The spatial protection of precious groundwater resources has to be further enhanced. The water management authorities have to undertake studies in this regard and prepare justified proposals for groundwater resources in need of protection.

Regional concept: The consequences of climatic and demographic changes for the ecological water cycle require a long-term, conceptual and systematic reconciliation with the demand for drinking- and groundwater. From this concept tangible measures for improving the regional water cycle are to be deduced.

Improve water cycle: In order to have continued access to high quality and seasonally adequate water resources measures for the improvement of the water cycle and in particular for the improvement of the water balance, the available groundwater and groundwater recharge are needed.

Protection within coastal areas: Because of the seasonal increase in demand for water due to tourism new drinking water resources have to be found. Thereunto belongs developing and implementing alternative water supply concepts. Groundwater catchments close to the coast have to be continuously monitored in terms of the saltwater-freshwater-divide.

10.7.3 Settlement and Urban Development, Mobility, Tourism, Climate Protection and Energy

The above issues are currently under assessment; therefore it is not yet possible to elaborate on them. It can be said to date however, that the population in the planning region Western Pomerania will decrease by a further 14% until 2030, according to the fourth Projection on Population Development in Mecklenburg-Western Pomerania. Therefore, urban concentration processes that have already begun have to be orientated towards creating energy efficient settlement structures. In this regard, the two independent towns of Greifswald and Stralsund have, for several years registered an increase in population, in contrast to the surrounding municipalities. Sustainable settlement and urban development also relates to the spatially relevant sectors tourism, industry and enterprise, and transport. In terms of the growth sector tourism and the increasing demand for real estate in the highly scenic coastal areas it is necessary to identify adapted and compatible solutions. The amenity value of the coastline has to be durably protected when developing the economic potentials of the area. To achieve this objective the following needs to be pursued:

- The promotion of energy efficient space-saving settlement structures by preventing further suburban housing (utilize findings of MORO 'Restructuring Instead of Growth'), by information and advice as well as by regulations of urban land use planning.
- The promotion of energy efficient construction, including technical infrastructure.
- The reassessment of local development plans, settlements and urban areas that are increasingly in danger by a rising sea level.
- The reassessment of local development plans and urban areas where difficulties in terms of drinking water supply can be expected as a result of increasing summer droughts (e.g. parts of the Island Usedom, in Anklam-Land municipality south of the River Peene).
- The adaptation of municipal plans and sectoral plans in terms of coastal changes, land loss, increasing costs for coastal protection measures, landslides on cliff coasts, keeping areas free that are in danger of storm surges, development of relocation strategies with regard to endangered coastal areas.
- The preparation of the tourism sector for positive and negative impacts of Climate Change.

In terms of climate protection the Spatial Development Strategy is anticipated to focus on the local sector. This refers to the delivery of nationwide climate protection goals through measures at local level. The Strategy will therefore call the towns and communities within the region to take part in a competition for the development and implementation of local climate protection concepts. Besides energy saving measures, first and foremost technologies for generating renewable energies and efficient public transport networks play here an important role. The Strategy is likely to focus on setting the framework for replacing fossil fuels in this regard.

10.8 Discussion and Outlook

Besides the changes of climate parameters, the worldwide rising sea levels pose one of the key problems that affected communities in regions with flat coasts have to tackle. The outline of an integrated Spatial Development Strategy for the planning region Western Pomerania presented in this article addresses important fields of action and the outline integrates them in such a manner that emerging regional problems and opportunities resulting from Climate Change can be identified. From this various strategic considerations become initially apparent that have to be reconciled within a Spatial Development Strategy. From the Strategy, implementation measures on project level can be derived. Such an approach in dealing with the consequences of Climate Change is particularly effective in those areas, where the flat coasts affected by a rise in sea level cannot be protected from land loss and an alteration of the coastline. Here, it is necessary to find appropriate solutions in the context of the regional capacity to deal with land loss, private assets and restructuring of land uses. The handling of emerging conflicts can be alleviated by applying planning instruments that involve civil society.

The main scientific limits of such a strategic approach are projection uncertainties in terms of the rising sea level, and in particular its progression and its local consequences. In terms of legislation, limits regarding interference with local governance and private property rights exist. These matters require informal planning instruments, in order to tie them into strategic developments. Nonetheless, there are limits that also cannot be overcome with the help of professional communication. One reason is that specific and sectoral interests cannot be entirely reconciled with an integrated approach to regional development. This again emphasizes the process-orientated character of the strategic approach.

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Chapter 11
Applying Climate Change Adaptation in Spatial Planning Processes

Philipp Schmidt-Thomé and Johannes Klein

Abstract Natural hazards play an increasingly important role in societal contexts due to rising casualties and costs observed in the last decades, which is often attributed to Climate Change impacts. Climate Change adaptation and natural hazards have entered European regional policy relatively recently but are quickly growing in importance. In addition to several national and regional Climate Change adaptation strategies the Territorial Agenda of the European Union and the EU White Paper on Climate Change Adaptation mention Climate Change and hazard related risk management as key role in European regional development. But in this argument it is often overlooked that human societies have developed settlements in hazard prone areas, sometimes despite better knowledge. Spatial planning could be a very useful tool to protect settlements from hazard impacts but its full range of potential is seldom applied or overruled by other priorities. It is of interest to observe how human beings have dealt with various natural hazards since the beginning of societies, first of all to understand motivations, and secondly to use this knowledge for new adaptation concepts, including potential impacts of Climate Change. The decision making processes that lead to hazard adaptation concepts are one of the key foci, as well as the possibilities and feasibilities to integrate Climate Change adaptation concepts. Concrete examples of human increases in vulnerabilities and the development of adaptation concepts are given from a case study in the Baltic Sea Region.

11.1 Introduction

There are clear developments of rising costs due to damages caused by natural hazards. A normalisation of these costs does not reveal any impact that can be attributed to Climate Change (Barredo 2009, Barredo 2010, Pielke Jr. et al. 2008). An attributable signal of a Climate Change impact on the frequency or the

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magnitude of hydro-meteorological hazards does not exist as yet. This lack of a Climate Change attribution as an impact to natural hazards thus reveals that current human vulnerability is constantly evolving, irrespective of ongoing climate changes. As shown in the case study presented in this text, there is a strong increase of valuable assets in hazard prone areas.

The rising costs caused by natural hazard damages reveal that extreme events could be integrated better into planning processes. It would thus be more appropriate to talk about climate adaptation tackling vulnerabilities towards the current climate first, instead of Climate Change adaptation abating potential future impacts. Besides this also geo-hazards, which are not affected by climate, are also not well respected in planning processes.

Therefore this article sheds light on human developments in hazardous zones, touching various examples from several areas around the globe. Finally the focus will lie on most recent applications of Climate Change adaptation practices in the Baltic Sea Region, as these give an example on how hazards, as well as potential developments of extreme events under Climate Change, can be integrated into decision making processes on land use planning.

As to date the institutional governance linkages from both natural hazards and Climate Change to planning and decision-making are not well developed. Climate Change adaptation and natural hazards have entered European regional policy relatively recently but are quickly growing in importance. In addition to several national and regional Climate Change adaptation strategies the Territorial Agenda of the European Union and the EU White Paper on Climate Change Adaptation mention Climate Change and hazard related risk management as key role in European regional development.

The active integration of Climate Change adaptation into planning practices is currently developed under the BaltCICA project in the Baltic Sea Region. Here, scientists and spatial planners work together to take the step forward from developing adaptation strategies towards Climate Change adaptation measures. This article analyses the developments of settlements in hazard prone areas and potential adaptation processes. The decision making processes that lead to hazard adaptation concepts are one of the key foci, as well as the possibilities and feasibilities to integrate Climate Change adaptation concepts. This article further develops approaches stemming from Climate Change adaptation projects in the Baltic Sea Region since 2002 (Klein and Schmidt-Thomé 2006, Schmidt-Thomé 2006, Schmidt-Thomé and Kaulbarsz 2007). The main questions address points concerning the reasons for the development of settlements in hazard prone areas and the communication processes towards corrective measurements. The core concepts of hazard adaptation, i.e. to protect, to adapt, or to retreat are discussed on the background of real-life possibilities of their implementation in planning practices.

The article starts with an overview on settlements in hazard prone areas and briefly addresses both historical and present management approaches. The discrepancy of scientifically obvious and logic adaptation concepts versus cultural and socio-economic realities play a most important, and probably all-too-often underestimated role in changing existing settlements areas. Concerning adaptation and protection measures the discussion also touches the development of adaptation measures in planning phases (pre and post hazard impact) and on what grounds these are assessed and finally implemented. In the light of Climate Change and the discussion of its potential effects the retreat concept is often mentioned as the ultimate solution. Planning responses, such as land use change and retreat are the ultimate measures, and from a scientific perspective retreat options do make sense (e.g. Schmidt-Thomé and Greiving 2008) but how realistic is the implementation of retreat?

The article concentrates on interdisciplinary science-stakeholder communication processes, as the visualisation of territorial extents of hazards and threats alone is a useful tool, but it is to be communicated and analysed thoroughly, especially in connection with underlying uncertainties. The role of large investments in adaptation measures are of particular importance when implementing uncertainty concepts. The analysis thus focuses on the kind of information that planners and other stakeholders require when discussing natural hazards and Climate Change impacts and how this information can be implemented and communicated in decision making processes.

The article finally presents some examples of recent decisions on land use changes to effectively implement Climate Change adaptation strategies, shedding light on the socio-economic and political decision making backgrounds that have led to their enforcement.

11.2 Conceptual Thoughts on Natural Hazards and Natural Processes

In the assessment of natural hazards, it has to be kept in mind that natural hazards are natural phenomena that only turn into a hazard when human beings or assets are affected. Natural hazards have, in some cases, even contributed to site-specific natural advantages that human beings depend on, e.g. fertile soils in flood plains or in the vicinity of volcanoes. It should be accepted that natural hazards are part of our living environment and that they cannot be fully mitigated. Human beings should take the potential impacts of natural hazards into account while organizing their living environment and settlements. Following this argumentation, consequently the often-used term ‘natural disaster’ is thus in fact a wrong concept, as a natural hazard does not cause a disaster for nature. It is the *natural hazard* that can lead to *human disasters*. Technological hazards, on the other hand, may well cause disasters on natural environments.

From a conceptual point of view it is furthermore important to distinguish between natural hazards, which are extreme events, and natural processes, which are permanent or long-lasting. Natural processes might, also, lead to adverse conditions for the living environment, from the human perspective. Therefore the definition of adverse natural effects on human assets and living conditions differentiates between *processes* and *events* (Schmidt-Thomé 2006). The *event* is the natural hazard that disturbs or disrupts or changes relatively constant situations or processes for a matter of seconds, days, months, or years, after which the initial or new ‘normal’ state is reached. Natural *processes* on the other hand are natural phenomena that are ongoing. For example, a storm surge, which is an extreme event, might cause severe coastal erosion, which is a process. So in the case of severe erosion caused by a storm surge, the erosion (process) is affected by the hazard (event), but this does not turn the erosion itself into a hazard. Also Climate Change is a process, as there is no clear understanding as to when it has started and when it might stop, especially as climates have always changed in geological timescales.

Natural hazards of hydro-meteorological origin might be potentially affected by Climate Change. Geo-hazards are generally not influenced with the only exception of mass movements (landslides), as these can be affected by meteorological events. The impact of Climate Change on the frequency and/or the intensity of natural hazards is currently under intensive scientific discussion (e.g. Emanuel 2005, Trenberth 2005). There are trends in storm intensities, but a change in frequencies is not proven as yet (e.g. Knutson et al. 2010, Storch and Weise 2008). In fact normalisation of damage data does not reveal any impact of Climate Change on frequencies nor magnitudes (Barredo 2009, Barredo 2010, Pielke Jr et al. 2008).

11.3 The Role of Natural Hazards, Risk and Climate Change in Spatial Planning

Natural hazards have always played an important and vital role in the development of societies and cultures. They have continuously posed threats to human beings and their assets and they have often lead to catastrophic disasters. Some of these disasters are very well documented (e.g. Pompeii), meanwhile others can only be detected by geological evidence, for example tsunamis in India (Chandrasekar et al. 2006). Other natural catastrophes reports are based on myths and have not been scientifically proven in duration or extent. Despite real or imagined threats to a settlement or a society, human beings have continued to dwell and settle in naturally hazardous areas, putting their lives and assets at risk. Often risks have been assumed deliberately, despite experiencing several disasters and continued threat of natural hazards. Many such settlements have developed into culturally and economically important cities over the centuries. Examples of large cities that have been recently severely affected by natural hazards can be found from all continents, such as Prague (floods in 2003), Kobe (earthquake in 1995), Canberra (bush fires in 2003), San Salvador (earthquake and landslide in 2001) and New Orleans (hurricane in 2005).

Most natural hazards rarely cause disasters in the human timescale, so that the real threat is often recognized too late, or has been deliberately taken as the other advantages of the settlement areas prevailed. Several international institutions, financially oriented actors, and increasingly also government expert groups, stress that since natural hazards cannot be avoided, more efforts should be put in vulnerability reduction and hazard adaptation (e.g. Marttila et al. 2005, Munich Reinsurance Company 2009, United Nations 2004, Consorcio de Compensación de Seguros 2008).

11.4 Natural Hazards and Spatial Planning

There are several, mainly economic, reasons for the recent stronger focus on natural hazards and planning. From a global perspective, the insured losses due to natural hazards have been rising in the past decades, with a large increase in losses in the last years (Munich Reinsurance Company 2009). An analysis of natural hazard related financial loss data reveals that there has been an increase in both catastrophic events and insured losses since the 1960s. However, looking back over the last two decades it can be seen that the dramatic increase of financial losses is not reflected to the same extent by the increase of (reported) catastrophic events or loss of human lives (e.g. Emergency Disasters Database 2006). Therefore it is probable that the trend of increasing financial losses is also a result of an increase in the total number of catastrophes that were actually reported. Additionally, data before 1980 are not as accurate as more recent data (UNDP 2004). Also, the insured losses have increased sharply due to steadily rising market values of insured goods and assets. In other words, there might be an increase in catastrophic natural hazards, but the dramatic increase in losses is also due to economic growth and subsequent increasing damage in monetary values. There has been a strong increase in the number of people affected by disasters, which is also caused by the increase of the world's population. On the other hand, the number of fatalities in natural disasters has not risen over the last 100 years. Even in 2004 (the year in which the tsunami disaster in the Indian Ocean occurred) has not reached the highest recorded number of fatalities (Emergency Disasters Database 2006). Nevertheless, in this analysis, it must be taken into account that there are no complete and coherent data sets covering all natural disasters and their effects.

The potential effects of Climate Change on the magnitude and the frequency of natural hazards is currently a topic that is of great concern to scientists and stakeholders alike, also on European scale (Territorial Agenda, Territorial State and Perspectives of the European Union 2007). Therefore this article focuses on the integration of natural hazards in planning practices, including the potential effects that Climate Change can have on natural hazards and how this information, which is based on scenarios, can be used in decision making processes.

Even if the awareness of natural hazards and associated risks is constantly rising and spatial planning is increasingly integrating hazard and risk management, the scope of most of these activities is limited as they focus on selected single hazards. An integrated multi-hazard approach is still rare. Among the planning systems of eight analysed European countries (Fleischhauer 2006) only France takes all spatially relevant natural (and technological) hazards into account in the planning system.

Problematic aspects that are often brought up when it comes to integrating Climate Change into planning are the uncertainty and the long time span of the models, as well as the problem of downscaling Climate Change models for appropriate use on local level (Schmidt-Thomé and Peltonen 2006, Halsnæs 2006). Despite these concerns, several planners involved in the projects that form the basis of this article have expressed their strong interest in integrating Climate Change into their planning practices, especially in connection with future land use (e.g. Schmidt-Thomé and Kaulbarsz 2007, Schmidt-Thomé et al. 2010). This because the sustainability aspect is considered more important than the fact that political decision making is often made on short term interests (e.g. Virkki et al. 2006). While planning can only contribute partially to Climate Change mitigation, its role on Climate Change adaptation side can be substantial (e.g. Vries 2006). The benefits of mitigation are not bound to the location, where planning contributes to the reduction of GHG emission. The costs and benefits of adaptive measures in planning, however, affect mostly one and the same area.

11.5 Adaptation Concepts

There are three general options to deal to natural hazards from a land use perspective: To *adapt*, to *protect* or to *retreat*.

Adaptation is a concept that can be found in several cultures around the world. Examples range from building houses on pillars in regularly flooded areas towards the use of temporary homes in agricultural fertile areas in close vicinity to volcanoes in South East Asia. In fact it is observable also throughout Europe that the oldest settlement structures and agricultural practices were usually adapted to potential natural hazards and / or extreme events. For example the oldest terraces in southern Spain were adapted to heavy rainfall events that can cause additional erosion by planting deeply-rooting trees on the rims of the terraces. These trees similarly gave shade to the fruits and vegetables planted on the terraces, which protected them from too high evapotranspiration. In addition, this variety in agricultural products made the harvest more resistant to droughts, as some product would always yield. In central Europe flood plains were not built up but used as grazing land. Most recent adaptation practices can be found from the Netherlands with the construction of floating houses in front of the (river) dike line. These houses, including their sewerage systems, etc, rise with floods.

Although the oldest dikes are more than 1,000 years old, modern *protection* was introduced along with the industrial revolution and extensive hydroengineering of river courses, reclamation of tidal flood plains, etc. Nowadays, protection is probably still seen as the most feasible aspect in dealing with natural hazards, and it is certainly a more common practice than adaptation. Examples comprise the building of dams or sea walls against floods and storm surges, respectively, implementing sophisticated building codes in earthquake prone areas, protective measures against slope instabilities, etc.

Retreat is, today, the most seldom applied concept (due to restrictions in technical solutions retreat was more commonly used in times before the eighteenth century). This lies in the nature of natural hazards, which are extreme events. By definition, such events occur so rarely, from the human perspective, that other reasons to settle in potentially hazardous areas prevail. In addition, human memory tends to forget the impacts of past hazards that have led to disasters. There are two concepts within retreat, pre- and post disaster retreat. The first concept is retreat prior to the impact of a hazard, born out of reasonable understanding of the potential disaster the impact of a hazard might cause. The post-hazard retreat concept implies abandonment of zones that were affected by a hazard as a protective measure, which is implemented prior to rebuilding. There are several examples for the second concept and very few for the first. Nevertheless the retreat is mostly only partial.

Examples of a total, sustainable, relocation of long existing settlements due to a potential threat by natural hazards are rarely found in human history. For example the capital of the Central American State of El Salvador, the city of San Salvador, was relocated to Santa Tecla after an earthquake in 1854, but was returned to its original location in 1895, mainly because of the lack of public support. Based on this experience, a relocation of the earthquake prone capital of Nicaragua, Managua, was assessed but not recommended (e.g. Lomnitz 1974). There are several reasons for not leaving or giving up settlements and dwellings. Besides the natural advantages of certain hazardous areas, traditional aspects are a reason for staying, for example people being deeply rooted in an area. Financial issues also play an important role, as many traditional and new settlements have certain strategic advantages (natural, trade, military, etc.) that are not easily found elsewhere. Also, giving up existing, functioning settlement structures is very costly and a potential natural hazard is thus perceived less problematic in comparison with a total relocation (e.g. Lomnitz 1974). Recently some scientists promoted the relocation of Port au Prince, the capital of Haiti. Port au Prince was widely destroyed during the last earthquake in 2010 and apparently the plates beneath Port au Prince are still under a high tension (Science Daily 2010).

The question is if retreat might become a more feasible concept in future land use practices because of two reasons: A better understanding of the potential effects of extreme events, and, containing even more uncertainties, the potential effects of Climate Change on natural hazards, such as floods. Even though the effects of Climate Change on the frequency and magnitude of storms and storm surges is still being scientifically investigated, it is no doubt that a risen sea level will have impacts on the territorial extent of storm surges. The question is thus if land use changes, which might include retreat concepts, might be introduced in Climate Change adaptation strategies and practices.

11.6 Integrating Natural Hazards and Climate Change Adaptation into Planning Practices

Besides the discussion on vulnerability and risk, one of the crucial aspects in the integration of natural hazards and Climate Change scenarios into planning practices remains the uncertainty factor. On regional and local scale, the Baltic Sea Region's INTERREG IIIB projects SEAREG and ASTRA used Climate Change scenarios to develop local Climate Change impact scenarios. The scenarios comprise, for example, sea level rise and changing flood prone areas, which are analyzed in interdisciplinary cooperation. The communication process developed under the

SEAREG project resulted in a set of tools that bridges the gap between Climate Change scenarios and spatial planning by specifically addressing integrated scenario interpretation and uncertainty issues, the so-called Decision Support Frame (DSF – www.gtk.fi/slr). The DSF applies GIS applications and models, but these are only one part of the entire DSF process. The other pillars of the DSF contain a vulnerability analysis, a knowledge base and a discussion platform. The vulnerability assessment and the discussion platform particularly focus on the communication process and thus distance the DSF from pure computer based decision-making. Both the vulnerability analysis and the discussion platform do not only help to identify the specific stakeholders to be addressed, but seek to identify and clarify Climate Change impacts, with the aim to take uncertainties into account in decision making processes. The SEAREG approach was successfully further developed by the ASTRA project (www.astra-project.org). For example, some of the cities and municipalities in the Baltic Sea Region have already taken decisions on future land use which were directly derived from SEAREG and ASTRA project results. The work conducted under SEAREG and ASTRA is continued in the BaltCICA project (www.baltcica.org), which sees to take the step forward from adaptation strategy formulation towards the implementation of adaptation measures. It might be stated that the structuring of the communication process under the DSF was first of all a very useful tool for the interdisciplinary communication among the scientists in the project team, which then supported the communication with the stakeholders. It is not possible to assess directly how much the projects contributed to the manifold decisions taken on flood prone area mapping and Climate Change adaptation design with the city of Helsinki. The SEAREG and ASTRA projects received very positive feedbacks and statements that they have contributed to the decision making processes. The background studies for the Climate Change adaptation strategy of the Helsinki Metropolitan Area, however, were partly prepared within the frame of the BaltCICA project (HSY 2010).

The Climate Change issues that fall under the remit of BaltCICA are numerous. Coastal erosion in the southern Baltic Sea region has already been identified as a major problem, and with increases in sea level rise this is likely to become worse. Coastal aquifers are vulnerable to the intrusion of brackish water caused by rising sea levels. Such potential difficulties need to be dealt with by either the adjustment of the water-pumping rate or the complete relocation of a well.

Additionally, fluctuations in the hydrological cycle and higher water and air temperatures caused by Climate Change can lead to shifts in the yearly groundwater cycle and run-off patterns in rivers and catchment areas (Graham 2004, Meier et al. 2006). Most Climate Change scenarios expect higher temperatures and higher rainfall in the yearly average, but especially in wintertime, which leads to changing snow cover and flood patterns. Higher evaporation in summer and a shift of the highest run-off in the catchment areas to a period earlier in the year (caused by less snow and more rain in winter) can contribute to droughts in summertime (Ruosteenoja et al. 2005).

One important component of the impact assessment process is the inclusion of uncertainty into decision-making. Thereby different elements contribute to uncertainty. Incomplete knowledge e.g. about climate sensitivity or the rate of heat uptake by the deep ocean contributes to epistemic uncertainty. This includes also that models have to depict reality necessarily in a reduced, hence, incomplete way. Natural variability of weather and climate contributes a stochastic element. Finally, there is uncertainty concerned with human behaviour (Dessai and Hulme 2004).

Epistemic and stochastic uncertainty can be addressed to a certain extent by ensemble simulations and the use of different climate models. This allows the representation of different potential futures, even though the human influence is assumed the same for all simulations. Human behaviour is represented in the different development paths that form the basis for e.g. the IPCC emission scenarios.

Two greenhouse gas emission scenarios are used as a basis for looking at the outcomes of Climate Change in the case studies of the BaltCICA project. The A1B and B1 scenarios, as devised by the Intergovernmental Panel on Climate Change in its Special Report on Emission Scenarios (SRES, Nakićenović et al. 2000), give alternate views of conditions in the future. The A1B scenario expects rapid economic growth but also considerable technological changes in the energy system. The B1 scenario imagines a convergent world with rapid changes in economic structures toward a service and information economy and the introduction of clean and resource-efficient technologies. Based on these scenarios the regional climate model COSMO-CLM provides results of two realisations for the period 2001–2100. It has to be noticed that these results do not reflect the full range of uncertainty. Stochastic and epistemic uncertainty is addressed only partly. The scenarios A1B and B1 show a certain range of possible human behaviour. However, at the current stage it seems that at least the B1 emission scenario is too optimistic, i.e. anthropogenic emissions have surpassed these modest estimations. But even a full range of scenarios (based on SRES) would deal with human behaviour under the assumption that actual mitigation (or adaptation) action as a reaction to the scenario-based statements does not happen (Dessai and Hulme 2004).

Hence, the process of ‘looking ahead’ based on scenarios provides a way of compiling information from a variety of sources, helping to create models of how Climate Change could affect society in the coming decades, and what kind of societies might evolve as a result of planning and adaptation. However, while these scenarios provide a great deal of insight, one important component of the impact assessment process is the inclusion of uncertainty into decision-making.

It is obvious that Climate Change can be only one factor among many having influence on spatial development. Economic and political interests, population development, social questions, requirements posed by laws, regulations or plans on a higher spatial level or the strength of the planning institution can have substantial impact.

11.7 Example Espoo, Finland

An example from Espoo (Finland) illustrates how coastal development is affected by a complex interplay of influences.

Espoo is located west of the Finnish capital Helsinki. It is the second largest city in Finland with approximately 245 000 inhabitants. It is one of four municipalities composing the Metropolitan Area. The city has not a city centre in its traditionally known form, but an urban network structure, made up of seven urban centers (Fig. 11.1). It comprises an area of 528 km^2 (312 km^2 land, 198 km^2 sea, 18 km^2 other water bodies) and has a coastline of 58 km.

Figure 11.2 shows the city's development in the coastal area below 2.4 m a.s.l. The data are extracted from a report about flooding in Espoo (Kotaniemi 2006). 2.4 m a.s.l. is seen as critical level for the lowest floor of buildings, since a flood with a recurrence of 100 years (including wave action) can reach 2 m. 40 cm are added as recommended construction level above ground (Espoon tulvatyöryhmä 2005).

Fig. 11.1 Overview of the location and the most important city centers of the city of Espoo (Source: City of Espoo)

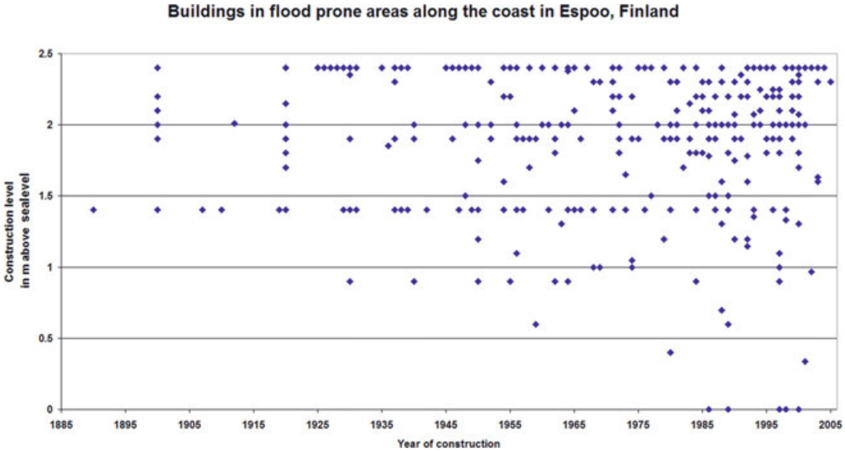

Fig. 11.2 Buildings in the coastal area of Espoo with a lowest floor level below 2.4 m a.s.l (Data source: Kotaniemi 2006)

Two phenomena can be seen from Fig. 11.2: The buildings are built constantly in lower areas and the density of buildings in low lying areas increases over time.

The development in these areas comprises a large variety of building types. Besides a large amount of assets of lower value for spare time activities, strong building activities for residential buildings since the 1970s increased the share of detached, semidetached and row houses to almost 50%. The number of office buildings is comparably small, but it has a huge influence on the value of the assets. Figure 11.3 shows that the number of buildings has increased rather linearly, while the value seems to develop exponential. Variations and temporary stagnations in the development could be explained by several factors, such as economic crisis or legal restrictions, but no factor can be identified as an exclusive driver.

Development activities in Espoo are regulated by a general plan (yleiskaava), detailed plans (asemakaava) and a building code (rakennusjärjestys). The building code of 1991 required the lowest floor level to be at least 2 m a.s.l (Pelin 2001).

