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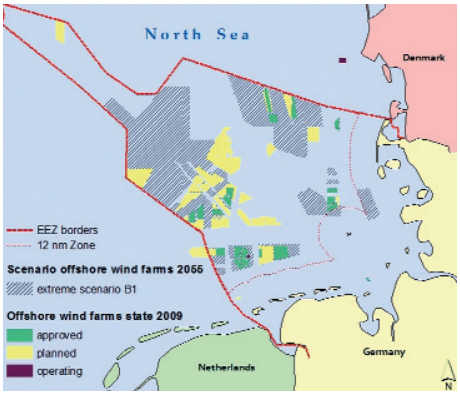

Analyzing Coastal and Marine Changes
– Offshore Wind Farming as a Case Study –

Zukunft Küste – Coastal Futures
Synthesis Report

Marcus Lange, Benjamin Burkhard, Stefan Garthe, Kira Gee,
Andreas Kannen, Hermann Lenhart & Wilhelm Windhorst

Zukunft Küste – Coastal Futures

GKSS FORSCHUNGSZENTRUM in der HELMHOLTZ-GEMEINSCHAFT

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Analyzing Coastal and Marine Changes

- Offshore Wind Farming as a Case Study -

Zukunft Küste - Coastal Futures

Synthesis Report

Edited by

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Cover: The cover shows a selection of photos from the west coast of Schleswig-Holstein and the marine offshore waters. Offshore wind mills, © Farm GE Power (top left), Guillemot, S. Garthe (left column center left), North Sea harbor, C. Sobiech (left column center right), People on a dike, K. Gee (bottom left), beach St. Peter-Ording, M. Lange (top right), offshore wind mill construction site Cuxhaven, M. Lange (right column center), map of German EEZ, © B. Burkhard (bottom right).

The LOICZ Research and Studies Series is published and distributed free of charge to scientists involved in global change research in coastal areas.

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Executive Summary

Many coastal areas are known for their resources and economic wealth, and many are famed for their scenic beauty. Use functions of the coast include among others fishing, shipping, port development, recreation, conservation, coastal defense or military defense. On the other hand coastal and marine areas experience physical and ecological as well as social and economic change caused by pressure from climate change and globalization processes. This change may include changes in species composition, hydrodynamic and morphological patterns, but also new patterns of land and sea use, all together translating into challenges for planning and management.

In the German North Sea the main challenge is the emergence of offshore wind farming because it demands a considerable proportion of the available sea space and because the sheer scale of the proposed developments has led to a series of environmental, social and economic questions. Against this background the research project *Zukunft Küste - Coastal Futures* had been designed to extend the knowledge base for Integrated Coastal Zone Management (ICZM) by using offshore wind farming in the German North Sea as a case study for sea use change. The project, which encompassed several German research groups, was funded by the Federal Ministry for Education and Research (BMBF) from April 2004 - April 2010.

In order to come to a holistic assessment of impacts from offshore wind farms on the coastal system, a range of existing approaches had to be adopted and new methodologies had to be devised. The resulting research design analytically integrates not only results of social and natural science investigations, but also links qualitative empirical research and quantitative modeling. *Zukunft Küste - Coastal Futures* research included a) to discuss future sea use patterns using a scenario approach, b) to analyze and model impacts of offshore wind energy on specific ecosystem services as well as socio-economic impacts at local and regional scale, and c) to analyze stakeholder positions and their underlying values and beliefs as well as related planning processes and policies. Design and interim development of the project considerably gained from and contributed to extended exchange within the global LOICZ science community.

Conceptually, *Zukunft Küste - Coastal Futures* applied a systems approach, particularly framing wind farming in the sea as a social ecological system with nested scales. Translating this way of thinking into a series of scenarios, which were structured along the DPSIR framework and represent different visions about the future of the North Sea, supported the identification of structures and processes at multiple scales. It also assisted in identifying antagonistic and synergistic cross scale interactions between existing sea and land uses, which can constrain the potential development of offshore wind farms.

Framed by the scenarios, the use of monitored data, model results and qualitative estimations contributed to the assessment of the impacts on the North Sea ecosystem services and related economic opportunities. A further step of integration was the merge of the DPSIR framework and the ecosystem services approach, which assisted in drawing connections between sea use, the provision of ecosystem services, the resulting level of ecological integrity and human well being. Even though the presented results are subject to many uncertainties and therefore have a mainly indicative character, they provide a spotlight on risks and opportunities associated with large scale offshore wind farm development.

In relation to planning and management of coastal and marine areas, a main result from Coastal Futures is the need to deal with use patterns in order to identify cumulative impacts and the compatibility of different sea uses within the same area. For example some bird species avoid both, wind farms and intensively used shipping areas. A spatial accumulation of both activities can therefore result in severe habitat loss. For planning and management this implies that cumulative impacts resulting out of the pattern of different sea uses are more relevant for ecosystem functioning than impacts resulting out of one particular wind farm project.

Given such direct and indirect impacts, maximizing spatial efficiency and minimizing conflicts of use is not a one-off, but a dynamic process that will need to adaptively respond to actual developments in sea use. Patterns of use can shift as a result of changing dynamics within individual sectors and in response to external forces. This can alter the balance of uses and the relative significance of certain uses over others. It follows that monitoring of external driving forces is particularly important in the coastal and marine context including processes of globalization (e.g. affecting port development and shipping), technological developments (e.g. use of hydrogen, energy technology or 'blue' biotechnology), or policy developments (e.g. energy policy, security of energy supply, climate policy).

Societal values and attitudes are another essential driving force that influences decision-making processes, preferences and political processes. Attitudes to new technology and risk, for example, will impact on what is deemed acceptable in terms of sea use and what might remain controversial. This has been shown in the different attitudes to offshore wind held by different stakeholder groups, for example. Traditional approaches to planning are not particularly suited to deal with contradictory value sets and the potential value conflicts surrounding offshore wind farms. Similarly, contradictory policy targets are difficult to overcome. Therefore accompanying tools are required that go beyond the classic approaches of planning such as zoning. These might have to include a holistic vision and coherent strategies for marine area development as well as targeted non-statutory participatory mechanisms for strategic dialogues. As shown by local examples statutory and non-statutory processes should be seen as useful complements within a broader governance system and are not necessarily contradictive.

Altogether, sea use changes such as offshore wind farming are examples of complex unstructured problems characterized by uncertain available knowledge and diverging stakeholder perceptions. Despite some shortcomings, the feasibility to use the DPSIR framework to link socio-economic drivers, pressures and responses along an integrated ecological impact assessment, which is based on the ecosystem service approach has been demonstrated in Coastal Futures. Applied more widely, such approaches have the potential to strengthen the information base for decision making in the context of ICZM and Maritime Spatial Planning (MSP) considerably.

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The project *Zukunft Küste - Coastal Futures* would not have been possible or successful without the openness, good will and cooperation of a wide range of collaborators.

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For the districts of Nordfriesland and Dithmarschen the heads of the district administrations, Dr. Olaf Bastian (until 2007 in Nordfriesland) and Dr. Jörn Klimant (in Dithmarschen) provided regional insights and assistance particularly in the initial stages of the project. Also many persons in the administration of the Federal State of Schleswig-Holstein supported the project with relevant information and comments. The international perspective of the Wadden Sea has been provided by regular exchange with Folkert de Jong and Manfred Vollmer from the trilateral Wadden Sea secretariat and with members of the trilateral Wadden Sea Forum.

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Overall much of the research work would not have been possible without the contributions of local people and decision makers at all levels of government, from NGOs and other organisations of civil society who were willing to answer questionnaires or to participate in interviews, specific workshops and public events of the project. Particular acknowledgement is given to the participants in the five future workshops on wind-hydrogen generation in the years 2007 to 2010 in Hamburg.

In addition the editors would like to express their gratitude to all the scientists and students who contributed to the project *Zukunft Küste - Coastal Futures*. Some of them contributed to the project in the background and not all of these are in the list of direct project participants at the end of this report.

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Prolog

Coastal waters and adjacent land all over the world are identified to be among the most important sources of ecosystem goods and services. They are a reflection of past and current socio economic and cultural development and mirror global change phenomena as well as the multiple dimensions associated with new forms of land and sea use such as renewable energy. Today coastal zones need to be defined with rather flexible boundaries to account for the complex geomorphic interplay between natural and human forcing, and to address the multiple feedbacks between man and the environment. Particularly the relevant spatial extension of coastal resource use, e.g., offshore wind farms, is subject to considerable debate and review in light of national and multinational efforts towards marine spatial planning. Recent disasters as the oil drilling accident in spring 2010 which hit the Golf of Mexico underlines that the devastating consequences of human activities in the coast are not limited to the place they occur but influence a wide range of ecosystems and challenge human society to respond on various technical and political levels. The moratorium on offshore drilling promoted by the US administration as an immediate response reflects the almost global consequences of such a disaster and shades new light on the various spatial and temporal scales of costal social ecological systems and their interaction.

Coastal management as a means to enable sustainable development of coastal zones needs to take this multiple scale perspective in order to serve as a participatory platform for informed decision making. It needs to look into both the sea-ward ecosystem–based issues as well as the preconditions and consequences on land and in communities that extensive coastal land and sea use will bring. The goal is to identify the stakeholders involved and to engage with these multiple actors involved in order to generate a collective thinking and ownership of the issues, the information needs and actions taken. Coastal management today therefore needs to build on scientifically sound assessment of the risks and opportunities coastal use brings in consideration also of the changes anticipated to derive from climate change and it has to generate a climate of trust in which the findings and consequences have to be communicated.

Coastal Futures which was originally motivated to establish research that feeds into advanced coastal zone management has indeed underlined that fertile grounds of good governance have to be in place for it to evolve. These grounds are represented by legal frameworks and the social willingness to get involved and assist in the information development as well as markets that are prepared to thoroughly explore the pluses and minuses of new developments in light of human welfare.

Coastal Futures was a collaborative effort. In fact the collaboration between the various institutes encompassing a wide array of multidisciplinary expertise across traditional disciplinary boundaries and the link to the global LOICZ project underlines the need for a new joined thinking. This refers to scales, processes and tools that are needed to adequately address the risks and opportunities of new forms of coastal land and sea uses e.g. offshore wind farms in light of global change challenges which simply cannot be handled as well by one actor alone as it can be done collectively in strategic partnerships. These partnerships as demonstrated in *Coastal Futures* need to bridge between different world views of 'anyone's coastal zone' and enable a collective understanding of the pros and cons of a change in the management of a cost. How exciting and challenging this task is may be taken from the fact that during the project the issue of offshore wind farming has even mobilized people's reflections of their 'coastal perception' irrespective of the phenomenon as such being planned and built so far offshore that it is invisible from coastal lands. These were psychology kicks in, in the value laden discourse on sustainably managed coastal systems.

Coastal Futures has demonstrated the complexity of the scientific approaches needed to meet this challenge and in so doing it has explored the rough waters of a meaningful link between social and naturals sciences with encouraging results. Findings are already reflecting in the national strategy toward coastal management thus feeding into the implementation of the new EU wide Marine Policy as expressed in the Marine Strategy Framework Directive and its commitments on national scale. *Coastal Futures* has also demonstrated that even in controversial discussions and issues a collective interest in shaping a new future and exploring new technological challenges can be equally attractive and forward looking to the coastal communities, as well as the private sector and the science. It is expected that the findings made regarding the industrial development of offshore wind farms and the complementary opportunities this may bring can be useful in informing comparable developments elsewhere. Thus *Coastal Futures*, while local to regional in focus, has potential to be relevant for coastal development and coastal people at multiple locations.

For LOICZ as a global change project *Coastal Futures* is an example of innovative research designed to enable multidisciplinary assessment of risks and opportunities arising from coastal management. It therefore addresses both the risk as well as the vulnerability of coastal systems including communities and the future options coastal use may bring as a response to global change. LOICZ will therefore assist in promoting the findings on regional sea and global scale.

A few words on LOICZ in general: Land Ocean Interactions in the Coastal Zone, is a Core Project of the International Geosphere-Biosphere Programme, IGBP, and the International Human Dimensions Programme on Global Environmental Change, IHDP. With a growing network of scientists working on global scale it has been analyzing coastal change and underlying processes and feedbacks since the early 1990s. During the recent past LOICZ evolved, however, from its originally biogeochemical focus global into a truly interdisciplinary Earth System Science experiment, which looks into the multiple features of coastal change in a holistic manner. The key objective is to inform sustainable development and use of coastal zones by applying a socio ecological systems perspective along the whole water cascade. It aims to provide the knowledge, understanding and prediction needed to allow coastal communities to assess, anticipate and respond to the interaction of global and local pressures which precipitate coastal change. For LOICZ, *Coastal Futures* is one of currently around 50 national and international affiliated research activities which all contribute different facets to the assessment and synthesis of global coastal change, regional and local drivers and governance response LOICZ is committed to provide to its parent programs.

In conclusion it is hoped that this report will be able to communicate the key findings and issues in current and future coastal wind farming and thus alternative energy discussions and research to multiple audiences. It may thus assist to open new avenues for advanced interdisciplinary research to be implemented by the leading environmental and social sciences research institutions world wide. Underlying is the appreciation of the multiple scales of coastal social ecological systems as defined by new forms of land and sea use.

