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Climate Change in the Oder/Odra Estuary Region

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Abstract

Integrated Coastal Zone Management (ICZM) often is implemented on a regional level where Climate Change and its global impacts are usually well known aspects while its impacts for the specific region are not clearly defined. This article briefly describes regional impacts considering the Oder estuary region as an example. Depicted is that on a regional level Climate Change impacts can have several deviations from common anticipated impacts. While neighbouring regions might be affected from drought due to Climate Change the Oder estuary region for instance is able to compensate dryness with a high ground water level. Furthermore changes in precipitation distribution effect on nutrient loads of the River Oder which are reduced during summer. In lagoon and coastal waters however the expected effect of a rising water quality can be counteracted by internal eutrophication (sudden and intensive phosphorus release from sediment under anoxic conditions). In addition changes in the regulatory chain of river, lagoon and bay may have severe impacts on primary production and especially on the incidence of toxic blue-green algae (cyanobacteria). This development might get in conflict with one of the main economic sectors: tourism.

1 Background

Coastal areas are high sensitive against Climate Change impacts. They are sensitive ecosystems with important functions for vegetation and biodiversity, they are regions of dynamic interactions between land and oceans and they are habitats of rare and specialized species. At the same time they are under high pressure by human settlement not only because of tourism but because of their function as home for more than 50 % of the human world population (UN-Stats 2006). An often discussed impact of Climate Change for coastal zones is of course sea level rise as it might be serious not only for especially vulnerable areas like coastal wetlands, coral reefs or small islands. But impacts of Climate Change on coastal areas have a much broader variety. Combining the efforts of different scientific disciplines one gets already today a detailed view of the future of a region under the aspects of Climate Change. Of course, this view into the future still suffers from uncertainties as it is based on climate predictions on a regional scale. Although today's scientific knowledge plus modern computing allow numerous statements to climate impacts especially on a global level, climate predictions on a regional scale are still of limited reliability (New & Hulme 2000, Volz 2004). But with modern climate models and different scenarios it is possible to identify the climate sensitive aspects of a region and to show the variety of possible climate impacts.

2 Location

With its length of 854 km and a basin area of 120,000 km² the Oder (German: Oder, Polish: Odra) is one of the most important rivers in the Baltic region. Its estuary is located on the southern Baltic Sea at the border region of Germany and Poland and consists of the Szczecin (Oder-) Lagoon and the Pomeranian Bay. The Szczecin Lagoon (687 km²) can be subdivided into the "Large Lagoon" (Polish:

Wielki Zalew) on the Polish territory and the “Small Lagoon” (German: Kleines Haff) on the German side. The lagoon is connected with the Pomeranian Bay by three outlets. Between these outlets two islands, “Usedom” and “Wolin”, are located (figure 1). With an average depth of 3.8 m the Szczecin Lagoon is shallow. Its maximum natural depth is 8.5 m, but dredging in the shipping channel produces depths exceeding 10.5 m. The channel intersects the lagoon to link the River Oder mouth and the harbour of Szczecin with the Baltic Sea. The entire estuary is dominated by the discharge of the Oder River into the lagoon.