The building code that came into force in 2003 requires a lowest floor level of 3 m for buildings on the shore. However, this is applicable only for buildings outside of the area of detailed plans (Espoon rakennusjärjestys 2002). Also the Finnish national law for land use and construction (Maankäyttö- ja rakennuslaki 1999) requires provisions for avoiding flooding and landslides only for buildings outside the area of detailed plans. Despite concrete requirements for flood protection, the nature of the building code and legal frameworks do not restrict active development in flood prone

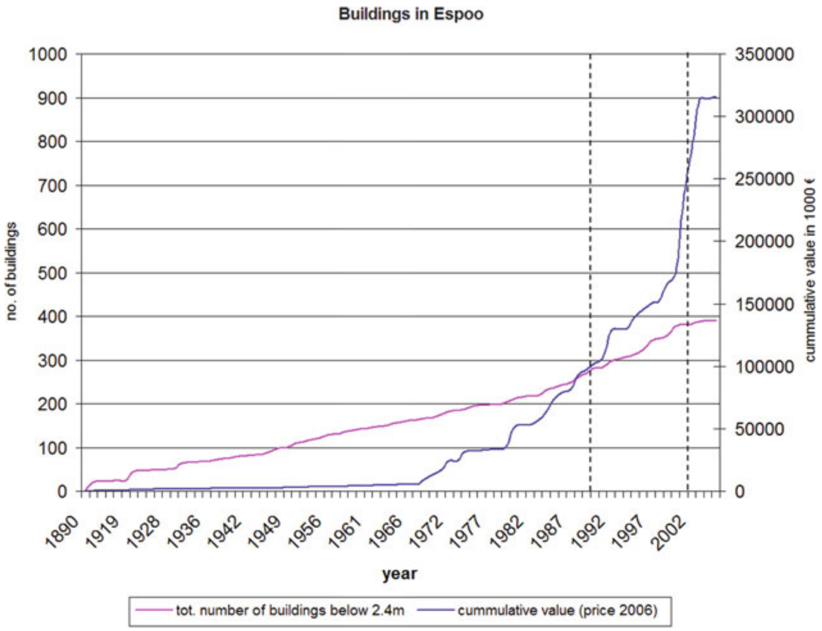

Fig. 11.3 Number of buildings and cumulative value (for the year 2006) in Espoo with the lowest floor level below 2.4 m a.s.l (Data source: Kotaniemi 2006)

areas, as can be seen in graphs presented above. In fact, in 2005 there was in Espoo only one detailed plan for a coastal area that included requirements for the lowest floor level (2 m a.s.l.) (Espoon tulvatyöryhmä 2005).

Climate Change and potential changes in sea level are not mentioned in any of the regulating documents at municipal level. On the other hand municipal regulations have to take into account national legislation and guidance. The lowest floor level of 3 m a.s.l. as set in Espoo's building code is based on the recommendations of the Finnish Environmental Centre, which in turn has a clear reference to Climate Change (Ollila 2002, Kahma et al. 1998).

At the very western border of Espoo, Kurttila (Kauklahti, see Fig. 11.1 above) is one of the last coastal areas without a detailed plan. The process for detailed planning for that area was started in 1999. The loosely populated and built area has been planned to be structured and more intensely developed. For many reasons the planning process was delayed and has not been completed until 2010. This made the process prone to changes in regulations and general conditions.

The first background report for the detailed plan mentioned a lowest floor level of only 2.4 m a.s.l., the planning instruction itself did not include any limitation, when it was presented to the city's planning board in 2005 (Kurttila IA – IB Asemakaavan selostus, 2006, Kurttila IA – IB kaavakartta ja – määräykset, 2006).

At the same time Espoo's building code asked for a lowest floor level of 3 m a.s.l. The same height was recommended by Finnish Environmental Centre. The report of Espoo's flood group maps flood prone areas and addresses Climate Change (Espoon tulvatyöryhmä 2005). Finland's National Strategy for Adaptation to Climate Change (Ministry of Agriculture and Forestry of Finland 2005) recommended to survey flood-sensitive areas and structures with respect to Climate Change.

After the preparation of the first draft for the detailed plan for Kurttila, reports and seminars in Espoo increased the knowledge about potential impacts of Climate Change on flooding. In 2006 a more detailed report on flood problems assessed in detail flood prone areas in Espoo, identified potential affected houses and areas, and estimated their value (Kotanimemi 2006). In 2007 a report prepared by the Environmental Centre of Espoo assessed the potential impacts of Climate Change in Espoo and adaptation measures (Soini 2007). A seminar jointly organized by the City of Espoo and the ASTRA Project addressed Climate Change with respect to mitigation and adaptation in May 2007. 105 representatives of municipal administration from Espoo and vicinal municipalities participated in the event.

In 2009 a new draft and background report for the coastal part of Kurttila (Mulby) was presented to the city's planning board and accepted in May 2010 for the next steps in towards coming into force of the detailed plan. The new planning instructions require a lowest floor level of 3 m a.s.l. and the detailed plan displays now building area below 2.6 m a.s.l. Climate Change is not mentioned as a potential drive for these levels.

The example illustrates well that the integration of Climate Change into planning at the municipal level takes time. It is a cross-cutting issue that affects many municipal departments and stakeholders. It is a challenging task to introduce a new topic in an administrative body with more the 14 000 employees, especially, if it requires measurements beyond the established communication paths and work flows. The example includes only documents and facts clearly related to Espoo. Other potential influences could be easily added, such as the fourth IPCC report in 2007, the Finnish research programme for Climate Change adaptation from 2006 to 2010 or activities in other cities in Finland or in Europe.

While recommendations for the lowest floor level taking into account Climate Change were available already in 1998 (Kahma et al. 1998), only in 2010 the respective values can be found in the detailed plan for Mulby, however, without reference to Climate Change.

11.8 Discussion

Integrating hazard, Climate Change and risk concepts into regional development and spatial planning has proven to be relevant to spatial planners. Natural hazard maps and overlays with Climate Change impacts lead to an enhanced understanding of future potential threats to spatial development. Vulnerability concepts are a valuable tool to assess risks and foster interdisciplinary communication. Nevertheless, one of the most important aspects is the communication process, as hazard data are very complicated and broad acceptance for decision making can only be achieved with a sound basis of understandable and comprehensive sources of information. This also applies to the communication and integration of uncertainty aspects. Since marking vulnerability and risk concepts in maps is very critical and difficult, it should be left for spatial planners and other stakeholders to carefully consider and decide if they need such concepts and corresponding data. Finally, the question of the specific purpose of risk maps, in particular the choice of variables used to measure vulnerability needs to be evaluated carefully. It might often turn out that it is easier to skip risk mapping and to use hazards maps, in combination with a sound vulnerability assessment, as a basis for decision making.

11.9 Conclusions

Despite uncertainties of Climate Change impacts on natural hazards, large parts of the increases in human current vulnerabilities to hazards may be addressed by a further development of spatial planning practices. It is not so much the need for more information, it could rather be a paradigm shift towards stronger focus on respecting potential extreme events, despite short-term financial interests. Once potential impacts of extreme events have been discovered and understood it may well be possible to go a step further and overlay natural hazard maps with potential Climate Change impacts, which may lead to an enhanced understanding of future potential threats to spatial development.

Certainly broad acceptance for decision making can only be achieved with a sound basis of understandable and comprehensive sources of information, but on the other hand it must be understood that extreme events rarely occur, also under Climate Change. It is thus a societal debate what are the acceptable risks that can be taken in order to fulfil economic, and how known potential risks may be integrated as a part of city planning, i.e. based on common societal acceptance. It is an inevitable fact that natural hazards will continue to affect human beings and their assets, even if Climate Change mitigation efforts (GHG reduction) might be successfully implemented some day. The climate will continue to change, but so will human vulnerability factors. So what are the risks we are willing to take?

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Chapter 12
The Impact of Driving Forces and Protection Policies on Future Coastal Landscapes: A Case Study of Latvia

Kristina Veidemane

Abstract Landscapes and related land cover changes are essential elements of sustainable coastal zone management in Europe and in Latvia. The issue of landscape protection, management and planning was promoted as a result of the adoption of the European Landscape Convention (2000), while the Recommendations concerning the Implementation of Integrated Coastal Zone Management were adopted by the European Community (2002) to address land use issues. The Recommendations also emphasise the need to recognise the threat to coastal zones posed by Climate Change. This paper aims to contribute to the enhancement of landscape and coastal zone management policies by addressing the changes in coastal landscapes. It presents an analysis of the development of major driving forces in the coastal zone of Latvia and evaluates the effectiveness of the existing policy instruments of landscape protection along the Baltic Sea coastline in this country. In Latvia and other Eastern Baltic Sea countries, landscape protection is mainly realised by setting a legal protection zone along the Baltic Sea coastline. Key aspects include the restriction of the expansion of built-up areas, the limitation of forestry activities versus the maintenance of natural and semi-natural landscapes and also the protection of coastal areas against erosion. We studied changes in the coastal landscapes using land cover data, aerial photograph images, statistical data and legal documents. This study concludes that the coastal protection areas in Latvia have prohibited any significant changes in the land cover during the period from 1995 to 2006. However, the results also indicate that the pressure in terms of timber felling and new construction is reallocated to the neighbouring areas. Considering the erosion intensity and potential impacts of Climate Change, estimates show that the coastal landscape structures will face major changes in the future. Therefore, a debate on the realignment of the protection zone and its integration in spatial planning should be initiated to prevent undesirable losses for the country.

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12.1 Introduction

Coastal areas including landscapes have received significant attention among researchers (Mander et al. 2004, Metzger 2008), although traditionally limited to the studies of terrestrial systems (Hinchey et al. 2008). The coastal areas being formed and shaped by marine and terrestrial conditions have resulted in unique landscape types, ensuring high and concurrently fragile biological diversity and productivity (Turner et al. 1996). The landscape features and ecological processes within the coastal zones also provide ecosystem services crucial to the well being of coastal economies and people (Agardy et al. 2005, Brenner et al. 2010). According to the Millennium Ecosystem Assessment (UNEP 2006), the benefits that people obtain from coastal areas are related to food provision, natural shoreline protection against storms and floods, water quality maintenance, the support of tourism and other cultural and spiritual benefits and the maintenance of the basic global life support systems.

At the same time, coastal areas have always been attractive to human populations for establishing settlements and using available natural resources (fish, timber, farming land, waters, etc.). In the long run, this desirability has caused pressure on landscapes in terms of land use intensity or pollution (Tzatzanis et al. 2003, Antrop 2005, Lopez y Royo et al. 2009, European Environmental Agency 2009). Although there are significant differences in the land cover change patterns between various countries and at regional levels, the indicators show an increasing trend in the cover of artificial surfaces, arable lands and permanent crops in the coastal zone of Europe during the last two decades of the twentieth century. Consequently, areas with pastures and mixed farmland, semi-natural and natural open space and wetlands have been disappearing, while forest cover has been experiencing a slight increase in coastal areas (European Environment Agency 2006b).

Recognising that coastal zones are of great environmental, economic, social, cultural and recreational importance, governments have undertaken efforts to safeguard these areas at the global, European and national levels (Vallega 2005, DEDUCE 2007). Relevant authorities are elaborating, adopting and enforcing different policies, planning tools and regulatory mechanisms. The response actions have been traditionally focused on protection and restrictions on human activities in certain areas (Cubbage et al. 2007, Harrop 2007). ‘Natura 2000’ is the EU’s principal policy instrument for ensuring the conservation of valuable European habitats, including coastal species and habitats (European Community 1992). The European Landscape Convention (Council of Europe 2000) primarily aims to promote landscape protection, management and planning, and the Recommendations concerning the Implementation of Integrated Coastal Zone Management (European Community 2002) highlight the protection of the coastal environment based on an ecosystem approach and sustainable management of the natural resources of the coastal zone.

The Recommendations also emphasise the need to recognise the threat to coastal zones posed by Climate Change. Emerging evidence affecting many biological and physical systems and also related to coastal zones has been observed (Parry et al. 2007). Rising sea levels and sea surface temperatures, storm surges, increased flood risks in coastal lowlands and altered water quality/salinity are among the main climate drivers affecting coastal systems (Nicholls et al. 2007). The impacts of rising sea levels are now being felt as coastal inundation and its consequence, an increased rate of coastal erosion (European Environment Agency 2007b, Church et al. 2008).

As the above-mentioned policy documents have stated the high importance of appropriate protection measures, it is necessary to analyse which major driving forces (non-climatic or climatic) influence coastal landscapes and to evaluate the effectiveness of the existing protection policy instruments. Even in light of Climate Change, it is important to look for changes of coastal areas in a broader context linking different impacts and adaptation or conservation needs (Nicholls et al. 2008, Felton et al. 2009). Assessment of any changes in the landscape patterns can support the adaptation policy planning to the Climate Change impacts (Opdam et al. 2009).

This paper aims to contribute to the enhancement of coastal zone planning and management policies by addressing the changes in coastal landscapes. It presents an analysis of the development of key driving factors, such as forestry, urban and port development, and of the significant changes spatially observed in the coastal zone of Latvia. The paper outlines the relationship between coastal landscapes and the potential erosion risk in light of Climate Change. Traditionally, protection policies have focused on special nature or landscape values, or the protection of areas against certain pressures, but it is uncertain how the implementation of such policies has impacted neighbouring areas. Therefore, this study separately evaluates how the land cover has impacted existing landscape protection measures along the Baltic Sea coastline in this country. The obtained results support a comprehensive long-term spatial planning of the coastal zone of Latvia, which has not been performed in a holistic way to date.

12.2 Materials and Methods

12.2.1 Study Area

Latvia, located in the southeast of the Baltic Sea region, has about 497 km of coastline straightened by erosion and deposition processes over time (Eberhards 2003). The country does not have any sea islands. Having ratified the European Landscape Convention and as a member of the European Union, Latvia has a duty to accordingly implement its political commitments and legal obligations. As the execution process of the requirements of the European policies has been delayed, a sound scientific basis concerning landscape development in coastal areas is a prerequisite for successful national and regional policy planning and implementation.

In Latvia, coastal landscape protection is mainly achieved by instilling protection zones along the Baltic Sea shoreline. Protection zones also serve to eliminate the development of coastal erosion processes. The protection status was established under the former USSR and was kept in similar manner after Latvia re-gained independence in 1991. Shoreline protection as a legal mechanism also still exists in neighbouring countries (e.g., Estonia and Lithuania), although the objectives of the establishing protection regimes slightly vary from focusing on nature protection to ensuring public access to coastal recreation resources (Erlich et al. 2002, Povilanskas and Urbis 2004, Palginõmm et al. 2007). The protection of coastal strips was also stipulated by a separate Recommendation of the Helsinki Convention for the Protections of the Baltic Sea (Helsinki Commission 1994).

According to the Latvian Law on Protection Belts, the coastal protection zone is divided into three categories: (i) a restricted economic activity zone up to 5 km wide; (ii) a sea protection zone; and iii) a coastal dune protection zone. The width of the coastal dune protection zone is different for urbanised areas (villages, towns and cities) and other areas. In general, the coastal dune protection zone is not less than 300 m inland, counted from the spot where natural land vegetation begins, while in areas it cannot be less than 150 m, and the protection of the habitats therein is mandatory (Latvijas Republikas Saeima 2003). The boundaries of the protected areas are identified in the spatial plans of the local municipalities.

Additionally, the national conservation policy in coastal areas is focused on the designation of protected nature areas. Generally, an area having a nature protection status must be excluded from any kind of development that could diminish its value. In practice, a business must undertake additional efforts related to environmental impact assessment, permitting and controlling. For example, forestry activities and potential forest felling are commonly limited in their ability to obtain timber resources in such areas.

Until now, the national policy towards Climate Change has been focused on mitigation measures by reducing the emission of greenhouse gases according to international commitments (Ministry of the Environment 2009). The development of an adaptation policy toward potential impacts of Climate Change has been launched (Aigars et al. 2009). However, the process of setting up the policy objectives and tasks has progressed rather slowly (Ministry of Environment 2009).

Considering the similar research related to coastal landscapes (European Environmental Agency 2006b, Kull et al. 2007) and the potential for international comparisons (DEDUCE 2007), the study area was defined as a 10 km wide coastal zone, measured from the shoreline towards inland. Within this 10 km zone, 1 km and 300 m strips and shoreline were selected for detailed assessments of the spatially changing landscape patterns. As different protection regimes have been set up for the coastal areas, this division will also allow the assessment of the impact of the protection policies on land cover change.

12.2.2 Spatial Data

Landscape structure is a type of indicator that is commonly used to assess the development in a certain area (Prior 2003, Wascher 2004, Carboni et al. 2009). Moreover, the land cover is widely presented as a state indicator to describe the temporal and spatial diversity change of landscapes at regional, national and international scales (Mander et al. 2005).

The analyses of the present and recent land cover changes were based on the digital land cover layers originally generated by the CORINE Land Cover (CLC) Projects of the European Environment Agency. The CLC inventory was performed for three periods (1990, 2000 and 2006) and presents the land cover and its changes in the form of maps for the Member States of the European Union, including Latvia. For Latvia, the CLC1990 data resulted from the interpretation of satellite images from 1994 to 1995, and likewise, the CLC2000 and CLC2006 data came from 1999 to 2001 and 2005 to 2007, respectively.

The standard CLC nomenclature includes 44 land cover classes. These are grouped into a three-level hierarchy. The five main (level-one) categories are the following: 1) artificial surfaces, 2) agricultural areas, 3) forests and semi-natural areas, 4) wetlands and 5) water bodies (Bossard et al. 2000). Although the 44 categories have not changed since the implementation of the first CLC inventory (1986–1998), the definitions of most of the nomenclature elements have been improved (European Environment Agency 2007a).

The CLC provides a resolution of scale of 1:100,000, a minimum mapping unit (MMU) of 25 ha and a minimum width of linear elements of 100 m. In addition to the CLC maps, the CLC-Changes were produced as a separate product. For that purpose, the MMU of the Land Cover Change database was set to 5 ha, indicating the true evolution process and not different interpretations of the same subject (European Environment Agency 2007a).

For the analyses of the Latvian coastal land cover status and changes, both the CLC and CLC-Changes products were used. More exactly, version 13 of 02.2010 was the actual data source.

To spatially assess the land cover change of forest landscapes, aerial photographic images produced by the Latvian Geospatial Information Agency were the main information source. The images were taken in 2007–2008 and visually reflect the recent changes in landscape with regard to the final felled and clear-cut areas. The pixel resolution was 0.5 m, offering detailed landscape structures for the assessment.

The spatial data on nature conservation were obtained from the layer of the Data Base GIS Latvija 9.2 developed by Envirotech Ltd., Latvia.

Spatial analysis was carried out based on the GIS methods and the tools provided by the ArcMap 9.3 version. By intersecting or selecting European CLC data within the relevant area (i.e. 10 km of coastal area), the land cover data of defined scales and scope were generated. By overlaying the two data periods on the land cover change, the spatial distribution of the changes was delivered in the form of a map. The Arc Map 9.3 version software also allows statistics to be performed on land cover patches.

12.2.3 Statistics

Statistical data on the key driving forces were used to assess the general trends with regard to coastal landscape changes. As the statistics were collected based on the administrative or management units, the relevant indicators cover a larger area than the exact direct landscape area. Two main data sources were used: i) the State Forest Service of Latvia for data on forest management; and ii) the Central Statistical Bureau of Latvia for economic, trade and population dynamics data.

Regarding forestry, the data on annual forest felling areas in coastal municipalities were collected to indicate the intensities of the pressure on landscapes. The pressure is caused by the demands for timber and its products in the local and international markets.

Data on annual population dynamics on the local level were compiled to assess the relationship between the change of artificial surfaces over time and urban sprawl.

12.2.4 Coastal Geological Processes

To assess the potential impacts of the coastal erosion caused by Climate Change on coastal landscapes, two main data sources were explored. The COASTLINE database linking CLC2000 data with erosion trends, which is freely available on the European Environment Agency web-site, was first explored. Then, information published by the University of Latvia involving long-term studies on coastal geological processes, including field studies and monitoring of the dynamics of the shoreline, was utilized. In the framework of the national research program ‘Climate Change impact on water environment in Latvia’, digital maps of the coastal processes and erosion risks were produced (Eberhards et al. 2008). These data and developed erosion maps served as a basis for the evaluation of the existing protection policies regarding realignment of the protection zones, due to the landscape structure.

12.3 Results and Discussion

12.3.1 Land Cover Status

The 10 km wide Latvian coastal area is represented by 27 out of 44 land cover categories, but just 15 different landscapes form the shoreline. The CLC2006 data shows that the Latvian coastal zone is dominated by forest landscapes, which form up to 61.6% of the area. This indicator value is higher than the average forest cover in the country, which is 45.8% of the territory (Central Statistical Bureau of Latvia 2007).

The Latvian forest coastal landscapes are dominated by coniferous (40% of forest cover) and mixed forest (30% of forest cover) stands. The wooded dunes, which are natural or semi-natural forest (long established) habitats of the coastal dunes with well-developed pine (Pinus sylvestris) woodland structures, are the prevailing forest ecosystem after strips of beaches and shifting or fixed dunes. The black alder (Alnus glutinosa) forests growing in the humid dune slack and the secondary forests of birch (Betula spp.) and grey alder (Alnus incana) form a part of the wooded dunes habitat (European Commission, DG Environment 2007, Auniņš 2010). The CLC2006 data reveal that 14.7% of the forest areas are so-called transitional woodlands. This land cover category represents either forest final felling areas, including clear-cuts, or forest expansion into abandoned agriculture land (Bossard et al. 2000). In the case of the Latvian coastal zone, the areas of transitional woodlands indicate the intensity of the forestry activities in some areas. The high share of clear-cut felling areas certainly causes landscape fragmentation, which in its turn has an effect on forest biodiversity (Jongman 2004, Kuuluvainen 2009). This may be beneficial to some species, such as pioneer organisms or edge 'ecotone' types of species, but highly detrimental to others, such as species affected by the loss of protective cover (Estreguil and Mouton 2009).

Due to the sandy soil and poor fertility in the coastal areas of Latvia, agricultural areas cover just 25.3% of the coastal zone. This share of arable land is smaller, at just 8.2% of total land cover, than the area of pasture, which accounts for 9.4% of total land cover. Such a low presence of agricultural landscapes is also observed in the coastal areas of the mainland of Estonia (Kull et al. 2007).

With respect to arable land areas, the 4.3% of cover of the artificial surfaces is a significant factor in the coastal landscapes. A total of 70.7% of the total land uptake by artificial surfaces is due to individual and public housing and related services and leisure areas. According to CLC2006, harbours occupy 3.1% of artificial surfaces.

Wetlands (bogs and marshes) cover 4.6% of the coastal area, while inland water courses and bodies account for 3.1%. The four larger lakes (Pape, Liepaja, Engure and Kaņiers), which are former coastal lagoons, provide an important character to the coastal areas of the country. They are particularly important for migratory water birds. As they are shallow, parts of the lakes are slowly overgrowing and forming wetlands. The estuaries of the four major rivers (Daugava, Lielupe, Gauja and Venta) also bring special features to the coastal land cover.

The landscape pattern differs with the distance from the shoreline (Table 12.1). Whereas the direct coastline is dominated by forests and semi-natural areas, the agricultural areas gradually increase with increasing distance from the sea. An interesting phenomenon is apparent with regards to artificial areas having their highest value in the 0–300 m zone, which again proves that urbanisation is an issue for sea-adjacent terrestrial areas.

Table 12.1 Share of the main land cover classes in the coastal zone of Latvia, according to distance from the shoreline (% of total land cover in the selected widths of the coastal zone)

Code	Land cover class	Coastline	0–300 m	0–10 km
1	Artificial surfaces	6.8	12.7	4.3
2	Agricultural areas	7.6	16.9	25.3
3	Forests and semi-natural areas	83.9	69.5	62.7
4	Wetlands	1.2	0.6	4.6
5	Waters	0.5	0.3	3.1
	Total	100.0	100.0	100.0

12.3.2 Land Cover Changes and the Main Human-Induced Driving Forces

Figure 12.1 shows the spatial change of the main landscape types in the coastal zone of Latvia in the period of 1995–2006. After the reinstitution of independence in 1991, land ownership changed from public to private in the main parts of the country. Consequently, it is also important to assess what kind of changes and where key changes took place in the coastal areas.

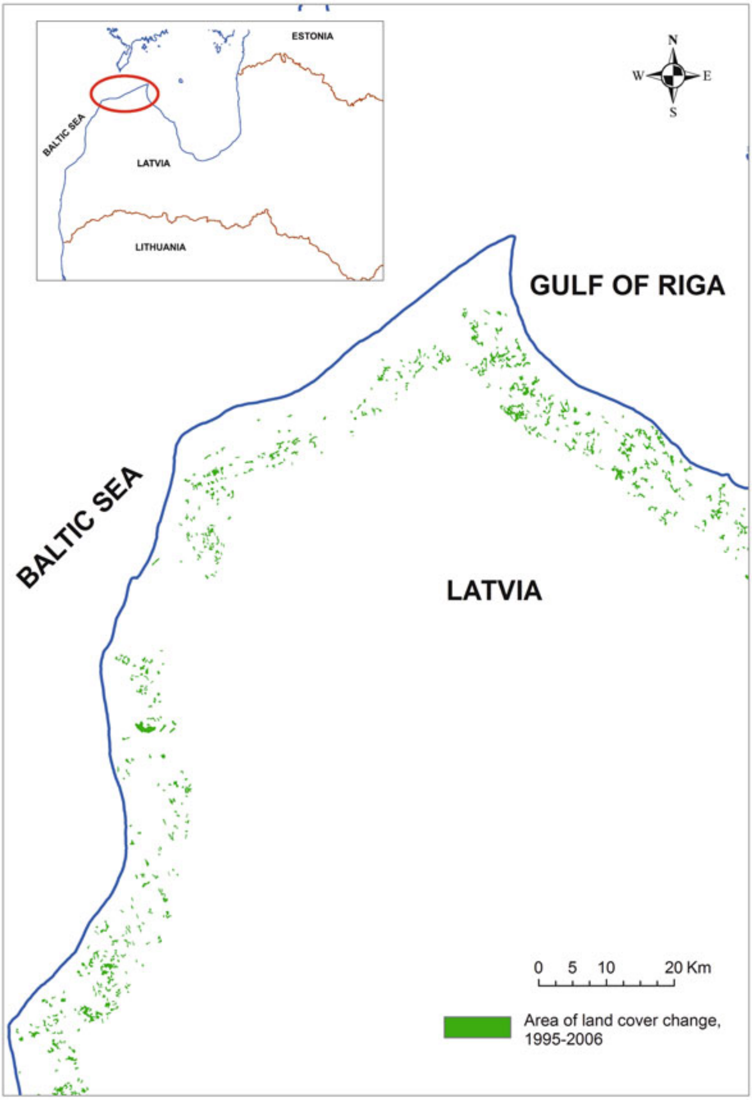

Fig. 12.1 Land cover changes in the 10-km wide Northwest Latvian coastal zone

About 18,500 ha, which is about 3.1% of the coastal zone of Latvia, underwent transformations during the period between 1995 and 2006. The magnitudes of these changes are similar to the ongoing land transformation processes in coastal EU countries (European Environment Agency 2006a). While the average and maximum sizes of the single plots of changed Latvian coastal landscapes were larger between 1995 and 2000, a number of patches were higher in the following period.

Having the largest share of forest cover in the coastal zone, these landscapes also experienced major changes, comprising 94% of all changes in the area over this time (Table 12.2). About 5% of the total coastal forest cover was reduced by felling activities during 1995–2006. Landscape changes due to the increase in clear cutting were recognised as a major issue in the 1990s and 2000s for all three Baltic States (Mander and Kuuba 2004).

Forest resources have high importance in the economy of Latvia, as well as in the whole region. Wood and wood products contributed 20–37% of the foreign trade balance of the country during 1994–2007 (Central Statistical Bureau of Latvia 2007). Moreover, the actual trade volumes gradually increased by more than ten times over the period. The same trend has been observed for the generated growth value added by the forestry and timber-processing sectors. To achieve such results, the forest felling activities have also been growing. The forest management statistics on coastal municipalities show that the average annual final felling area has been 0.8–0.9% of the forest land. These statistics show an even higher speed of change compared to the statistics generated by data of the CLC.

Even agricultural land is not prevailing in the coastal zone of Latvia, with its share of the land cover decreasing by either the overgrowing of woodlands or the expansion of artificial surfaces. Changes of pastures to non-irrigated arable land, and vice versa, can be explained by agricultural practices, wherein arable land plots are turned into pasture after intensive use while the relevant pastures are cultivated into arable land. An increase of pastures is an overall trend in the agriculture of the country (Central Statistical Bureau of Latvia 2007).