Dr. Hartwig Kremer

CEO LOICZ, International Project Office

List of abbrevations

BBR	German Federal Office for Building and Regional Planning
BfN	German Federal Agency for Nature Conservation
BMBF	German Federal Ministry of Research and Education
BMWi	German Federal Ministry of Economics and Technology
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMVBS	German Federal Ministry of Transport, Building and Urban Development
BSH	German Federal Maritime and Hydrographic Agency
BTS	Bottom Trawl Survey
CPUE	Catch Per Unit Effort
DHI	Danish Hydraulic Institute
DPSIR	Driver-Pressure-State-Impact-Response
ECOHAM	Ecological Model Hamburg
EBM	Ecosystem-based Management
EEA	European Environment Agency
EEG	Renewable Energy Sources Act
EEZ	Exclusive Economic Zone
ES	Ecosystem Services
EU	European Union
EE	Ecotrophic Efficiency
FINO	Research Platforms in the North and Baltic Seas
GEnS	Good Environmental Status
GIS	Geographic Information System
GNP	Gross National Product
HAMSOM	Hamburg Shelf Ocean Model
ICES	International Council for the Exploration of the Sea
ICZM	Integrated Coastal Zone Management
IMP	Integrated Maritime Policy
MA	Millennium Ecosystem Assessment
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive

MSP	Maritime Spatial Planning
MW	Megawatt
NGO	Non-Governmental Organization
NSW	Nearshore Wind farm
OECD	Organisation for Economic Co-operation and Development
OWF	Offshore Wind Farm
RBM	River Basin Management
SAS	Seabird at Sea (monitoring program)
SPM	Suspended Particulate Matter
SRU	German Advisory Council on the Environment
UN	United Nations
WBCSD	World Business Council for Sustainable Development
WFD	Water Framework Directive
WWF	World Wide Fund for Nature

1 Introduction: Analyzing Coastal and Marine Change in *Zukunft Küste - Coastal Futures*

Andreas Kannen, Wilhelm Windhorst

Coastal and marine areas experience physical and ecological as well as social and economic change, caused by pressure from climate change and globalization related processes. This change may include changes in species composition, hydrodynamic and morphological patterns, but also new patterns of land and sea use, all together translating into challenges for planning and management.

As a response new forms of coastal (and marine) management approaches like Integrated Coastal Zone Management (ICZM), Ecosystem Based Management (EBM) and Adaptive Management evolved as alternatives or additions to traditional ad hoc and sector-based planning and management. Within this context inter- and transdisciplinary research, which addresses the numerous ecological, perceptual, normative, cultural and economic interactions between society and coastal (eco)systems becomes more and more prominent.

In this report the German research project *Zukunft Küste - Coastal Futures* (in short: *Coastal Futures*) is described as an example of an interdisciplinary research approach. *Coastal Futures* was one out of two research projects funded by the Federal Ministry for Education and Research (BMBF) from 2004 - 2010 in order to accompany the process of developing a national ICZM strategy for Germany. The *Coastal Futures* approach analytically integrates not only results of social and natural science investigations, but also links qualitative empirical research and quantitative modeling.

Specifically in complex unstructured problems, for which the available knowledge is uncertain and stakeholders perceptions diverge, rational decision making based on traditional scientific support finds its limitations (Hommes et al. 2009). Integrated approaches such as chosen within *Coastal Futures* aim to improve understanding of interactions at system level. By design and nature they are better suited to trigger ideas and concepts into medium and long term policy processes than providing short term technical support. Therefore the role of a project like *Coastal Futures* is to stimulate debates about policy formulation at a strategic level and effects might be more long- than short-term.

1.1 Coasts as areas of change

Many coastal areas are known for their resources and economic wealth, and many are famed for their scenic beauty. Activities that make up use functions of the coast include among others fishing, shipping, port development, recreation, conservation, coastal safety measures or military defense (Glaeser et al. 2009).

Wilson et al. (2005) estimate that total coastal ecosystem goods and services may add up to more than 40 % of the whole global value although they are generated on only 8 % of the world's surface. This quantitative estimate does not take into account the many non-use values which would undoubtedly add another substantial share. In addition to economic production, ecological regulation, socio-cultural and aesthetic considerations - as seen in traditions, landscapes or seascapes - form also part of the overall coastal zone context. This context is not static, but has become increasingly dynamic over the last three decades.

Offshore wind farming and marine protected areas, or other upcoming issues that increase the mix of diverse resource and areas uses, form the symbols of a new development that signify profound changes in how these areas are looked at by parts of society.

This implies numerous challenges for coastal and marine policies, planning and management. A particular challenge for research is therefore the integration of research on ecological processes and functions with research on social, economic and institutional processes. The project *Coastal Futures* aimed for the development of approaches and tools towards an integrated assessment of changes in the use of coastal areas by analyzing the example of offshore wind farm development in the German North Sea and related challenges at the Schleswig-Holstein North Sea coast as a case study.

Technically and commercially, wind energy is one of the most advanced renewable energy technologies (Foxon et al. 2003). According to the Global Wind Energy Council (GWEC), "wind power is on track to supply 10-12 % of global electricity demand by 2020, reducing CO_2 emissions by 1.5 billion tons per year" (GWEC 2009: 4). According to latest figures from the Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH, www.bsh.de) 95 offshore wind farm projects are currently listed in the German North and Baltic Sea and 26 (of which 23 are located in the North Sea) have so far received planning permission, but only one has just become operational.

As these figures illustrate, offshore wind farms have become a major driver for coastal and marine change (Kannen & Burkhard 2009). The increasing interest of developers concerning offshore wind farming is caused by several advantages compared to the conditions onshore: Wind speeds are higher and more predictable, fewer conflicts with other types of land use are to be expected (e.g. nature protection or tourism), and public resistance against new wind farm developments seems less likely. However, a new 'player' like offshore wind energy (and its related institutions) also places new demands on the allocation of limited space. Local, regional and national debates focus on different or even conflicting perspectives (Byzio 2005, Kannen et al. 2008). As confirmed by research in *Coastal Futures* many debates among local residents move around local and regional benefits versus risks, including those for existing local activities and the ecosystem. Therefore, as subsequent chapters will demonstrate, some of the above named advantages should not automatically be taken for granted and need careful consideration in policy making and planning.

1.2 Defining the coastal zone

According to Sorensen (1997), the coastal zone includes offshore waters, the coastline, and the adjacent shores. Quantitative definitions put forward in the context of economic development or human population dynamics often limit their view of the coast to a 60 to 100 kilometer strip of land that begins where the sea ends. Other definitions (including the one that is used in the German ICZM strategy from 2006) include the seaward side, extending to 12 nautical miles or encompassing the exclusive economic zone (EEZ). *Coastal Futures* uses a functional definition, which looks at several spatial units and at different spatial and non-spatial scales depending on the specific impacts of offshore wind farms analyzed in the project (see chapter 3 and 4). This can include the individual pile of a windmill as well as the German EEZ, regional economic impacts at county level or national energy supply. Generally, different uses and functions thus determine how spatial context and spatial and non-spatial scales need to be defined. The definition of the coastal zone and the boundaries of a specific analysis will thus always vary according to the issues at hand.

However, as shown by *Coastal Futures* research, for many problems it can be expected that definitions will have to include interactions between multiple scales and management levels. Furthermore, while the ecological impacts of offshore wind farms are particularly located in the marine ecosystem, socioeconomic changes manifest themselves on land. Therefore research, policies and planning need to span the land-sea interface in order to capture the human-environment interactions.

1.3 ICZM as a new approach for governance and planning

Integrated Coastal Zone Management (ICZM) or Integrated Coastal Management (ICM) is commonly seen as a process-oriented participatory approach that aims at the sustainable development of coastal areas (e.g. Sorensen 1997, Cicin Sain & Knecht 1998). The two terms ICM and ICZM can be used interchangeably; throughout this report the term ICZM will be used because it is more commonly used in the European and German context in which *Coastal Futures* is embedded.

The European Commission defines ICZM as a mechanism to create a balance between the benefits of economic development and utilization of coastal regions by humankind, the benefits of protection, preservation and restoration of coastal zones, the benefits of minimization of losses of human life and property as well as the benefits of public access to and enjoyment of the coastal zones, at all times within the limits set by natural dynamics" (CEC 1999: 16). It has been developed as an alternative to traditional ad hoc and sector-based approaches which fail to address the complexity of the coast and specifically the interactions between natural, social, economic, cultural and institutional parts of the coastal system.

Therefore ICZM can be viewed as a relatively open, flexible concept for the adaptive planning and management of coastal areas whose concrete expression and realization needs to reflect regional needs and constellations of interest. This is where ICZM meets with interdisciplinary coastal and marine research (Glaeser et al. 2009). Interdisciplinary and integrative research projects, such as *Coastal Futures,* in this context form a tool to develop a holistic system perspective, which is a prerequisite for adaptive and integrative policy making, planning and management.

1.4 Structure of this Synthesis Report

A basic feature of ICZM is the view of the coast as complex social-ecological systems (Glaeser et al. 2009, Kannen & Burkhard 2009). As documented in subsequent chapters, different methods are used in *Coastal Futures* to discuss ecological, socio-economic and institutional risks and opportunities arising from offshore wind farm development.

Sea use changes with particular emphasis on offshore wind farming in the German North Sea are described in chapter 2 as a starting point. In *Coastal Futures* the DPSIR framework (Driver-Pressure-State-Impact-Response) was used to structure different data and information for the systems analysis. An overview of the chosen methodological approach and its main components is provided in chapter 3. The system analysis started with the construction of scenarios, describing driver-pressure relations (chapter 4). Here scenarios are archetypal descriptions of future alternative images created from mental maps or models that illustrate different perspectives on future developments by describing assumed but logical cause-and-effect chains.

Inventories were used to describe the current state of the system and to provide the background data or information needed for an analysis of the impact on system elements potentially originating from the construction and operation of offshore wind farms. Chapter 5 provides the results of a range of analyses looking at the impacts from offshore wind farms on the marine ecosystem. Stakeholder analysis (chapter 6) and an analysis of potential effects for local and regional economic development (chapter 7) look at social and economic impacts, linking also the sea(use) perspective with the human dimension onshore. Holistic perspectives which were integrated into the project frame particularly focus on the Ecosystem Service Approach (chapter 8), as well as capacity building (chapter 9) and governance (chapter 10).

Results from the impact assessments in chapters 5, 6 and 7 (looking at Pressure-State-Impact interactions) have been aggregated into the ecosystem services approach (see chapter 8), following the concept applied in the Millennium Ecosystem Assessment (MEA 2003). This aggregation allows an estimate of impacts on ecosystem services and human well-being in the German North Sea. The basic innovation in the ecosystem service approach is its holistic and comprehensive characterization of ecosystem functions along four intersecting categories (supporting, regulating, providing and cultural services), thereby putting single effects into the broader (eco)system context. Analysis of governance and policy aspects (chapter 10) referring in *Coastal Futures* to the Response category of the DPSIR framework focused on challenges for spatial management and policy development in the (German) North Sea region, particularly looking at Maritime Spatial Planning (MSP) and Integrated Coastal Zone Management (ICZM).

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2 Sea Use and Offshore Wind Farming

Kira Gee

Over the last few years two main trends have converged to increase pressure of use on Germany's seas. One is the intensification of many sea uses. Shipping for example has grown enormously both in terms of transport volume and shipping frequency. The port of Hamburg, for example, is forecast to nearly treble its cargo volume by 2025 compared to the 2004 figure, which corresponds to a growth rate of 5.3 %. The total volume of cargo handled is expected to rise from 793 million t (2004) to 1.658 million t (2025) (BMVBS 2007). At the same time, new forms of use have emerged that not only represent new competitors for marine resources but are changing the nature of sea use altogether. Offshore wind farming stands out amongst these because it demands a considerable proportion of the available sea space and because the sheer scale of the proposed developments has led to a series of environmental, social and economic questions.

Coastal Futures aims to understand the impacts of offshore wind farming as part of a wider systems perspective (see chapter 3). This chapter places offshore wind farming in the context of wider trends that shape patterns of sea use and considers some of the specific driving forces that guide its development in Germany.

2.1 Changing spatial patterns of sea use

Maps of sea use are provided by the Federal Maritime and Hydrographic Agency (BSH) in its CONTIS (Continental Shelf Information System) database (Figure 2.1). A comparison of various editions of the North Sea map of sea uses shows the dynamic nature of developments in the EEZ of the German North Sea. Differences are particularly apparent in the case of offshore wind farming, where larger 'project areas' were originally set aside than were later taken up by planning applications for actual wind farms (Figure 2.2 and 2.3). The 2002 map was drawn up during the very first stages of offshore wind farming when many open questions still existed with respect to the technological and financial feasibility of offshore wind farming; the licensing procedure had only just begun to take shape at that point. Later editions of the map thus not only reflect the respective status of the offshore wind farming debate, but also a maturing of the planning process. The latest edition of the map of uses shows an increase in the area set aside for offshore wind farming, in particular in the deeper waters of the EEZ (Figure 2.1). Apart from more precise mapping, the period 2002 - 2010 also shows a broadening of perspective, indicated for example by the gradual inclusion of the international North Sea space.

The maps show overlap between areas set aside for various uses (military, sand and gravel extraction, Natura 2000 sites and offshore wind farms); there is additional overlap with linear forms of use (primarily data cables, shipping routes (traffic separation lines), gas pipelines and high voltage cables). On top of these, transient uses such as fishing need to be taken into account, which can take place anywhere in the EEZ unless they are prohibited or restricted for reasons such as nature conservation. The latest map of sea uses demonstrates that the German North Sea is far from empty space: On the contrary, it is rare to find an area that is not given over to some form of use. It also demonstrates that many of these uses are dependent on particular locations, either because of specific marine resources (sand and gravel extraction, marine nature reserves) or investment in built structures as a secondary effect (including cable connections to the mainland in the case of offshore wind farms).