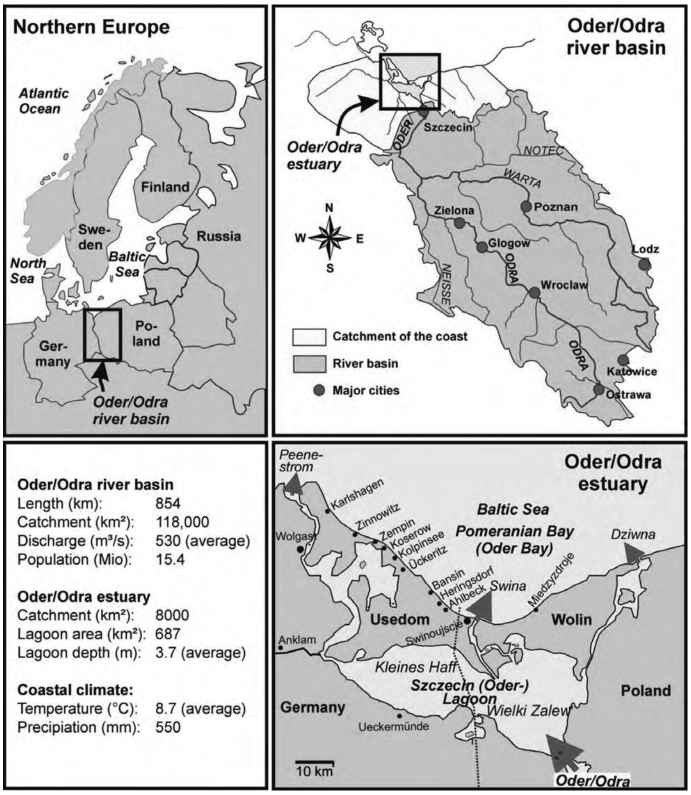

Figure 1: The Oder/Odra estuary region with river basin (Schernewski et al. 2005)

As a border region between Germany and Poland the Oder estuary region has little economic development with few industry and declining traditional branches like fisheries or agriculture. While tourism is the most important economic sector with a high density at the coastal zone it has low effects in the hinterland. As a result social and economic declines between west and east as well as between the coastal area and the hinterland form the area.

At the same time the region is a rich and diverse natural heritage. Due to the geological formation with river, lagoon and bay the Oder estuary region is a habitat where marine and limnic systems overlap. Fens and highmoors, moorlands, land dunes, marsh areas, shallow waters, large woodlands and other sceneries form a landscape with rare species where protection of habitat and species is of prime importance. The Oder estuary region for instance together with neighbouring bay areas (“Bodden”) is the most important area for waterfowl to overwinter in the Baltic Sea Region (Loeser et al. 2005).

Choosing river basin and coastal area issues as a viewpoint the aspects of flooding, eutrophication and species mitigation come into focus. The sinking coast and Climate Change caused a relative sea level rise of about 1 mm/a during the last century (Glaeser et al., 2005). At the same time the likelihood of floods and extreme events grows. Intensive agriculture, industries and cities along the River Oder cause high loads of heavy metals and organic pollutants and especially high loads of the nutrients nitrogen (average N values 1980–2000 in the Szczecin Lagoon: from 110 to 230 µmol/l, max. 500

µmol/l) and phosphorus (average PO4-P values 1980–2000 in the Szczecin Lagoon: from 2 to 6 µmol/l, max. 25 µmol/l) (Bangel et al. 2004). Within the coastal area these loads are a main reason for algae bloom and have effects on the water quality which causes a serious problem for a region whose main economic sector is tourism. And because linked river-coast systems provide a convenient path for the spreading and migration of species and alien species the original fauna in the River Oder system is already partly replaced. These aspects are of special interest when researching Climate Change in the Oder estuary region.

3 Climate Change in the Oder/Odra estuary region

Basis for impact assessments made within the Oder/Odra estuary region are regional climate projections done by Climate & Environment Consulting (CEC) Potsdam with the model WettReg. All projections are based on the scenarios A1B and A2 from the Intergovernmental Panel on Climate Change (IPCC TAR 2001a; 2001b; IPCC SRES 2000). These projections show changes in temperature from 2.2 to 2.3 °C (period 2071-2100 compared with period 1961-1990) in annual mean values (figure 2). Values for the catchments area (western part) are similar to predicted values for the estuary region (2.1 to 2.2 °C).