Urban sprawl in coastal areas is also becoming a trend in Latvia. The change is apparent in the CLC2000–2006 data, showing an increase in the area covered by artificial surfaces, particularly during that period. This development has caused a loss of pastures and other agricultural areas. Even certain areas of forest have been turned into built-up areas. The growth of artificial surfaces has resulted in the expansion of such territories by 1%, which is much less intensive compared to the trend in Europe (European Environment Agency 2006b).

The growth of urban areas is unevenly spatially distributed, with new overtaken lands mainly close to the largest cities within these areas (Fig. 12.2). This pattern also correlates with the population migration during this period, as the statistics reveal that the populations of coastal municipalities at distances of 50–60 km from Riga, Ventspils and Liepaja increased (Central Statistical Bureau of Latvia 2007). Due to similarities in recent history and economic development, the urban sprawl in coastal areas over the last decade has also been confirmed by studies in neighbouring countries (Kull et al. 2007).

Table 12.2 Area of land cover change in the 10-km-wise coastal zone during the two time periods of 1995–2000 and 2000–2006

CLC at the beginning of the period	CLC at the end of the period	Area of change (ha)	
		1995–2000	2000–2006
133 Construction sites	112 Discontinuous urban fabric	–	29
211 Non-irrigated arable land	231 Pastures	1,060	89
231 Pastures	112 Discontinuous urban fabric	–	14
231 Pastures	121 Industrial or commercial units	–	7
231 Pastures	133 Construction sites	–	74
231 Pastures	211 Non-irrigated arable land	560	–
231 Pastures	324 Transitional woodland/shrub	–	80
242 Complex cultivation patterns	121 Industrial or commercial units	–	31
242 Complex cultivation patterns	133 Construction sites	–	9
242 Complex cultivation patterns	243 Land principally occupied by agriculture, with significant areas of natural vegetation	–	32
243 Land principally occupied by agriculture, with significant areas of natural vegetation	324 Transitional woodland/shrub	37	21
311 Broad-leaved forest	324 Transitional woodland/shrub	534	1,105
312 Coniferous forest	324 Transitional woodland/shrub	2,682	3,286
312 Coniferous forest	133 Construction sites	–	22
312 Coniferous forest	131 Mineral extraction sites	–	7
312 Coniferous forest	122 Road and rail networks and associated land	–	64
313 Mixed forest	121 Industrial or commercial units	6	–
313 Mixed forest	133 Construction sites	–	5
313 Mixed forest	324 Transitional woodland/shrub	4,695	3,857
324 Transitional woodland/shrub	312 Coniferous forest	–	37
324 Transitional woodland/shrub	313 Mixed forest	–	159
412 Peat bogs	324 Transitional woodland/shrub	–	15

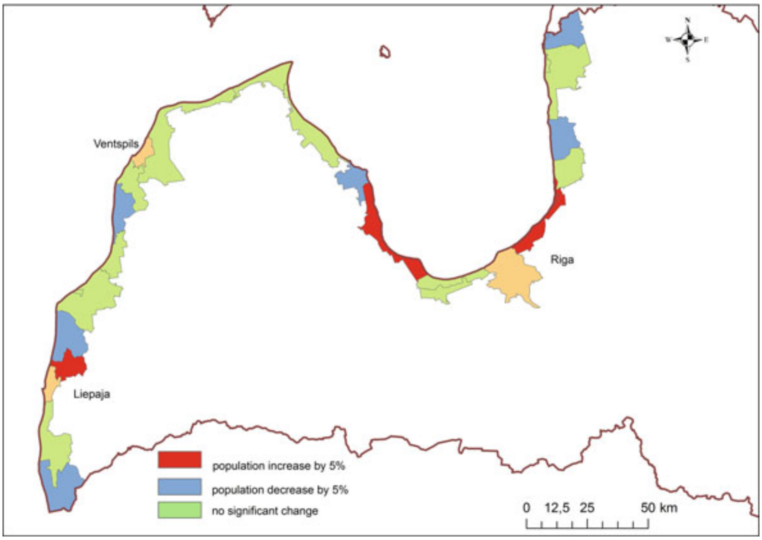

Fig. 12.2 Population dynamics in the coastal municipalities of Latvia (Data source: Central Statistical Bureau of Latvia 2007)

Ports (three large and seven small) have always been significant contributors to the economy of Latvia. Although their functions have partly changed over time, they are important for coastal zone development. Currently, traditional fishery harbours also serve for goods transport or recreational and leisure activities. To ensure increasing sea transportation, ports need an adequate infrastructure, which is also related to land demands and expansion policies. Of course, this trend causes pressure on the neighbouring original landscapes, which are often semi-natural or natural habitats with high biological value (Reise 2005, Ruskule 2009). Consequently, compromises between nature and landscape protection are required, and the best solutions consider both interests (Maes et al. 2004). Although the CLC data do not indicate changes in the sea port areas, the national regulations establishing harbour boundaries, which passed during 2006–2008, have increased the area assigned to this transport sector by two-fold during this period (from 2,025 to 5,059 ha). Consequently, these changes may soon result in the port areas occupying 1% of the coastal zone.

An assessment of the coastal land cover's spatial distribution reveals that the cover structure is different depending on the distance from the shoreline. CLC data outlining the changes that are larger than 5 ha did not record any change in the 300 m stretch along the coastline of Latvia. The changes in the 1-km zone were also minor, at just about 115 ha in total during 1995–2000 and 50 ha between 2000 and 2006. The changes were mainly caused by forest felling activities.

The analysis of aerial photograph images reveals the same phenomena as the CLC data. There were no major changes in the 300 m stretch with regard to forestry activities. It is clear that there were no clear-cut and final felling areas in this zone of

Fig. 12.3 Aerial photograph image of part of Mersrags parish, demonstrating the forest felling intensification towards the inland (Source: Latvian Geospatial Information Agency)

coastline. As the requirements for felling activities are not so strict for inland areas, the forest land cover structure is different there. The final felling and clear-cut areas appear in the 300 m to 1 km stretch, and the density of the felling patches increases towards the inland (Fig. 12.3).

To spatially assess the details of urban development, it is necessary to have older images with the same resolution. In Latvia, a housing plot in coastal villages is in the range of 0.1–0.5 ha, in rare cases up to 2 ha, partly hiding in the forest area. The minimum size for setting up of a new construction area outside a village is 3 ha. Considering the high price of land in coastal areas, new estate owners would prefer to establish smaller land units. Therefore, one can assume that the CLC data did not fix the urban sprawl to the full extent. Rapid development of the residential areas is also supported by statistics on the established dwellings of larger coastal towns (Central Statistical Bureau of Latvia 2007). An additional and more detailed study is needed to assess the development in this field.

12.3.3 Erosion Risks and Impact on Coastal Landscapes

A review of the CLC Coastline database indicates that about half the length of the Latvian coastline has a stable equilibrium between the erosion and accumulation of sediments. However, about 34% of the coastline is exposed to erosion.

Considering the large share of beaches and particularly sandy coasts (according to the CLC data, these form up to 85% of the shoreline), the beaches and dunes are the most susceptible to erosion. With about 24 km of pine forests, these landscapes comprise the next largest place (by area) under the pressure of erosion. Traditionally, urban settlements, industrial areas and ports have been a public concern with regards to coastal erosion. In total, a 11.2 km long coastal stretch might be suffering from this impact. Thus, various defence measures against sea attacks have been implemented in the past. For an overview on the landscapes exposed to coastal erosion (Table 12.3).

Because the majority of Latvian coasts have experienced an increase in erosion intensity and erosion risks are assessed as high (Eberhards et al. 2009), the coastal landscapes are vulnerable to changes of the coastline due to severe storms or rises in sea level. Severe storms (with wind speeds higher than 30 m sec^{-1}) along the open Baltic seacoast, with SW, W and NW winds, recur every 2–6 years, causing significant erosion (Eberhards et al. 2009). The rate of coastal erosion during any single storm has increased, averaging at three to six m, with maximums reaching 20 m (Eberhards et al. 2009). Thus, based on simplified estimates, certain stretches of the coastline may have retreated by about 20 up to 400 m by 2050.

Therefore, there is a need to reconsider the long-term effectiveness of the existing protection zone, as the lifetimes of the new houses and buildings are certainly more than 50 years. Consequently, the present width of the 150 m protection zone where

Table 12.3 The coastal landscapes exposed to erosion (length in m)

CLC Code	Erosion probable but not documented	Erosion confirmed, localised on parts of the segment	Erosion confirmed, generalised to almost the whole segment	Total
112 Discontinuous urban fabric	–	1,425	3,327	4,752
121 Industrial or commercial units	–	–	616	616
123 Port areas	–	–	5,664	5,664
141 Green urban areas	–	–	317	317
231 Pastures	1,320	–	9,037	10,357
242 Complex cultivation patterns	2,802	1,202	4,535	8,539
243 Land principally occupied by agriculture, with significant areas of natural vegetation	3,997	–	1,248	5,245
311 Broad-leaved forests	1,654	–	21	1,675
312 Coniferous forests	–	3,215	20,760	23,975
313 Mixed forests	1,524	–	564	2,088
324 Transitional woodland/shrub	–	–	668	668
331 Beaches, dunes, sands	4,016	8,797	90,433	103,246
333 Sparsely vegetated areas	–	–	463	463

new building development in coastal areas is limited might need to be expanded. Additionally, political positioning and approaches on how to compensate for the loss of valuable forest and semi-natural ecosystems should be developed. Despite the convenient environmental shifts that support the faster growth of the tree species in the region (Metzger et al. 2008), the forest ecosystems still need many decades to reach maturity. At least, a national debate on a new realignment of the protection zone should be initiated to ensure that the relevant landscape types and structures are preserved in the long term.

12.3.4 Impact of Nature Protection Policies

Latvia, as a Member State of the European Union, has transposed the relevant nature conservation directives, thus designating Natura 2000 sites for the network of nature protected areas in Europe (European Community 1992). As proven by this study, the

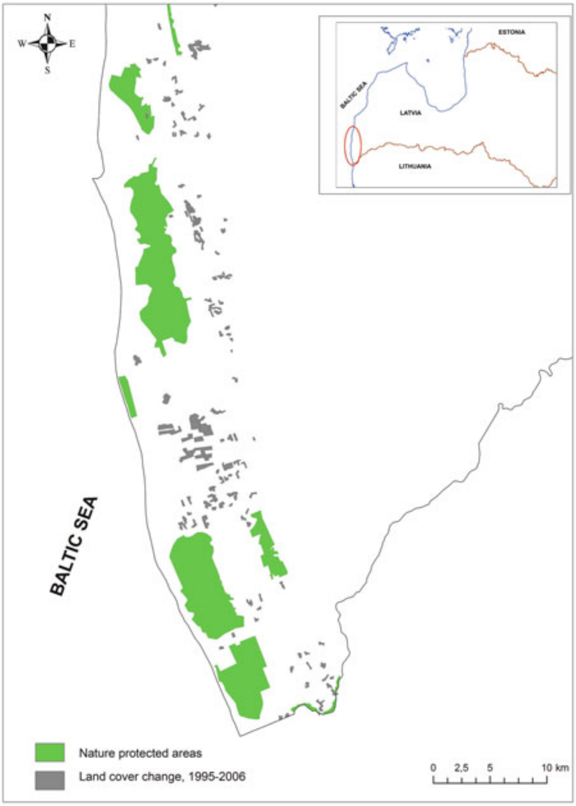

Fig. 12.4 Land cover changes in nature protected areas in the 10-km-wise Southwest Latvian terrestrial coastal zone

nature conservation policy also supports the ecological needs for forest landscape conservation to a certain extent. The assessment of the land cover changes in the coastal areas along the Latvian coast has reflected that forest felling activities have a much lower intensity in nature protected areas compared to other areas (Fig. 12.4). Moreover, the spatial distribution of final felling patches and the number of patches correlate with either the nature protection status or the available forest resources.

Nature protection legislation also limits the peat-cutting and drainage activities in the coastal areas, thereby ensuring the maintenance of the wetlands and marshes. However, the situation might change in the future. As the computed sea-level rise under global scenarios is about 30 cm by 2050 (UNEP 2007), there is a risk for seawater inundation in many areas of the Latvian coast. Then the coastal wetlands, marshes and meadows will be also exposed to the risk of disappearance or stepping back towards the inland.

12.4 Conclusions

The management of socioeconomic driving forces after the reinstitution of independence in 1991 has delivered certain results in the landscape structures of the Latvian coastline. The largest changes were driven by timber felling activities, leading to fragmentation of the forest ecosystems in the 10 km-wise terrestrial zone adjacent to the sea. Similar to the coastlines of other European countries, the Latvian coastline has also gained more artificial surface due to lost agricultural areas.

This study concludes that the coastal protection areas in the form of protection zones or nature conservation areas have been an effective mechanism to prevent significant land cover structure changes in these areas during 1995–2006. There have been no apparent clear-cuts in the protection zone of 300 m and a zero or low density of felling areas in Natura 2000 sites. However, the results also indicate that the pressures in terms of timber felling and new construction have been reallocated to the neighbouring areas. Therefore, when discussing the impact of the conservation policy on the landscapes, one needs to consider a wider scale then just a single habitat or ecosystem or narrow coastal strip. This principle should be earnestly considered and implemented in the spatial planning of Latvia or other locations or regions where similar strong sector-oriented policies have been set up, and an integrative approach of the spatial planning is rather formal.

As the markets demands either resources for timber or land for dwelling areas, each business sector (either forestry or estate development) must focus its strategy on those area where such limitations are weaker or are not imposed at all. As found in the case of the Latvian coastal zone, the pressures on landscapes become polarised, from untouched areas to the areas with the highest exploitation of resources.

Having regarded the recent trends in coastal erosion processes and considering the potential impacts of Climate Change, estimates show that coastal landscape structures will face major changes in future. Coastal beaches, dunes and forests are in danger to be lost to significant extents. While the existing human-developed structure will most likely be defended as much as possible, adaptation measures regarding natural and semi-natural landscapes also need to be developed to prevent undesirable losses for the country.

Although scientific details on the sizes or thresholds of the full range of Climate Change impacts on Latvian coastal areas are not currently available, the realignment of the protection zone should be a focus of future debate by means of practical adaptation measures. This precautionary approach will ensure better readiness for the coming challenges of the future.

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Part IV
Adaptation to Changes

Chapter 13
Adaptation of Urban Regions of the Baltic Sea Coast to Climate Change: Challenges and Approaches

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Abstract Climate change is occurring and its potential impacts pose manifold risks for the Baltic Sea Region. Due to their exposure, coastal urban regions are highly vulnerable to possible effects of climate change, like for instance sea level rise, floods or extreme weather events. Also, the urban regions are characterized by complex and manifold internal and external interplays and pressures for spatial development. In the first part, the article presents the particular conditions of coastal urban regions as well as the relevance of urban and regional planning in adapting to climate change. The second part refers to two selected urban regions of the Baltic Sea Region (Stockholm and Copenhagen) and their approaches of adaptation to climate change impacts, based on a documentary analysis. The third part presents an orientation for adaptation strategies from the urban and regional planning perspective. This includes the suggestion of comprehensive approaches with the integration of sectoral planning, of a regional focus as well as of an iterative and flexible planning. More specifically are proposed to tackle the following fields of activity: building aspects, open spaces, infrastructure and services and complex and spatially relevant social processes.

13.1 Introduction

Climate change is occurring and can be expected to cause several effects in the Baltic Sea Region. The rise in temperature, for example, is expected to exceed global warming by approximately 50 percent, with regional and seasonal varieties. By the end of the twenty-first century, the rise in temperature could be three to five degrees (BACC 2006). As a result, the number and intensity of heat waves could increase

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(Beniston et al. 2007). Furthermore, climate scenarios show a higher annual precipitation in the Baltic Sea Region, especially in winter (BACC 2006), while in summer, particularly in the south, precipitation could decrease (BACC 2006).

Therefore, in addition to mitigation strategies, adaptation to climate change impacts plays an increasing role. Not only the direct coastal zone and marine ecosystem are affected by impacts of climate change, but also coastal urban regions. For various reasons, such as the concentration of humans and infrastructure, they are highly vulnerable to possible effects of climate change, for instance sea level rise, floods or extreme weather events (cf. Storch and Omstedt 2008). Furthermore, due to their economical activities and functions, role as transport nodes or attractiveness for tourism and housing purposes, the urban regions of the Baltic Sea Coast are experiencing pressure for spatial development. Also, urban regions are characterised by complex and manifold internal and external interplays (Colding 2007), which will be highlighted in the context of adaptation to climate change. These specific characteristics cause the urban regions to be even more vulnerable to and challenged by certain climate change impacts (BMVBS and BBSR 2009).

In this context, the question arises how future land use structures within these urban regions can be planned, and how sustainable adaptation strategies towards climate change impacts can be developed. In such a situation, land use planning is especially challenged (Ritter 2007) to assure and achieve a sustainable structure of land use under the conditions of climate change, above all in urban regions with their specific characteristics.

The particular characteristics of coastal urban regions that confront future climate change impacts and the relevance of spatial planning in adaptation to these impacts are sketched out below (Section 13.2). Subsequently, the approaches implemented by the Stockholm region and Copenhagen are then presented as two examples of recent approaches in the Baltic Sea Region that have already developed adaptation strategies and are still in the ongoing process of further developing their strategies (Section 13.3). Underlined by these empirical findings, the general and theoretically driven specific characteristics of urban regions adapting to climate change impacts mentioned before are further developed to define specific challenges and aspects of adaptation strategies in urban regions and to outline overarching approaches as well as important activity fields (Section 13.4).

13.2 Particularities of Coastal Urban Regions and Relevance of Spatial Planning

13.2.1 Particular Conditions of Coastal Urban Regions

Urban regions are complex systems with manifold interrelations between human systems and ecosystems. On the one hand, humans, their livelihood and, therefore, cities and urban regions are dependent on ecosystems; on the other hand, they also alter landscapes and influence ecosystems (Alberti et al. 2003). Acknowledging strong interrelations between human systems and ecosystems, changes in the ecosystem due to climate change suggest impacts on the human systems (Davoudi et al. 2009). In fact, climate change impacts on cities and urban regions have been numerously analysed (BMVBS and BBSR 2009, Kropp et al. 2009, Mahrenholz 2007). The main specific characteristics of costal urban regions and their potential interplays with future climate change impacts are considered to be as follows:

(1) Due to some specific characteristics, urban areas are considered to be highly affected by climate change impacts. It is the concentration of humans as well as the density of buildings and infrastructure that lead to a high exposure of urban areas to climate change impacts (Dosch et al. 2008, Dawson et al. 2009). This is particularly the case in coastal urban areas, which are counted among the most densely populated areas (WBGU 1998). This is due to several advantages being located at the coast, such as access to transportation and trade, opportunities for food production and recreation (Klein 2002, Ruth and Rong 2006). In the Baltic Sea Region, development of the population has especially strengthened the metropolitan areas, whereas rural areas mainly lost inhabitants (Schmitt and Neubauer 2009). The consequence is further growth that goes along with an ongoing pressure on further land use, despite an increasing exposure to climate change impacts. Moreover, this leads to increased pressure on the coastal regions of the Baltic Sea, which consist of sensitive ecosystems between the land and the sea.

The extent and quality of climate change impacts on urban regions is assumed to be strongly influenced by local conditions, such as density, the quality of buildings, urban forms or land use (Satterthwaite et al. 2009a). Following this, the impacts of climate change on urban regions are not inherent to cities or urban areas, as Satterthwaite et al. (2009b) stresses, but can be seen 'as the product of inadequate planning and governance' (Satterthwaite et al. 2009b).

Even if the specific characteristics of urban regions can be disadvantageous with regard to climate change, they can be seen as an advantage, because they represent several opportunities for adaptation to climate change impacts (Dawson et al. 2009, Satterthwaite et al. 2009b).

(2) At the same time, the specific characteristics of urban areas tend to intensify climate change impacts. Urban areas are already characterised by a specific urban climate. It can differ highly from the environs, e.g. with regard to temperature, precipitation, thermal radiation or wind conditions (BMVBS and BBSR 2009). For example, the built environment and urban structure can cause higher temperatures in the city compared with the environs, the so-called Urban Heat Island effect (Souch and Grimmond 2006). An Urban Heat Island effect has also been verified in several cities in the Baltic Sea Region (Wienert 2001). Another example is urban wind conditions, which depend highly on density and urban structure, and can entail lower wind speed (Kuttler and Barlag 2002). Regional climate scenarios demonstrate that climate change could intensify the specific urban climate and related effects such as the Urban Heat Island effect (Endlicher and Kress 2008, Smith and Levermore 2008).

(3) For several reasons, urban areas in general play an important societal role. Firstly, they concentrate a large proportion of infrastructure and services, including

very important and highly vulnerable ones (Satterthwaite et al. 2009b). Therefore, they perform important functions not only for the urban area itself, but often also for the environs (e.g. hospitals, schools). Secondly, they contribute to economic development: enterprises and jobs are mainly located in urban areas (Ruth and Rong 2006). And thirdly, they include complex subsystems and are interlinked to regional, national and global structures (Fleischhauer 2008). Consequently, damages or losses in urban areas can cause very strong and severe effects, which can exceed the specific urban area and affect other cities or regions as well as other economic or societal systems (Ruth and Rong 2006). As most coastal urban regions make an important contribution to social and economic well-being and are still growing (Klein 2002), they are of particular importance for future development.

(4) Finally, coastal areas are especially affected by climate change impacts. They are considered to be regions with an increasing risk, e.g. with reference to extreme weather events or sea level rise (Endlicher and Kress 2008, WBGU 1998). As mentioned, the rise in temperature in the Baltic Sea Region is expected to exceed global warming by approximately 50 percent (with regional and seasonal varieties). By the end of the twenty-first century, the rise in temperature could be three to five degrees (BACC 2006). This could lead to less cold days or an increasing number of warm nights (BACC 2008). Furthermore, climate scenarios show a higher annual precipitation in the Baltic Sea Region, especially in winter (BACC 2006). In summer, and particularly in the south, precipitation could decrease (BACC 2006). Due to the land uplift of some regions, statements on the sea level rise in the Baltic Sea Region are difficult. By the end of the twenty-first century, some regions could experience a rising sea level, especially coasts along the south and east of the Baltic Sea Region (Fenger et al. 2001). In addition, coastal urban areas in general are affected by land use problems because of lack of space. The possibilities of spatial development are limited one the one hand by the sea and on the other hand by sensitive eco-systems.

For these reasons, special attention must be paid to coastal urban areas against the background of climate change. This particularly applies, because the aspects outlined above reinforce each other and increase the demand for adaptation of coastal urban areas. What renders the situation even more difficult is the complexity of cities together with the heterogeneity of urban regions characterised by developments which are non-linear, temporally and spatially dynamic, manifoldly interlinked as well as emergent (e.g. Alessa 2009, Allen et al. 2008, Batty et al. 2004, Manson and O'Sullivan 2006). If urban regions are understood as coupled and manifoldly interlinked socio-ecological systems, but dominated by humans (Alberti 2008), understanding their characteristics, interplays and dynamics becomes even more difficult. Here, it has explicitly been taken into account that the interplays between social and ecological processes of relevance for urban regions are not necessarily happening on the same spatial or temporal scale. Apart from the large resource demand demonstrated by urban regions, emerging and non-linear social, economic, cultural and political processes and their dynamic interplays also have to be taken into account if one looks at cities (Eckardt 2009) and urban regions. This is especially the case if the latter are also understood as heterogeneous regions where humans and their social systems dominate their immediate environmental surroundings. Still, they are resource based. Due to this complex setting, the concrete impacts of climate change, and especially of sudden, surprising and unknown events evoked by climate change, are producing a highly uncertain situation together with the already given uncertain aspects of slow-moving climate change, rendering any efforts to look forward and plan ahead very difficult. Under these circumstances, citizens and stakeholders as well as political and administrative decision-makers in the urban region will probably assess the problem and judge the need for action differently, depending on their subjective perceptions, norms and interests; they will doubt or approve the need to adapt to potential climate change impacts, and support or possibly block efforts to adapt (Becker et al. 2008, Overbeck et al. 2008, Renn 1984, Scharpf 2000).

With reference to the initially raised question of how land use should be adapted to climate change impacts, this means tackling this challenge of complexity with manifold dynamic interplays in its entirety. Here, spatial planning approaches are supposed to be of certain relevance.

13.2.2 Relevance of Urban and Regional Planning in Adapting to Climate Change in Coastal Urban Regions

It is widely recognised that spatial planning plays a pivotal role in adapting to climate change (i.a. Davoudi et al. 2009, Dawson et al. 2009, Fleischhauer and Bornefeld 2006, Fuerst 2006, Termeer et al. 2009). In the European Union, the 2001 report by the Intergovernmental Panel on Climate Change (IPCC), in particular, provided an important impetus for tackling the topic of adaptation to climate change (Termeer et al. 2009). International and national programs and reports set up after this IPCC report acknowledge the importance of spatial planning for mitigation as well as adaptation (Davoudi et al. 2009).

Mitigation and adaptation are regarded as two complementary aspects which have to be taken into account in spatial planning (i.a. Blanco and Alberti 2009, Davoudi et al. 2009, Wheeler et al. 2009). To avoid conflicts on the one hand, and to take advantage of synergies on the other hand, an integrated view of both aspects is recommended (Hall 2009, Davoudi et al. 2009), even if the relations between mitigation and adaptation have so far been barely examined (Howard 2009). However, there are some differences between the two aspects which require different approaches and specific measures (in detail Hall 2009, Howard 2009). In contrast to the topic of mitigation, aspects of adaptation have, until now, been less regarded in spatial planning (Davoudi et al. 2009, Satterthwaite 2009b), although the role of spatial planning in adaptation is partially valued higher than in mitigation: ‘While spatial planning has something to contribute to mitigation, its main challenge is to help prepare for the rather uncertain future of climate change’ (de Vries 2006).

Both impacts of climate change and adaptation strategies have a spatial relevance. For example, decisions about land use and the current and future location of buildings or infrastructure can be questioned against the background of sea level rise or flooding (Ritter 2007). Spatial structures of urban regions strongly influence the urban climate, such as the temperature or urban wind conditions, and technical standards and building materials determine if a building is prepared for extreme weather events or higher temperatures (Smith and Levermore 2008). Spatial planning plays an important role for all of these issues, because it influences the spatial configuration, type and degree of building and land use as well as landscapes and green spaces (BMVBS and BBSR 2009). Moreover, spatial planning plays an important role in integrating all of the different existing stakes and interests in land use coming from different actors and fields, and in trying to come to comprehensive and common solutions on land use in a specific area.

Adapting to climate change confronts spatial planning with growing challenges which mainly result from the high level of uncertainty and the long-time horizon of climate change. The uncertainty of climate change is seen as a pivotal challenge for spatial planning (i.a. Hall 2009, Hallegatte 2009). Spatial planning has always had (and still has) to deal with future developments and, consequently, their uncertainties, but climate change is seen as increasing this aspect (Heiland and Kowarik 2008). It is difficult to assess whether uncertainty of climate change is higher compared to other future developments. What seems to be the difference is that uncertainty is named, and one of the requirements is that this uncertainty must be dealt with.

Another challenge lies in the long-time horizon of climate change. While the time horizon of climate change scenarios is usually set to the end of the twenty-first century, planning horizons often focus on the next ten or 15 years (Ritter 2007, Fleischhauer and Bornefeld 2006). Nevertheless, planning has to consider long-time developments such as climate change: decisions on spatial development made today have consequences for the next 100 years or even longer. This means that buildings and infrastructure need to be adapted to the current as well as future climate (Hallegatte 2009).

Even though all planning levels are seen as relevant for adaptation to climate change, particular attention is given to the level of urban and regional planning (i.a. Ritter 2007, Blanco and Alberti 2009). As climate change impacts differ substantially from one region to another, strategies and measures have to be developed at the local and/or regional level (Blanco and Alberti 2009, Hall 2009). Furthermore, the regional level enables an integrated perspective which includes different sectoral planning aspects such as transport planning or landscape planning. In conclusion, the regional level, in particular – and consequently regional planning – allows the coordination of different demands on an adequate scale as well as the development of sufficiently concrete strategies and measures (Overbeck et al. 2008). In contrast, the local level has legally binding mechanisms and instruments lacking at the regional level (Sussman and Major 2010). As regional and urban planning make different contributions to adaptation, it seems to be important to integrate both according to their specific competences.