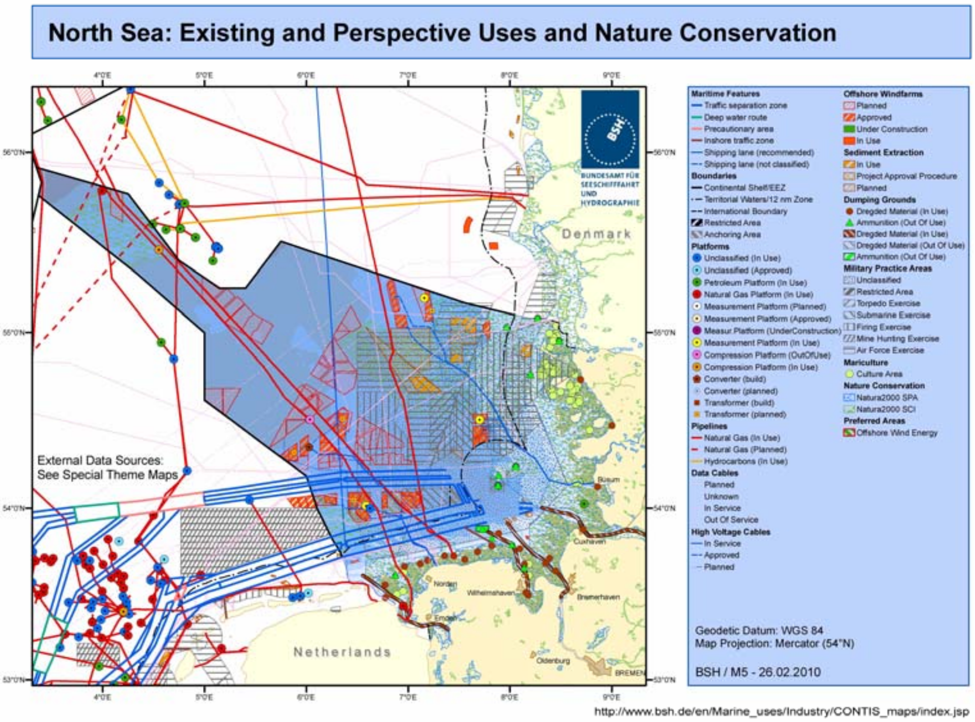

Fig. 2 .1: *Multiple sea uses emergi ng in the German Nor th Sea demonstrating the multitud e of i nterests in territorial waters and the EEZ (BSH CONTIS Information System, www.bsh.de, accessed March 2010).*

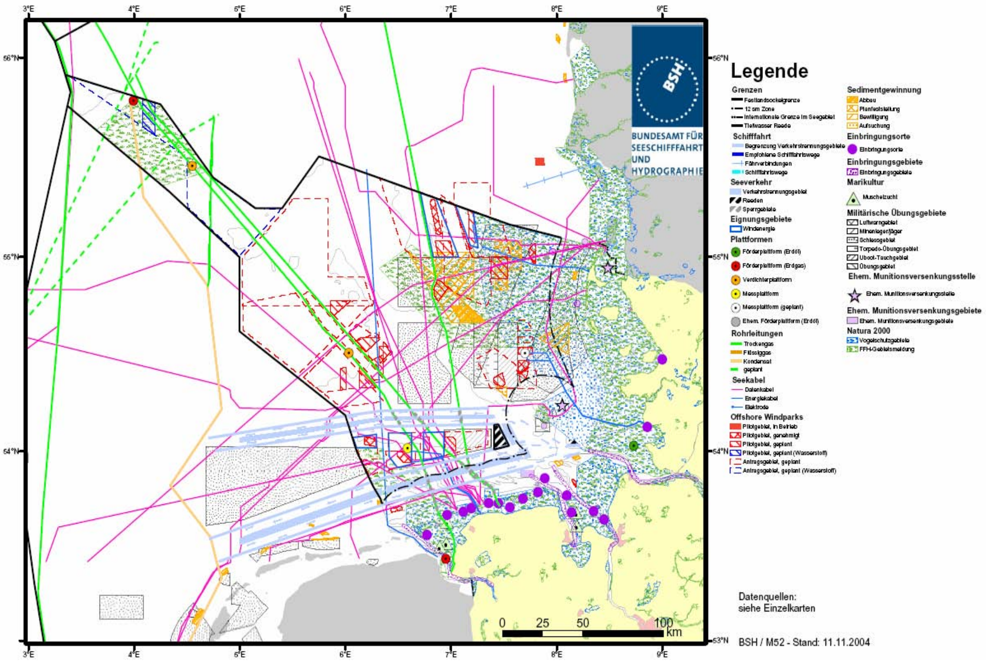

Fig. 2.2: *Multiple sea uses in the German North Sea as of November 2004 (BSH CONTIS Information System, www.bsh.de, accessed November 2004).*

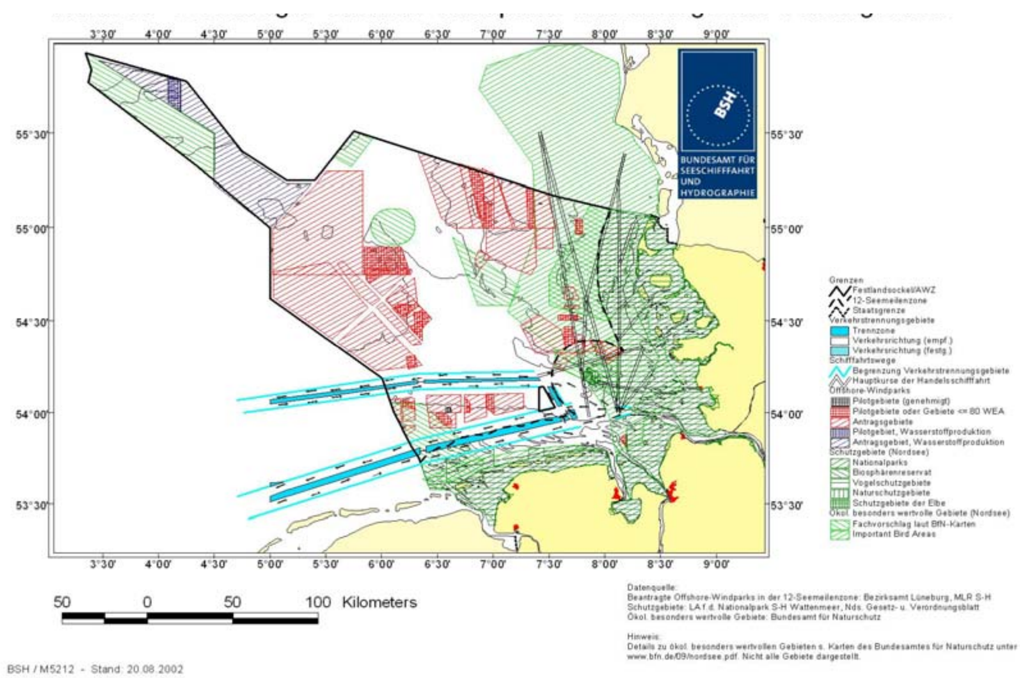

Fig. 2.3: *Multiple sea uses in the German North Sea as of August 2002 (BSH CONTIS Information System, www.bsh.de, accessed September 2002).*

2.2 Drivers of change in the sea

The increasing complexity of spatial patterns of sea use in the German North Sea is the result of driving forces acting in different policy arenas and at several geographical scales (see chapter 4). One such driver that acts with reasonable consistency at several scales is economic development. Here, global developments provide the general framework, such as economic liberalisation which leads to generally changing patterns of trade, greater volumes of goods to be shipped and greater shipping intensity. This is complemented by the EU Maritime Policy (CEC 2007) which acts as a political driver and has stimulated interest in the regional seas as transport corridors, sites for energy generation, and new maritime industries, identifying them as key areas for innovation and growth. At the national level, Germany also considers the maritime economy a key sector for the German economy and the sea a strategic area for development (BMWi 2008). A total of 12,6 billion Euro are set to be invested in German sea ports by 2012; the BMWi has earmarked another € 200 million Euro for investment in research, development and innovation in the maritime economy between 2007 and 2010 (BMWi 2008). In this example, forces are pulling together, converging within the sector to facilitate development. But other drivers pull in other directions. One example is the EU Habitats Directive, which demands the designation of marine protected areas and limits the availability of sea areas to other forms of use. In total, 31,49 % (1,04 million ha) of the German EEZ (North Sea and Baltic) have been classed as Natura 2000 sites (BfN 2010); within the 12 sea miles zone there is also the German Wadden Sea National Parks where offshore wind farming has been excluded as an option.

The above shows that drivers can be thought of as creating opportunity (see Figure 2.4 for an overview of drivers that shape patterns of sea use). They provide an 'enabling framework' which either opens up or closes down space for development. Depending on their degree of convergence driving forces can create opportunities for rapid change, although this does not mean that development opportunities are necessarily taken up (see Figure 2.4). An interesting observation is the emergence of a new societal norm, which is the shift towards a 'maritime' rather than predominantly 'marine' perspective of the sea. Rather than focusing on the marine environment per se, this perspective is more openly utilitarian, concentrating on technologies and human exploitation of sea and ocean resources. See for instance the distinction between marine and maritime research in the EU Strategy for Marine and Maritime Research (http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/08/553&format=HTML.%C2%A0, accessed 3 May, 2010) Investment in technology and infrastructure goes along with calls for the long-term allocation of sea space, pushing for formal processes such as marine spatial planning as a means of achieving planning security. A process is also required to link marine and land-based planning, in order to ensure any necessary land-based infrastructure (e.g. transport routes linked to ports and harbors) is put in place to accompany expanding uses.

As the sea becomes more crowded, it is therefore not only a greater number of uses, but also a broader range of types of uses that have to be dealt with. Instruments will need to be capable of balancing new paradigms of use with more traditional views of the sea: Some forms of use will respond well to approaches such as zoning, whilst others will require greater flexibility in space and in terms of their management (Gee 2010) (see chapter 10).

Typical driving forces with impacts on patterns of sea use:

- trade barriers or incentives,
- commodity prices and markets,
- technological innovation and development,
- international and national economic policy,
- societal norms and values, as well as freedom of choice,
- energy and climate policy
- social and political framework,
- demography,
- institutional and cultural globalization,
- raw materials and energy demand.

Fig. 2.4: *Driving forces responsible for triggering change and shaping sea use (adapted from Schultz-Zehden et al. 2008)*

2.3 Offshore wind energy: Driven by change and a driver of change

The particular dynamism of offshore wind farming in the German North Sea results from the coming together of global, national and regional driving forces.

First is the fact that renewable energies have gained increasing prominence as a means of reducing CO_2 emissions and thereby mitigating climate change. Wind energy has long emerged as a major contributor, with global capacity amounting to 120.798 megawatts in 2008. In that year 65.946 megawatts were installed in Europe and 23.908 in Germany (GWEC 2010). Dedicated policy support has played a strong role in facilitating the steady growth of the sector, such as the EU Renewable Energy Sources Directive (RES-E) as well as the national targets for renewable energies set by the respective member states. In Germany, this target is reasonably ambitious, seeking to increase the share of renewables in electricity generation to 12.5 % by 2010. A key policy instrument is the German Renewable Energies Act (EEG), which was introduced in 2000 and last amended in 2009 to create favourable feed-in tariffs for offshore wind (WWEA 2008).

At a federal level, government expects offshore wind energy to play a major role in reaching the German renewable energy target. If current plans go ahead, offshore wind farms could provide between 20.000 and 25.000 megawatts by 2030, meeting about 15 % of the German electricity demand. But offshore wind farming also yields other benefits. Federal and state governments point to the purported economic effects of wind farm development (BMVBS 2009, BMU 2007, MWWV 2007), with additional employment generated at a national and regional level (BMWi 2008). Offshore is also of increasing interest to developers because of higher and more predictable wind speeds, fewer conflicts with other types of land use, and less likelihood of public resistance against new developments. The current interest in expanding offshore wind can therefore be described as a point of convergence, a coming together of various push and pull factors emanating from several policy arenas and geographical scales (Kannen & Burkhard 2009). Priority issues include climate change and energy policy (international and national level), regional economic development (Länder level), or involvement and loss of control (local level).

2.4 Barriers to offshore wind farm development in the German EEZ

Despite these favourable circumstances, progress in offshore wind farm construction in Germany has been slow. Although more than 50 offshore wind farm projects are now at the planning stage and 21 have received planning permission from the Federal Maritime and Hydrographic Agency, only one has so far become operational (as of March 2010, www.bsh.de). This delay is often attributed to the deeper water setting of the German offshore wind farms, which implies higher costs and financial risks as well as greater difficulties with respect to grid connection. Market-related barriers have also been identified that delay investment in offshore wind (www.ewea.org, Neukirch 2008). Some of the initial delay was caused by administrative barriers: A responsible authority first had to be appointed (the Federal Maritime and Hydrographic Agency, BSH), a dedicated planning application and approval process developed for the EEZ, and the Federal Spatial Planning Act extended to the 12 sea miles zone in order to enable planning approval of cable connections to the mainland.

In this context, 'maritime space' has emerged as a valuable good in its own right, a claim to be staked and defended against competing claims. Marine aggregate extraction, nature conservation and fisheries all compete with offshore wind farms for space (Gee et al. 2006a); other uses such as mariculture, CCS or hydrogen generation could also begin to demand significant sea areas. Given that the diversity of uses is likely to increase rather than decrease, the competition for space can be expected to intensify.