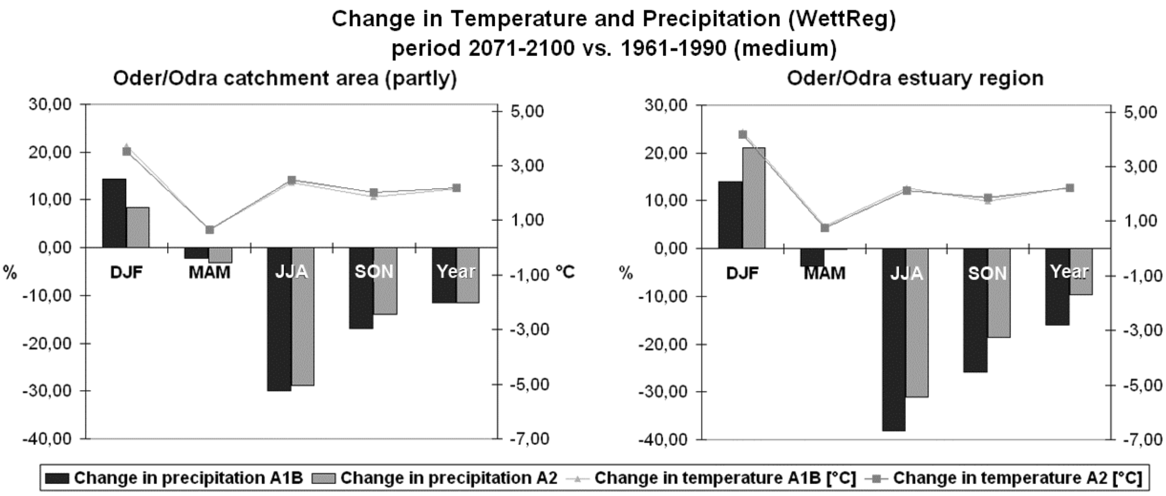

Figure 2: Changes in Temperature and Precipitation for the Oder/Odra catchment area (western part) and the estuary region, projection by WettReg, CEC Potsdam.

In contrast the development of catchment area and estuary region differs in changes of precipitation. The southern located catchment area is expected to get partly even less precipitation than the estuary (scenarios A1B as well as A2: -11.6 %). Values for the estuary region itself differ from -9.6 % (scenario A2) up to -15.9 % (scenario A1B).

A more detailed view on possible future is given by seasonal values for changes in precipitation. Both, catchment and estuary region, have according to the WettReg model a positive development in winter. Values reach from +8.4 % (A2) to +14.3 (A1B) for the catchment and from +14.1 % (A1B) up to +21.0 % for the estuary region (meteorological season winter: December, January, February (DJF)). For all other seasons negative changes are shown. For the catchment area spring comes with -2.3 % (A1B) or -3.1 % (A2) (March, April, May (MAM)), summer (June, July, August (JJA)) with -30.0 % (A1B) or -28.9 % (A2) and autumn (September, October, November (SON)) with -16.8 % (A1B) or -13.9 % (A2). Obvious is that seasonal values can reach much higher values than annual mean values. Similar is the developing in the estuary region. Here spring (MAM) is projected with -3,8 % (A1B) and -0.1 % (A2) while for summer (JJA) values like -38.2 % (A1B) and -31.1 % (A2) are given. Autumn (SON) is expected to develop with -25.9 % (A1B) and -18.6 % (A2). It can be recognized that negative shift in precipitation occur not all over the year but especially during summer and autumn with peaks higher than -30 %.

Looking for impacts of these projected changes different economical and ecological sectors come into mind. For the Oder estuary region agriculture, construction, fishery, forestry and tourism are important economic sectors while sea level rise and possible changes in vegetation, biodiversity, landscape or water quality are integral parts for the development of the environment. Together both aspects, ecological and economical development, will set the future of the region. A listing with Climate Change impacts on the above mentioned economic and ecologic sectors has been developed for the region before (Janßen & Schernewski 2007). It was shown that impacts of Climate Change in the Oder/Odra estuary region vary. While in principle all sectors are threatened by Climate Change they have different degrees of vulnerability. The seasonal shifts in precipitation stresses for example agriculture using today's crop mix. But high ground water level within the region as well as the possibility to adapt the crop variety limits the vulnerability of agriculture against Climate Change. Another example is fishery which is also affected by Climate Change. But fishery is a declining branch in the region and effects of e.g. overfishing seem to have more consequences than impacts of Climate Change. Invasive species might enter the region but again already today's strong anthropogenic influence has impacts on biodiversity which seem to be much stronger than the expected influence of Climate Change. Furthermore the Baltic Sea is a brackish water sea. And a lot of marine (invasive) species are simple unable to survive in brackish water because of the low salinity especially in parts east of the Darss barrier ("Darßer Schwelle") with values lower than 10 psu. All in all it has been shown that in a lot of fields Climate Change has no central impacts on the region but changes conditions. But in spite of these examples Climate Change is still meaningful for the Oder/Odra estuary region for some main sectors. Tourism, for example, was mentioned above as a central economic sector. On the first view tourism might benefit from Climate Change. Warmer, dryer and longer tourism seasons are attractive for the people. More tourists and a rising occupancy of hotels and guesthouses should be expected. This scenario seems to be plausible as long as the southern Baltic beaches are as attractive as today. Will they? Or is there maybe something in Climate Change which might get in conflict with a proper development of tourism?