As mentioned above, spatial planning has always had to deal with uncertainties, but also with different demands on land use and environmental issues. One specific approach for tackling these aspects in coastal areas is Integrated Coastal

Zone Management (ICZM) which, furthermore, includes concerns about climate change (Tol et al. 2008). ICZM is a dynamic, multi-disciplinary and iterative process for promoting the sustainable management of coastal zones which attempts, ‘over the long-term, to balance environmental, economic, social, cultural and recreational objectives, all within the limits set by natural dynamics’ (COM 2000). It is based on eight principles, such as a long-term perspective, adaptive management and reflection of local specificity (COM 2000). Theoretically, it could also contribute to adaptation to climate change. However, Tol et al. (2008) conclude that it is ‘still unclear how adaptation to sea-level rise relates to and would fit in with current coastal management practices, although these linkages are widely acknowledged’ (Tol et al. 2008). With regard to adaptation to climate change, further research needs to be carried out on the linkages and applicability of approaches such as ICZM. But what is already transferable or what could be integrated into regional and local spatial planning strategies on climate change is the specific area-related approach, especially for the coastal zones.

13.3 Examples of Approaches for Adaptation to Climate Change Impacts of Selected Urban Regions of the Baltic Sea Coast: Stockholm Region and Copenhagen

Two selected urban regions are presented below as examples of adaptation approaches to climate change impacts within the Baltic Sea Region. Thereby, the focus is neither on the legal framework of these two countries nor on the planning system, nonetheless acknowledging their relevance. Rather, the aim is to highlight exemplarily two urban regions and their ways of dealing with climate change impacts. On the basis of a documentary analysis of about 70 scientific and non-scientific documents, there seem to be very few cities in the Baltic Sea Region which have developed an integrated adaptation strategy to climate change impacts yet. If adaptation to climate change impacts is tackled, the majority of the cities and urban regions focus, in particular, on technical measures, such as flood protection, including the heightening of dykes and disaster management. Two urban regions in the Baltic Sea area which seem to deal comprehensively with climate change impacts are the Stockholm region and Copenhagen. They are presented by way of example for analysing the challenges of adaptation to climate change.

13.3.1 The Stockholm Region

13.3.1.1 Background and Climate Change Impacts

The Greater Stockholm region is spread throughout 26 municipalities and populated with about 1.9 million people with varying socio-economic profiles and exposures to impacts of climate change. With its 800 000 inhabitants, the City of Stockholm is the largest municipality and the capital of Sweden. This monocentric region has a good public transport system and is marked by large rural areas, mostly forest and agriculture (Nilsson and Swartling 2009, Viehhauser 2010).

It is expected that, by the year 2100, the average annual temperature in the City of Stockholm will have risen by 2.5–4.5°C, and the region will also experience increased amounts of precipitation and higher water levels in the sea and lakes. Further, the coldest winter days will decrease, which means that, essentially, there will no longer be cold winter days with a mean daily temperature of below −10°C and, consequently, less snow and a shorter snow and ice season. It is expected that spring floods will come 2–4 weeks earlier and the harvest season will be 1–2 months longer. The summers will be dryer and severe weather such as torrential rain, storms, etc., more frequent (Stockholm Environment Administration 2009, Ekelund 2007).

The Stockholm region is marked by Lake Mälaren, which connects to the Baltic Sea in the central parts of Stockholm. Mälaren, which has been regulated since the 1940s, is the major drinking water supply for many municipalities, including the City of Stockholm. Therefore, sea level rise could affect the water quality because of salt water intrusion, which is a primary concern in the Stockholm region (Nilsson and Swartling 2009, Viehhauser 2010). A further concern is the potential danger of flooding from Lake Mälaren as well as from sea level rise. A lot of low-lying populated areas and crucial facilities in Stockholm would be potentially flooded at a water level of 2.15 m (Schmidt-Thomé et al. 2006, Ekelund 2007).

13.3.1.2 Approaches for Adaptation to Climate Change Impacts

Several starting points triggered the adaptation activities in the Stockholm region: at the international level, the reports by the Intergovernmental Panel on Climate Change (IPCC) of 2001 and 2007, the EU's White Paper on Adaptation and some Interreg projects such as SEARREG and ASTRA. At the national level, the study on 'Sweden facing climate change – threats and opportunities' (Swedish Commission on climate and vulnerability 2007:60) and flooding and land slide studies for all of Sweden as well as climate scenarios by Sweden's Meteorological and Hydrological Institute (SMHI) were essential (Viehhauser 2010). In reaction to these, the City of Stockholm presented 'Stockholm's Action Programme on Climate Change' in 2007 (Ekelund 2007). Recently in 2010, a project plan for climate adaptation in the Stockholm region was completed by the State Board of Stockholm, and there are plans to integrate the issue of adaptation in the regional plan.

In 'Stockholm's Action Programme on Climate Change', three areas of actions for dealing with climate change impacts are being considered: flooding, soil contamination and biodiversity.

With respect to flooding, the County Administrative Board has recommended that no new construction should take place in areas at risk of flooding within 100 years, i.e. where the likelihood of flooding within 100 years is 63 percent or more, with the exception of unoccupied buildings such as garages and sheds. Elements of risk or important public services should only be considered in areas that are not at risk of flooding within 100 years or subject to the highest dimensioned flow, e.g. hospitals, nursing homes, schools or other significant infrastructures, water supply and sewage management plants, power plants and telecommunications as well as industries of a substantial environmental impact (Ekelund 2007).

With reference to the effects of climate change on soil contamination, further ongoing work is required. Firstly, an increased awareness in general, and especially among municipal planners and land users, is necessary. Secondly, additional inventory and critical area analysis is the basis for further action, such as prioritising areas for the post-treatment of polluted areas. Thirdly, a storm water strategy that allows for a change in climate is required (Ekelund 2007).

Several actions are recommended in ‘Stockholm’s Action Programme on Climate Change’ for reducing climate change impacts on biodiversity. In terms of planning, minimization of landscape fragmentation, maintenance of pathways for the dispersal of species and creation of areas for new habitats are measures for reducing climate change impacts on biodiversity. In addition, climate change should be taken into consideration when planning for the preservation of protected areas and caring for municipal parks, and plants. Furthermore, Stockholm needs new run-off water and surface drainage strategies and a continuous review of the role of nature for recreation and health in the city (Ekelund 2007). The positive effects of green areas that surround the city and extend in wedges into the city’s central districts are mentioned not only with respect to climate change mitigation, but also with regard to the adaptation to climate change effects. Green areas ‘even out the water flow, filter contaminations, produce oxygen and provide refreshment’ (Stockholm Environment Administration 2009).

In 2007, the City of Stockholm formulated some overarching aims to support the work of adjusting to a changing climate, such as performing a vulnerability analysis, deciding on municipal strategies for necessary adjustment, developing municipal strategies and action plans for all areas, implementing the relevant strategies and actions in all areas, and following up, summarising and reporting to the rest of the world (Ekelund 2007).

Climate change adaptation is becoming increasingly important and has been established more and more in regional administration. In 2009, a project started with the overarching aim of supporting the local communities of Stockholm in adapting to climate change. Apart from communication and capacity building measures, the following objectives are to be achieved (Adolphi 2010): establishment of regional responsibilities, adaptation to climate change as a ‘mainstream’ to be taken into account during daily work, coordination between sectors and authorities to be supported by district government, establishment of a network of all relevant institutions and persons who are involved in adaptation to climate change, data collection and supply of specific knowledge regarding climate change impacts in the Stockholm region, cost-benefit analysis of adaptation measures, support of concrete measures, guidelines for new constructions and visual representation of drinking water quality and sea level rise.

At the regional level, climate change adaptation is playing an increasingly important role. According to Viehhauser (2010), the plan is to integrate issues regarding vulnerability, robustness and adaptation in the regional plan. In the short term (until 2030), adaptation requirements such as new standards of water and sewage systems, reinforcements of power systems and alteration of rain water systems are mentioned. In the long term, safeguarding eco-systems, handling sea level rise and preserving the drinking water basin of Lake Mälaren are regarded as important (Viehhauser 2010).

As indicated above in ‘Stockholm’s Action Programme on Climate Change’, measures for the Stockholm region to adapt to climate change impacts include safeguarding the drinking water supply from Lake Mälaren, integrating adaptation work in ordinary planning procedures and programmes, handling flood risks in municipal planning, and making long-term decisions on new investments in infrastructure (Viehhauser 2010).

13.3.2 Copenhagen

13.3.2.1 Background and Climate Change Impacts

Copenhagen is located on the eastern shore of the island of Zealand (Sjælland) and the largest city and the capital of Denmark with a population of about 1.3 million inhabitants (metropolitan area), of which only 2 percent live in areas with an elevation of less than 1 m above sea level (COM 2009, Hallegatte et al. 2008).

Copenhagen, as a low-lying city, is potentially vulnerable to coastal flooding (COM 2009). According to an OECD study, Copenhagen will have problems in future with handling extreme, temporary water increases of 1.5 m or more, but currently, the coastline is considered well-protected by dykes and the city harbour by quays that are about 2 m above sea level (Hallegatte et al. 2008, COM 2009). Due to Danish legislation, measures for coastal protection must be financed by the persons who profit from them (COM 2009). Therefore, measures are being realised only when the persons affected regard these measures as necessary. In addition to sea level rise, precipitation will increase by 30–40 percent up to 2100, and the city centre is getting warmer because of rising temperatures (Rasmussen 2009, City of Copenhagen 2010).

Since 1 January 2007, the planning system in Denmark has been changed: the 14 counties have been transformed into five regions. The regions are now responsible for the hospitals, including health care services and a few other tasks in the field of environment, public transport and regional development (KL 2010). About 97 percent of the budget is for hospitals and health care and only 3 percent are remaining for regional development issues such as environment and transportation companies (Capital Region Copenhagen 2009). The loss in significance of the regional level has the consequence of a more difficult process of regional coordination (Leonardsen 2010). There are no more funds for cooperation and tackling further questions at the regional level than for roundtables without legally binding actions. The activities of the regions are paid by subsidies from the municipalities and the state; the regions themselves have not the right to impose taxes (KL 2010). The regions can only co-finance projects and not initiate those, so the instruments are really limited (Capital Region Copenhagen 2009).

13.3.2.2 Approaches for Adaptation to Climate Change Impacts

Obviously, there are no comprehensive approaches for adapting to climate change impacts for the greater region of Copenhagen. As tasks of spatial development are nearly of no significance at the regional level, there is consequently no adaptation strategy at the regional level. Therefore, the focus of the next section only refers to the City of Copenhagen.

The City of Copenhagen developed a 'Copenhagen Climate Plan'. On the one hand, it aims at reducing greenhouse gases and, on the other hand, at adapting to possible climate change impacts. Concerning adaptation, it is confirmed that 'the municipality of Copenhagen will develop a climate adaptation plan to ensure that the city is ready for the weather expected from climate change' (City of Copenhagen 2010).

The importance of the issue of adaptation to climate change is expressed in the following quote, 'It is of key importance that we safeguard our city for the future and for extreme weather events' (City of Copenhagen 2010).

To reach this goal, five adaptation initiatives have been suggested:

1. The municipality will develop various ways of draining water from torrential downpours and apply these methods throughout the city.
2. Additional green areas, pocket parks, green roofs and green walls will slow rainfall run-off, thereby reducing the risk of flooding.
3. More buildings will use alternatives to air-conditioning units, such as sunshades, improved ventilation and insulation.
4. Safeguarding against flooding and rising sea levels.
5. The municipality will develop a comprehensive climate adaptation strategy.

The 'Copenhagen Climate Plan' mentions that long-term planning and long-term investments play a highlighted role, and that synergies are required between several values. Climate change adaptation is seen as a chance to transform the city into a 'better place to live' (City of Copenhagen 2010) and to use the changing climate as a trigger to valorise the city. Benefits of climate change adaption are seen by way of example in the use of rainwater as local water features, harbour bath, re-opening of streams and pocket parks (Rasmussen 2009).

The City of Copenhagen suggests the lighthouse project 'pocket parks as breathing spaces' to translate the idea of combining quality of life with adaptation measures into practical terms (City of Copenhagen 2010).

Pocket parks are little patches of green space which help to cool down the city on hot summer days and bring fresh air into the city. Additionally, they can absorb rain water and be used for leisure activities and recovery. Pocket parks are a possibility for combining beauty with necessity. The green spaces enrich the quality of life in the city, pushing it in the direction of sustainable urban development, 'in the midst of the concrete, tiles and asphalt and between skyscrapers, in alleys and side streets. We can develop a green and healthy environment in an urban setting, providing meeting places for Copenhageners and our guests' (City of Copenhagen 2010).

These ‘living oases’ should include variations of plants, functions, elements and atmospheres to assure attractive places in the city. It is planned to create at least two new pocket parks for Copenhagen each year (City of Copenhagen 2010). The vision is a green and blue capital, where the majority of all Copenhageners have less than 15 min’ walk to a park or beach, and where Copenhageners will visit green areas twice as often as they do today (Rasmussen 2009).

The adaptation functions are various: on the one hand, people can spend their time in cooler areas of the city on hot days, and the surroundings of the green parks profit from green breathing spaces. During rainy periods, the pocket parks absorb water. This will buffer the flow of heavy rains to sewers, storing water for warm and dry days (City of Copenhagen 2010).

The combination of sustainable urban development and adaptation measures such as pocket parks can be highlighted. The aim of the City of Copenhagen is to create a place worth living in for everyone, which is enthusiastically expressed, ‘We could draw on many solutions to adapt to the future climate. But we choose the green one. In many ways it’s the cheapest solution while being an investment into a more beautiful, healthier and better city, allowing us to combine environment with city life and play. The solution which offers greatest benefit and happiness to us all.’ (City of Copenhagen 2010).

13.4 Challenges for Planning and Aspects of Climate Change Adaptation

Summarising the particular conditions for coastal urban regions and the relevance of urban and regional planning outlined above, several aspects for adaptation to climate change can be derived, which should be taken into account by urban and regional planning acknowledging the particular competences and responsibilities. Additionally, the adaptation strategies presented and the approaches implemented by the Stockholm region and Copenhagen are used to underline the importance and practical relevance of these aspects.

As mentioned above, the impacts of climate change vary regionally and temporally. Therefore, it does not seem useful to recommend general or standardised adaptation measures and strategies. The examples of Stockholm and Copenhagen demonstrate this very well while focusing on different issues, acknowledging the specific local impacts of climate change as well as the particular spatial circumstances. Consequently, the derived aspects should be understood as an ***orientation for adaptation strategies from the urban and regional planning perspective***. It should be emphasised that this contribution focuses on spatial measures and strategies, not on the adaptation process itself, while fully acknowledging its importance.

Any action within these aspects is determined by the challenges of uncertainty, the long-term horizon as well as the impacts of climate change on the one hand, and the complexity and specific characteristics of coastal urban regions and their vulnerability towards these impacts and changes as evoked by climate change on the other hand. Keeping this in mind, the following aspects concerning, firstly, the overarching strategic adaptation ***approach*** and, secondly, the specific ***fields of adaptation activity*** for land use planning can be pointed out (Fig. 13.1):

- comprehensive approach and integration of sectoral planning (first approach),
- regional focus (second approach),
- iterative and flexible planning (third approach),
- building aspects (first field of activity),
- open spaces (second field of activity),
- infrastructure and services (third field of activity),
- complex and spatially relevant social processes (fourth field of activity).

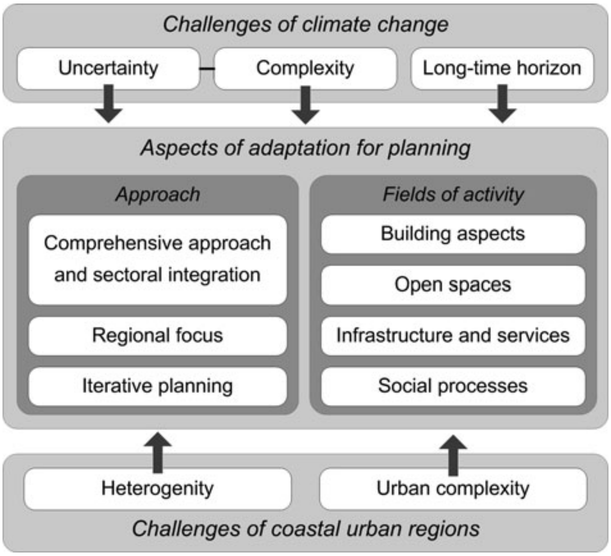

Fig. 13.1 Orientation for adaptation strategies from the urban and regional planning perspective. Challenges of climate change combined with the challenges of coastal urban regions require specific approaches and the consideration of specific fields of activity (compiled by authors)

13.4.1 First Approach: Comprehensive Approach and Integration of Sectoral Planning

As urban regions are complex systems, climate change causes numerous effects which, in turn, are characterised by manifold interrelations. Therefore, adaptation to climate change in urban regions cannot be handled by sector or on one dimension. Rather, it requires a comprehensive approach, integrating different issues, and also, from the perspective of urban and regional planning, especially sectoral planning, e.g. transport, environmental planning or water management. Moreover, the complex social processes and interactions related to land use in urban regions have to be taken into account, as well as their interlinkages with ecological processes.

The City of Stockholm as well as the Greater Region already address this challenge. Climate change adaptation is to become a mainstreamed issue in the daily work of urban and regional administration with (theoretically) all of the actors involved being included. Particular emphasis is laid on the coordination between different sectors and authorities and the establishment of a network of all relevant institutions. These objectives indicate a high awareness for the importance of a comprehensive approach. The City of Copenhagen aims to develop a comprehensive climate adaptation strategy, already indicating topics such as downpours, flooding, sea level rise, green areas and buildings. With regard to the adaptation strategy, the city underlines the synergies between all environmental initiatives.

13.4.2 Second Approach: Regional Focus

Cities and their environs are characterised by complex interactions. Therefore, it seems useful to include the regional level when adapting to climate change. This also applies, for example, to regional green areas which influence the air quality in the city, as well as to flooding which cannot be tackled solely within administrative borders.

Apart from 'Stockholm's Action Programme on Climate Change', the Stockholm region also addresses adaptation to climate change. Several issues are planned for integration in the forthcoming regional plan. With regard to the spatial level, the city and region are tackling different aspects. While the City of Stockholm is also dealing with municipal parks, recreation and health, the Greater Region focuses on regional topics such as rain water, sea level rise or drinking water. Copenhagen, in comparison to that, is hardly acting at the regional level which experienced a loss of relevance as a result of the local government reform in January 2007.

13.4.3 Third Approach: Iterative Adaptation Planning

Due to the given uncertainties and potential nescience concerning climate change and its impacts on complex urban regions as shown above, it seems necessary to understand the adaptation planning as open to new information and new generated knowledge, as well as flexible enough to integrate this new information in decisions on land use. As potential new trade-offs might also be produced through the implementation of adaptation strategies, they have to be identified, made explicit and integrated into adaptation planning. This requires an understanding of an ongoing and iterative planning process.

13.4.4 First Field of Activity: Building Aspects

An important field of activity deals with aspects concerning buildings and the settlement structure, which mainly contribute to adaptation to climate change. This covers not only the urban and regional spatial structure, but also the type and degree of building and land use and the quality of buildings.

Due to the high relevance of water, one important recommendation in the Stockholm region is not to permit any new construction in areas that are at risk of flooding within 100 years. Further attention is paid to new building standards and guidelines for new construction. Until now, the City of Copenhagen has pointed out technical measures, such as sunshades or insulation for buildings.

13.4.5 Second Field of Activity: Open Spaces

In addition to building aspects, the development of open spaces is considered an important field of activity (such as areas of vegetation in settlements, squares, green belts, parks or undeveloped vacant sites). Open spaces mainly contribute to the urban climate and play a pivotal role for recreation and health of the population.

Concerning open spaces, Stockholm addresses large-scale development (such as minimization of landscape fragmentation or green areas around the city) as well as small-scale aspects. The City of Stockholm mentions municipal parks, plants, and trees or the role of nature for recreation and health. Copenhagen even concentrates on ‘green’ measures that allow environmental aspects to be combined with positive effects for the inhabitants.

13.4.6 Third Field of Activity: Infrastructure and Public Services

Urban areas provide a huge number of important infrastructure and public services, such as hospitals, fire service, schools, transport or energy infrastructure, and water supply. They are of high relevance both for the city, the region and sometimes even for the country and, therefore, require special attention.

In the Stockholm region, so-called ‘elements of risk or important public services’, such as hospitals, nursing homes, schools, water supply and sewage management plants, power plants and telecommunications as well as industries of a substantial environmental impact, should only be considered in areas that are not at risk of flooding within the next 100 years or subject to the highest dimensioned flow. Even new standards, reinforcements and alteration of infrastructure systems are mentioned.

13.4.7 Fourth Field of Activity: Complex and Spatially Relevant Social Processes

As social processes determine urban structure and land use, their feedback and interlinkage with ecological processes as well as with other fields of activity must especially be taken into account.

The establishment of regional responsibilities and the reinforcement of networks between the crucial actors in Stockholm in the field of adaptation to climate change can trigger social learning processes.

13.5 Conclusion

The presentation of the examples for both the region of Stockholm and the City of Copenhagen demonstrate the importance of developing locally specific adaptation measures, strategies and approaches. Both prioritise different aspects according to their spatial conditions and the specific local climate.

With regard to the uncertainty, complexity and long-time horizon of climate change adaptation, the selected examples shown either subconsciously or actively, a pragmatic route, starting with one or two aspects and focusing on the most important measures as well as those which are easy to implement.

The developed orientation should be understood as a starting point for further research to develop, complement and improve this orientation, and for practitioners to support the development of an adaptation strategy.

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Chapter 14
Adaptation to Climate Change: Viniculture and Tourism at the Baltic Coast

Gerald Schernewski

Abstract In 2000, the European Union acknowledged Denmark as an official wine growing country. Recently Rattey and Burg Stargard (near the German Baltic Sea coast) received its official recognition as the northernmost German wine-growing area. These are just exemplary cases, which reflect the ongoing northwards extension of vineyards and the ongoing re-introduction of viniculture around the Baltic Sea. It is already a clear indicator of a recently warmer climate. Grapes favour warm and sunny summers, with average temperatures of at least 13–15°C during the growing season (April–October), sufficient precipitation and mild, dry autumns. For wine growing the average annual temperatures should be between 9 and 13°C and the annual accumulated sunshine hours should at least reach 1,100 h. Along the southern Baltic Sea coast these conditions are already met, suitable grape varieties like Helios or Solaris exist and allow a commercial wine production. These new grape varieties, possess a high degree of resistance towards fungal diseases, considerably reduce plant protection measures and thus allow an environmental friendly viniculture. Viniculture in marginal regions, like at the Baltic Sea coast, is more laborious, bears more risks, and the crop yields will be lower compared to the traditional wine regions. On the other side, tourists, collectors, and the increasing wine interested audience are willing to pay much more per bottle than for a comparative product from a traditional German wine region. However, viniculture at the Baltic Sea coast has to be regarded as an attraction and can hardly become a large-scale agricultural product. Large amounts of tourists visit the southern Baltic Sea coast during summer-month. In future, warmer summers and higher water temperatures will allow an increase in tourism and an extension of the summer season. However, the rural coastal hinterland does not benefit much from these tourists, because attractions are lacking. The growing interest in wine as cultural element and increasing wine-tourism indicate that vineries could serve as attractions and support the sustainable rural development. Further, viniculture is labour-intensive, would create jobs in rural areas and could contribute to a revitalization of the countryside.

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14.1 Introduction

According to the United Nations Framework Convention on Climate Change (UNFCCC), the term Climate Change means a climatic change attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. According to IPCC (2007), 11 of the last 12 years (1995–2006) rank among the 12 warmest years since 1850. Observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level provide clear evidence of an ongoing global warming. In recent years research activities addressing Climate Change shifted their focus from analysis and evaluation of consequences via mitigation strategies towards adaptation approaches. This is well reflected in recent large national and international projects like BaltCICA (Climate Change: Costs, Impacts and Adaptation in the Baltic Sea Region) or RADOST (Regional Adaptation Strategies for the German Baltic Coast). Adaptation is the topic of this article, as well.

The regional impact of Climate Change is very different. In Europe, especially the Mediterranean will be affected very much. Climate Change is projected to increase heat waves and droughts during summer, reduce water availability and decrease crop productivity. The negative consequences in the Mediterranean are overwhelming and Climate Change is regarded as a major threat for the future (e.g. Giupponi and Shechter 2003). In the Baltic, the effects as well the perception and evaluation of the consequences is different. More and more people become aware that Climate Change offers opportunities and the economical and social benefits of a warmer climate are of increasing interest. The problems of Climate Change for viniculture are well addressed in recent literature for many regions (e.g. Jones et al. 2005, Maixner et al. 2007, Müller 2006, Prior 2007, Webb et al. 2007). Positive aspects of Climate Change for single regions are much harder to find.

This article addresses viniculture and its potential for tourism in the Baltic. It gives an overview of viniculture in the Baltic, the consequences of a changing climate in the past and future and outlines new opportunities for viniculture in northern countries due to new grape-varieties. Against this background the opportunities of viniculture along the Baltic Sea coast as a tourist attraction, for the development of the rural coastal hinterland and the revitalization of the countryside is discussed. The topic viniculture and tourism in the Baltic can serve as an example. In general, this idea can be applied to several specialised crops requiring a warmer climate.

14.2 Viniculture as Climate Indicator

During the medieval warm period, temperatures were up to 1°C higher than today and viniculture covered many areas north of today's traditional wine regions. The names of towns indicate that viniculture was common in northern Germany and

Poland up to the southern Baltic Sea coast (e.g. Stock et al. 2003). Examples are the Cistercian monastery in Doberan, the castle of Stargard, the cities Schwerin, Güstrow and Neukloster in Mecklenburg as well as the monastery Paradise in Poland. During temperature declines in the fourteenth century many northern vineyards died, because the growing seasons became too short. Despite that, wine production near the city of Sabile in Latvia is reported from the sixteenth century and several early wine growing areas produced wine until the nineteenth century. In Silesia about 14 km^2 of land, possessed mainly by monasteries, were in the nineteenth century still covered with vineyards. 2 km^2 of vineyards dating back to the medieval can still be found near Zielona Gora (Poland). However, only very few Baltic vineries survived until the twentieth century, covered only small areas and the quality of the wine often was poor.

The development in other northern regions, like in England, was very different. Already during roman time, viniculture was common there and an important agricultural branch. During the following centuries, this tradition was largely lost and reintroduced only after the Second World War, when the first vineyard was planted in Hampshire. During the last two decades, vineyards grew fast in number and size (7.5 km^2 in 2003) and wine growth was extended towards northern parts of the country.

The ongoing northwards extension of vineyards can be seen in other countries, as well. In 2000, the European Union acknowledged Denmark as an official wine growing country and allowed commercial viniculture on about 1 km^2 (100 ha). In 2007, several very small Danish producers grew wine on 0.24 km^2. However, Danish wine still is hardly more than a local attraction. The same is true for several recently established wineries in northern Germany. For example, in Rattey and Burg Stargard, 50 km south of the Baltic Sea coast close to the Polish border, viniculture was re-introduced in the 1990s and grape-vine is nowadays grown on nearly 0.04 km^2 (4 ha). In 2004, it received its official recognition as the northernmost German wine-growing area and has the permission to produce and sell wine commercially.

The ongoing northwards extension of vineyards and the re-introduction of viniculture around the Baltic Sea is already a clear indicator of a recently warmer climate. Of course, the search for new attractions and a growing interest in wine as cultural element plays a role, as well.

There are other indicators for a recently warmer climate, like phenological growth stages. According to Hönig and Schwappach (2003) the grape variety Müller-Thurgau in Franken shows an earlier date of shoot of about 8 days compared to the late 1980s. The same is true for the blossom, which nowadays takes place 8 days earlier. Today, the blossoming period is shorter and grapes become ripe 11 days earlier. Stock et al. (2003) give examples for other regions. In the Rheingau, the Riesling grape harvest is about 15 days earlier compared to 1960. In Bordeaux, the phenology of grapevines has tended towards a shortening of phenological intervals, and a lengthening of the growing season over the last two decades, as well (Jones and Davis 2000). Further, during the last 20 years the red wine production in Germany has tripled. This is partly driven by customers demand, but red grape varieties generally require a warmer climate, and can be regarded as indicator for warming, as well.

14.3 Climate Chance and Viniculture – Future Perspectives

Climate Change has consequences on existing wine growing regions and offers opportunities to expand viniculture further north. In general, the growing season of grapes is between about 160 days for the grape-variety Müller-Thurgau (Hönig and Schwappach 2003) and 240 days for red grape varieties. Grapes favour warm and sunny summers, with average temperatures of at least 13–15°C during the growing season (April–October), sufficient precipitation and mild, dry autumns. For the vine growing the average annual temperatures should be between 9 and 13°C and the annual accumulated sunshine hours should at least reach 1,100 h. For a stable high quality wine, 1,300 sunshine hours are needed and the best quality is obtained with 1,700–2,000 sunshine hours. Prolonged temperatures above 10°C in spring initiate vegetative growth and determine the start of the growing season. During the maturation stage, a high diurnal temperature range leads to the beneficial synthesis of grape tannins, sugars, and flavours (Jones et al. 2005).