2.5 Compatibilities of sea uses and a polyculture of use

Given the intensity of spatial competition in the EEZ, as well as calls for achieving a balance between the various demands, it follows that the scale of implementation of offshore wind farming partly depends on its compatibility with other uses. Compatibility can be thought of in terms of spatial compatibility, co-use and ecological compatibility. Compatibility is not a static concept, but a dynamic one that needs to be re-evaluated regularly in the light of future trends and new available knowledge.

The fact that space is limited has received attention because the German target of achieving up to 25.000 MW by 2030 is likely to translate into a sea area requirement of 2.000 to 4.000 square kilometers (BMU 2002). Although offshore wind is spatially incompatible with some uses (e.g. shipping), compatibilities have been established with others (Gee et al. 2006b, see chapter 10). Other uses could even draw indirect benefits from offshore wind farming, such as fishing where wind farms provide automatic no-take zones and nurseries for certain fish species (Gloe 2009). Maximizing spatial efficiency by establishing a polyculture of the sea uses is therefore a real option, although cumulative impacts of uses and the ecological carrying capacity of the marine environment will be key factors here. Technical, social and economic barriers will also need to be overcome for co-use to become an accepted concept in practice (e.g. Michler-Cieluch 2009, see also chapter 7). Much will thus depend on the development of suitable indicators, both for monitoring spatial compatibility and the ecological impact of individual and combined uses.

2.6 Challenges in dealing with sea use trends

Technological advances mean that extensive sea areas can now be populated by fixed structures. Whilst this has direct impacts on the marine environment, repercussions can be felt further afield, triggering yet other impacts in places distant from the actual site of use. Shipping, for instance, takes place in the sea but requires considerable land-based infrastructure in order to function; the same can be said for offshore wind farming and its associated servicing infrastructure. Spatially, thus, the impacts of new or more intense sea uses have to be considered for land and sea at the same time. This must bear in mind that land-based impacts can affect much wider 'catchment areas' than the immediate coastal regions (e.g. extending the transmission grids to cope with offshore wind energy). In dealing with dynamic developments in the sea, it is clear that land and sea can no longer be thought of as separate entities; it follows that an alignment of the respective planning processes is required.

Maximizing spatial efficiency and minimizing conflicts of use is not a one-off, but a dynamic process that will need to respond to actual developments in sea use. As stated above, patterns of use can shift as a result of changing dynamics within individual sectors and in response to external forces; this can alter the balance of uses and the relative significance of certain uses over others. It follows that monitoring of external driving forces is particularly important in the marine context. This includes processes of globalization (e.g. affecting port development and shipping), technological developments (e.g. use of hydrogen, energy technology or 'blue' biotechnology), or policy developments (e.g. energy policy, security of supply, climate policy). Societal values and attitudes are another essential driving force that influences decision-making processes, preferences and political processes. Attitudes to new technology and risk, for example, will impact on what is deemed acceptable in terms of sea use and what might remain controversial. This has been shown in the different attitudes to offshore wind held by different stakeholder groups, for example (see chapter 6). The biggest challenge arising from the current dynamism of developments, however, might be to not merely be swept along by the current window of opportunity and the rush to stake and defend claims on marine space. An important part of the overall framework that needs to be put in place to guide sea use is a clearer vision of what the future should hold for the German EEZ and what perspective should be guiding developments over the next decade or more.

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3 The Integrated Approach in *Zukunft Küste - Coastal Futures*

Andreas Kannen, Benjamin Burkhard, Wilhelm Windhorst

When recognizing the current dynamics of change and taking into consideration the multitude of demands that are placed on coastal areas (see chapter 2), it becomes obvious that coastal and marine areas are systems characterized by increasingly complex interactions. An important challenge to science and research is to gain insight into complex system behavior. Linking a series of existing concepts and tools, *Coastal Futures* aimed at an integrated assessment of coastal and marine change, seeking to develop and test a methodology that can be transferred to other systems contexts. Key elements of the research included a) discussing future sea use patterns using a scenario approach, b) modeling and analyzing impacts of offshore wind energy on specific ecosystem services, c) modeling and analyzing socio-economic impacts of offshore wind energy at local and regional scale, and d) analyzing social values and problem perceptions, institutional networks and related policies. Building on Kannen & Burkhard (2009) this chapter sets out conceptual and methodological key elements applied by the project and aims to provide an overview of the integrated framework applied in the project.

3.1 *Zukunft Küste - Coastal Futures* as an interdisciplinary case study

Coastal Futures has been designed as a case study analysis with focus on the issue of offshore wind farming and the region of the German North Sea (see Scholz and Tietje 2002, Yin 2003 and Walker et al. 2007 for details on the use of case studies as a research strategy). As such the project aims to function as an example for an integrated type of research strategies, even though always issue and location specific adaptations of the approach will be necessary and additional work on the methodology hopefully will improve it in order to make it operational and applicable in several contexts and regions world wide.

To ensure methodological integration across scientific disciplines and in order to bridge borders between natural and social sciences, a common interdisciplinary structure was used to describe a particular social-ecological system within defined spatial, temporal and thematic boundaries. Within this common framework, individual work packages applied natural and social science tools with the purpose to investigate opportunities and risks associated with offshore wind farms in the German North Sea. Even though work primarily drew on available data, modeling and expert assessments, particularly in the social sciences additional field work (questionnaires and interviews) had to be performed to gain relevant information. Specific approaches and results are presented in subsequent chapters of this report.

3.2 Offshore wind farming in the North Sea as a social-ecological system

Offshore wind farming is embedded in a complex and dynamic social-ecological system (Figure 3.1). A social-ecological system is an ecological system that is intricately linked with and affected by one or more social systems (Anderies et al. 2004). Berkes & Folke (1998) use the term social-ecological system to emphasize the idea that humans form part of nature and that the delineation between social and ecological systems is artificial (Folke et al. 2005).

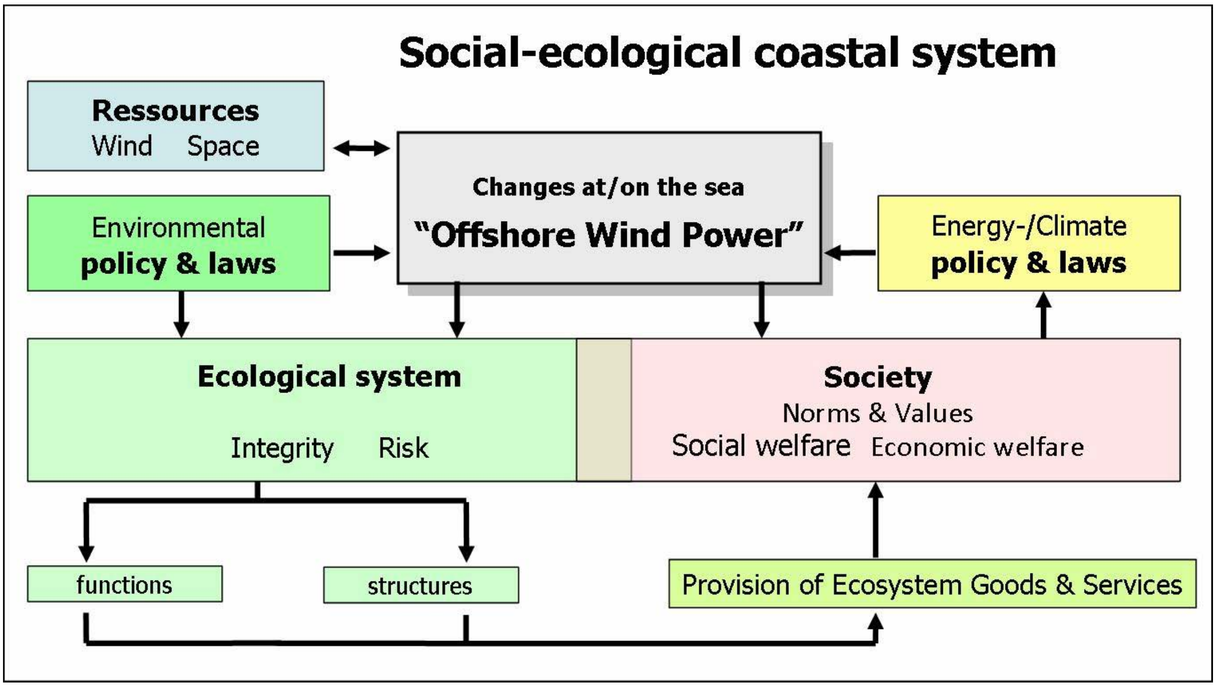

Fig. 3.1: *Conceptual diagram of interactions in the social-ecological system 'offshore wind power' in the project cluster Zukunft Küste - Coastal Futures (Kannen & Burkhard 2009)*

The dynamics of the system, which is analyzed in *Coastal Futures* and illustrated in Figure 3.1 can briefly be sketched as follows: Political support and economic instruments like feed-in-tariffs provide a stimulus to private sector agents to invest in large-scale wind farm projects. Resources used directly are wind and particularly space, the latter being in competition with other spatial demands such as shipping and nature protection (see chapter 2 and 10). Anyhow, wind farm projects affect marine and coastal ecosystems: first and directly ecosystem structures and functions and as a result the provision of ecosystem goods and services utilized by humans. This happens through various direct and indirect interactions, which are analyzed in chapters 5 (ecosystem functions and structures) and 8 (ecosystem services). In addition offshore wind farming can directly (or indirectly through change in ecosystem services which are used by particular economic sectors such as fisheries and mariculture) impact on the coastal economy, relating it to issues of regional development such as employment, income generation and infrastructure needs (see chapter 7).

Human perceptions of the seascape, its goods and services and the perception of renewable energy production are societal factors (Gee 2010, partly chapter 6), which become relevant in policy decisions concerning future offshore wind farm development and future coastal and marine governance in general (chapter 10).

The approach of social-ecological systems provides a useful framework for analyzing complex interdependencies between system elements. The nature of such systems, including the human use of specific marine areas, is characterized by path dependent, emergent, surprising and unpredictable system behavior as well as by highly complex scales of time and space in social, economic, ecological and institutional processes (see chapter 3.4 for scaling issues).

3.3 The DPSIR framework: A tool to structure information

Methodologically, the DPSIR framework (Driver-Pressure-State-Impact-Response, see among others Bowen and Riley 2003, MA 2003, Burkhard & Müller 2008) is one way of simplifying the multiple cause-and-effect relationships that need to be considered in integrated analysis of social-ecological systems. Although the DPSIR framework does not provide for full modeling of complex chains of cause and effect, it does conceptually link causes (drivers and pressures) to environmental outcomes (state and impacts) and activities (response, policies and decisions). Available information can therefore be structured along the five DPSIR categories in order to support an integrated and holistic view. However, definitions of the DPSIR categories can vary. For *Coastal Futures*, the definitions applied (see Table 3.1 on next page) were adapted from the Millennium Ecosystem Assessment (MA 2003) to suit a spatial planning perspective (Gee et al. 2006).

3.4 Scales in integrated analysis

The importance of scales (not only spatial) is reflected among others in Cash et al. (2006), who distinguish between scales in terms of space, time, jurisdiction, institutions, management, networks and knowledge. Young (2006) analyzes the vertical interplay of scales for governance. Concerning offshore wind farms in Germany, Kannen et al. (2008) sketched social effects of scale, e.g. different interests and perceptions of the coast and the sea by local, regional and national stakeholders. Of high importance in a planning context are particularly differences between local and national actors, the latter more often acting in a political and strategic environment with conflicting targets and patterns of power while local actors often argue from their specific local context, sometimes focusing on aesthetical and sometimes emotional issues.

The selection of spatial and temporal scales in scenario formulation (chapter 4) is crucial because some social as well as natural and ecological effects are appearing only on very local levels while others emerge on much larger scales as for example the whole North Sea. Within *Zukunft Küste - Coastal Futures*, therefore a multiple scale approach has been chosen. Spatial scales taken into account range from a) European to national, regional and local decision making arenas and b) from the Southern North Sea down to the German Bight and individual piles in assumed wind farms for ecological investigations (see chapter 4 and particularly Figure 4.1).

***Tab 3.1:** The use of the DPSIR approach in Zukunft Küste - Coastal Futures*

DPSIR Category	Definition	Elements in *Coastal Futures*
Drivers	Natural or man-made factors which cause changes in a system, either directly or indirectly. 'System' here refers to coastal and marine systems and includes social, economic and institutional as well as ecological components (see chapter 4)	direct drivers: societal demand for materials and energy, health, social relations, security, freedom of choice and action, education; indirect drivers: demography, economy/markets/ trade, economic globalisation, institutional and cultural globalisation, social policy, norms and values, science and technology;
Pressures	Pressures of use acting on the coastal and marine system as a result of the drivers (see chapter 4).	coastal and marine uses: military, protected areas, fishery, shipping, coastal protection, raw materials, tourism, agriculture, cable and pipelines, waste disposal, mariculture, infrastructure, offshore wind energy, …;
State	System characteristics which are influenced by drivers and pressures. In the context of coastal uses, state analyses include ecosystems, social and economic state, infrastructure and the institutional system governing coastal and marine resource use.	ecological integrity: energy cycling, nutrient cycling, storage capacity, minimization of nutrient loss, abiotic heterogeneity, biotic diversity, organization; social state: social infrastructure (schools, medical care, public services,…), social cohesion, regional identity, individual quality of life; economic state: economic structure, labour market structure, regional wealth based on capital stocks and fixed assets, personal wealth data and regional dependency on social transfers;
Impact	Effects of state changes on coastal and marine systems. The classic definition of impact in environmental assessment refers to the knock-on effects of ecosystem deterioration and impacts on the provision of ecosystem goods and services (see chapter 8)	regulating ecosystem services: e.g. climate regulation, sea bed control, water purification and waste treatment, storm protection; provisioning ecosystem services: e.g. food, wind energy, biochemicals; cultural ecosystem services: e.g. aesthetics, beauty of landscape, sense of place, cultural heritage, habitat and species value, regional image, inspiration, informal education, knowledge systems, recreation; human well-being: effects originating from changes in ecosystem services on human well-being, e.g. loss of income, employment, demography, strengthening or weakening of regional identity, education, safety, … (see chapter 8.3);
Response	Societal forms of response to systems change. Central elements include management options, institutional responses and their framework conditions, as well as individual changes of behaviour. Response also includes changes to the existing legal framework, the introduction of monitoring systems, or investment decisions affecting the location of businesses.	Changes in governance architecture or governance processes, use of planning tools such as Maritime Spatial Planning (MSP) or Integrated Coastal Zone Management (ICZM), changes in legislation, rules, political priorities and political or public support for specific development paths, investment decisions in economy, …. (see chapter 10);

For the temporal scale in the *Coastal Futures* scenarios the year 2005 was chosen as base year and as successive time steps the years 2010, 2030 and 2055 were selected. These time steps were related to the initial German planning for the consecutive expansion of offshore wind energy in the German North Sea. In terms of expected installed capacity this included to move from zero to 3.000 to 25.000 MW until 2030 and even more for 2055 as a projected end point. However, given the delays of several years in the construction of offshore wind farms in Germany, the time steps assumed in the scenarios do not correspond to developments in reality.