To find an answer on this question lets have a look on what might happen with water because of Climate Change. Water is a central element in Climate Change. The water cycle is part of the climate system and is connected directly to other climate variables like temperature, radiation or wind. Possible impacts like dryness or flooding have already been mentioned. They are results of shifted precipitation from summer to winter and increased evaporation and evapotranspiration because of rising temperatures. The shifting of precipitation can be surveyed already today and it is expected to continue in future (Zebisch et al. 2005). Restrictions for agriculture, forestry or shipping on the River Oder could follow as consequences. The provision of drinking water is expected to be secure (BMU 2001) but adaptations could become necessary for water-suppliers. Another impact of Climate Change on water can be eutrophication. As Eisenreich (2005) showed changes in run-off (lower water level in shallow and warm waters) connected with higher temperatures and swirled up sediments can be responsible for an increased growth of phytoplankton and zooplankton which raises the danger of eutrophication. In the Oder estuary region this effect is limited to small lakes in the southwest of the region and has no influence on the River Oder or the lagoon. But weather also has an impact on nitrogen and phosphorus loads in the Oder estuary. In wet years the phosphorus and nitrogen loads can be up to twice as high as in dry years (Schernewski et al. 2001).

Furthermore warm estuary waters in combination with calm winds (wind speed below 2m/s) can cause a sudden dissolving of sediment stored phosphorus loads into the water body. Under these conditions stable stratifications are developed which cause oxygen depletion near the sediment. In a process called "internal eutrophication" large amounts of phosphorus may be released from the sediment under anoxic conditions, especially if phosphorus is bound to iron like in the case of the

Oder lagoon. PO4 concentrations can be up to 4 times higher than usual (5–6 mmol/m³). Because of the shallow lagoon waters this effect is limited to single days. Average daily wind speeds above 2–3 m/s are sufficient to cause mixing down to bottom and to stop this process. With some delay these additional loads intrude into coastal waters where they cause algae bloom. Especially blue-green algae are problematic for bathing tourism. Exactly those weather conditions (warm and calm days) appear to be enhanced. So the likelihood of short-term but intensive phosphorus loads in lagoon waters increases. The aim of the European Water Framework Directive to achieve good quality of ground and surface waters does not seem to be realistic for the Szczecin Lagoon. The phosphorus release from sediment under anoxic conditions can contribute up to 400 t phosphorus in short periods which is equivalent to loads of the River Oder during three month. Such amounts counteract all remediation measures.

Being more than a pollution source for the Baltic Sea the Szczecin Lagoon serves as a transformator and sink for nutrients and pollutants. Reasons are sedimentation and dredging (10–20 % of N and P load) as well as loss to the atmosphere due to denitrification (15 % of the N load). Nutrient water stays in the lagoon for a period of 35–75 days (Schernewski et al. 2001) because of the cordoning off to the Baltic Sea by the islands Usedom and Wolin which increases sedimentation whereas water in the Pomeranian Bay is exchanged after 8–10 days. As the annual precipitation is expected to be nearly changeless in the region as well as in the river basin the total river run-off will stay constant and nutrient loads by the river should be more or less constant, too. This is why impacts on the water quality in general are not anticipated. But the lessened precipitation during summer causes reduced nutrient loads in this time. Effects for the lagoon are limited as it is highly eutrophied (polytrophic) and mostly light limited. Because of a constant nutrient supply by the River Oder nutrients usually have no limiting effect on the phytoplankton growth in the lagoon. The primary production in the Pomeranian Bay however is controlled by phosphorus and nitrogen availability. This is why reduced nutrient loads during summer limit algae blooms in coastal waters (positive effect for bathing tourism).