The demand differs very much between different grape varieties. In general, white grapes prefers colder climate than red grapes. Müller-Thurgau, Pinot Gris, Gewürztraminer and Riesling grow well at average temperatures of 13–15°C during the growing season. In contrast, most red vine varieties, like Cabernet-Sauvignon, Syrah or Merlot have their optimum between 17 and 19°C.

The Mosel region in western central Germany (50° northern latitude) belongs to the northernmost and coldest wine growing areas worldwide, with average growing season temperatures close to 13°C some decade ago. Between 1990 and 1999, the temperatures increased by 0.5°C and are nowadays close to the estimated optimum average growing season temperature of 13.9°C for this region and the existing grape varieties (Jones et al. 2005). It shows that the Mosel region still can benefit from Climate Change. The observed lengthening of the growing season in Bordeaux over the last two decades caused higher sugar to total acid ratios, greater berry weights, and greater potential wine quality with respect to Merlot and Cabernet Sauvignon varieties (Jones and Davis 2000).

In hot areas with average growing season temperature close or above 20°C, like Hunter and Barossa Valley in southern Australia, southern Portugal or southern California, viniculture is facing serious problems due to Climate Change. Extremes of heat can cause a too early change of colour and sugar accumulation, high grape mortality through abscission, enzyme inactivation, and partial or total failure of flavour ripening (Mullins et al. 1992). Webb et al. (2007) discuss adaptation strategies to reduce the impact of Climate Change on wine industry in Australia. The options are to preserve the current Australian wine styles by moving to cooler regions or to preserve the current infrastructure and to change to varieties better adapted to warmer climates. Even regions like Rioja in Spain and Alsace in France are already beyond their optimum temperature for viniculture and have to adapt to Climate Change (Jones et al. 2005). This short overview shows that the northernmost vine growing regions will benefit from Climate Change and many traditional wine regions have to deal with negative consequences. However, practically all regions have to implement specific adaptation measures. Some regions like southern central Australia or northern Africa, where heat and drought already today are a challenge for high quality wine production will have to look for alternative crops. On the other side, new possibilities for regions off the northern (northern hemisphere) and southern boundary (southern hemisphere) of present wine production will arise.

A comparison of the climatic conditions between the Baltic Sea coast (54° northern latitude) and the Mosel area shows that the annual sunshine hours at the German Baltic Sea coast of Mecklenburg-Vorpommern (Fig. 14.1) of about 1,700 h is well suitable for wine growth, while about 1,358 h in Bernkastel in the Mosel area are much closer to the minimum value. The same is true for precipitation. Dry summers might cause serious problems in the Model region in future. In northern Germany, precipitation during growing season is still sufficient and it is likely that this will be the case in future, as well.

According to the official German Weather Service (DWD) the average temperatures between April and October (period 1960–1990) at the Baltic Sea coast were about 12.7–12.8°C. Therefore, the temperature is the major limiting factor for wine growth along the German Baltic Sea coast. However, during the last decades the average temperatures during growing season exceeded the critical threshold of 13°C for viniculture at the German Baltic Sea coast. Ueckermünde at the Szczecin

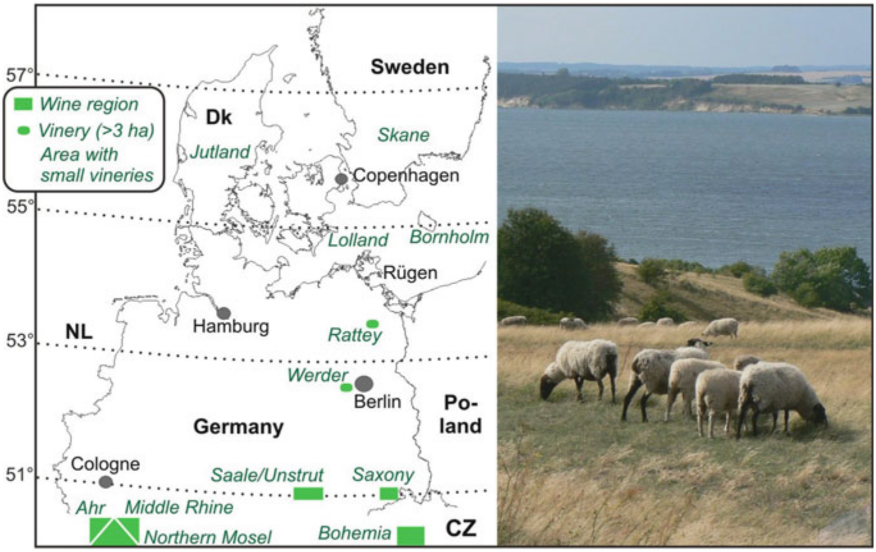

Fig. 14.1 Overview of wine growing areas in northern Germany and the south-western Baltic region. The picture gives an exemplary impression of the hilly, sandy, ground morainic landscape at the eastern German Baltic coast (Gager, Island of Rügen). Usually loamy soils predominate

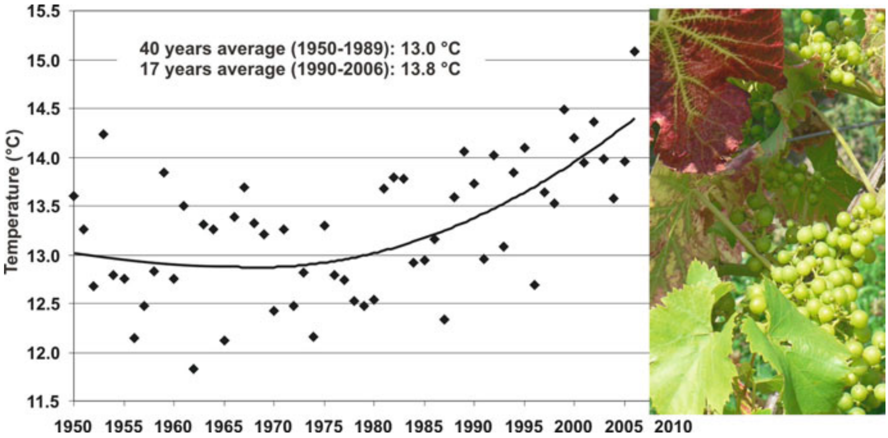

Fig. 14.2 Average annual temperature during the growing season (April–October) at the station Ueckermünde (Location: 53°45′N, 14°04′E close to the Baltic Sea in northern Germany). Data: German Weather Service (DWD)

Lagoon, about 30 km north-east of Rattey (Fig. 14.1) can serve as an example: Between 1950 and 1989, the average growing season temperature was 13°C (Fig. 14.2). Nine years did not even reach 12.5°C. In these cold years it would have hardly been possible to produce an acceptable wine in quality and quantity and would have caused serious economic problems for a winery. Before 1990 it was simply too risky to produce wine in northern Germany. During the last 17 years the average growing season temperature was 13.8°C and during the last 10 years never fell below 13.5°C.

Assuming an average increase of temperatures during the next 50 years of 2°C during the growing season, the entire Danish, German, Polish, Latvian and Lithuanian Baltic Sea coast will provide suitable conditions for viniculture. The boundaries for viniculture could be expanded to 60°C northern latitude. Cities like Turku in Finland, Tallin in Estonia and areas north of Stockholm would form the northern boundary. The existing climate model simulations suggest a strong increase in winter temperatures in the Baltic. In Stockholm, Tallin and Turku, the average winter temperatures would be closer to 0°C and extreme frost below –25°C would become very rare, especially in coastal parts of Scandinavia.

This allows grape-vine to survive the strong winters, which are a problem for viniculture today. In 100 years viniculture might be common in large parts of the Baltic region. What kind of wine will be produced, which grape varieties are most suitable for a northward extension? A short analysis for the German Baltic Sea coast can give some insights.

The Huglin-Index is a complex indicator for the temperature and climatic demand of grape varieties (e.g. Petgen 2007). It takes into account the average and maximum daily temperature during the growing season between April and September as well as the geographic day-length. Figure 14.3 shows the estimated

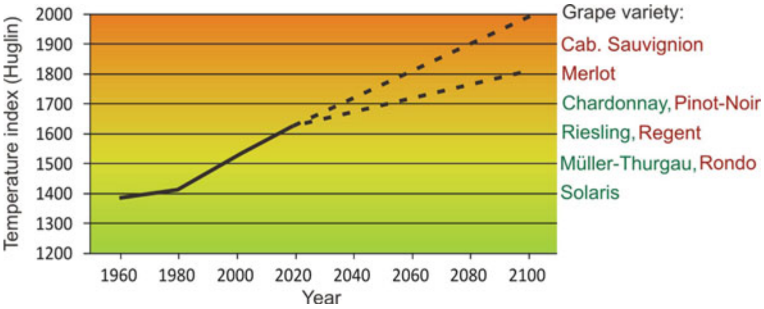

Fig. 14.3 Estimated temperature index (Huglin) for German Baltic coastal areas (Mecklenburg) for the last decades and future Climate Change projections as well as the demand of different *red* and *white* grape varieties (after Basler 2003, Stock et al. 2003, Jörger et al. 2004, Petgen 2007)

Huglin-Index for the German Baltic Sea coast in Mecklenburg for the last decades and future Climate Change projections. Additionally the demand of different red and white grape varieties is indicated. This figure underlines that already nowadays the German coast is a suitable region for growing wine on a commercial basis without the risk of crop failures. Today this is limited to certain suitable grape varieties, especially white ones. Already during the next decade the climatic conditions will allow a successful commercial growth of several red grape varieties. At the end of the century even demanding varieties like Merlot or Cabernet Sauvignon will find suitable conditions at the Baltic coast.

14.4 Coastal Viniculture – A Contribution to Sustainable Agriculture?

Climate Change will improve the climatic conditions for viniculture along the Baltic Sea coast further. Extreme temperatures, water shortages or serious draughts in summer are unlikely in the Baltic. On the opposite, precipitation in average might increase in many Baltic regions during the next decades. However, there are problems linked to viniculture, as well.

Viniculture is an intensive agriculture and requires intensive soil cultivation and plant protection. Especially viniculture in marginal northern regions always has to deal with the problem of fungal diseases (*Plasmopara*, *Oidium*, *Botrytis*). *Oidium* is responsible for powdery mildew and *Plasmopara viticola* is the causal agent of downy mildew, which is a serious problem in humid climates and during wet periods. These fungal diseases traditionally require the intensive application of pesticides 6–9 times year^{-1} (Basler 2003).

Is viniculture desirable at the Baltic Sea coast? Can it contribute to a sustainable agriculture? According to Pigott (2007), the four northern-most wine growing areas in Germany, Süsser See (near Halle), Wachtelberg (close to Potsdam), Schloss Rattey and Burg Stargard cover an area of 0.85 km^2. The dominating white grape varieties are Müller-Thurgau (0.18 km^2), Pinot Blanc (0.16 km^2), Riesling and Silvaner. Only about 15% of the area is covered by red grape varieties, like Portugieser (0.07 km^2), Dornfelder and Pinot Noir. These traditional grape varieties are suitable for the northern German climate and have proven to allow the production of quality wines, but they are very sensitive to fungal diseases. Basler (2003) concluded that the leaves and grapes of Müller-Thurgau and Pinot Noir have a high to very high risk for fungal infection with *Plasmopara* and *Oidium* and a medium risk towards *Botrytis*.

Alternatives are already available for years. New grape varieties with a high degree of resistance to viniculturally important fungal diseases considerably reduce plant protection measures or even make it unnecessary and thus contribute to an environmentally friendly viniculture. New fungi-resistant white grapevine varieties are for example Solaris und Helios. Solaris was created in 1975 at the grape breeding institute in Freiburg, Germany. According to Basler (2003) it is a very resistant, hardy variety, suitable for northern marginal winemaking climate. It is well suitable to replace traditional grape-varieties like Müller-Thurgau.

A fungal-resistant red grapevine variety, Regent, was created in 1967 and released for cultivation in Germany in 1996. It is at present the most important new fungal-resistant grapevine variety and the cultivated area increased fast to over 21 km^2 (2,100 ha) in 2006 in Germany. The red wines of Schloss Rattey, in northern Germany, are already made mainly from Regent. During the 1990s the Dansk VinCenter tested many grape varieties whether they are suitable for the Danish climate. Nowadays they grow the resistant grapevine varieties Rondo, Leon Millot, Castel and Regent on three ha. Bolero, Rondo, Regent, Leon Millot and Solaris are very popular grapevine varieties among other Danish vineries like Annisse Vingard, Domain Aalsgaard or Frederiksborg vin, as well. The predominance of red varieties shows the readiness among Danish vineries to assume risk and reflects the Danish preference of red vines. However, the Danish example shows that fungal-resistant varieties are of increasing popularity and this is true not only in regions north of the 52°C northern latitude. The number of fungal-resistant red grapevine varieties which are suitable for a cool climate is increasing. Cabernet Cortis or Cabernet Jura is other recent examples (Basler 2003).

Fungal-resistant grapevine varieties allow an environmental friendly, sustainable viniculture. A strong reduction of pesticide applications reduces soil compaction and offers opportunities for organic farming. These varieties increase the diversity and give wine-makers flexibility to adapt to Climate Change and to conquer new region for viniculture.

Global change and the increasing demand for food and bio-energy will most likely cause an extension of arable farmland and a reduction of pasture farming in northern Germany. The prices for land are already rising and the rents for agricultural land will very likely follow this trend. The pressure to increase the revenues per hectare of land, the increasing demand for agricultural products and possibly higher prices will altogether cause an intensified agriculture. The application of fertilizer will increase. Maize or rapeseed, important field crops for the production of bio-energy, needs about 200 kg nitrogen (N) fertilizer ha^{-1} year^{-1} for a quantitatively high production, while pasture needs only a very limited amount of fertilizer. A significant share of applied fertilizer is always lost to the environment. Therefore, the loads of the nutrients nitrogen and phosphorous to the environment will increase in future again and will cause serious problems for surface water eutrophication. In coastal waters, eutrophication is still a major ecological problem and poor water quality hampers tourism in some regions, like the Szczecin Lagoon.

Is viniculture a solution towards a sustainable and environmental friendly agriculture? The total area covered by vineyards along the German Baltic Sea coast will hardly exceed 1 km^2. Therefore, viniculture will remain quantitatively insignificant compared to the total available agricultural area. However, even intensive, traditional viniculture aiming at high yields comes along with a fertilizer application of 40 kg N ha^{-1} (Müller and Ziegler 1997). Special soil treatment or the introduction of greenbelts between the rows increase N-mineralization and reduce the fertilizer demand. Legume covers during winter can enrich the soils with atmospheric nitrogen and makes nitrogen fertilizing entirely redundant. The ongoing trend towards high quality wine production does not aim at high yields per hectare and the fertilizer application is usually very limited. Complete abandonment of N-fertilization is possible and does not affect the aroma and quality of the grapes or the wine (Linsenmeier and Löhnertz 2006).

14.5 Viniculture – A Profitable Business in the North?

Altogether Wine-growth in Northern Germany, with resistant grape varieties and carried out as organic farming could be a small contribution towards a sustainable agriculture. It would help to reduce the losses of nutrients into ground- and surface waters and to reduce eutrophication of coastal waters.

Already today it is possible to produce wine of high quality in Northern Germany. After tasting the red wine at Schloss Rattey in Mecklenburg, Pigott (2007) confirmed that the wine in style and quality is competitive to wines from well-known regions, like Beaujolais. This shows that the quality is not the problem anymore, but can viniculture become a profitable business?

Viniculture in marginal regions, like at the Baltic Sea coast, will be more laborious, bears more risks, and the crop yields will be lower compared to the traditional wine regions. Müller (2006) discussed the need of irrigating in German wine growing regions as a response to Climate Change and drier summers in future. In some areas it might be needed to maintain the quality and quantity of wine production. Irrigation would require significant investments. Hot years, like 2006, already caused problems for wine growth in Germany (Prior 2007). Botrytis infection took place early and required measures in the vine-yard and additional amounts of work. Maixner et al. (2007) point out the risk of new grapevine diseases caused by Climate Change. Despite the fact that some traditional wine regions in Germany will benefit from a warmer climate, these examples show that production costs in traditional wine regions will probably increase in future. However, the costs of wine production in northern Germany's coastal regions will remain higher than in southern regions?

Will viniculture be competitive in northern regions? In a region like northern Germany, where wine production is not common, new established wineries would have the benefit of being regarded as an attraction and their wine would be a niche product. Visitors, tourists, collectors, and the increasing wine interested audience would be willing to pay a higher price per bottle than for a comparative product from a traditional German wine region. This effect can be seen in the smallest official German wine regions, Saale-Unstrut and Sachsen where the producers are able to realise a high profit per bottle of wine. The northern-most German vinery, Schloss Rattey (Fig. 14.4), sells its white and red wines for 14 € per bottle (2007) via Internet. The winery is able to supply only few selected wine-shops in the regions, where the customer has to pay around 17 € per bottle. Comparative wines from large German wine regions like the Pfalz or Rheinhessen would cost only around one third or one fourth. Danish vineries can serve as another example, where 30–40 € per bottle red vine are more the rule than the exception.

My conclusion is that, as long as only few vineries exist at the Baltic Sea coast, this niche product and attraction can be sold easily. Small vineries in tourist areas have the possibility to sell via the 'farm gate'. In the United Kingdom about 65% of all produced wine is directly sold to visitors and provides the producer with an increased profit margin and cash flow (Howley and van Westering 2000). This profit margin should be sufficient to overbalance the higher production costs. Therefore, it is likely that wineries can be run profitable in northern Germany.

Fig. 14.4 Schloss Rattey, located 50 km south of the Baltic Sea coast, is the northernmost official wine-area in Germany. The vineyards cover 3.7 ha with *red* (mainly Regent) and *white* grape (e.g. Huxelrebe, Müller-Thurgau, Ortega) varieties. The winery includes a shop, a tasting-room and a museum and is linked to a hotel

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14.6 Viniculture and Tourism – A Synergy to Develop the Countryside?

Large amounts of tourists (about 7 million arrivals and 28.4 million overnight stays in 2009) visit Mecklenburg-Vorpommern every year (Statistisches Amt Mecklenburg-Vorpommern 2010). The numbers are still increasing, but tourism is concentrated mainly in coastal regions and limited to the summer-month. The rural coastal hinterland does not benefit much from the tourism-boom. Therefore, a major aim of spatial planning is to develop tourism in the hinterland. On one hand, tourism shall help to create jobs and income and stop the migration especially of young people towards the cities. On the other hand, tourism attractions in the coastal hinterland shall reduce the tourism concentration at the sea coast. One aim is to extend the tourism season towards spring and autumn. The advantage is a higher degree of capacity utilization of the existing tourism infrastructure and a stabilization of the coastal economy. In many resorts along the coast the capacity utilization of 32.5% in 2009 (Statistisches Amt Mecklenburg-Vorpommern 2010) is too short to guarantee that especially private accommodations, restaurants and shops run profitable. An early and late extension of the tourism season bears the risk of instable or poor weather, which might restrict beach and bathing activities. In this respect, Climate Change is beneficial. It will provide higher bathing-water temperatures and therefore allows a prolongation of the summer (bathing) season. However, this prolongation requires additional and alternative tourism attractions, which are less weather dependent.

Wine-growing estates could be a suitable option. Viniculture is labour-intensive, would create jobs in rural areas and could contribute to a revitalization of Mecklenburg-Vorpommerns countryside. Further, small scaled viniculture increases the attractiveness of the landscape. On the other hand, they can be attractions for tourists. The world wide growing wine tourism is a clear indicator.

Wine tourism includes the visitation to vineyards, wineries, wine festivals, wine shows and wine tastings (Hall et al. 2000a). Wine tourists have a broad spectrum of motivations (Cambourne and Macionis 2000) like sampling and buying of wine, attending wine-events, socializing with friends and enjoying a day out, meeting the wine-maker, enjoying the country setting, learning about wine and wine-making, tour on a winery and visiting additional attractions at the winery (restaurant, gift-shop etc.).

For wineries, wine tourism has several advantages, like increased consumer exposure, brand awareness and loyalty as well as marketing intelligence on consumers (customer database) and on products (fast feedback) (Hall et al. 2000a). Probably most important for wineries in northern Germany would be the increased margins through direct sale to customers and that the wineries do not have to guarantee volume or constancy of supply. To establish a winery as a tourism attraction requires capital and causes increased costs, e.g. for the operation of a tasting room and additional staff. However, Cambourne and Macionis (2000) come to the following conclusion: 'For small wineries, particularly in emerging or non-traditional wine producing regions, wine tourism is often an economic necessity, providing cash flow and assisting them to achieve a better sales mix at higher yield while at the same time providing opportunities to brand their product and winery successfully'. The importance of wine tourism for wineries can be seen in the United Kingdom. According to the English Wine Producers statistics, in 2007, 383 registered vineyards produced about 1.3 million bottles of wine on 6.97 km^2 of land. Approximately 65% is sold directly to visiting customers (Howley and van Westering 2000).

The example of the United Kingdom shows that small wineries with 2–3 ha vineyards can well survive if most wine is sold directly to customers. At the German Baltic Sea coast the large amounts of tourists are a suitable customer basis to run wineries profitable. The examples of the United Kingdom and New Zealand further show the close synergy between tourism and viniculture. Accommodations, a café or restaurant, gift-shops and souvenirs, information trails, picnic facilities, tours and events etc. at the winery are important supplementary attractions for tourists (Hall et al. 2000b, Howley and van Westering 2000). Linking cultural places of interest, historic buildings, museums etc. to wineries or the co-operation with local artisans are other possibilities to increase the attractiveness and the number and spectrum of visitors. In Mecklenburg-Vorpommern a possible synergy between the numerous cycling-paths and wineries is obvious. Altogether, viniculture can be regarded as a local nucleus and an element to support a sustainable development of the coastal countryside.

14.7 Adaptation to Climate Change – Options and Obstacles

Viniculture in northern Germany is a new and realistic option to adapt to Climate Change. It could be a chance to support a sustainable rural development and could become an attraction for tourism. It shows that Climate Change is not only a threat, but offers opportunities, as well. To utilize these opportunities requires flexibility and adaptivity.

It is obvious that Climate Change is a challenge for agriculture along the Baltic Sea Coast and that adaptations are needed. Different species or new field crops will be necessary. Soil cultivation and land management has to be adapted. In vegetable farming, for example, this adaptation can be carried out within a short-time of several years. Permanent crop, like viniculture, is less flexible. A vineyard, once established, is a commitment for decades. The grape varieties have to be chosen carefully and have to consider practical aspects, climate and soil and customer demands. The investment costs for a vineyard are high and wine production requires investments in technique and infrastructure. Further, experience, well-educated staff and a marketing strategy are necessary. To introduce viniculture needs a clear long-term strategy, a vision, money, and the willingness to take on risks. However, the perspectives are promising.

Winemakers have to show flexibility with respect to new grape varieties and to re-evaluate their distribution channels. Customers have to show flexibility by accepting wines of a new style, from new regions and made from new grape varieties.

Policy has to provide a suitable legal and planning framework as well as funding for adaptations. The European Union e.g. provides funds for regional development and social cohesion. The European Regional Development Fund (ERDF) and the LEADER-programme are examples (Hall et al. 2000b). However, the agricultural policy of the European Union is a major obstacle for adaptation processes, as well. The wine law does not allow an extension of wine growing areas or the foundation of a new wine region. The establishment of vineyards especially outside of traditional wine regions is complicated and a time-consuming process. New grape varieties cannot simply be planted, but according to the German wine law, require the official registration and permission of a national authority, the Bundessortenamt.

Up to 99 grapevine plants can be kept by private persons for their own consumption. Associations with many private members can utilize this option and cultivate a vineyard of a few hectares. However, they are not allowed to sell the produced wine. This example shows that the existing policy restricts flexibility and can be regarded as a main obstacle for a fast adaptation to Climate Change.

14.8 Concluding Remarks – Wine and Climate Change Communication

During recent workshops, meetings and discussions with local and regional stakeholders and mayors in Mecklenburg-Vorpommern about Climate Change three things became obvious: a) Climate Change has a temporal scale beyond the term of mandates and is not regarded as a priority issue for daily policy. b) If not doubted at all, Climate Change is regarded as a global problem and the impact on and responsibilities of local communities and districts are considered to be insignificant. The result is a lack of concernment and responsibility. c) There is a certain tiredness to focus discussions on long-term risks, threats and problems, especially if the daily perception of Climate Change is different. At the Baltic Sea coast warmer summers and higher water temperatures are already a benefit for tourism, the major source of income.

Drinking vine becomes more and more popular in northern Germany and wine becomes a competitor to beer, the traditionally preferred alcoholic drink. However, not many people at the Baltic Sea coast are really familiar with viniculture. The climatic favoured wine growing areas with an early spring and long warm autumns are, in the perception of many northern Germans, associated with an easiness of living and a holiday feeling. The widely spread interest in wine and the positive emotions linked to it makes this topic attractive and very suitable to communicate Climate Change. It helps to raise interest in Climate Change among local and regional stakeholders and serves very well as a carrier for information about possible threats and problems, as well.

Viniculture at the German Baltic Sea coast is an example which shows future opportunities of Climate Change. To present new opportunities instead of focussing on negative aspects alone is a very important aspect in communication. It helps to maintain interest and open-mindedness, especially if the opportunities are unexpected and surprising. In practise, the example of coastal viniculture has an important educational effect.

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Chapter 15
Emerging Climate Change Coastal Adaptation Strategies and Case Studies Around the World

Grit Martinez, Livia Bizikova, Daniel Blobel, and Rob Swart

Abstract Presently about 40% of the world's population lives within 100 km of a coastline. Climate Change and sea level rise being a relatively new policy challenge, experience as to the choice and design of appropriate response measures is scarce and fragmented in coastal areas. Increasing the availability and transfer of pertinent knowledge across national boundaries can assist in furthering coastal safety. This chapter focuses on the management of adaptation activities encompassed by the RADOST (Regional Adaptation Strategies for the German Baltic Sea Coast) project and its international partner regions. Attention is given to the operationalization of regional adaptation measures, ways to increase resilience, as well as to regional adaptive governance and learning processes. Success factors to increase the resilience of coastal areas include cooperation of a broad range of organizations and the engagement of stakeholders; carefully planning of a sequence of policies and measures over time; designating risk areas; revising principles for natural resources management along the coasts; awareness raising about preferred development practices; and integrating climate concerns with other social, economic and environmental objectives. This requires maintaining connections to existing policy and decision-making processes and building or strengthening partnerships among the relevant sectors of the local or regional communities.

15.1 Introduction

The aim of this chapter is to establish the potential of, as well as limits to, the transfer of good practice in regional approaches to coastal adaptation from one region to another by comparing examples from different places. Cases from industrialized,

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emerging and developing coastal countries are discussed. Developing and emerging countries face the most serious consequences of Climate Change. Their coasts are particularly vulnerable but at the same time, their capacity to adapt is limited. The impacts of Climate Change on coastal areas and elsewhere also present important challenges to industrialized countries and given their greater technical, economic and institutional capacity, these countries can make important contributions to adaptation policy in general and to the transfer of technology and knowhow in particular.

The chapter begins with a short overview of national, regional and local adaptation strategies on the Baltic Sea Coast and in Europe. This is followed by a short outlook on other approaches at the global scale. The central focus of the chapter, however, is on the analysis of promising regional adaptation approaches in different coastal regions. The selected cases do not represent a comprehensive scientific analysis, but rather a presentation of good practice examples, i.e., interesting and instructive approaches. Finally concluding remarks illustrate the potential of knowledge transfer of good practice methods for the scaling up of adaptation strategies in and between regions, and beyond national scopes. Conclusions will be also drawn from and for the forthcoming project work of the RADOST project.

Two criteria determined the selection of regional cases: Firstly, the chosen regions in the seven countries (Bangladesh, Canada, Germany, Hungary, Morocco, Netherlands and the United States), are already making national and regional efforts to adapt to the impacts of Climate Change. Secondly, the individual cases illustrate how different coastal regions in developed, advanced developing and least developed countries respond to different climatic conditions. In this way, the study illustrates the broad range of possible adaptation measures. Finally given their extreme coastal vulnerability and the longstanding experience with floods and other natural disasters, an example from the coastal belt in Bangladesh was selected.