Apart from this, temporal scaling plays a role

- in natural and social processes and their interaction (e.g. lag time between origin and effect, in DPSIR terminology lag time between pressures, state changes and impacts), and
- for the institutional response (e.g. time lag between first recognition of a problem and political reaction).

The latter is illustrated by the Multiple Streams framework of political sciences (Kingdon 1995, Meijerink 2005, Zahariadis 2007). The assumption here is that a problem stream develops over time like a shifting baseline. It might be recognized by some scientists and subsequently over time by an increasing network of experts (building a so-called epistemic community). From the problem stream and partly in parallel to it a policy stream develops, e.g. civil servants or NGOs developing proposals for a new policy, but not being able to implement it due to lacking political support and funding or due to resistance against a change and its implications (such as monetary costs, but as well political costs). This situation lasts until either the new ideas become a widely shared mainstream or - typically due to a crisis or catastrophe - a 'Window of Opportunity' opens for changing existing practices. Nevertheless, there is a time delay between problem recognition by pioneers, policy development by experts and political commitment/support to implement a new policy.

3.5 Scenarios: A tool to deal with uncertainty

For decision-makers, the unpredictability of emergent system behavior implies that decisions have to be taken in the face of high degrees of uncertainty. Scenarios have become an increasingly popular tool among scientists and practitioners for dealing with uncertainty and for assessing potential environmental and societal impacts along several plausible development paths (Van der Heijden 2005). The power of scenarios lies in their ability to reflect a range of assumptions on current trends, the roles of critical uncertainties and dynamics, and unexpected factors which could become important under certain future circumstances (WBCSD 1997).

Within *Coastal Futures* scenarios represent a central tool for integrating and structuring different aspects of change. Focusing on the entire North Sea area, five scenario storylines were developed that describe distinct patterns of anthropogenic use that could plausibly emerge over the next 50 years (Burkhard 2006, Kannen et al. 2009). Use patterns, defined as pressures in the DPSIR terminology as it is interpreted in *Coastal Futures* (Table 3.1), are considered to be the result of specific driving forces which lead to preferences in resource use. The approach chosen for scenario development in the project and the resulting storylines are discussed in chapter 4 of this report.

Developing the scenario storylines in *Coastal Futures* was primarily an interdisciplinary exercise without any stakeholder involvement. Their use as a visionary planning tool is therefore limited. Their purpose, however, is altogether different in that they are intended to form a basis for assessing impacts resulting out of different degrees of wind farm development incorporated in the different sea use patterns. Pointing towards possible 'futures' (including different intensities of offshore wind farm development), they are a useful tool for analyzing and discussing the systems context in which offshore wind farming will need to take place in the years to come.

3.6 Approaches to model state changes and impacts

While scenarios described driver-pressure relations (chapter 4) as starting point for the system analysis in *Coastal Futures*, inventories marked the current state of the system and provided the background data or information needed for impact assessments. This included for example the analysis of the state of marine spatial use and related trends (chapter 2, Gee et al. 2006), assessments of local and regional data on social infrastructure and economic key parameters from national accounts, an analysis of the positions of institutional stakeholders (see chapter 5), an empirical assessment of communication between actors for regional development (Zahl & Spiekermann 2005, Zahl et al. 2006), framing of offshore wind energy in local newspapers (Fuchs 2006), and an analysis of values of local population (Gee 2006, 2010). Impact assessments (looking at Pressure-State-Impact interactions) were based upon issue specific and disciplinary modeling (see particularly chapters 5 and 7).

To analyze the impacts of offshore wind farm development on marine ecosystems involved a rather complex modeling approach, linking a wide range of different models. Because until 2009 no offshore wind farms have been built in the deeper waters of the North Sea, suitable monitoring data upon which assessments of potential system shifts could be based, are still missing. Hence, hypotheses on the potential effects of offshore wind farms range from the development of productive and diverse artificial reef ecosystems to the degradation of marine ecosystems (Burkhard et al. 2009). A more detailed description of the ecological impact analysis is given in chapter 5.

In order to assess the opportunities of offshore wind farm development in the context of regional development, an economic input-output model was applied (Hohmeyer 2006, see chapter 7). The model quantifies the impacts of different intensities of offshore wind farm construction (measured in terms of installed capacity) in terms of CO_2 emissions and regional development, particularly employment. Realizing such benefits for regional development in a particular region however depends on suitable local and regional economic policy, particularly the development of the necessary infrastructure to attract investors.

In order to avoid a jigsaw of non-related investigations from natural and social sciences, the results were aggregated into the ecosystem services approach (including related human well-being components, see chapter 8), following the concept applied in the Millennium Ecosystem Assessment (MA 2003). This allows an estimate of impacts which result out of the implementation of offshore wind farms in the German North Sea.

Policy analyses (chapter 10) representing in *Coastal Futures* the Response category of the DPSIR framework, focused on the current state of spatial management spatial policy in the (German) North Sea region. This concerned particularly structures and concepts related to Maritime Spatial

Planning (MSP), Integrated Coastal Zone Management (ICZM) and approaches to participatory planning and management.

3.7 Integrating impact assessments in the ecosystem service approach

The concept of ecosystem goods and services provides a useful tool to link environmental systems with the needs of societies. By assessing the benefits people obtain from ecosystem processes and the capacities of the environment to provide services, an accounting of demand and supply can be derived. The application of this concept in *Zukunft Küste - Coastal Futures* proved to be very useful in order to integrate the work of the individual scientific disciplines. The ecological systems analysis (chapter 5) provided assessments of state changes of ecosystem integrity under different human use activities (pressures; foremost offshore wind power as defined by the case study approach). The integrity of ecosystems forms the base for the provision of all other ecosystem services (Müller & Burkhard 2007). Therefore, integrity components have been categorized as 'supporting services' in other studies (e.g. MA 2003). Based on structures and functions described by ecological integrity, environmental systems can provide regulating services (e.g. climate regulation, storm protection), provisioning services (e.g. food, energy) and cultural services (e.g. landscape aesthetics, recreation). The supply of these services again is the base for human well-being as well on an individual as on a community or a societal scale. More detailed information can be found in chapter 8.

3.8 Summary

This chapter described the conceptual approach and the integrative framework behind the *Zukunft Küste - Coastal Futures* research project. The project looked at one issue (offshore wind farms) from a range of different disciplinary perspectives, and at the same time tried to combine disciplinary science with an integrative approach. The framework had been designed to gain new insights into the complex social-ecological system of the German North Sea coast by applying a range of tools from natural and social sciences and linking them together as part of a common methodological framework and by focusing on a particular case study.

This approach aimed to improve understanding of interactions at system level in order to inform transparent and scientifically guided decision making at a strategic level. While this chapter provides an overview of the research framework, the design of the more specific analyses and their results can be found in subsequent chapters of this report.

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4 Scenarios for Driver - Pressure Relationships

Benjamin Burkhard

The aim of the future scenarios' application in the project *Zukunft Küste - Coastal Futures* was to enable the project consortium to describe and to assess potential future developments of offshore wind farming at the German North Sea coast. Although there is a broad range of further human activities in coastal zones, the installation of offshore wind farms and its impacts were defined as the main driver-pressure relation within the project. The future assumptions on offshore wind power were intended to reach beyond today's official planning, especially in their longest temporal horizon. The longest temporal horizon defined for the scenarios in *Zukunft Küste - Coastal Futures* is the year 2055 with intermediate time steps in the years 2010 and 2030. These time steps correlate with the offshore wind farm assembling stages as initially planned by the German government (BMU 2002). However, when looking at offshore wind farming in Germany today, the scenario assumptions made in the beginning of the project (in the year 2004) as well as official planning have not been met by real developments yet.

4.1 Scenarios as a tool for integrative future assessments

Scenarios are useful to illustrate cause-and-effect chains in complex human-environmental systems (Kahn & Wiener 1967, van der Hejden 2005, Raskin 2008). They are archetypal descriptions of future alternative images (Rotmans et al. 2000) created from mental maps or models that reflect different perspectives on past, present and future developments. In *Zukunft Küste - Coastal Futures*, scenarios were used to provide systematic guidelines for assessing uncertain future developments in the coastal zone. Moreover, they became a means of interdisciplinary integration for the individual scientific (i.e. ecological and socio-economic) sub-projects. Hence, the scenarios were a product as well as a working tool of the whole interdisciplinary project (Burkhard 2006, Kannen & Burkhard 2009). The scenarios were developed following the DPSIR framework (see chapter 3 and Burkhard & Müller 2008). In this framework, drivers behind human actions, resulting pressures and their relationships stand at the beginning of the DPSIR model. The scenarios and their different driver-pressure relationships' systematic development are described more in detail in the following chapter. Thereupon, assessments of ecological and socioeconomic impacts (chapters 5 & 7) and evaluations of impacts on ecosystem services' provision and on human well-being (chapter 8) were carried out.

While thinking about future developments we have to take into account that:
a) our understanding is limited (which might lead to a certain ignorance of presumably substantial features),
b) developments are not static (there are always surprises and unexpected innovations capable of altering the direction of dynamics) and
c) human beings act upon consciousness and preferences (which might change slowly or rapidly, depending on a broad range of factors).

These factors can limit our thinking about the future and scenarios can help by providing plausible alternative future developments, each an example of what *could* happen under certain predefined assumptions (Raskin 2008). They are told as stories supported by model calculations and quantifications, questionnaires or expert evaluations. Hence, scenarios are different from prognoses, projections or forecasts. They can be classified into i) explorative scenarios (which describe a sequence of possible events, starting from the present situation), ii) anticipatory scenarios (describing developments backwards starting from a certain specified future vision), iii) baseline scenarios (so called non-intervention scenarios, excluding regulating actions related to the main theme of the scenario development) or iv) policy scenarios (showing a future in which certain interests are supported by political decisions). Depending on the kind of data used for the scenario description, a further differentiation between qualitative and quantitative scenarios can be made.

4.2 Scenarios in *Zukunft Küste - Coastal Futures*

In *Zukunft Küste - Coastal Futures*, a combination of the scenario types mentioned above was deployed. The scenarios were anticipatory as the starting points were five different future visions of the North Sea in the year 2055:

A. the North Sea primarily used as a nature protected area
B. the North Sea primarily used as an energy park
C. the North Sea primarily used as an industrial region
D. the North Sea primarily used as recreation space
E. the North Sea primarily used as shipping space

The scenarios were explorative with regard to the sequential development of future offshore wind farms' installations, starting from the present (respective the year 2005) situation with no offshore wind farms in German coastal waters. Finally, they can be regarded as policy scenarios, where different interests (i.e. coastal and marine use activities) were supported by future political decisions. Concerning the data used for the scenario assessments, a combination of quantitative (from ecological modeling, monitoring) and qualitative (from interviews, expert assessments) data was used. Following the definition of temporal scales and data availability, spatial scales and their interactions had to be defined. In *Zukunft Küste - Coastal Futures* an approach of nested spatial scales was chosen. These scales had to be adapted to the respective objects of research. In the socio-economic analyses, the smallest scale 'local' corresponds to individual municipalities or island communities whereas in ecological impact assessments 'local' refers to a single wind turbine. The subsequent scales follow a similar concept: the socio-economic scale 'west coast Schleswig Holstein' corresponds to the ecological scale 'single offshore wind farm'. The spatially largest scales consist of 'German North Sea' and 'Southern North Sea' (see Figure 4.1).