But an opposite trend is a shift within phytoplankton: the diversity of phytoplankton is reduced while diatoms and cyanobacteria become dominating. Because cyanobacteria are able to absorb nitrogen from atmosphere they might be able to compensate the reduced nitrogen loads from river waters (further investigations are required for clear statements). Today the primary production in coastal waters is often limited by phosphorus. Changes like internal eutrophication and reduced nutrient loads as shifts in river run-off have impacts on the regulatory chain of river - lagoon - bay. Phosphorus intrusion due to internal eutrophication and reduced nutrient loads might switch the limitation of phytoplankton from phosphorus to nitrogen. This increases the principle risk of blue-green algae, especially cyanobacteria would benefit from phosphorus limitation due to its ability to absorb nitrogen from atmosphere. Cyanobacteria in the Baltic can be toxic (Nodularia spumigena, Aphanizomenon flos-aquae, Anabaena sp.) but not necessarily. During the summers of 2001, 2003 and 2006 parts of the German Baltic Sea beaches had to be blocked because of cyanobacteria. Such occurrence might happen more often in future, at Baltic Sea beaches as well as at lagoon areas not only as a consequence of changes in nutrient loads but also because of rising water temperatures. Cyanobacteria form strong blooms only in waters with temperatures above 16 °C.

Talking about water see level rise is of course another important aspect to have an eye on. The vulnerability in fact is high due to rising waters. Depending on the scenario projections for sea level rise are between 21 and 30 cm for 2100 (compared to period 1961 to 1990). As the islands of Usedom and Wolin have a sea coast as well as an estuary coast they have a double increased risk of flooding by rising sea level on one side and rising floods by the River Oder in spring due to higher precipitation during wintertime in the river basin area, an effect called “Coastal Squeeze”. On the other hand in this region rising waters are a phenomenon one could come up against by technical measures like coastal defence if sea level rise would not get to high. In the Oder estuary region the effect of sea level rise is amplified by an isostatic sinking coast (relative sea level rise of about 1 mm/a). For coastal defence issues a new design flood and in consequence the adaptation of coastal defence constructions like dikes could become necessary. But due to the low tide of less than 20cm sea level rise impacts on the coastline will be controllable as long as adaptation strategies are implemented in time. Of course, this could also mean the controlled loss of single lowland areas or to abandon land use for new or empowered coastal defence constructions. As costs for adaptation of coastal defence or sand wash up run into the millions the degree of coastal defence adaptation will depend on public opinion and political decisions.

Taking a look on possible floods because of heavy precipitation by the River Oder (e. g. as an impact of a Vb-weather regime) the masses of water are not the only problem to deal with. River floods also are accompanied by increased loads of nutrient and harmful substances. Events like the River Oder flood of 1997 show that e.g. nitrogen loads locally can be 3-4 times higher than normal. Harmful substances like heavy metals (e. g. Pb, Cu, Ni, Zn) reached doubled values. Sources can be flooded areas and facilities as well as remobilised contaminated sediments. These loads also reach the lagoon waters and the Pomeranian Bay. The flood in 1997 brought higher concentrations of nitrogen, phosphorus, silicate, copper and some pesticides into the lagoon. And an amount of 5 km² freshwater intruded into the lagoon and the Pomeranian Bay. Impacts were an increased primary production, a shift to freshwater species (Coscinodiscus) and an extreme lack of oxygen within the bay caused by calm meteorological conditions as well as by oxygen depletion resulting by high nutrient loads. The microbial and hygienic functions in the lagoon were not affected by the flood. In general flood loads seem to have no long lasting impacts on the environment because of their short-term effect. But a higher frequency of floods could cause negative impacts on recovery times and the eutrophication of the Baltic Sea. And, of course, flood events have impacts on public perception and tourism (bathing) which could affect the economic situation of the Oder/Odra estuary region.

4 Summary

Impacts of Climate Change have a broad variety. This variety, from direct influences like rising temperatures to downstream impacts like eutrophication, can be shown for a specific region as done for the Oder estuary region. Depicted was that sectors differ within their vulnerability against Climate Change. Main impact of Climate Change is the expected increase of temperature and its influence on water. Higher temperature raises the evaporation and evapotranspiration which has an influence on the water balance. Indirect impacts like increased water need of vegetation because of extended vegetation periods will have further influences on water balance. On the other hand changes in sea level and precipitation are also influenced by rising temperatures. These impacts on water usually cause a chain of effects on vegetation, biodiversity and follow-up economic sectors like agriculture or forestry. In the Oder estuary region these impacts mostly can be compensated because of high ground water level due to the river and the Baltic Sea. Impacts on cultivation and agricultural land management are limited if irrigation is affordable. Furthermore agriculture could profit from increased photosynthesis. Most trees have access to ground water and only afforestation at dry location could be affected by drought.