15.2 Overview of National Coastal Adaptation Policy Strategies: The Riparian States of the Baltic Sea, European and Other Examples

Coastal areas are the most populated regions of the world. They often offer a unique mix of ecologically valuable areas connecting both land and water ecosystems, along with considerable economic opportunities and assets such as ports, tourism, a priced living environment, and a highly developed service industry. At the same time, they are known as vulnerability hot spots with regard to Climate Change. Sea level rise in particular, but potentially also alterations in water currents, storm and associated wave activity and other phenomena, threaten the coastline. Events such as flooding, storm surges and seawater intrusion add to the already existing pressure on land use (IPCC 2007). To address such complexity, there has been an increased recognition of the need to explicitly focus on coastal impacts and vulnerabilities to Climate Change, to develop adaptation responses while promoting overall sustainable development (Sathaye et al. 2007) and to explore the opportunities for knowledge transfer from one coastal region to another (Kane and Shorgen 2000, Wilbanks 2005).

There have been a number of regional, national and international coastal adaptation programs and initiatives directly aiming to increase the resilience of sensitive coastal areas and to some extent promote knowledge generation, information exchange and practical adaptation actions.

Coastal zones *of the European Union* are an important living space, since almost 50% of the EU population lives within 50 km of the sea (European Commission. Eurostat 2010) (Fig. 15.1). In the majority of the European states coastal zone adaptation is part of more comprehensive Climate Change adaptation plans (Policy research cooperation 2009). Only a few countries have adaptation plans specifically dedicated to their coastal zones.

Especially the countries that have suffered from severe weather events in the past have taken the initiative to investigate the potential impacts of Climate Change adaptation for their coasts and countries. In particular the Netherlands and the UK

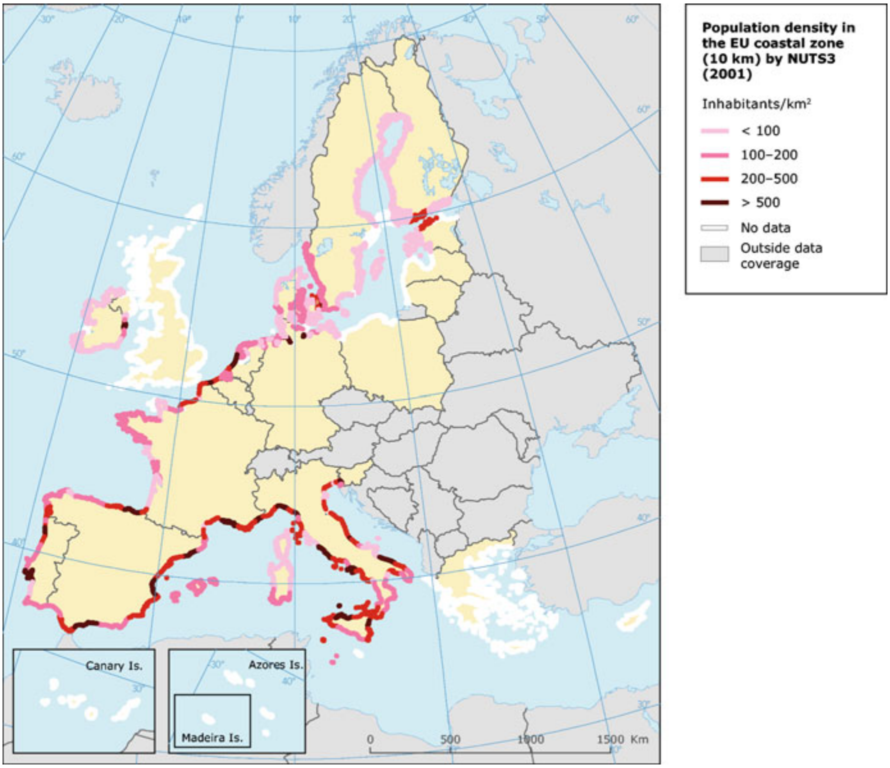

Fig. 15.1 Population density in the European coastal zone (0–10 km) in 2001 (©European Environmental Agency 2005, based on population density disaggregated with CLC2000, information provided by Joint Research Centre, 2005)

are very active examples. Together with Germany, Spain and Italy they are projected to cover about 85% of the total coastal protection expenditure in Europe over the period of 1998–2015.[1]

In terms of examples from specific coastal areas, the coastal area of the Baltic Sea form an ecosystem under great stress from harmful and unsustainable human activities and practices. The Baltic is one of the most polluted regional seas worldwide due to eutrophication. In addition, possible effects of Climate Change have to be incorporated. Hence, various coastal adaptation strategies have been integrated into the overall national Climate Change adaptation strategies in many riparian states of the Baltic Sea. For example, Finland and Germany have already concrete implementation plans for their coastal zones (Hilpert et al. 2007). Finland is one of the first countries to have a comprehensive adaptation strategy in place since 2005. This resulted in the implementation of concrete measures for coastal and flood protection.[2] In Germany the adjacent states to the Baltic Sea as well as the North Sea coast,[3] begun to prepare their own Climate Change adaptation plans embedded into the framework of an Integrated Coastal Zone Management. Such activities are supported by research funding on the national level (for more detail, see the example of the RADOST project in Section 15.3.8).

Canada, a country with one of the longest coastlines in the world, is especially vulnerable to the rising sea levels and other impacts of Climate Change (Natural Resources Canada 2007). Attention to Climate Change has been on the agenda of the Canadian government for some time. On the regional level, the federal government supports the Regional Adaptation Collaboratives (RACs) Climate Change Program, which is a 3-year, cost-shared federal program of $30 million.[4] The program also stresses the importance of preparing case studies, highlighting region-specific adaptation knowledge, developing tools for community and resource planning, and establishing 'Communities of Practice' to share knowledge and best practices about Climate Change impacts and adaptations (NR Can 2010). However most of the specific measures have been developed and implemented by individual provinces or municipalities. Some provincial governments have already developed their own adaptation strategies.[5]

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[1] The economics of climate change adaptation in EU coastal areas, study for the EuropeanCommission Directorate-General for Maritime Affairs and Fisheries, p. 2. http://ec.europa.eu/maritimeaffairs/climate_change/report_en.pdf

[2] Finland's National Strategy for Adaptation to Climate Change: Seminar 'The Coast under Threat' Marseille, 3 February 2006 Outi Berghäll, Ministry of the Environment.

[3] Schleswig-Holstein, Mecklenburg-Western Pomerania and Lower Saxony.

[4] The Program helps communities prepare for and adapt to climate change impacts in areas such as changing water supply and droughts; floods and coastal erosion; and changing forestry, fisheries and agricultural resources. In coastal areas, assessing coastal erosion, vulnerability and infrastructure susceptibility to climate change are prioritized as well (Natural Resources Canada 2010).

[5] In 2008, the government of British Columbia published its own climate action plan. The plan discusses adaptation measures for flood protection.

In *the United States* adaptation to Climate Change has been part of the discussion on the climate protection legislation being debated in Congress. The federal government's primary approach to adaptation has been rather research oriented with limited funding for state and local adaptation initiatives. Nevertheless currently the critical need to bridge the existing gaps between providers and owners of climate-related information and local stakeholders has been recognized.[6] In October 2009 the government set up an Interagency Climate Change Adaptation Task Force. The sub-task force, responsible for coasts and oceans, currently develops tools and applications for decision support at regional and local levels. Some states are also in the process of developing adaptation strategies and implementing adaptation measures. Alaska, California, Florida and the northern states of the East coast are on the forefront of these activities. A coordinated adaptation planning in the US is in the early stages.

Rising sea levels prompt a special challenge to *Australia* as 80% of the Australian population lives within 50 km or less from the coast line. This implies the need for extensive adaptation measures in infrastructure and the structure and location of urban areas. Australia has recently published its first national assessment of Climate Change Risks to Australia's Coast to form a basis for the country's coastal adaptation strategy. The assessment provides an initial evaluation of Climate Change's future implications for nationally significant aspects of Australia's coast, with a particular focus on coastal settlements and ecosystems and identification of high risks areas (Commonwealth of Australia 2009). Australia is now developing this coastal adaptation strategy. The key priorities include generating information and disseminating it nationally to support diverse stakeholder groups' actions, improving the management of assets exposed to Climate Change impacts on the coasts, and leading institutional reforms to enable adaptations, while aiming to maintain a strong and flexible economy with social safety nets (Parkinson 2010). An important part of the Australian adaptation framework is to improve and coordinate Australian research activities and information campaigns, as well as practice-oriented research programs, for example, to help coastal settlements to adapt to future climates.[7]

Coastal Climate Change poses particular risks for *emerging and least developed countries*. Their vulnerability to the impacts of Climate Change is not evenly distributed – often those countries who have not significantly contributed to Climate Change are affected most by it and have the lowest capacity to cope.[8] Considerable focus on water resources and coastal areas can be identified in the National

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[6] To help coastal and waterfront communities to manage growth and development in the specific context of climate change, NOAA is, for example, operating a website entitled Coastal and Waterfront Smartgrowth. http://coastalsmartgrowth.noaa.gov/. Accessed 6 October 2010. Other tools provided by NOAA include the Pacific Islands Climate Change Virtual Library. http://pigcos.soest.hawaii.edu/piccp/joomla. Accessed 6 October 2010.

[7] CSIRO. http://www.csiro.au/science/SustainableCitiesAndCoasts.html. Accessed 06 October 2010.

[8] World Water Council, International Union for Conservation of Nature, Co-operative Programme on Water and Climate (2009).

Adaptation Programmes of Action (NAPAs) developed by least developed countries under the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). The main goal is to involve coastal and other stakeholders in the planning process, to collect information on local climatic changes, and to give each stakeholder an opportunity to benefit from other's experiences. In addition an expert group was established, which guides the process and helps countries implement concrete adaptation measures (UNFCCC 2007). In an analysis of the sectors covered by NAPAs, 9% cover coastal zones and marine ecosystems (UNFCCC 2009). At the same time, these countries have only very limited governmental and financial capacity to implement the NAPAs and effectively deal with the impacts.

For this and other reasons, the *Nairobi Work Programme* (NWP) was adopted by the UNFCCC as a 5 year program (2005–2010) that aims to assist all Parties, especially developing countries, 'to improve their understanding and assessment of impacts, vulnerability and adaptation to Climate Change and make informed decisions on practical adaptation actions and measures to respond to Climate Change on a sound scientific, technical and socio-economic basis, taking into account current and future Climate Change and variability' (UNFCCC 2009). Within the NWP specific attention is devoted to promote experience and knowledge sharing on best practices, challenges and opportunities by shared learning dialogues as an iterative process of learning between local communities, climate scientists and governments. Such planning processes are expected to lead to more cost-effective solutions that are people-centered rather than large-scale top-down approaches.

Bangladesh is on the Climate Change front line, with reducing vulnerabilities related to coasts and water being its highest priority (Agrawala and Carraro 2010). The UNDP has ranked Bangladesh as the most vulnerable country in the world in relation to tropical cyclones and the sixth most vulnerable country in the world in relation to floods.[9] Its high level of vulnerability has been recognised by the UNFCCC (UNFCCC 2010) and by the Bangladesh government[10] which already completed its NAPA in 2005. It was estimated that $500 million will be necessary in the first 2 years for strengthening disaster management, research and knowledge management, capacity building and public awareness, and urgent investment in cyclone shelters and selected drainage programmes.[11]

In June 2010 the Government of Bangladesh and development partners reached an agreement to establish a national Climate Change resilience fund. Development partners will provide an initial contribution of $110 million[12] which will be

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[9] Government of the People's Republic of Bangladesh, Ministry of Environment and Forests (2008) p. 4.

[10] Government of the People's Republic of Bangladesh, Ministry of Environment and Forests (2005).

[11] Ibid., p. 29. The total cost of programmes for the first five years could be in the order of 5 billion US $.

[12] The World Bank. Bangladesh: Economics of Adaptation to Climate Change Study. http://beta.worldbank.org/content/bangladesh-economics-adaptation-climate-change-study. Accessed 6 October 2010.

managed by the government.[13] Even though Bangladesh is taking Climate Change seriously; it faces serious problems in managing these resources since corruption is deeply rooted in society[14] as well as in institutions, hence undermining coastal and other adaptation measures.

15.3 International Case Studies of Actual Regional Adaptation Practices

15.3.1 Introduction

This section presents and analyzes a selection of coastal adaptation projects from different parts of the world. It includes projects situated in the following regions:

- Bras d'Or (Nova Scotia, Canada)
- Chesapeake Bay (Maryland, United States)
- Waddensea (The Netherlands)
- Lake Balaton (Hungary)
- Northeastern coastal region of Morocco (Nador and Berkane)
- Coastal belt of Bangladesh
- RADOST (Baltic Sea Coastline, Germany)

A world map (Fig. 15.2) showing the cases in their geographic settings can be found on the next page.

All of these projects have a regional level focus and a strong emphasis on the involvement of local stakeholders. It is often easier to have technical solutions identified by experts than to develop participatory approaches and governance structures that lead to broadly supported plans that can actually be implemented for different types of adaptation options (Swart et al. 2009) and therefore in this chapter we focus on stakeholder participation and institutional factors. The selection of examples reflects a variety of adaptation scenarios which include developed, emerging and least developed countries. At the same time, two of the regions (Chesapeake Bay in the US, the Northeastern coast of Morocco) are official partner regions to the RADOST project. The Lake Balaton case is specific in that it represents a freshwater lake, not a marine coast. However, it has been included as a reference project of

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[13] Ministry of Foreign Affairs of Denmark, Embassy of Denmark Dhaka, Building Resilience to Address Climate Change, 23 September 2010, http://www.ambdhaka.um.dk/en/menu/TheEmbassy/News/BuildingResilienceToAddressClimateChange.htm. Accessed 6 October 2010.

[14] According to the Corruption Perception Index (CPI) released by Transparency International, corruption in Bangladesh has been perceived to be the highest in the world from 2001 to 2005. http://www.transparency.org/policy_research/surveys_indices/cpi/2009. Accessed 6 October 2010.

Fig. 15.2 Coastal adaption caste studies around the world

international development cooperation on adaptation[15] which provides another relevant example of stakeholder participation techniques. Furthermore, it shares some important characteristics with marine coasts, such as the importance of the tourism sector and the associated land use pressures on aquatic species habitats.

In order to compare the projects, we have assessed them according to a series of key criteria (Table 15.1).

Table 15.1 Criteria for analysis of the case studies

Criteria	Key aspects of the criteria reviewed in the case studies
Project design including stakeholders involved	Overall project governance structure, stakeholder involvement and public participation Inter-institutional cooperation (e.g. between different administrative departments) Network building and stakeholder dialogue including the involvement of the public Major sources of finance for the project
Scientific basis	Availability of scientific information (including both types and scale of the information such as projections of precipitation, temperature, sea level rise as high-resolution regional climate data)
Coverage of sectoral climate change impacts	Examples of estimated consequences of Climate Change on biodiversity, resources and sectors including expected frequency of coastal flooding, impacts on water quality (e.g., fertilization/algae blossoms, salinization) and impacts on tourism, fisheries, ports and other coastal infrastructure
Synergies and trade-offs with sustainable development priorities	Integration of adaptation measures with broader sustainable development objectives for example by creating innovative adaptation solutions that support economic development, exploring Climate Change mitigation opportunities when identifying adaptation options and promoting co-benefits of adaptations with nature conservation
Lessons learned and transferability	Factors of success and failure in applying participatory processes including Data accessibility, usability of the projections in adaptation planning Success and obstacles to implementation of adaptation options in the context of current policy-making Transferability of outcomes and applied processes to other regions

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[15] The Balaton project was one of the first adaptation projects supported by the Global Environment Facility (GEF) in the region and was included in the Adaptation Learning Mechanisms of the United Nations Development Programme (UNDP).

The key criteria include: stakeholders involved; scientific base of impact assessment and its sectoral coverage; synergies and trade-offs with sustainable development priorities; and lessons learned.[16] The criteria used to describe and analyze projects are described and analyzed in Table 15.1.

However, each of the studies were conducted by independent groups following their own methodology and thus not always all criteria were addressed and documented in each of the studies. Nevertheless the main emphasis of the comparative analyses lies on the illustration of the broad range of needed adaptation measures for coastal zones.

15.3.2 Bras d'Or Case Study (Nova Scotia, Canada)

This case study focuses on the Bras d'Or ecosystem, an estuarine environment with more than 1,100 km of shoreline providing opportunities for tourism and recreation, and a home for aquaculture and many valuable ecosystems. The project described here was initiated in 2009 by the local Bras d'Or Institute in collaboration with the regional Collaborative Environmental Planning Initiative (CEPI) and the International Institute for Sustainable Development (IISD). Provincial agencies were involved in providing climate projections and information on impacts. The financial support was provided by the federal government, with in-kind contributions from all involved partners. The community wanted to explore adaptations in a sensitive estuary while trying to promote tourism in areas with significantly diverse trends in population growth, declining economic activities and in a complex decision-making environment in which the federal government is responsible for the management of the oceans and species conservation while local and provincial governments are in charge of the coastal development.

Building upon existing vulnerability assessments for the area, a series of workshops were held with key sectoral experts, climate scientists and policy-makers to identify consequences of Climate Change on prioritized sectors including fisheries, coastal habitat, coastal infrastructure and aquaculture, tourism, forestry and community development. On this basis, three future socio-economic scenarios for the region were collaboratively developed by communities and diverse organizations, sectoral experts and policy-makers. The key drivers of the future development identified for the scenarios included assumptions about the extent of changes in precipitation, the success of becoming a member in the UNESCO MaB Program,[17]

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[16] The criteria applied reflect the ongoing discussion on guiding principles and prioritization criteria for adaptation measures, in which the Ecologic Institute is involved via projects at EU level as well as at national level in Germany. See, for instance, Laaser et al. (2009) for the EU context and Dialogue on Land and Water Management for Adaptation to Climate Change (2009) for international level.

[17] Because of the valuable ecosystems in the region, the area is considering applying for the United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and the Biosphere (MaB) Program.

different rates of population growth and the degree of integration of land-use policies. Although during the experts' workshops sea level rise was identified as one of the key drivers of future changes in the region, the stakeholders ranked changes in precipitation most highly. At first the scenarios were developed with precipitation as the only climatic variable, then projections on temperature, sea level rise and the impacts on forestry and fisheries were introduced as boundary conditions to estimate the resilience of each the scenarios. Subsequently, the participants identified adaptation options to increase the resilience within each of the scenarios. This included considerations of the different levels of uncertainty in climate projections.

In addition to identifying specific adaptation options, and improving awareness and education of public and private companies and investors about shoreline protection, permitting of shoreline development and sustainable practices were recognized as crucial for long-term behavioural changes in the region and to ensure broad engagement in adaptation efforts. In all of the scenarios, the suggestions for adaptive responses to Climate Change emphasized the importance of integrated land-use planning and ecosystem-based policy development. All scenarios emphasized that economic activities including tourism, shoreline property development and aquaculture need to be better coordinated.

The results of this project were built into a management plan of the CEPI that was adopted several months after the project completion. The outcomes also identified specific gaps in climate projections, especially regarding extreme weather events and the lack of capacities and experiences of local agencies, policy-makers and planners to effectively incorporate needed adaptation actions into their work. Some of these issues will be addressed by activities planned in the Regional Adaptation Collaborative. CEPI also commissioned a review of current shoreline vulnerability studies that so far only focussed on physical vulnerability, including socio-economic issues and key policies. The results also show that sustainability of the sensitive shoreline and managing it thought integrated policies working across sectoral priorities is a very strong priority for the residents and that Climate Change issues should be part of the discussion about the sustainability of the whole region, rather than treating Climate Change as a narrow, sector-specific challenge.

15.3.3 Chesapeake Bay (Maryland, United States)

The Chesapeake Bay is the largest estuary in the United States with a complex ecosystem comprised of important habitats and food webs. Due to land subsidence, the Chesapeake Region has among the highest rates of relative sea-level rise in the world (on the order of 3–6 mm per year in Stevenson and Kearney 1996). These high rates contribute to the acceleration of shoreline erosion, especially along low lying areas, which characterizes the eastern shores of Maryland and Virginia (Stevenson and Kearney 1996). The Chesapeake Bay and its many tributaries are contaminated by *nutrient pollution, chemicals* and *air pollution. Landscape changes, erosion* and *over-harvesting of fish and shellfish* also contribute to the alteration of ecosystems.

As an inland sea which has limited water exchange with the open ocean, the Chesapeake Bay suffers from nutrient pollution much like the Baltic Sea.

To exchange ideas, discuss new tools and implement methods which support adaptation and restoration of endangered estuarine systems, the Chesapeake Bay Environmental Center (CBEC) undertook multiple projects with the active participation local stakeholders including research institutes, federal and state agencies, non-governmental organizations, communities and civil volunteers. Here two adaptation projects (artificial reefs, duration 2002–2007 and living shorelines, 2002–2003)[18] are discussed which provide important lessons on stakeholder involvement.

Sedimentation from runoff and shoreline erosion has led to the destruction of natural fish habitat and oyster bar building substrate. To address this, volunteers helped install artificial reef ball pieces of concrete (recycled from a large demolition project) in the Chesapeake Bay. The objects serve as colonization grounds for oysters, attract juvenile sport fish and support the bay's natural self-cleaning mechanism.[19] The reef balls also act as havens for a variety of fish and shellfish. In addition, large pieces of rubble were spread out at varying depths in an attempt to compare rates of attachment for benthic organisms, especially oysters. These artificial underwater structures can also increase shoreline protection by absorbing wave energy.

In the shoreline restoration project a pine timber bulkhead, concrete pad and timber jetties which had been installed by previous property owners, were removed to restore sandy beach habitat. In addition two small peninsulas were created from dredged materials which reach out from the shoreline, helping to absorb wave energy and protecting the shore from erosion. Marsh grass plantings help to stabilize the peninsulas, provide animal habitat and add to the aesthetic appeal to the project. The project was carried out under the leadership of CBEC involving numerous partners and with the support of many volunteers who joined the bay restoration effort and planted native grasses along the restored shoreline.

In these projects, the co-operation of various governmental organizations with CBEC, a relatively small not-for-profit organization, has leveraged much support from public and local organizations and has led to suggestions for practical and hands-on measures that might be taken in the future to offset coastal problems in the Chesapeake Bay area. The projects led by the CBEC have demonstrated that practical adaptation actions with wider co-benefits can be identified and implemented even in an area with large environmental challenges. The key appears to be involvement of a large segment of the local population to raise awareness and build acceptance for political and planning decisions.

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[18] Chesapeake Bay Environmental Center. http://www.bayrestoration.org/rest&rsch_reefs.html. Accessed 6 October 2010.

[19] Oysters act as natural water filters. The oyster populations of Chesapeake Bay have been severely depleted due to overharvesting and damaged habitat, which has contributed to the further deterioration of water quality. In total 7.5 million oysters were planted during the course of the project.

15.3.4 Wadden Sea (Netherlands)

The Wadden Sea is a large intertidal zone in the North Sea that reaches from The Netherlands to Denmark. Since 2009, the Netherlands and German parts are on UNESCO's World Heritage List. The Wadden Sea represents a diverse system with high spatial and temporal variability and high ecological and economic value. Temperature change and sea level rise are the main potential Climate Change impacts in the area, but also changing rainfall, storminess, wave action and carbon dioxide levels, changing river discharges, soil subsidence, changes in the sediment balance, changes in fisheries, tourism, and exploitation of natural gas reservoirs.

Over the last decade, a lot of scientific information has been collected, based on observations as well as projections, periodically summarized by the Quality Status Reports of the Common Wadden Sea Secretariat Trilateral Monitoring and Assessment Group. Climate Change information is provided by the Royal Netherlands Meteorological Institute KNMI, using four scenarios and using their regional climate model RACMO (van den Hurk 2006). In 2010 a revised Wadden Sea plan was adopted, with Climate Change as one of the overarching issues. A long-term trilateral strategy on the adaptability to Climate Change will be developed, containing projects and programs on adaptations, the natural resilience of the ecosystem and coastal protection (Wadden Sea Plan 2010).

The main challenge in the Wadden Sea is to reconcile different objectives: (a) reshaping robustness and resilience, with nature and landscape as the basis for the ecological and economic vitality and quality of life; and (b) stimulating sustainable economic growth. Climate Change may complicate the choice between 'natural dynamics first?' or 'people and economy first?', but on the other hand increasing the resilience to Climate Change will generally benefit from a more sustainable use of the ecological and economic functions. The Netherlands is seeing Climate Change not only as a threat, but also as an opportunity, with adaptation boosting technological innovation and making planning in general more sustainable.

The Dutch Wadden Sea has a well-established history of collaboration between governmental, academic, private and other societal stakeholder groups. Various ministries, three provinces, municipalities, water boards, energy companies, regional drinking water companies and nature protection organizations have well-defined roles in various management and advisory mechanisms, which increasingly mainstream Climate Change into their activities. The Wadden Sea is one of the eight hotspots of the Knowledge for Climate research programme, a participatory programme with the ultimate objective to jointly develop a regional adaptation agenda. Because of the special nature of the area, a special Wadden Fund has been established that subsidizes projects in the areas of enhancing the ecological and landscape values; reduce external threats; sustainable economic development; and the development of a sustainable knowledge base. This fund and other government support are likely to facilitate the actual implementation of the adaptation strategies that are developed.

15.3.5 Lake Balaton (Hungary)

The focus of the project described here was to address adaptation to Climate Change in water resource and shoreline management in a very sensitive area of Lake Balaton, Hungary. Lake Balaton is in a uniquely vulnerable situation because of its very shallow profile and the heavy reliance on tourism as a primary source of livelihoods; consequently, the socioeconomic implications of ecological deterioration of the lake could be severe and immediate. During 2000–2004, the region experienced a significant decrease in summer precipitation, creating a drop in the average water level of 15–20% (Istvánovics et al. 2007). The frequency of years with a negative water balance is expected to increase in the future, as indicated by many Climate Change scenarios (Chatenoux and Lehmann 2008). The aims of the project in reference were:

- To develop a lake- and watershed-specific indicator system designed to identify and track issues critical for vulnerability and sustainable development;
- To translate Climate Change impacts into more tangible indicators, such as changes in water level, in water quality and in the tourist sector and to use these indicators to shape development priorities; and
- To identify strategies that help the community respond to Climate Change in the context of future development priorities and policy initiatives, especially in the most sensitive shorelines.

The study was co-led by the local development agency and researchers from various universities and institutes. To help understand the dynamics of environment and community interactions, 32 indicators were created and divided into three sets covering ecological, economic and social dimensions of local changes (Pinter et al. 2008). These indicators were selected by the three working groups of local experts, policy-makers and representatives of civil society.[20] These indicators supported the assessment of current trends and helped in developing a vision of the future.

A series of local public workshops involving more than 80 participants was conducted to investigate current and potential future impacts of weather-related events and adaptation responses in tourism, agriculture, biodiversity conservation and infrastructure development. This included the use of analogies to recent weather events, such as the decreasing precipitation resulting in a lake level drop in 2004–2006, to help envision future adaptation options. Projected climate impacts mostly focused on basic climatic variables such as temperature, precipitation, water level and occurrence of droughts suggest similar future declines in water level. During these sessions it was clear that the participants were strongly concerned about the sustainability of the region, especially over the future of the sensitive

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[20] This method is described as participatory indicator development, for example, by Reed et al. (2008).

lakeshore ecosystems further threatened by expanding tourist facilities. The participants also had a strong desire to encourage energy efficiency, renewable energy; ecotourism; public transportation and other low-carbon development choices.

Outcomes of the project were used to inform the national Climate Change strategy. The local agency revised their evaluation of proposals for local development projects, so that any projects supported would fit with the short- and medium-term actions identified. The project outcomes also showed that some of current actions, for example, limiting development in high-risk shorelines, reforestation, and the protection of agricultural lands, that had already been included in regional development plans also increase adaptive capacities and therefore their implementation should be prioritized.

15.3.6 Northeastern Coastal Region of Morocco (Nador and Berkane)

Impacts from rising sea levels, coastal flooding and storm surges are becoming challenging policy issues for planners, local authorities and stakeholders on Morocco's northeastern coast. The ACCMA project[21] supported capacity building and development of tools and methods to respond to climate-related events in coastal zones. The northeastern coastal landscape of Morocco substantially changed over the last 3 decades due to development pressures interlinked with changing climatic conditions. This resulted in multiple destruction of wetlands and the loss of several beaches due to erosion.

An international research team verified the vulnerability of the population in the coastal areas of the neighbouring provinces Nador and Berkane and identified appropriate adaptation strategies and land use guidelines. The project in particular aimed to help local stakeholders understand the impacts of Climate Change their environment might suffer from and identify ways to adapt. Hence the methodological approach involved the collection and presentation of basic ecological and socio-economic data; the evaluation of risks based on various Climate Change scenarios on a small scale; vulnerability assessments of the different socio-economic and environmental areas included in the study; and the review of earlier Integrated Coastal Zone Management (ICZM) action plans.