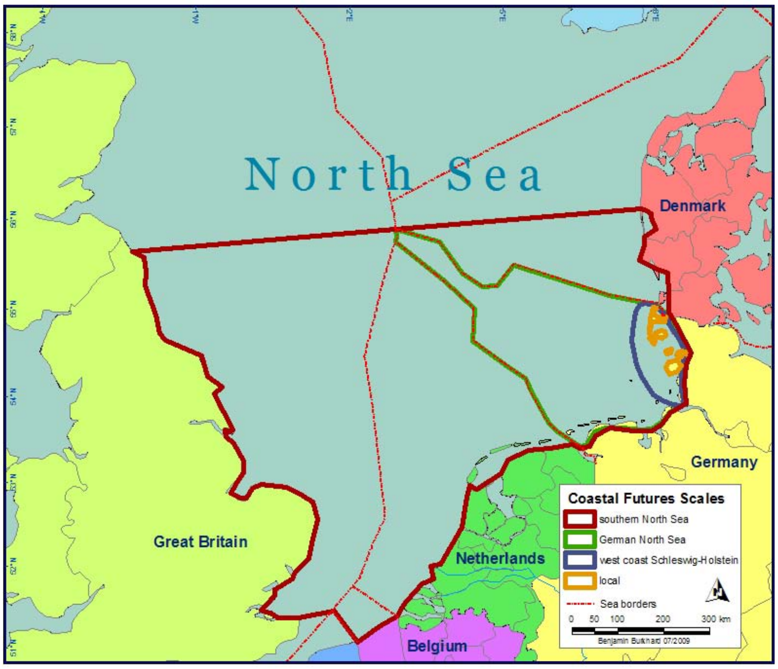

Fig. 4.1: Nested scale approach used for the Zukunft Küste - Coastal Futures scenarios.

In the next step, the driving forces (short: *drivers*) behind the assumed developments, their themes, the degree of their integration and their changes' dimensions must be identified. The assumed future developments in *Zukunft Küste - Coastal Futures* are changing patterns of sea use focusing on offshore wind power in particular. They have been addressed as *pressures*. Both drivers and pressures and their assumed developments are usually described in form of a narrative, i.e. the so-called scenario storyline. The different storylines' elaboration for the German North Sea's different future developments was carried out in joint project workshops, in interdisciplinary working groups and in individual work. The storylines of the project consist of a short text of about 1.000 words, descriptions of individual drivers and pressures, descriptions of disparities across different spatial scales, tables describing drivers and pressures and potential indicators for their quantification, references, diagrams and maps. To improve the texts and the results' content and scientific quality, all material underwent a project internal review procedure.

4.3 Identification of drivers

Drivers are various factors that cause changes or lead the behavior of a system (Burkhard & Müller 2008). They can be natural or human-induced. In this case, they apply to the development of offshore wind farming in the German part of the North Sea. The main questions behind the identification of driving forces are: which factors would have the capacity to alter the course of offshore wind farm development, in which direction would these drivers act and which consequences (pressures and impacts) are to be expected? At least three aspects of human-environmental systems are relevant when identifying drivers of human action: 1) social dynamics (e.g. demography, norms and values, lifestyle, demand of certain goods and services, health), 2) economy (supply and demand of goods and services, progress, globalization, trends) and 3) environment (resource availability, ecological integrity, resilience).

Within these multifaceted aspects, a differentiation between direct and indirect drivers can be useful. Whereas direct drivers have an apparent direct influence on the system, indirect drivers act on the system by influencing at least one of the direct drivers. In the case of coastal zones and the installation of offshore wind farms, a change in norms and values towards the support of renewable energies would be an indirect driver, influencing the direct driver energy demand. This leads to pressures on the environment due to the effects of wind turbines on the marine ecosystems (see chapter 5).

As a starting point, selected drivers from the MA's framework (MA 2005) were used and adapted. Additionally, sustainability indicators suggested by the UN (www.un.org/esa/sustdev) were integrated into the following list of **direct drivers**:

- **Demand for materials and energy**: The demand for a safe and decent existence; including income, permanently available and sufficient food, accommodation, energy, clothes and access to goods.
- **Health**: The desire to be healthy, feel well and have a healthy natural environment.
- **Social relations**: The desire for social cohesion, mutual respect, good gender and family relations and the ability to help each other and to support the family.
- **Security**: The demand for safe access to natural resources, for security of the individual and its possessions and for a life in a predictable and controllable environment protected against natural and anthropogenic catastrophes.
- **Freedom of choice and action**: The desire to have control over developments and to be able to attain a desired position in life.
- **Education**: The general access to basic learning, the attempt to reduce illiteracy, the integration of sustainable and interdisciplinary learning concepts, awareness raising within broad levels of the population and improved professional and scientific learning.

As **indirect drivers** of change were defined:

- **Demography**: Changes in population numbers, age and gender structures or the spatial population distribution.
- **Economy, markets, trade**: Changes in national and personal income, in macroeconomic policy or in international trade and capital flows.
- **Economic globalization**: Changes in the economic process of international division of labor, in policy based trade barriers between states, in global mobility of capital and the unlimited use of new communication technologies.
- **Institutional and cultural globalization**: the increasing or decreasing homogenization of traditions, customs, world-views, cultures, religions, consumer goods, lifestyles and harmonization of administrative, legal and education systems, languages or media.
- **Social policy**: Changes in democratization, the role of women, the civil society and the private sector and international dispute mechanisms.
- **Norms and values**: Changes in individual decisions about quality and quantity of consumption and cultural as well as religious values.
- **Science and technology**: Changes in investment rates for research and development and share of implementation of new technologies, including bio- and information technology.

For an appropriate assessment of trends and the individual drivers' developments, suitable indicators are needed. Table 4.1 gives an overview of potential indicators.

***Tab. 4.1:** Drivers of human action and potential indicators for their quantification (driver selection based on MA 2005, indicators were developed within the project).*

Direct drivers	**potential indicators**
Demand for materials & energy	prices for energy & materials, usage per inhabitant, share of renewable energy and recycled material
Health	sick days/jobholder, life expectancy, share of people with overweight
Social relations	number of single households, single vacationers, members in associations or clubs
Security	insurances, military and police statistics, private security enterprises
Freedom of choice & action	voter participation, number of public referenda
Education	schools, pupils/teacher, graduations, placement PISA study
Indirect driver	**potential indicators**
Demography	immigration, migration, births, deaths, population structure
Economy, markets, trade	GNP, market structure, income, employment
Economic globalization	import vs. export of products and services
Institutional & cultural globalization	international enterprises (e.g. franchise), international institutions
Social policy	poverty, welfare recipients, homeless, public assistance
Norms & values	honorary posts, donations
Science & technology	science & technology budgets, number of patents

Looking at data and information referring to the development of these particular drivers in the past, trends for future developments can be extrapolated. Thus, our analysis of drivers was based on the depiction of existing trends and their extrapolation. For example, final energy use in the EU 25 - member states has increased by more than 11 % within 15 years only: from 1.014.302 t roe (tons raw oil equivalent) in 1990 to 1.140.880 t roe in the year 2004 (data from EUROSTAT). Hence, an increase of energy demands can be assumed for the next decades as well and will be an important driver of human action. This will lead to increased trade and energy conversion installations. Furthermore, institutional, cultural and economical globalization will increase in future. This again will lead to additional need for shipping and changes in peoples' norms and values and social systems. Demographical trends in German coastal zones show a development towards low birth rates and aging which can still be compensated by gains from immigration in the first years of the new millennium. After 2010, these gains will not suffice to prevent a negative population development and an aging of people (BBR 2005). Hence, demography will be an important driver of change in these regions and will indirectly have further consequences, as for example an increased demand for health services or social relations. Figure 4.2 gives a synoptic overview of the drivers' potential future development at German coastal zones for the next 25 years.

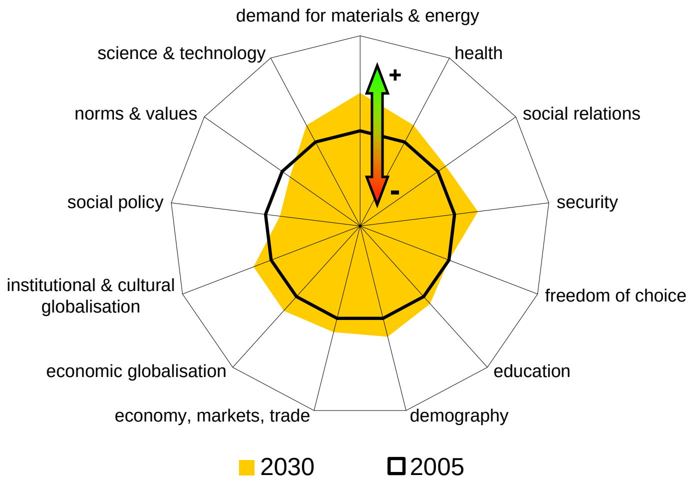

***Fig. 4.2:** Possible developments of drivers in German coastal zones; the diagram shows reference states in the year 2005 and increasing or respectively decreasing importance of the particular drivers in the year 2030.*

4.4 Identification of resulting pressures

Particular constellations of drivers result in a particular set of pressures. All human activities affecting the environment can be defined as pressures (Burkhard & Müller 2008). Hence, in *Zukunft Küste - Coastal Futures* all human uses of the coast and the sea were defined as pressures. The North Sea provides space and function for a wide range of anthropogenic uses. The probably most traditional and established forms of use are fishery and shipping. Both are connected to demands for food and goods as essential drivers. In the 19th century, when people in Europe became more prosperous, the need for recreation and wellness was one main driver to start a boom in tourism as a new pressure in coastal regions. Nowadays, developments are characterized by increasing economic and cultural globalization causing an immense increase in global trade. Both are indirect drivers leading to an increase of exchange of goods. This exchange is driving the pressure international shipping with increasing sizes and numbers of vessels and harbors (SRU 2004, BBR 2004). A direct driver development typical for the last decades has been the increasing demand for energy (EEA 2006). The rise of offshore wind farming is the result of various drivers, including fossil fuel depletion and climate change, which gave rise to the political aim to promote alternative, less CO_2-releasing forms of energy. First wind farms were installed in Denmark, the United Kingdom, the Netherlands, Sweden and, very recently, in Germany. Besides these sea-bound activities, different forms of adjacent anthropogenic land use, like agriculture, industry or housing, affecting the coastal environment by fertilization, waste water discharge or aerial emissions. Thus, the North Sea is under severe pressure in certain areas and far from being a natural and undisturbed place.

Besides human land or sea use, there are other human activities affecting the environment and therefore can be classified as pressures. A very important pressure dominating current environmental debates is global climate change due to anthropogenic green house gas emissions. Especially in coastal zones, climate change can potentially cause severe impacts by increasing frequency and intensity of storm events and rising sea levels. However, as the socio-economic causes and effects of global climate change are extremely manifold and complex, they were addressed as an exogenous factor not considered any further in this project, neither as driver nor as pressure (Figure 4.3).

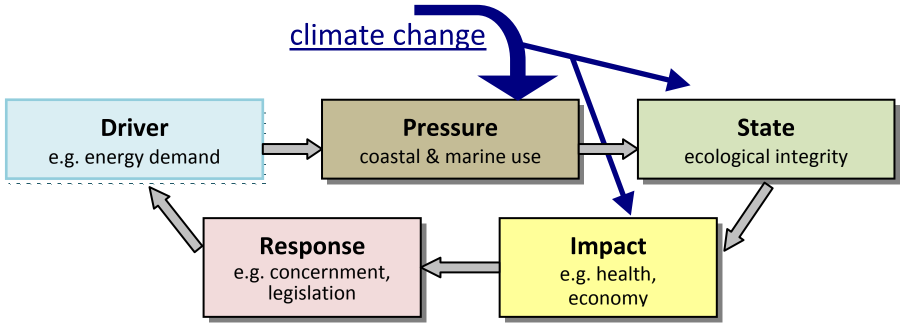

Fig. 4.3: *The role of global climate change as an external factor in the DPSIR model.*

Hence, within the project *Zukunft Küste - Coastal Futures*, the research area's existing or future forms of human land or sea use were defined as pressures:

- **Military:** Areas dedicated to military activities and exercises. The German exclusive economic zone includes areas for marine shipping, torpedo test areas, firing ranges, submarine dive areas and areas of former ammunition disposal. During military exercises, these areas can be closed for other forms of use.
- **Protected areas:** The establishment and management of protected areas aim at protecting particular and characteristic habitats and species. Most parts of the German North Sea coast and the Wadden Sea are protected by national parks. Additionally, there are European Nature2000 areas and further nature protection areas.
- **Fishery:** The North Sea is one of the most productive seas in the world and supports a high diversity of fish, whales, algae, mussels, shrimp and further shellfish species. The utilization of these natural resources by fisheries is one of the most traditional and established forms of anthropogenic sea use.
- **Shipping:** The transportation of goods at sea and their unloading in harbors is of great importance - locally as well as globally. The North Sea provides a very good transportation network and connection to the global transportation routes. The port of Hamburg is the biggest in Germany and the third biggest in Europe. The new JadeWeser port in Wilhelmshaven will provide further facilities for shipping in the North Sea.
- **Coastal protection:** Coastal protection aims at the protection of coastal residents and their property against the destroying powers of the sea. Common measures are, for example, dikes, groins, walls, flood barrages or scavenging sand. The German main land at the North Sea is protected by dikes.
- **Raw materials:** The most established form of raw material exploitation is the extraction of marine sand and gravel. They are used for construction either directly at the coast (e.g. coastal protection) or for export. Additionally, since 1964, natural oil and gas exploitation exists in the North Sea, including seismic exploration research and offshore installations.
- **Tourism:** Each year, millions of visitors are attracted by the ecological and cultural peculiarity of the coast. During the last decades, tourism has become the most important economic factor in many regions. Environmental pressures related to tourism are ground sealing, destruction of ecosystems, noise and emissions, water contamination, growing traffic and air pollution.
- **Agriculture:** Agriculture can exert pressure on coastal zone ecosystems due to fertilization materials and matter transported from the rivers' entire catchment area into the sea. In the marine environment, over-fertilization with nutrients can lead to excessive growth of algae.
- **Cable and pipelines:** These are related to oil and gas exploitation. A dense network has been established there already. Moreover, an increasing number of electric and data cables has been installed.
- **Waste disposal:** Sewage, industrial waste and sediments from capital and maintenance dredging have been dumped in coastal areas of the North Sea for a considerable time span. As the negative effects of these activities became more recognized, they were banned in many countries in the 1990s. Nevertheless, high amounts of pollutants still remain in the sea and new contaminations are dispersed, e.g. from drill cuttings from oil and gas exploration and exploitation.