Taking a mid-term or long-term view species mitigation will happen in the region as well as in the country and the whole continent. And Climate Change will have impacts on landscape and economy. But both, impacts on biodiversity and landscape, are limited in the Oder estuary region. The mitigation of alien species already today is a continuous process and could increase further while the loss of biodiversity should be limited as the water supply is secured due to high ground water. The shift of climate conditions will not lead to another climate classification (still Cfb, classification by Koeppen) and impacts on landscape are more depended on economic processes than on Climate Change. However, the most important impacts of Climate Change on a tourism area like the Oder estuary region are impacts on tourism facilities and water quality. Tourism in general is expected to benefit from Climate Change. Extended tourism seasons with warmer summers and waters will be attractive to tourists. The utilisation of tourist infrastructure might be stabilized or even raised and further private investments in tourist infrastructure and facilities can be anticipated. The disadvantage of Climate Change for tourism occurs in the form of shifts in water quality. While reduced nutrient loads of the River Oder during summer (decreased precipitation) should increase the water quality in the Szczecin Lagoon and the Pomeranian Bay the effect of internal eutrophication (sudden and intensive phosphorus release from sediment under anoxic conditions) counteracts the reduce of nutrient loads by the river. This occurrence might happen more often as the necessary condition of warm and wind calm days probably is to appear more regularly. With a certain delay those additional loads intrude in coastal waters and might switch the limitation of primary production from phosphorus to nitrogen. This would affect the incidence of phytoplankton, especially diatoms and cyanobacteria. Cyanobacteria itself is able to absorb nitrogen from atmosphere and increases eutrophication processes in the Baltic Sea. On the other hand cyanobacteria can be toxic which means a concern to bathing and tourism. During the summers of 2001, 2003 and 2006 some Baltic Sea beaches in Germany had to be blocked because of cyanobacteria and changes in the regulatory chain of river-lagoon-bay might increase occurrences like this.

Of course, such an attempt to look into the future always is full of uncertainties and so is a listing of Climate Change impacts. One reason for this is the necessary choice of a Climate Change scenario. In these scenarios the development of climate is estimated on the basis of assumptions about future developments of world economy, technical advances and changes in society. Such assumptions can come true or not as any prediction is just based on actual knowledge. Especially for long term scenarios over 50 or 100 years used to describe Climate Change unexpected developments remain an important factor which can not be assessed presently. A second reason for uncertainties in Climate Change impact assessment is climate modelling. While different climate models show similar results on global level their results often differ on regional scale. Latest models give detailed results with high resolutions but changes in climate modelling and results have still to be expected. A third reason especially for uncertainties in attempts to predict Climate Change impacts on economic sectors is the fact that economic development depends not only on Climate Change but also on other influences on the markets. While, for instance, during the last years the common estimation for agriculture in Europe was based on decreasing development and a concentration on fertile grounds which can be cultivated easily were expected. But since renewable energies play an important role this estimation changed and land shortage is expected because of the amounts of colza, maize and other plants needed to produce methylester or to supply biogas plants. Changes like these have influences on viewable Climate Change impacts. While increasing dryness raises restraints for agriculture the conditions at markets are decisive for adaptations like in this case changes in landmanagement.

Changes in influences on markets can happen in any economic sector. That is why the possibility to numeralise Climate Change impacts on economy is limited. The impacts of Climate Change as they can be anticipated so far differ from region to region. While for instance the viewed Oder estuary region is not affected intensively by common impacts like drought neighbouring regions in the hinterland like for instance the "Schorfheide" are expected to have serious drought impacts and transformation into veld is anticipated. On the other way regions downstream the River Oder might benefit from reduced nutrient loads while processes like internal eutrophication during summer months are possible impacts for estuary regions like the Oder estuary. It should be noted that a planned adaptation is the result of a policy decision, based on the awareness about Climate Change, its possible impacts and required actions. That is why awareness rising plays an important role in adaptation strategies. In opposite autonomous adaptations are triggered by ecological changes in natural systems or economical changes at markets. They need no conscious response and will happen anyway.

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