National and regional Moroccan officials responsible for environment, tourism, agriculture, education, health, forestry, water and landscape planning together with appointed civil society groups contributed regional and local knowledge and shaped decisions on land use for farming, fishing and tourism. The project team gathered

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[21] Adaptation to Climate Change in Morocco (ACCMA): Enabling stakeholders in Moroccan coastal management to develop sustainable climate change adaptation policies and plans (2007–2010), implemented in the framework of Climate Change Adaption in Africa (CCAA) program, funded by The International Development Centre (IDRC), Canada and the Department for International Development (DFID), U.K., lead: Ecole Nationale Forestière d'Ingenieurs, Morocco.

the majority of information through household surveys, farmer interviews and workshops while sharing data and progress of the project in return. A wealth of local knowledge was collected leading to the development of initiatives. A variety of technical measures were brought forward to local residents, decision makers and civil society such as the restoration of dune massives and a lido that separates the Nador lagoon from the sea; rebuilding of the eroding beaches using sand from coastal areas where it had been accumulated too much; and the installation of drainage channels. Other practices include the selection of tree varieties that easily adapt to water scarcity, soil salinity and erosion (such as olive, carob, almond and fig trees); alternative farming techniques that promote high value-added crops; building a reservoir to store the water resources available in the villages; digging new reservoirs and favouring the drip irrigation system, as well as testing and applying new techniques aimed at sustaining soil quality.

The ACCMA project also advocated for the establishment of a zone with no contraction permitted along the most vulnerable coastal parts and the reorganization of flooding zones.

15.3.7 Coastal Belt of Bangladesh

Bangladesh, a low-lying country located in the deltaic plain of the largest river deltas in the world, formed by three major rivers and encompasses a network of 230 streams in total. Over 133 million people live in a territory less than half of the size of Germany and about 75% of the population lives in rural areas (World Bank 2002). Bangladesh has always had to fight floods and other natural disasters. Therefore, despite limited resources the country has developed a comprehensive system in order to handle these threats. In this regard, Bangladesh's case offers some best adaptation practices in the fields of raising awareness regarding preventive measures in areas threatened by floods, protective building measures against floods, and repairs of significant damages. Additional projects concern coastal water supply, reforestation of the coast line and other emergency provisions (UNDP 2007/2008). The case study chosen for this chapter refers to the ongoing project initiative Cyclone Preparedness Programmes (CPP's) which is carried out by the Bangladesh Red Crescent Society (BDRCS).[22]

The Bangladesh authorities have established a system primarily based on volunteers. Data on imminent storms and floods are collected by ships, radar stations, and weather satellites, and then transmitted via radio to remote areas. In the Cyclone Preparedness Programmes great emphasis is placed on training volunteers who play a crucial role in disseminating cyclone warnings, carrying out evacuations,

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[22] World Resource Institute (2007) Bangladesh: Cyclone Preparedness Program. http://projects.wri.org/adaptation-database/bangladesh-cyclone-preparedness-program. Accessed 6 October 2010.

rescue and first aid emergency relief as well as the operating of radio communication equipment. The trained volunteers are equipped with megaphones, hand sirens, and bicycles to sprawl out to warn their neighbourhoods of an upcoming natural disaster. The goal of the system is to allow people to take refuge in special protective buildings.[23] The measures have proven to be successful. Although cyclones still cause many casualties in Bangladesh, the number of victims has been substantially reduced (Huq and Khan 2006).

15.3.8 RADOST (Baltic Sea Coastline, Germany)

Unlike other cases presented in this section, the RADOST project (‘Regional Adaptation Strategies for the German Baltic Sea Coast’) is not yet completed and the most important part of results is still to be expected.[24] Nevertheless, the authors consider it relevant in the given context. RADOST has provided a starting point for our investigation and, with its comprehensive, cross sectoral approach and the emphasis on stakeholder involvement, has the potential to become a main reference project for adaptation in the Baltic region.

The project is funded by the German Federal Ministry of Education and Research as one of seven regional adaptation projects in Germany within the funding activity KLIMZUG (‘Managing Climate Change in the regions for the future’). This background does not only provide the basis for funding but also offers a framework for an intensive exchange with other regions in Germany that follow similar approaches. In line with the overall KLIMZUG concept, RADOST puts a strong emphasis on science-stakeholder dialogue and the establishment of lasting regional network structures adequate to the cross-cutting nature of the adaptation challenge.

RADOST is embedded in a number of related activities. In addition to several international research projects in which RADOST partners are involved, this includes a first official assessment of Climate Change impacts for the State of Mecklenburg-Western Pomerania (2007–2008). The responsible ministry is closely involved in the RADOST project, as well as other relevant ministries and agencies of both Federal States covered by the project region. This offers a potential to contribute to a greater integration of adaptation policies across administrative boundaries. The project also builds on integrated coastal zone management activities in both Federal States involved, including the ICZM-Oder project.[25] Participatory

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[23] There are almost two thousand of these protective buildings in Bangladesh, each holding 1,500 people. In contrast to residential buildings, usually made of wood and other light materials, these buildings are made of concrete and can withstand strong storms and floods.

[24] The duration of the project is scheduled for mid-2009 to mid-2014.

[25] Research for an Integrated Coastal Zone Management in the German Oder Estuary Region, 2004–2010.

approaches aiming at reconciling different interests, such as coastal protection and tourism, have been applied before and provide a valuable background of experience.[26]

To advance scientific understanding of climate impacts in the region, RADOST uses coupled models processing climate, hydrological, ecological, as well as socio-economic data. Stakeholders were involved at the beginning of this process to ensure that model outputs will meet their information needs. A major part of the project will be dedicated to utilizing modelling results in practical research activities structured along the main sectors and adaptation challenges of the region. This will include the implementation of pilot adaptation solutions with local partners. An emphasis is put on highlighting innovative concepts that simultaneously address different sectoral objectives. These include the construction of artificial reefs that serve coastal protection objectives as well as recreational activities, the combination of coastal protection structures with geothermal energy generation, or the promotion of sustainable aquaculture techniques that offer perspectives for a transformation of the fisheries industry and at the same time contribute to improving water quality.

Among regional stakeholders, large differences in awareness of adaptation challenges can be detected. Coastal protection authorities in particular, actively communicated the need for reliable long-term assessments of coastal conditions. By contrast, the tourism industry usually thinks ‘from one holiday season to another’ and sees Climate Change as a less urgent challenge, potentially even as beneficial for its business. Despite this, there is already a widespread awareness of the sector’s share of responsibility for Climate Change mitigation efforts. While the current debate about tourism and climate does not always make a clear distinction between adaptation and mitigation issues, this may also create opportunities for integrated sectoral strategies. Within RADOST, the ‘Climate Alliance Kiel Bay’ created in early 2010, which is formed essentially of resort towns of the Kiel Fjord and adjacent areas, provides a forum to address both mitigation and adaptation and potentially forms a model for other places within the project region and beyond.

15.4 Comparative Analysis of Case Studies and Conclusions

In this section, we discuss the cases according to the criteria introduced in Section 15.3.1.

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[26] See, for instance, the Bay of Lübeck case study in Nandelstädt (2008, pp. 48–54), illustrating a process of developing a coastal protection concept that takes account of the touristic features of a place.

15.4.1 Project Design, Involved Stakeholders and Sources of Finance

The reviewed projects were mostly led by regional and local organizations assuming leadership roles in the regions. Regional and local authorities and agencies as well as civil society organizations and regionally-based research institutions had a collaborative relationship with government and research institutions to provide Climate Change projections and information on sectoral impacts.

15.4.2 Lasting Personal and Financial Commitments are Crucial for Successful Adaptation

Leadership through a regional, well-established organization created a link between the higher levels of government and local and regional stakeholders. In the Bras d'Or and Chesapeake Bay cases, a partnership with, and funding from, the national governments were critical. In other cases, foreign and international agencies such as UNDP, Red Crescent Society, IDRC and DFID provided the support. Regional leadership had a strong influence on the focus of the cases; the selection of impacts investigated thus took account of the concerns of the public and stakeholder groups in each coastal area. Climate impacts were assessed in connection with other pressures on the coasts, including tourism in Bras d'Or, water pollution and overharvesting of marine resources in the Chesapeake Bay, increasing development pressures in Morocco and human safety and health aspects in Bangladesh.

It is important to involve stakeholders from the start through this full cycle. Stakeholder collaboration, in several cases including the private sector played an important role in the selection of methods, identification of priority areas, assessing consequences of Climate Change, identifying adaptation options and implementation measures.

15.4.3 Scientific Basis

An essential element of most of the projects was to make use of currently available projections of Climate Change and vulnerability assessments, making them relevant for the particular questions, sectors and regions. The available scientific basis included projections of basic climatic variables, such as temperature, precipitation and sea-level rise, as well as assessments of impacts, including those on key agricultural crops in coastal zones, fish species and habitats. However, these projections were often developed by a small group of experts and climate scientists, whose views did not necessarily reflect the concerns and questions of stakeholders. For example, in the Bras d'Or case, vulnerability assessments were available for coastal erosion and sea-level rise without considering precipitation changes and heavy rainfall.

Making Climate Change projections relevant for coastal adaptation actions requires translating them into changes in the shoreline, in hydrology and ecosystems, and also considering their socioeconomic implications. This requires a set of different methodological approaches in which stakeholder involvement can come into play at various stages. The approaches applied in the reviewed projects included: household surveys and workshops along the north-eastern coast of Morocco to gather information about current impacts and coping strategies; participatory indicator development to monitor changes in climatic variables in the context of other socioeconomic variables in Lake Balaton; using scenario development techniques to place future climate projections into the context of potential socioeconomic futures in Bras d'Or; and creating voluntary monitoring schemes of key species in Chesapeake Bay and using training of trainers approach in Bangladesh to encourage wider information dissemination. This combination of tools provided an opportunity to overcome a lack of information as well as uncertainties in Climate Change projections that may otherwise discourage action. In some cases, new knowledge triggered by Climate Change and response options is seen as an opportunity for innovation, such as in the Wadden Sea.

15.4.4 Coverage of Sectoral Climate Change Impacts

The projects presented above addressed Climate Change impacts and adaptation in a variety of areas and sectors; this also reflects the diversity of stakeholder groups involved. In a more general perspective, the overarching concern was to maintain coastal settlements and their economic potential, in various cases attempting to reconcile this economic potential with protecting valuable coastal ecological systems. As a consequence, in addition to a number of economic and environmental themes, the projects addressed social and governance issues such as the collaboration between levels of government to support the implementation of adaptations.

In terms of economic sectors, tourism is an area of outstanding importance for many coastal regions. In most of the cases, including the Bras d'Or, Baltic Sea, Wadden Sea, Lake Balaton and the north-eastern coast of Morocco, the stakeholders were also interested in exploring the impacts of Climate Change on aquaculture and recreational fishing as these activities are either part of their current sources of revenue or are being considered as potential development options. Agriculture is relevant for a number of areas as well. Most of these economic activities are strongly related to environmental quality. As a consequence, accounting for the environmental impact of Climate Change on sensitive ecosystems, including biodiversity conservation and water quality in coastal habitats, often has direct relevance for assessing economic consequences. Another economic aspect, the costs and benefits of upgrading infrastructure, relates to the broader, cross-sectoral question of how to effectively incorporate climate projections into spatial planning. A number of practical questions in this regard were addressed such as: What are the maximal water levels predicted – taking account of sea-level rise, storm surges and tides – to inform infrastructure planning? What areas are most at risk given projections of Climate

Change, allocation of infrastructure and population density? What areas are most at risk for coastal flooding? Should we impose new restrictions on development in these areas?

15.4.5 Integration of Adaptation with Sustainable Development Priorities

Most of the studies show that the overall sustainability of the sensitive coasts is a strong priority for the residents. Activities addressing Climate Change issues, and especially adaptation responses, are often seen as opportunities to advance the sustainability of the whole region, as opposed to treating Climate Change as a narrow, sector-specific challenge. This led to considerations on how to develop sustainable regional strategies to guide preferred adaptation options and develop targeted information campaigns for different stakeholder and population groups (e.g. developers, seasonal tourists and school children) to encourage sustainable development. In several cases, including the artificial reefs and peninsulas in Chesapeake Bay, infrastructure measures are being designed in such a way as to simultaneously create benefits for wave absorption, natural flood protection and biodiversity.

In many of the regions studied, including the Bras d'Or, Lake Balaton and the German Baltic Sea coast, the involvement of stakeholders led to suggestions for Climate Change mitigation measures, i.e. the reduction of greenhouse gas emissions. The need to promote ecotourism, public transportation for tourists, eco-friendly construction materials and renewable energy sources were seen as priorities when outlining new development opportunities for the regions. This suggests that when discussing action on Climate Change, while large groups of the population are well aware of the need for mitigation, the adaptation topic still remains less tangible for many of them. This concerns the need for adaptation as well as the identification of response measures that stakeholders can take themselves. While the strong interest in contributing to Climate Change mitigation can be rated positively, it does not necessarily imply systemic thinking and the actual exploitation of synergies between adaptation and mitigation. It may also mean that when confronted with adaptation challenges, people tend to switch to familiar themes.

15.5 Concluding Remarks – Lessons Learned and Their Transferability

Working on a local or regional scale allows examination of 'real world' vulnerabilities and opportunities to identify effects of Climate Change as well as relevant adaptation options. Thus the selected case studies illustrate the importance of the knowledge transfer of good practice methods for the scaling up of adaptation strategies in and between regions and beyond the national scope. The fact that very different types of coastal zone settlements can be found around the world contributes to the diversity of approaches to resilience and adaptation strategies. Since for example, 30–70% of Bangladesh's land surface is normally flooded each year (Agrawala and Carraro 2010) and natural disasters are frequently occurring. Because of this experience, the country offers some good adaptation practices e.g. in the area of disaster warning and control. Paradoxically, there may be instances that exposed and poor communities prove more adaptable than their richer counterparts: They may be for example able to move away from risk zones with greater ease since they are not bound by large investments in buildings and infrastructure (Ecologic Institute 2008). This of course in no way changes the urgent need to develop adaptation structures that ensure effective support to poor populations losing their land to the sea. Vice versa the obvious need for adaptation strategies in the low-lying 'rich' Netherlands spurred efforts from the country's politicians, planners and architects to develop a variety of innovative solutions such as the renowned 'floating' houses.

The projects described in the case studies were investigated because of their instructive approaches. They were conducted by strong regional leadership with collaboration partners including governments, research institutes, local organizations and agencies. Building on the results of the case studies, it is clear that the concerns of the citizens are different from those of the climate modellers and experts; therefore, identifying key questions and concerns at the early stages of the projects that were relevant for the stakeholders and suitable for integration into models, including those assessing impacts on sectors and natural resources, was crucially important in increasing the relevance of the results.

To facilitate the successful implementation of the outcomes, the cooperation of a broad range of organizations and the engagement of stakeholders are both necessary. Ideally, a regional adaptation project would result in a plan outlining a sequence of policy recommendations and suggested measures, such designated at-risk areas, revised principles for natural resources management along the coasts and awareness raising about preferred development practices to increase the resilience of the coastal areas. This also requires maintaining connections to relevant policy and decision-making processes and carefully evaluating progress by examining the development of explicit partnerships among the relevant sectors of the local or regional community. Such partnerships offer the potential to begin to articulate the business plans, policies and actions required to implement adaptations. In the Bras d'Or case, it was important to link the project outcomes to the overall policy cycle in order for the results to be available before the planning agency's management plan was finalized. At the level of 'on-the-ground' adaptation actions, the measures described in the Chesapeake Bay case study and, more generally, the way of encouraging extensive voluntary contributions in their implementation such as in Bangladesh, might serve as a model for other coastal areas.

Finally, most of the case studies preceded the formal regional and national adaptation programmes in their countries. These case studies provide useful information on how to design effective adaptation process that would necessitate allocating time and efforts for relationship building between organizations, for linking Climate Change impacts information with users' needs and for connecting adaptation needs with overall development priorities of the regions.

However, most of the analyzed case studies did not devote significant attention to share and to disseminate gathered knowledge and identified adaptation practices especially regionally, nationally and even internationally. The regional coastal adaptation programmes could play an important role in addressing this gap by applying tools and processes that enable exchange of best practices and lessons learned in coastal adaptation, which is one of the important foci of the RADOST project.

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Chapter 16
Integrating the Common Fisheries Policy and the Marine Strategy for the Baltic: Discussion of Spatial and Temporal Scales in the Management and Adaptation to Changing Climate

Tim O'Higgins and Eva Roth

Abstract The Marine Strategy Framework Directive (MSFD) requires the achievement of Good Environmental Status (GES) by 2020 and the adoption of the Ecosystem Approach. The former sectoral approach to management must be transformed to adhere to the requirements of the new directive. Fishery is a particularly important example, because it relies heavily on the ecosystem, sustains many coastal communities and still has large economic impacts at national level. We examine the cod fishery in the Eastern Baltic and the feasibility of integrating the intermediate and final ecosystem services and benefits associated with the fishery into the 'programmes of measures'. We use Decision Space Analysis to visualize the spatial challenges concerning competing priorities and expectations for uses of the marine area, as well as the temporal challenges of achieving GES under the very short time constraints of the MSFD.

Abbreviations

MSFD	Marine strategy framework directive
GES	Good environmental status
CFP	Common fisheries policy
EEZ	Exclusive economic zone
CAP	Common agricultural policy
NPV	Net present value
MSY	Maximum sustainable yield
MEY	Maximum economic yield
TAC	Total allowable catch
ITQ	Individual transferrable quota

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16.1 Introduction

The Baltic Sea has supported human populations and provided a source of food (in particular cod) to humans since prehistoric times (Limburg et al. 2008). The Baltic Sea Basin is now home to about 85 million individuals with over 26 million living within 50 km of the coast and 15 million within 10 km (Sweitzer et al. 1996). The modern residents of the Baltic continue to benefit from the local marine environment and the many services it provides, from active uses such as commercial harvest of food, to recreation and tourism as well as passive use services such as the existence value of the sea and its inhabitants. In recent decades the Baltic has, amongst other, been used as a sink for waste products from agricultural land, and for the extraction of cod and other fish. However the benefits of economic and social exploitation of the Baltic have not been without environmental costs. The damage caused to the Baltic Sea ecosystem by human activities has long been recognised (Elmgren 2001).

The Baltic has the largest anthropogenic hypoxic area in the world (Diaz and Rosenberg 2008). The area of hypoxia is related to both natural fluctuations in climate as well as anthropogenic effects (Conley et al. 2009) with the chief anthropogenic sources being oversupply of wastewater and agricultural run-off. Despite recent attempts at alleviating nutrient pressures, existing loads of nutrients within the system (Neumann 2007) as well as continuing supply of nutrients from diffuse sources (Humborg et al. 2007) mean that the eutrophication problem is likely to persist for many years (Neumann 2007) and the system is unlikely to follow a simple trajectory to its pre-eutrophied state (Duarte et al. 2008).

Eastern Baltic cod stocks, the natural resource base of the most valuable of the Baltic fisheries, have suffered severe decline due to human activities. The collapse in cod stock has been linked to overfishing as well as environmental conditions (MacKenzie et al. 2007). Recruitment and recovery of the fishery are dependent on the 'spawning volume' (Plikshs et al. 1993) which is determined by the prevailing physical structure and oxygen conditions of the water column and by natural stochastic oceanographic processes as well as anthropogenic oxygen depletion (MacKenzie et al. 2000, Conley et al. 2009). Anthropogenic Climate Change also threatens to radically alter the functioning of the Baltic Sea ecosystem. Though there is great uncertainty in predictions, the most widely accepted scenarios see a reduction in salinity of eastern Baltic waters due to increased freshwater inflows. This will profoundly alter the physical structure of the sea and make the prevailing hydrographic conditions less favourable to cod (HELCOM 2007).

If the long term abundance of cod is to be achieved the changing conditions brought about by Climate Change mean that the resistance and resilience of the species could be highly dependent on the genetic diversity in the surviving population. Since the changes in climate are not known and the levels of diversity required to meet the demands of climate are not known, sustaining the long term abundance of cod will require maximizing genetic diversity as insurance against complete collapse of the stocks.

The recognition of the anthropogenic threats to environmental conditions has lead to pan-European attempts to regulate the anthropogenic pressures on the ecosystems through legislation. Several existing European laws, the Birds Directive (EU 1979), the Habitats Directive (EU 1992) and the Water Framework Directive (WFD) (EU 2000) deal with the protection of various elements of the marine ecosystem. In 2008 the Marine Strategy Framework Directive (MSFD) came into force (EU 2008). This directive is the first comprehensive law focused specifically on management of the environmental quality of Europe's regional seas. The overall aim of the MSFD is to promote sustainable use of the seas. The directive encompasses most human activities relating to the seas, provides a more coherent basis for management and protection of the marine environment and unifies the previous legislation. The founding concept of the MSFD is that of the Ecosystem Approach (to management) recognising the connections between the environment and human activities, institutions, social and economic structures. The goal of the directive is to achieve Good Environmental Status (GES), a concept necessitating value judgements on the desired state of the environment (Mee et al. 2008). The MSFD takes effect at the level of member states' Exclusive Economic Zones (EEZs), and provides for cooperation between nations on a regional seas basis. The Ecosystem Approach replaces the previous sectoral approach and aims to account for the costs of damage to the environment (which are commonly economic externalities) as well as the benefits (ecosystem services) resulting from marketed commodities and other active and passive use values associated with marine ecosystems (Millennium Ecosystem Assessment 2005, Fisher et al. 2009). The MSFD is the 'environmental pillar' of the EU Integrated Marine Policy with a reformed Common Fisheries Policy contributing the economic pillar (Mee et al. 2008) and reflects a change in European values from food security toward other concerns (Suarez de Vivero 2007).

Though the Ecosystem Approach has rapidly gained popularity, few examples exist of a comprehensive application of such an approach at a regional scale as mandated by the MSFD. As such the MSFD represents an experiment in application of the Ecosystem Approach to management. Below we describe the essential steps of the MSFD, and examine the implications of an Ecosystem Approach for the reform of the Common Fisheries Policy (CFP).

16.2 The Plan for Implementation of the Marine Strategy Framework Directive

A timeline showing the obligations of the European Commission and the European Union member states under the MSFD is set out in Fig. 16.1. There are five major steps which contribute to the final delivery of Good Environmental Status in 2020. The first step concerns the definition of methodological criteria and standards (by July 2010). GES is to be assessed on the basis of 11 descriptors contained in Annex 1 of the directive (Table 16.1) and the criteria for these descriptors have been laid down in a recent Commission decision (EU 2010). The second step, setting targets and indicators (by July 2012) will establish the vision for what 'Good Environmental Status' should resemble, and will require choices about the

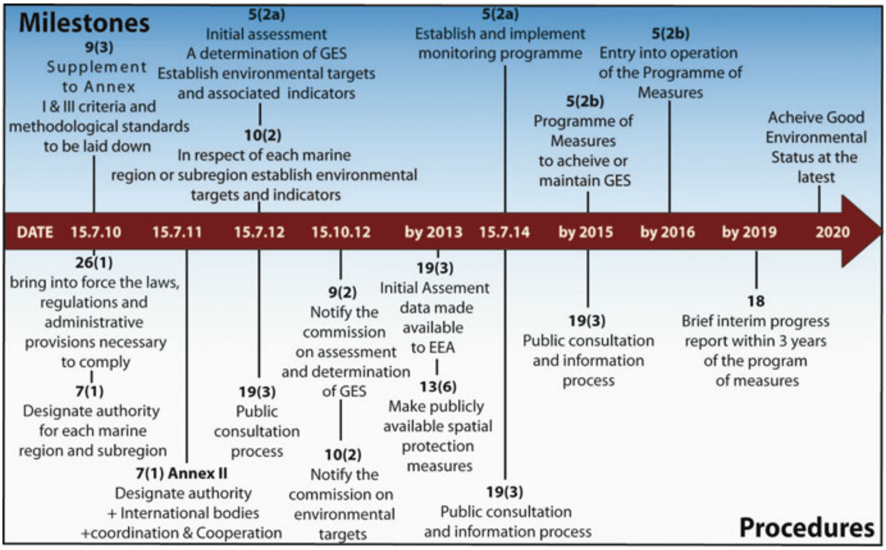

Fig. 16.1 Timeline for the implementation of the Marine Strategy Framework Directive

desirable status of the ecosystem (Mee et al. 2008). Once the targets are established the remaining steps involve assessment of the current situation through monitoring (by July 2014); development (by 2015) and implementation (by 2016) of a program of measures to reach the target of GES by 2020. The directive specifies as a first step toward the preparation of a program of measures, an economic and social analysis on the use and cost of degradation of the marine environment. The scope of the program of measures is set out in Annex VI of the MSFD. It includes input, output and spatial control measures; management coordination measures; measures to improve traceability of pollutants; economic incentives; mitigation measures and methods for communication and stakeholder involvement.

16.3 The Development of the New Common Fisheries Policy

The Common Fisheries Policy (CFP) was established in 1983 and the present reformed version stems from the 2002 reform of the CFP. The policy covers direct fisheries management aimed at ensuring long term sustainable exploitation of the living aquatic resources. Furthermore, the policy includes market measures and a structural policy aiding and coordinating fishing fleets' development and modernisation of on-shore installations. The 2002 reform allowed for a long-term approach especially targeted at multi-annual recovery plans and for progressive implementation of an ecosystem-based approach to fisheries management.

Table 16.1 Descriptors of environmental status from Annex I of the MSFD. An asterisk marks those particularly relevant to fisheries in the Baltic

	Descriptors of good environmental status from Annex I of the MSFD
1*	Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions
2	Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems
3*	Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock
4*	All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity
5*	Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters
6	Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected
7	Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems
8*	Concentrations of contaminants are at levels not giving rise to pollution effects
9*	Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards
10	Properties and quantities of marine litter do not cause harm to the coastal and marine environment
11	Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment

A second reform process was launched in 2009 both as a public consultation process and an impact assessment comparing different scenarios for future policy changes of the CFP. The Green Paper (EU 2009) argues that:

> Rethinking the CFP requires us all to take a fresh look at the broader maritime picture as advocated by the Integrated Maritime Policy (IMP) and its environmental pillar, the Marine Strategy Framework Directive (p. 5).

Current specific targets for fisheries management were set at the world summit on sustainable development (2002) and the current goal is to restore fish stocks to Maximum Sustainable Yield by 2015. This target is clearly not in line with the Ecosystem Approach as it continues the practice of management to deal with fish stocks individually and to maximise potential harvest with no consideration of the economic potentials (resource rent, costs of production) and long term welfare of the fishing communities. The descriptors of the MSFD specify that 'all elements of the marine food webs occur at normal abundance and diversity'. This requirement is not consistent with management of stocks on an individual basis.

The Green Paper describes the inherent problems faced by the fishing industry. The measures to ensure long term ecological and economic sustainability build on traditional measures, but a clear change in responsibility to the private sector is envisaged. The interests of the sector of both short term and long term income possibilities does not change with a shift toward the private sector, but the collective behaviour of the sector may change. It is however still an open question whether this vision for future stakeholder involvement can encompass measures targeting intermediate and final services (generally not marketed) in addition to securing benefits with direct use value.

16.4 The Ecosystem Approach

Ecosystem services are the aspects of ecosystems utilized (actively or passively) to produce human well being (Fisher et al. 2009). Human welfare and survival is dependent on an adequate supply of ecosystem services. Food, water and habitable climate are some amongst many of the services provided by nature, yet human activities frequently result in damage and degradation of the ecosystems which provide these services. Recognition that ecosystems are essential to the sustainable development of human activities and growing understanding of the severe ecosystem damage caused by these activities has lead to an increased awareness of the benefits provided by nature (Millennium Ecosystem Assessment 2005). The concept of the Ecosystem Approach to management (which is synonymous with 'Ecosystem Approach' and 'Ecosystem Based Management') is based on the recognition that humans live in coupled social-ecological systems. (Daily 1997, Daily and Walker 2000, Boumans et al. 2002, Ehrlich and Ehrlich 2008).

While there is a sound conceptual basis for an Ecosystem Approach and the concept has grown rapidly in popularity in many circles, the practice of the approach is still in its infancy. With the introduction of the MSFD there has been a very real mandate to put the Ecosystem Approach into practice. However there is no universally accepted definition or set of standards. We chose the following broad definition of the Ecosystem Approach

> the Ecosystem Approach is a resource planning and management approach that integrates the connections between land, air and water and all living things, including people, their activities and institutions.[1]

Key to the definition is the integration of the connections between natural resources (biotic and abiotic) and human activities. Successful implementation of an Ecosystem Approach must recognise (and account for in management practices) the complexities within the ecosystem. Ecosystems exhibit non-linear behaviour, positive and negative feedback mechanisms, time lags and scale dependent processes; and these affect the flows of ecosystem services to humans.