- **Mariculture:** Mariculture offers an alternative way of growing marine organisms in the sea. At present, the main organisms produced include seaweeds, blue mussels, macroalgae, oysters, shrimps, prawns, salmon and others.
- **Infrastructure**: Infrastructure is essential for a functioning economy and social system. Common carriers are roads, railroads, water, cable and air. Moreover, facilities like hospitals, sewage plants or shops belong to infrastructure.
- **Offshore wind energy:** Electrical power from offshore wind farms was prepared to make an important contribution to future energy and climate policies in the North Sea. Average wind forces at sea are high enough to promise a great potential in energy. In Germany, the installation of wind farms has just started. The pressure also includes maintenance activities like helicopter flights, supply ships or specialized shipyards.

Further important pressures as defined by the MA (2005) are for example (invasive) species introduction and removal, technology adaptation and use, external inputs (e.g. fertilizers, pesticides, irrigation water), harvest and resource consumption and natural physical and biological events (e.g. volcano eruptions, evolution). Since the installation of offshore wind farms and its impacts were defined as the main driver-pressure relation within the project, these additional pressures were not directly addressed.

Land and sea use (as pressures) can be indicated more easily than the drivers (Table 4.2). Using remote sensing data, maps or GIS, patterns of spatial use can be described. In order to characterize intensities and dynamics, socio-economic or environmental statistical databases can be explored. Because of the close linkage of pressures to human activities, pressure indicators are more directly responsive to changes and developments in the system (Burkhard & Müller 2008).

***Tab. 4.2:** Pressures on the environment in form of human action and potential indicators for their quantification as developed within the project.*

Pressure	potential indicators
Military	spatial extension of military areas, number of soldiers/marine, number of exercises
Protected areas	spatial extension of protected areas, types and use restrictions
Fishery	amount catches, fulltime vs. side business fishermen, fishing areas
Shipping	number of vessels, size of shipping lanes, number and size of ports, amount of cargo
Coastal protection	annual costs for protection, size of polder areas, lengths and heights of dikes
Raw materials	amounts of oil, gas, sand, gravel extracted per year, size and number extraction sites
Tourism	number of tourists, overnight stays, incomes from tourism
Agriculture	kg yield per year, size of fields and pastures, number of employees, turnover rates
Cable and pipelines	lengths of cable and pipelines, areas used
Waste disposal	amount of waste disposal per year, quality of sewage treatment, efforts beach cleaning
Mariculture	kg yield per year, employees, number of licenses provided
Infrastructure	lengths of road or railway network, number of ferries and passengers, hospitals
Offshore wind energy	installed capacity in MW, number of turbines, spatial extension, employees

For a first overview of potential future developments, free available German, European and worldwide online and printed data sources, like the UN Statistical Yearbook, EUROSTAT, FAOSTAT, globaldefence.net, the OECD fact book, EU energy and transport figures, German statistics (e.g. agricultural data) and Euromonitor International, were explored in order to discover trends and developments in the last decades. These general trends were used as background information for the scenario storylines. Most of the data refer to the county level or to the level of national statistics which in some cases might not be fully representative for the coastal zones but nevertheless, the numbers enable a rough estimation of past dynamics and future trends. Based on these numbers, an evaluation of the anthropogenic uses' particular future developments in the German coastal zones was carried out for a time span reaching from today to the year 2030 and is shown in Figure 4.4.

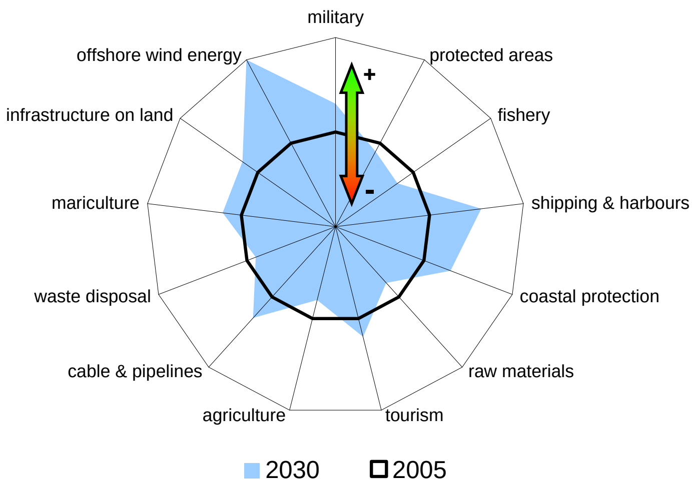

***Fig. 4.4:** Possible developments of pressu res in the Ger man coasta l zone; the d iagram sh ows the referenc e states in the year 20 05 a nd potenti ally i ncreasing or r espectively decreasing i mportance of the particu lar pressures in the year 2030.*

Figure 4.4 shows the consequences of the drivers' constellation described before (Figure 4.3). It shows a certain pattern of pressures (anthropogenic uses) on coastal and marine systems. As a consequence of Germany's political targets (BMU 2002, 2007) and the increased demand for energy, the installation of offshore wind power facilities has become a big issue. It can be a main pressure in marine and coastal areas in future. Beside offshore wind power, cable and pipelines, infrastructure on land, shipping and harbors will also increase in future as an effect of increased globalization and high demands on goods. As a first consequence of climate change, coastal protection measures and investments will increase. The potential increase in tourism is limited, because today high numbers have already been reached and existing capacities are fully utilized. Anthropogenic uses that will probably continue to be reduced in coastal zones are fishery, waste disposal, raw material exploitation and agriculture. Due to increasing human demands of space in marine and coastal areas, nature protection areas might be diminished.

4.5 Scenario applications - quantifications of drivers and pressures

In *Zukunft Küste - Coastal Futures*, assessments of driver-pressure relationships were carried out for all five scenarios of the project (see chapter 4.2). The quantifications of drivers and pressures were based on evaluations carried out in the project team and backed by literature and statistical data as described in chapter 4.4. Figure 4.5 shows one exemplary application for the scenario E1 - 'the North Sea primarily used as shipping space'.

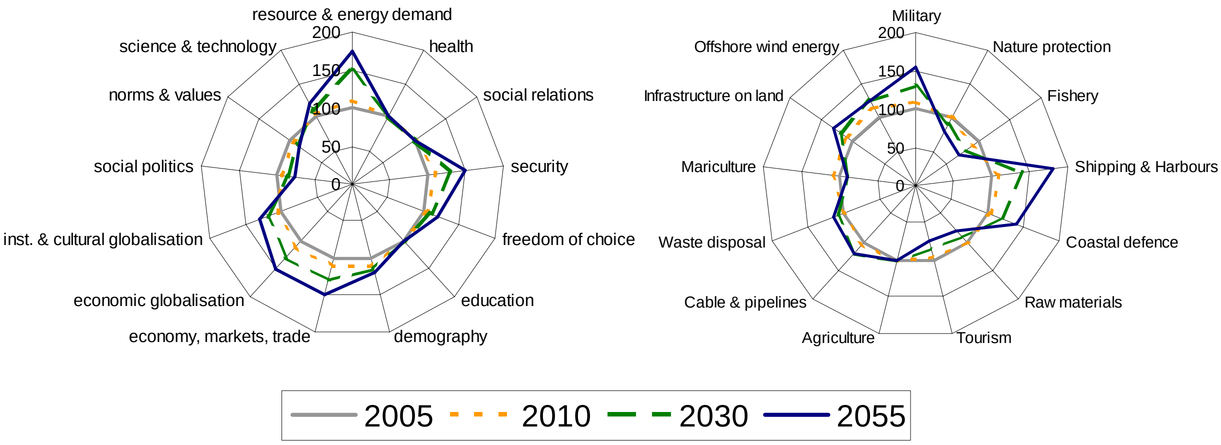

Fig. 4.5: *Future developments of drivers (left) and resulting pressures (right) according to scenario E1 - 'the North Sea primarily used as shipping space'.*

Figure 4.6 gives an overview of driver-pressure relationships estimated to be most relevant within the five scenarios. The drivers' assessment showed that the drivers 'demand for materials and energy' as well as 'norms and values' were identified to be key drivers for almost each of the five scenarios. This is probably due to the fact that the main topic of the case study was the installation of offshore wind farms, based on the demand of renewable energy. Therefore, all scenarios were linked to varying intensities of offshore wind power installations, ranging from no offshore wind power in the extreme case scenario 'A2 - the North Sea primarily used as nature protected area' to an installed offshore wind power capacity of 90.000 MW in the complementary extreme case scenario 'B1 - the North Sea primarily used as energy park' in the year 2055. In the latter scenario, about 25 % of the German North Sea area would be used as offshore wind farms (see Figure 4.7). Environmental impacts expected with such a development were assessed within the ecological impact assessments of the project (see chapter 5).

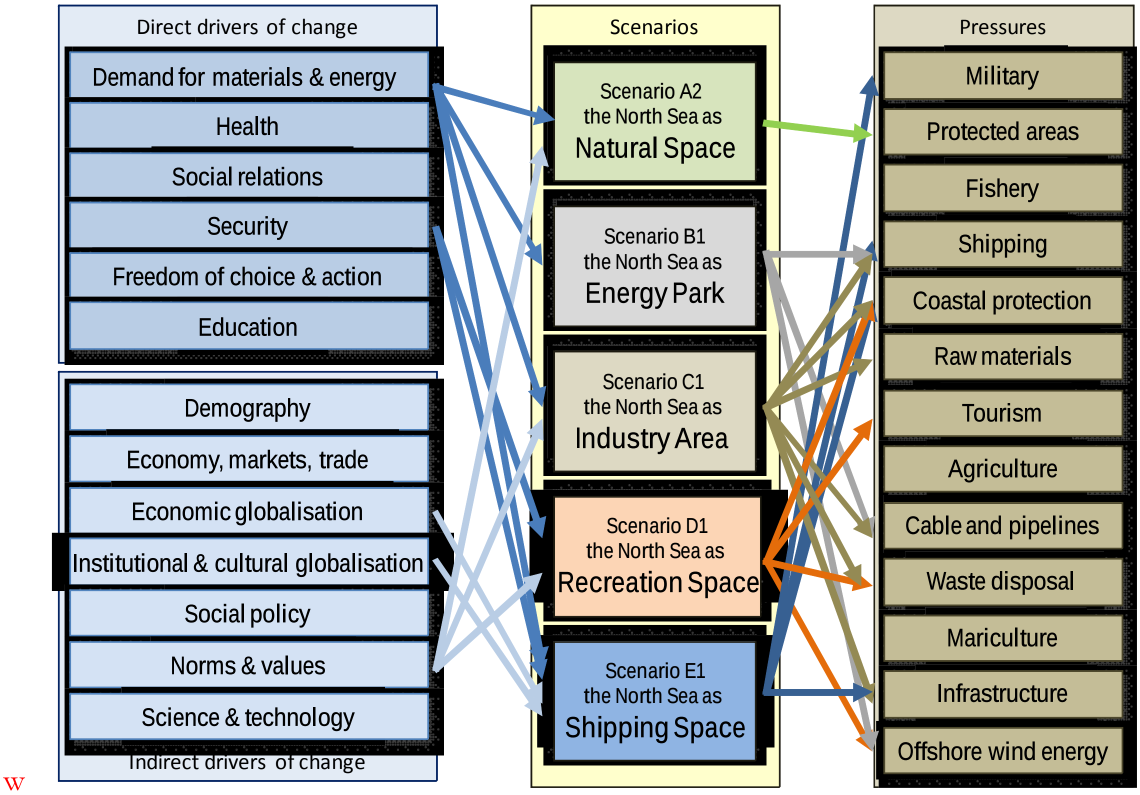

Fig. 4.6: The most relevant relationships between drivers (direct and indirect) and pressures of the five Zukunft Küste - Coastal Futures scenarios.

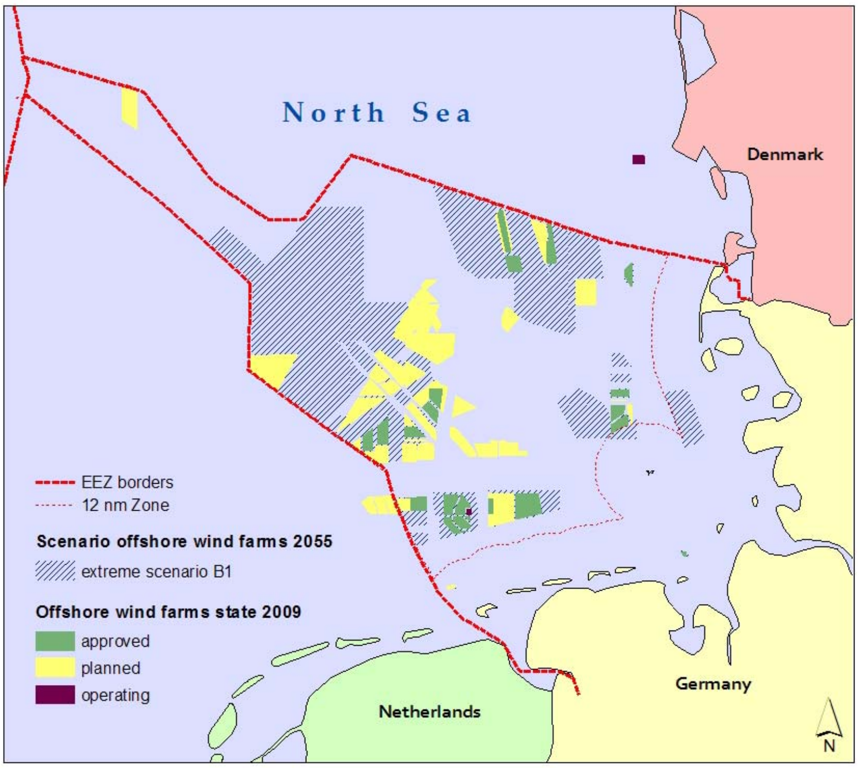

Fig. 4.7: Future offshore wind farm installations in the year 2055 as assumed in the extreme case scenario B1 - 'the North Sea primarily used as energy park' (data sources: project data and BSH).