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[1] This is the working definition of the KnowSeas project adapted from that of the Ontario ministry for natural resources. A full rationale for the choice of the definition is contained in KnowSeas deliverable 2.1 which may be obtained by contacting the authors.

Appropriate methods for integrating the supply of nature's services (most of which are not marketed) with existing economic activities has not proved simple. To examine ecosystem services it is essential to classify them according to a typology. While many typologies have emerged for different purposes (Costanza et al. 1997, Millennium Ecosystem Assessment 2005, Boyd and Banzahf 2007, Fisher and Turner 2008), the 'Classification of Ecosystem Services for Decision Making' (Fisher et al. 2009) is best suited to our purpose. This classification provides a clear delineation between intermediate services, final services and benefits thus avoiding double counting. This scheme also recognises that ecosystem services are benefit dependent allowing the focused selection of benefits and the final and intermediate services which underpin them. Table 16.2 shows our classification of services related to fisheries in the Baltic.

Though we identify seven distinct intermediate services, the final services and benefits which these support are 'joint products' of these services i.e. in reality the intermediate services are interlinked and exhibit dynamic interactions which combine in complex ways to provide the final services and ultimately the benefits to humans. The complex interactions between nutrient cycling and primary productivity in the Baltic and the relationship between eutrophication and nursery and breeding conditions for Cod have been well studied (Plikshs et al. 1993, Vallin et al. 1999). Similarly there is a good understanding of how climatic conditions affect habitat conditions for Cod in the Baltic and how these might change with global warming but the exact nature and timing of the changes is uncertain (HELCOM 2007).

The complexity and uncertainty associated with ecological processes in the Baltic ecosystem and the joint nature of the services they provide reduce our ability to predict how the systems will behave in the future. Recognition of the linkages between ecosystem components must be central to management in order to achieve

Table 16.2 Classification of intermediate and final services and benefits related to fisheries the superscripts indicate the relevant descriptors from Annex 1 of the MSFD (Source: Modification from Fisher et al. 2009, Hanley and Barbier 2009 in Kronbak and Roth 2010)

Intermediate services	Final services	Benefits
		Active use:
Primary production^{4,5}	Fish production^{3}	Commercial harvesting of species and their consumption^{3}
Nursery and breeding^{5}	Maintenance of beneficial species^{4,1}	
Habitat provision		Commercial growout of fish and crustaceans (mariculture)
Predator-prey relationships^{4}		Recreational fishery
Sea water quality^{8,9}		Non-consumptive use (e.g. visual benefits/cetacean and seal tourism activities)
Nutrient cycling^{5,6}	Maintenance of Biodiversity^{1}	
Climate regulation		
	Resistance and resilience^{1}	Passive use
		Existence value of species^{1}
		Option value^{1}
		Bequest value^{1}

an Ecosystem Approach. Integration of the complexity (and attendant uncertainties) associated with ecosystems into management actions can be seen as success criterion for implementation of an Ecosystem Approach.

16.5 Can the Marine Strategy Framework Directive Accommodate the Ecosystem Services Classification?

The stated aim of the MSFD is to achieve an Ecosystem Approach but the legal obligation for member states under the MSFD is to achieve Good Environmental Status (GES). GES is described by the 11 descriptors (Table 16.1) in the directive and is to be assessed according to recently published criteria (EU 2010). The degree to which the MSFD can deliver an Ecosystem Approach in the Baltic is dependent on the applicability of the descriptors of GES to the selected ecosystem services.

Descriptor 1 directly addresses three of the ecosystem services in our typology. It is a direct mandate to maintain *biodiversity* at the species, habitat and ecosystem level (EU 2010). Maintenance of biodiversity also adds to the *resistance and resilience* of the ecosystem (Tilman and Downing 1994, Naeem and Li 1997, Hughes and Stachowiz 2004, Tilman 2005). The stability provided by resistance and resilience ensures continued supply of ecosystem services over time. Within a species genetic diversity also enhances resistance and resilience over time, and preservation of genetic diversity with eastern Baltic cod stocks would enhance the ability of the stock to survive Climate Change (Johannesson and André 2006). Maintenance of biodiversity also ensures the *maintenance of beneficial species.* These include species which have non-consumptive use and passive use values.

Descriptor 3 (concerning commercial fisheries) is directly relevant to the final services of *fish production* as well as the active use benefits of *commercial harvest*, but the emphasis on commercial fisheries means that it is unlikely to achieve balance in predator prey relations. This descriptor is anthropocentric.

Desciptor 4 (food web structure) addresses the intermediate services of *primary production*, and *predator prey relationships* and is also relevant to the final service of *maintenance of beneficial species* as well as *biodiversity*. By contrast to descriptor 3 the focus on food web structure is bio-centric.

Descriptor 5 (minimisation of eutrophication) is relevant to the intermediate services of *primary production, nursery and breeding, habitat provision,* and *nutrient cycling* and to the final services of *biodiversity, resistance and resilience*.

Descriptors 8 and 9 (reduction in pollutants) deal with the intermediate service of *sea water quality*.

Management of each of the services listed in Table 16.2 is well within the scope of the MSFD descriptors. Though not explicitly mentioned in the MSFD or in the guidance on descriptors (EU 2010), all but one of the final and intermediate services we identified as relevant to Baltic cod fisheries are captured by just 5 of the 11 descriptors of GES. At least for this example, it appears that the descriptors are suitably broad to support an Ecosystem Approach. The single service in our list not encompassed by the descriptors is climate stability. Climate regulation is of vital importance but is a global phenomenon and cannot be managed at the scale of European regional seas. While the Baltic Sea can contribute directly to the mitigation of Climate Change through storage of CO_2 and indirectly through the provision of space for mitigation activities such as the construction of offshore renewable energy technologies, particularly wind farms, these are not addressed within the directive.

The relevance of the descriptors to the ecosystem services in question, though encouraging, is not the only criteria by which we may judge the ability of the MSFD to deliver an Ecosystem Approach. These descriptors define the scope of the directive. The goals and the means of achieving these goals are set out in the environmental targets and the programme of measures.

The environmental targets will reflect a vision of what constitutes ‘Good Environmental Status’. In a complex system with many competing human interests and associated drivers and pressures and subject to forcing by stochastic process of climate, there are many possible desirable ecosystem states. Therefore the definition of GES is not a trivial matter.

Descriptor 3 proscribes that commercially exploited fish stocks should have age and size distribution indicating a healthy stock, while descriptor 4 requires ‘normal abundance and diversity’ of all elements of marine food webs. Current fishing practices preclude ‘normal’ abundance of those fish commercially caught and the balance between achieving GES for each of these objectives will require a tradeoff between the interests of commercial fisheries and the interests of a ‘normal’ ecosystem. In the Baltic significant anthropogenic alterations to the food web have been apparent for the last century (Conley et al. 2009). Characteristics of a more natural food web would involve higher numbers of top predators and these in turn would require prey, naturally cod (MacKenzie et al. 2007). Eutrophication also represents a shift in the food web structure (which is contrary to the goals of descriptor 4), from the perspective of the cod fishery however a degree of anthropogenic eutrophication may be beneficial since increased primary production may increase fish biomass (through increased food availability) (Thurow 1997) while over supply of primary production leads to reduced oxygen concentrations and adversely affects cod recruitment.

Since the food web of the Baltic is already so radically altered, the vision for Good Environmental Status or indeed for a “normal” food web, is a matter of choice. Balancing food web elements and fisheries will necessitate trade offs and prioritisation of interests. Provisions for stakeholder engagement are made within the MSFD. The directive proscribes 3 public consultations. Stakeholder engagement mechanisms are also specifically mentioned as instruments to be used in the programme of measures. The success of the MSFD requires a socially acceptable choice of GES.

Furthermore, once these targets are set, an economic and social analysis must be carried out as a first step towards the preparation of a program of measures and the directive provides for non-compliance with targets on the basis of economic criteria (MSFD, article 14, 4).

The choices of achievable GES targets available to us are constrained by certain biological and social realities. Our ability to manage the ecosystem is dependent on the spatial and temporal scale of the existing processes in the environment as well as the existing social and economic structures which act towards or against management activities.

Using Decision Space Analysis we examine the temporal and spatial scale for environmental and social phenomena relevant to the management of cod and eutrophication. We identify the consequences for setting environmental targets. Setting appropriate targets in the system requires a cohesive response to the following question: What kind of ecosystem do we want? And how can we use the programme of measures to achieve it?

16.6 Decision Space Analysis

Decision Space Analysis is a technique for analysing and communicating spatial and temporal mismatches between environmental problems and the decisions which regulate them. It is based on the idea that, for any given management issue there exists a particular spatial and temporal scale over which management objectives may be achieved. By understanding the relevant spatial and temporal scale a 'decision space' may be identified. Understanding the degree to which environmental objectives may be achieved within this 'decision space' allows decision makers to make more informed judgement as to the best options for management. While the technique of Decision Space Analysis can apply to any management issue, we focus here on the time and space scales of the MSFD and the issues of eutrophication and cod in the Baltic.

16.6.1 Temporal Scales

The temporal requirements of the MSFD have been discussed earlier; the onus on member states is to achieve GES by 2020, 4 years after the implementation of the program of measures. Though specific targets have not yet been set for determination of GES, achievable goals should incorporate the existing knowledge on eutrophication and cod stocks as well as the uncertainties associated with likely future challenges caused by changing global climate.

Despite recognition of the eutrophication problem in the Baltic in the late 1960s and attempts at alleviating nutrient pressures (Elmgren 2001) nutrient budgets for the Baltic remain substantially unchanged since the peak eutrophication period in the 1980s and nutrient reduction policies have shown little effect on eutrophication (Aritoli et al. 2008). Restricted exchange with ocean waters mean that existing pools of nutrients in the Baltic Sea may have residence times of up to 30 years (Neumann 2007). This fact combined with other 'memory effects', such as nutrient saturation within terrestrial and freshwater sources, ensures continued elevated concentrations of nutrients in Baltic. Increasing livestock densities in newly acceded EU nations, with higher demand for animal protein may mean that nutrient supply to the Baltic may actually increase in the near future (Humborg et al. 2007). It is highly likely therefore that the drivers and pressures of eutrophication in the Baltic will continue. Substantial improvements in eutrophication are unlikely without radical efforts to reduce the emerging drivers of this new wave of eutrophication. Given the emerging new sources of nitrogen and the significant residence time for nutrients within the Baltic, a timescale in the order of several decades is more appropriate to solving the problem of eutrophication. The program of measures for the MSFD must therefore tackle the root pressures of the problem, in particular agriculture. Expectations for improvement of the eutrophication status of the sea should be modest within the timescale of the MSFD and GES targets must be modest if they are to be achieved.

There is a great degree of uncertainty regarding the timing and magnitude of future changes in environmental conditions which accommodate cod recruitment and survival in the Baltic. Coupled atmosphere-ocean models project an increase in temperature and a decrease in salinity. Salinity in the Baltic is projected to decrease by 4–45% by the year 2100 (HELCOM 2007). These changes are likely to result in Baltic cod recruitment becoming increasingly stressed (MacKenzie et al. 2007). Modelled scenarios of Climate Change and fishing effort suggest that stock collapse of eastern Baltic cod cannot be prevented and that with ‘fishing as usual’ and rapid Climate Change scenarios the stocks could collapse entirely by 2026 (Röckmann et al. 2007). However with appropriate closures, the stock may be buffered from the effects of Climate Change for at least 20 years. It is clear given the uncertainty of future conditions and the possibility of rapid collapse that urgent action will be required to control fishing mortality in the timeframe of the directive. However given the uncertainty associated with Climate Change the measures to be taken should be adaptable on short timescales to accommodate climatic events as they occur.

16.6.2 Spatial Scale

Figure 16.2 illustrates a Decision Space Analysis map of the Baltic focused on the issues of cod fishing and eutrophication.

The map uses a variant of the classic Driver Pressure State Impact Response (DPSIR) causal framework for analysis, which has been adopted by the European Environment Agency. In this modified version of the framework the Impact (I) is replaced with Welfare (W) to avoid ambiguity between environmental and economic impacts.

For cod the major pressure is catch (symbolised by the cod image in the red oval). The size of the symbol is scaled based on the most recently available catch data for each of the ICES statistical areas (ICES 2010). Similarly the state of the cod stocks (symbolised by the cod image) is taken from the most recent ICES data (ICES 2010); the stocks are assessed for the eastern and western areas separately hence two symbols on the map. Total EU fishery subsidy (under the CFP) is used as a proxy for the welfare generated by the fishery. Data are based at the NUTS III level (this EU nomenclature of territorial units for statistics) and are derived from

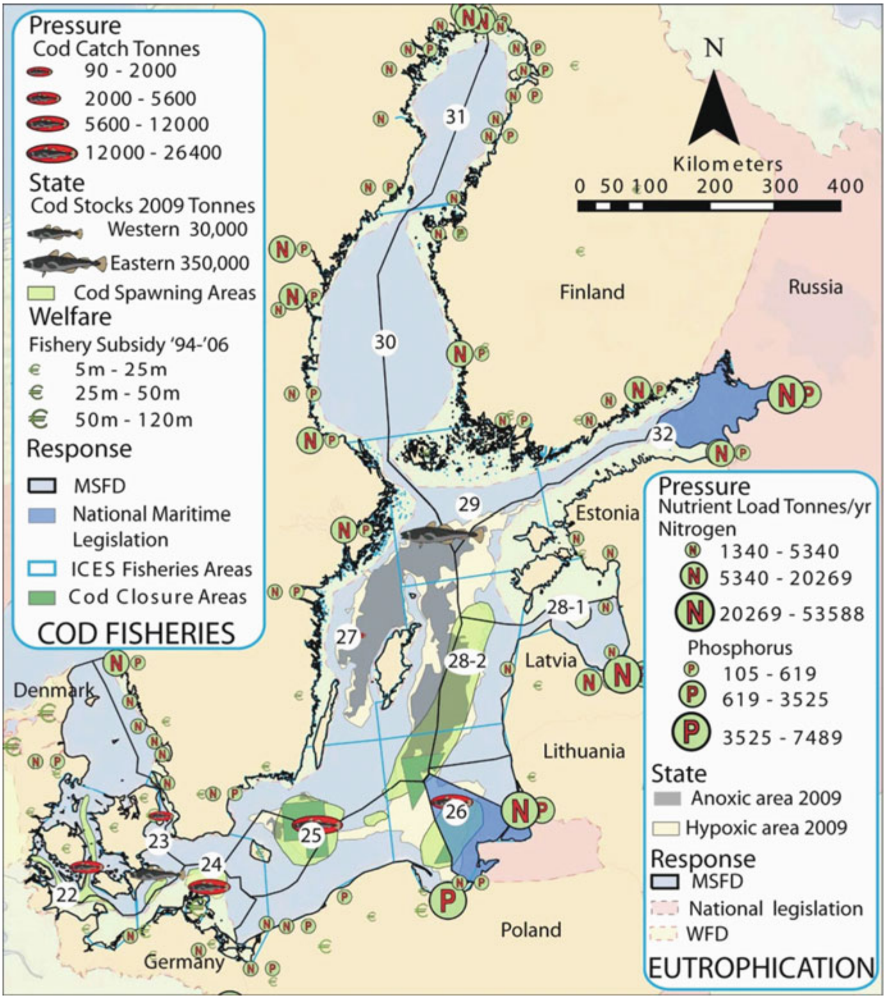

Fig. 16.2 Decision space analysis map for cod fisheries and eutrophication in the Baltic Sea (a detailed explanation is contained in the text)

an online database of EU fishery subsidy (http://fishsubsidy.org). The potential for response is mapped according to the jurisdiction of legislative instruments. For the MSFD (the member state EEZs are shown as light blue areas delineated by black), areas under national legislation where the MSFD does not apply are shown in darker blue. Current cod closure areas are shown in dark green.

For eutrophication the main pressures are nutrient inputs. The symbols (red letters N and P) are scaled according to measured riverine nutrient loads using data from the geospatial portal of HELCOM. Eutrophication State is illustrated by the extent of anoxia and hypoxia in 2009 (georeferenced from Hansson et al. 2009).

As with the cod example, potential for response is mapped according to the legislative jurisdiction. The Water Framework Directive is delineated in dark red (filled with yellow on land and light green in coastal waters) areas under national legislation are shown in red.

The map serves as a decision support tool, allowing easy reliable and informative visualisation of the geographic scope and scale of the two problems as well as the sphere of influence of the relevant legislation.

Though most of the Baltic Sea area is under the jurisdiction of the MSFD as indicated by the light blue EEZs, significant portions of ICES boxes 26 and 32 are subject to the national maritime legislation of Russia. Russia's EEZ off Kalinigrad also contains a large part of the cod spawning ground in the area.

Hypoxia is more prevalent in the eastern Baltic (ICES areas 26, 27, 28 and 29) and the expected decreases in surface salinity are likely to increase hypoxia through reinforced vertical stratification of the water column these areas are also expected to experience lower salinity conditions with Climate Change than the ICES box 25. Similarly the spatial distribution of nutrient inputs indicates higher loads, particularly in the areas not covered by national legislation for nutrient levels (shown in pink).

This illustrates that the most while ICES boxes 27 and 28–2 are of great importance and that nutrient pressures from many individual nations could be the focus of response measures. Effective policies to manage cod stocks under the jurisdiction of the MSFD for the eastern Baltic should continue to focus on the ICES zone 25 and would require cooperation between Poland, Sweden and Denmark.

16.7 Discussion and Results

The MSFD represents a first step towards an Ecosystem Approach. The list of descriptors of GES in the directive was able to accommodate the intermediate and final ecosystem services relevant to cod fisheries in the Baltic and the directive seems to have the potential to integrate the developing Ecosystem Services framework. However in order to be workable and to attain an Ecosystem Approach the Common Fisheries Policy must also be integrated. There is great potential for conflict between the interests of fishing and the descriptors of GES as set out in the MSFD. In particular pursuing fisheries and maintaining a normal abundance and diversity of food web elements (descriptor 4) is problematic.

An Ecosystem Approach does not offer a panacea. Optimizing the benefits achieved from the ecosystem will involve trade-offs between competing objectives and there will be clear winners and losers.

For example, in the Baltic, top down pressures on fish stocks was removed in the twentieth century (Elmgren 1989) with the reduction in numbers of marine mammals and resulted in increased cod biomass. Increase in primary producers and release of the bottom up control of fish biomass have also occurred. A return to more normal/natural levels of abundance and diversity could thus increase mammalian predators (with their attendant non-consumptive use values) and reduce primary production resulting in a cod stock at levels lower than present. Achievement of GES might then represent a loss in benefits for commercial exploitation of fisheries. On the other hand, building up the cod stocks do give promise of future higher yield in the cod fishery without violating sustainability objectives.

The choice of targets for GES which will occur in 2012 will essentially require a vision for how our oceans are to be used. The MSFD makes provision for stakeholder engagement through public consultation at the point when environmental targets are set (Fig. 16.1). Inclusivity (or lack thereof) in this process will play a role in determining the national targets for GES, however the means of public engagement in the consultation process will be critical to determining the outcomes of these tradeoffs. Given the lack of appreciation by the general public of the importance of undersea landscapes in parts of Europe (Rose et al. 2008) and the loud national voice of those stakeholders involved in direct resource extraction, trade-offs are likely to be weighted in favour of the direct users of the marine environment. GES shall not be implemented at any costs. To safeguard unintended and unnecessary costs of implementation, as well as inefficient use of public funds; 'Member States shall ensure that measures are cost-effective and technically feasible, and shall carry out impact assessments, including cost-benefit analysis, prior to the introduction of any new measure' (EU 2008, chapter 13, article 13.3)

The targets must be set with specific ecosystem goals in mind. Given the uncertain future of the Baltic ecosystem in the face of Climate Change it is prudent to manage the resource to protect and enhance resistance and resilience to change. Ecological theory suggests that this might be best carried out through protection and conservation of biodiversity. For example if the long term abundance of cod is to be achieved the changing conditions brought about by Climate Change mean that the resistance and resilience of the species could be highly dependent on the genetic diversity in the surviving population. Since the changes in climate are not known and the levels of diversity required to meet the demands of climate are not known, sustaining the long term abundance of cod will require maximizing genetic diversity as insurance against complete collapse of the stocks.

Whatever the eventual targets are, the ability to achieve major environmental improvements within the tight timeframe of the directive is limited. Baltic eutrophication in all its complexity offers a particularly good example of an environmental problem that despite great efforts has not been possible so far to reverse even given the decadal timescale of the remediation efforts.

The directive requires implementation of all elements of the MSFD (Article 14, 4) except where 'costs would be disproportionate taking account of the risks to the marine environment'. This statement provides a necessary possibility of dispensation from the general rules, but also a loophole whereby member state may refrain from implementing part of the directive. The requirement of 'proof' in the form of a cost-benefit analysis further strengthens the legal framework.

Economic analysis of the benefits obtained from environmental remediation projects may reveal that costs of remediation outweigh future benefits at a level incompatible with public interest. Given the two main environmental problems in the Baltic, collapse of the cod stock and eutrophication, are directly related to active use benefits which result in market values (fishing supported by the CFP and agriculture supported by the Common Agricultural Policy (CAP)) and that the benefits (including expected built up of cod stocks and higher future yearly yield) accruing from remediation will be mostly non-marketed (such as visual benefits and existence values) it is likely that many of the remediation actions to be taken under the MSFD will have negative Net Present Value. Even though standardized methods to measure non marketed active use values and passive use values are available, it will also be costly to establish these parameters, as very few valuation studies of these benefits have been carried out.

The crucial factor of these long term investments is the numerical scale of the discount rate (Stern 2006, Hoel and Sterner 2007). Discount rates are weights given to future costs and benefits in order to overcome time differences and measure Net Present Value of for example environmental investment projects. The higher the discount rate, the lower the value placed on benefits accruing in the future. The rationale for a societal discount rate has two sources, the societal time preference rooted in the pure time preference (impatience and the assumption of richer future societies) as well as the productivity of capital (positive yield of invested capital/opportunity cost) (Pearce and Turner 1990). The longer the time horizon of the investment, the more important the discount rate (ρ) becomes in determining the Net Present Value (NPV) of the investment. Hoel and Sterner (2007) point out that use of environmental goods may lead to scarcity over time and influence the relative prices of the environmental goods. This may mean that the discount rates used should have lower values.

$$NPV = \sum_{t=0}^{n} (B - C)(1 + \rho)^{-t}$$

Where NPV is Net Present Value, B is yearly gross benefits, C is yearly gross costs, ρ is the discount rate and t is the time.

Thus given the relatively long expected timeframe for recovery of the marine environment, the choice of discount rate and the length of the time horizon selected for analysis are crucial to the outcome of the cost benefit analysis.

Less focus has been allotted to the time profile of the investment projects. Most investment projects exhibit a time profile of an initial investment (cost) and future benefits. The most common time profile of any investment is large costs at the beginning followed by a stream of net benefits over a longer period of time. A positive scrap value of the initial investment might conclude the project. However investment projects may exhibit different time profiles. Nuclear power plants for example show a huge initial investment, followed by a stream of net benefits over a long span of years of power generation and huge costs of dismantling the plant and storing or reprocessing excess nuclear material.

The largest social investments in Europe over the past 60 years have been the establishment of welfare societies, where self-sufficiency in food production was particularly high on the agenda. The public investments in farming, farming technology and fishery technology driven by the Common Agricultural Policy (CAP) and Common Fisheries Policy (CFP) have essentially eradicated hunger, malnutrition, infant mortality etc. but the time profile of these investments has not yet been fully catered for. The initial costs have been covered and the stream of benefits enjoyed, but the backlog of final costs of these investments are not yet paid. The costs of this historically very rapid social development project are pollution and eutrophication of both freshwater and the marine environment and the fisheries management through the CAP has not been able to counteract the overfishing developed through the former 'open access fisheries regime', whilst aiding the technological and market development.

Thus the implementation of the MFSD cannot be viewed simply as a social environmental investment project subject to only future time preferences of goods and services rendered from the marine environment but can more reasonably be viewed over the longer time scales associated with the CAP and CFP. These final costs of the original European project (broadly food security) seem to have been omitted as costs of the long term societal development project and included in the cost benefit analysis of the future goods and services of the marine environment. This point of departure analytically therefore hampers the implementation of Good Environmental Status for Europe's seas. The underlying conceptual model of the present MSFD is skewed and the consequences may be that many of the environmental investment projects planned for implementation as part of the Marine Framework Strategy Directive will show a negative Net Present Value at the outset. The question is not whether the investments are beneficial in the narrow sense, but whether society is willing to bear the costs associated with our past use of the marine environment.

16.7.1 Integrating the CFP into the MSFD

A recent Commission decisions on the descriptors (EU 2010) states that fishing mortality should be equal to or lower than the level capable of achieving Maximum Sustainable Yield (MSY). The decision makes a provision for catch levels lower than MSY in mixed fisheries in order not to prejudice the exploitation of MSY in other species and thereby acknowledges multispecies interactions.

It is more important however in the context of the Ecosystem Approach to balance both active and passive use values as specified in Table 16.2. Consistent assessment and valuation methodologies may aid the policy process, but the ethical and allocative decisions rest with the political system.

For an integrated management approach to commercial fisheries the choice of MSY as a target for fisheries policy is unlikely to be consistent with an Ecosystem Approach. It does not integrate the connections between human activities and institutions with the ecosystem. Maximum Economic Yield (MEY) would represent a goal more closely aligned with integration of human activities and institutions with the ecosystem, as it aims to maximize the benefit (catches the resource rent) from the commercial fishery rather than optimize the volume of fish caught from the fishery.

The use of MEY would also provide a further safeguard to endangered stocks, as reaching MEY under present cost conditions would require less fishing effort than targeting the MSY as a management objective.

The present decisions on TAC (Total Allowable Catch) and the consequent quotas allocated to the individual EU countries builds on recommendations from ICES based on individual species stock assessment. The knowledge and vision for an improvement of the scientific recommendations has been present for the last generation. Multispecies and multifleet fisheries models have been shown (Flaaten 1991, Gislason 1999) to be superior to the present single species models used.

The inclusion of economic assessment for maximizing economic rent in the fishery would further improve the basis for sound advice and more robust political solutions.

The scientific effort has been limited in the sense that neither the multispecies assessment models nor the evaluation of economic impact (economic rent and allocative impacts) have reached a stage where they are generally applicable to be implemented in the Common Fisheries Policy. Worldwide there are many fisheries that have included economic rent in the policy decisions; Shrimp in Greenlandic waters (Vestergaard et al. 2010) and the mussel fishery in the Limfjord – an estuary in Denmark (Frost et al. 2009). Economic assessment of fisheries prior to the introduction of Individual Transferable Quota-systems (ITQs), where property rights are most often allocated to individual vessel owners with historical fishing rights can create the condition for capturing resource rent in the fisheries. The ITQ system has been introduced in many fisheries, e.g. Iceland, New Zealand and individual fisheries in many European countries.

There are many reasons for continuing the historical practices of ICES and the EU. One reason may be the inadequacy of the scientific community to communicate the benefits of developing the very complex model tools necessary for qualifying policy decisions in the future (science translation). Another factor may be institutional inertia. The ICES practice of recommendations to the EU follow the management system of single species 'Total Allowable Catch Quotas' allocated between the countries in a fixed proportion. This system of regulation (quotas on each individual species) has led to EU policy decisions with unintended problems of by-catch, discard, and high-grading. Development of new more efficient fishing technology, investment subsidies and open access conditions have led to dissipation of resource rent, overcapitalization and both economic and ecological overfishing in most fisheries within the EU waters.

An ecosystem management approach for the Common Fisheries Policy and an integration of the CFP with the Marine Strategy Framework Directive can hardly be reached without a radical political decision to do just that. The Green Paper does not in itself facilitate a more research based approach for the fisheries to comply with the descriptors 1 and 3. Both presuppose a multispecies model approach to fisheries, as Good Environmental Status implies a naturally sound distribution and abundance of species an which objective may not be reached without a radical change of both management and its underlying advisory capacities.

16.8 Conclusions

While the MSFD has the scope to manage the problems associated with eutrophication and cod fisheries in the Baltic, it does not have the capacity to deal specifically with climate mitigation in the Baltic.

The integration of economic and ecological aspects of management has the potential deliver GES for the Baltic, but achievement of this status will require societal choices. The trade-offs required to reach GES may not deliver economic benefits in the short-term but can be seen as a clean –up cost of historical European investment in food security involving.

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