4.6 Discussion and conclusion

The identification of drivers and pressures is an important part and should be the starting point in the DPSIR approach's application. It has been demonstrated to be a useful tool to organize the interdisciplinary work in a joint research project and to find a common conceptual framework. The quantification and assessment of driver-pressure relationships and their application in future scenarios for the German North Sea coast produced promising results and supported the understanding of cause-and-effect chains in a complex human-environmental system. One major challenge in such holistic interdisciplinary assessments is the high demand on data. Although a huge amount of data and information was generated within *Zukunft Küste - Coastal Futures*, the assessments of drivers and pressures had to rely on qualitative judgments in many parts. Therefore, the development of appropriate indicators and corresponding monitoring schemes in coastal zones is an important contribution in the context of integrated management of coastal zones. Monitoring schemes and indicators have to report on environmental pressures but also on direct as well as indirect drivers in order to gain information and early warning on potential future developments.

For the practical application of this complex framework in the project, agreements on the DPSIR components and on indicator definitions had to be made. Yet, some important components of human-environmental systems can be *drivers* as well as *pressures* and also *impacts*, like for example 'health'. Unfortunately, the DPSIR application was rather static due to methodological constraints and data limitation. However, as developments under real conditions and in future scenarios often show stochastic behavior, more dynamic simulations would have been appropriate. Nevertheless, the experience gathered in the course of the project showed that the identification of cause-and-effect chains and respective indicators is very useful and can help to support a responsible management of space and resources. The development of the different scenarios proved to be an appropriate method for the integrative assessment of future sea and coastal use patterns. They are a useful tool, applicable for internal project organization as well as for communication with stakeholders, decision makers and other scientists. The systematic DPSIR-based approach deployed in *Zukunft Küste - Coastal Futures* is transferrable to other regions and other case studies.

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5 Ecological Impact Assessment

Hermann Lenhart, Kai Ahrendt, Benjamin Burkhard, Stefan Garthe, Dominik Gloe, Wilfried Kühn, Bettina Mendel, Petra Nerge, Silvia Opitz, Anke Schmidt

In the summer of 2009 the German Government proclaimed the goal to establish an electricity production of 20.000 MW based on offshore wind energy by the year 2020 in order to reach the CO_2 reduction target and to mitigate the effects of climate change (see chapter 1). Along with this goal a law for the spatial planning within the German Exclusive Economic Zone was established, which had to solve the conflict between the high demand for space of these offshore wind farms (OWF) and their interference with shipping activities (chapter 2). Within this spatial planning framework the Federal Maritime and Hydrographic Agency (BSH) has been authorized to carry out the planning and licensing of OWFs. One possible reason for a refusal of applications for the construction of OWFs would be threats to the marine environment. In case of for example the red-throated diver this already leads to the exclusion of certain areas for the construction of OWFs (chapter 5.6). Nevertheless appropriate tools to assess the overall impact of OWFs to the marine environment are needed.

In the *Zukunft Küste - Coastal Futures* project a theoretical framework, as well as detailed model studies and data analysis were combined in order to assess the impact of OWFs on the marine environment in the German Coastal Zone (see chapter 3). Since the first piles from the Alpha Ventus offshore wind research site (for further information see: http://rave.iset.uni-kassel.de/rave/pages/welcome) were introduced not before 2009 in German coastal waters, hypothetical installations of future OWFs had to be chosen as case studies in form of scenarios (see chapter 4 for the scenario framework). For example, we considered that during wind farm construction phases, the insertion of turbine fundaments into the seabed is a disturbance of the rather sandy and muddy environment by increasing the suspended matter concentration in the water considerably. This will increase light attenuation which results in periods of light limitation for the primary production. How long the system will need to recover from this massive disturbance is not clear. On the other hand, scour protections along with installations of turbine fundaments as new hard substrate offer the possibility for the settlement of epifaunal communities. This could trigger a remarkable system dynamics leading to the establishment of artificial reef ecosystems with a high biodiversity. Another, less optimistic projection of future development is the assumption that the disturbance during the construction phase is so severe that the ecosystem might face continuous degradation after the construction is finished (see also Burkhard et al. 2009).

Starting with the illustration of possible progress options in the development of the marine ecosystem with regard to the installation and the operational phase (Figure 5.1), an impact assessment was applied that covers a wide range of aspects related to possible changes of the marine environment. The assessment was based on scenario simulations from different models, GIS application of seabird observations as well as existing data analysis from research results from existing OWFs within the North Sea, like Horns Rev. The results from these different methods (Figure 5.2) were combined with a standardized output so that defined key parameters finally entered the impact assessment (see chapter 5.7).

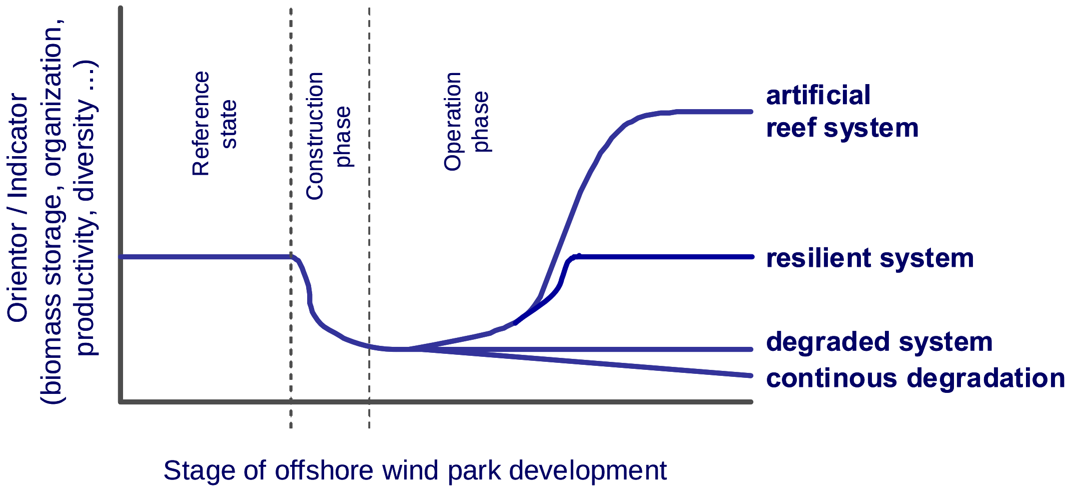


***Fig. 5.1:** Hypothetical dynam ics of marine ecosystems regarding the insta llation of offs hore wind far ms (Figure from Burkhard et al. 2009).*

With regard to the research framework of the whole *Zukunft Küste - Coastal Futures* project, the assessments described here denote the ecosystem State component within the DPSIR model (see chapters 3 and 4). The individual ecosystem components which were analyzed were all integrated into the holistic ecological integrity assessment. Ecological integrity again is the base for the provision of regulating, provisioning and cultural ecosystem services, as further elaborated in chapter 8.

Generally one can distinguish between the construction and the operational phase of the OWFs (Figure 5.1). For the construction phase the duration and the increase in the suspended matter concentration are analyzed, both on the physical environment alone (chapter 5.1), as well as on the possible impact on the ecosystem via changes in the net primary production (chapter 5.2). In relation to the operational phase a number of different aspects are looked at, starting with the impact of the wind field changes by the wake effect on the hydrodynamics within and outside the OWF (chapter 5.3). Further changes due to the introduction of the piles on the velocity field and the resulting impact on the bottom topography were part of the analysis in chapter 5.1.

The question whether the introduction of additional hard substrate by the piles and the scour protection might lead to a possible increase in mussel colonies that might start the development towards an artificial reef structure is dealt with in chapter 5.4. In which way the fish community reacts on these possible artificial reef in form of an increased diversity is analyzed on the example of the Dutch Nearshore Wind Farm (chapter 5.5).

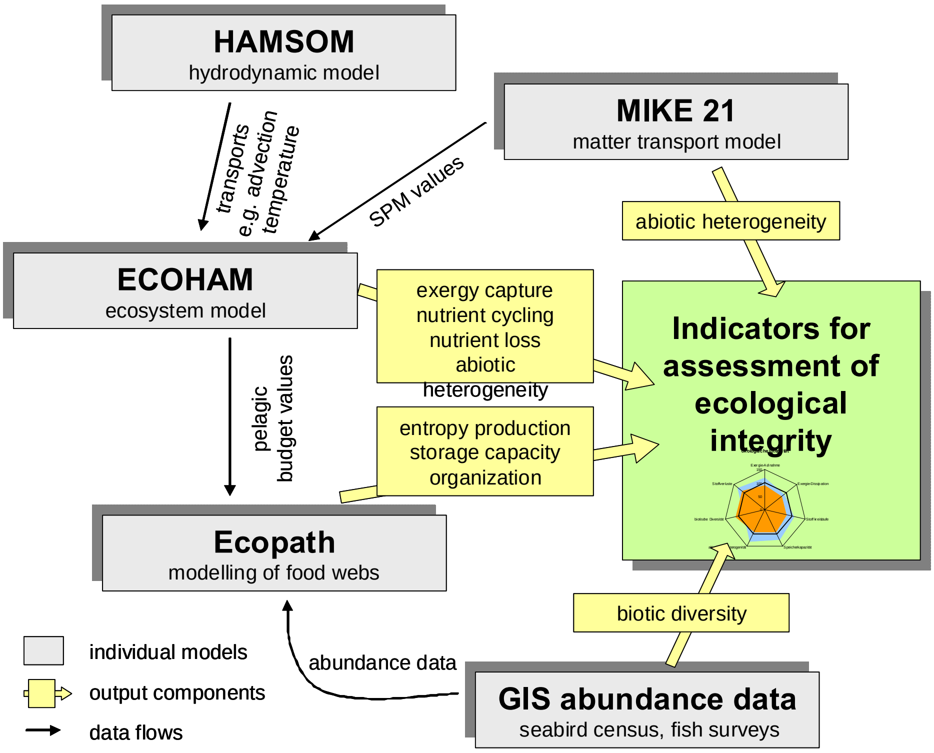


Fig. 5.2: Model used for the quantification of ecological integrity indicators, their linkages and data flows (Figure modified from Burkhard et al. 2009).

In contrast to these 'positive' development options, the situation for the seabirds above water appears to be more difficult. The German part of the North Sea hosts internationally important aggregations of seabird species during all seasons of the year. These birds face a variety of anthropogenic activities that are assumed and/or known to exert pressures on some or all species. Effects of offshore wind farms are described, with particular emphasis on habitat loss, by two diver species. It has furthermore been shown in chapter 5.6 that cumulative effects may occur. This issue needs far more attention in the future due to increasing demands of marine resource use by humans. Other species which might be seriously harmed by offshore installations are marine mammals (Gilles et al. 2009). However, marine mammals were not analyzed any further in the project.

Finally these different aspects are combined into an ecosystem integrity analysis to derive an overall impact assessment for the ecosystem. How the different parts of the individual model and GIS-activities are integrated into this overall assessment ecosystem in presented in chapter 5.7.

5.1 Impacts of offshore wind farms on sediment structure and the water column during construction, and changes in bottom topography during the operation phase

Kai Ahrendt, Anke Schmidt

Constructions in the sea will have influences on hydrological parameters, i.e. currents and waves. Depending on the extension of offshore constructions and the current field, the influence will be varying in their extent. For the introduction of offshore wind farms (OWF), this can lead to turbulences which consequently can result in erosion in the direct proximity of a wind mill pile.

During the installation of the wind mill foundation, suspended sediments will be discharged. This can lead from reduction to light attenuation or to the direct sediment cover of organisms.

Both these effects during construction and operational phase have been considered in the *Zukunft Küste - Coastal Futures* project. Therefore, manifold environmental impact assessment studies are carried out for planning these OWFs. From the large amount of wind farms planned in the German EEZ, a representative area in the northern part of the German EEZ was chosen (Figure 5.3). The wind farm DanTysk was selected as test site for our model study, which is planned 70 km west of Sylt Island with local water depths of about 25 to 35 m.

Model application

For the model study the model MIKE21 from the Danish Hydraulic Institute (DHI, http://www.dhi.dk), one of the leading sediment transport models world wide, was used. The modeled area covers the northern part of DanTysk and was extended 6.000 m in W-E direction and 5.400 in S-N direction to eliminate effect during the modeling at the edges.

As the basis for modeling sediment transport and the extension of the suspended matter during erection, two different hydrodynamic models (HD) were established: one for the complete area and one for the 600x600 m area.

The bathymetry in the study for the complete area (OWF scenario) within MIKE21 is based on a 20x20 m grid, which is a compromise between calculation time and resolution. A grid with a mesh size of 20x20 m was calculated using the Kriging methodology with the program SURFER 8. The calculated error was less then 0.1 m. The topography input data were derived from the official map 'Deutsche Bucht Nord' (1508) from the BSH, mapped in 1990.

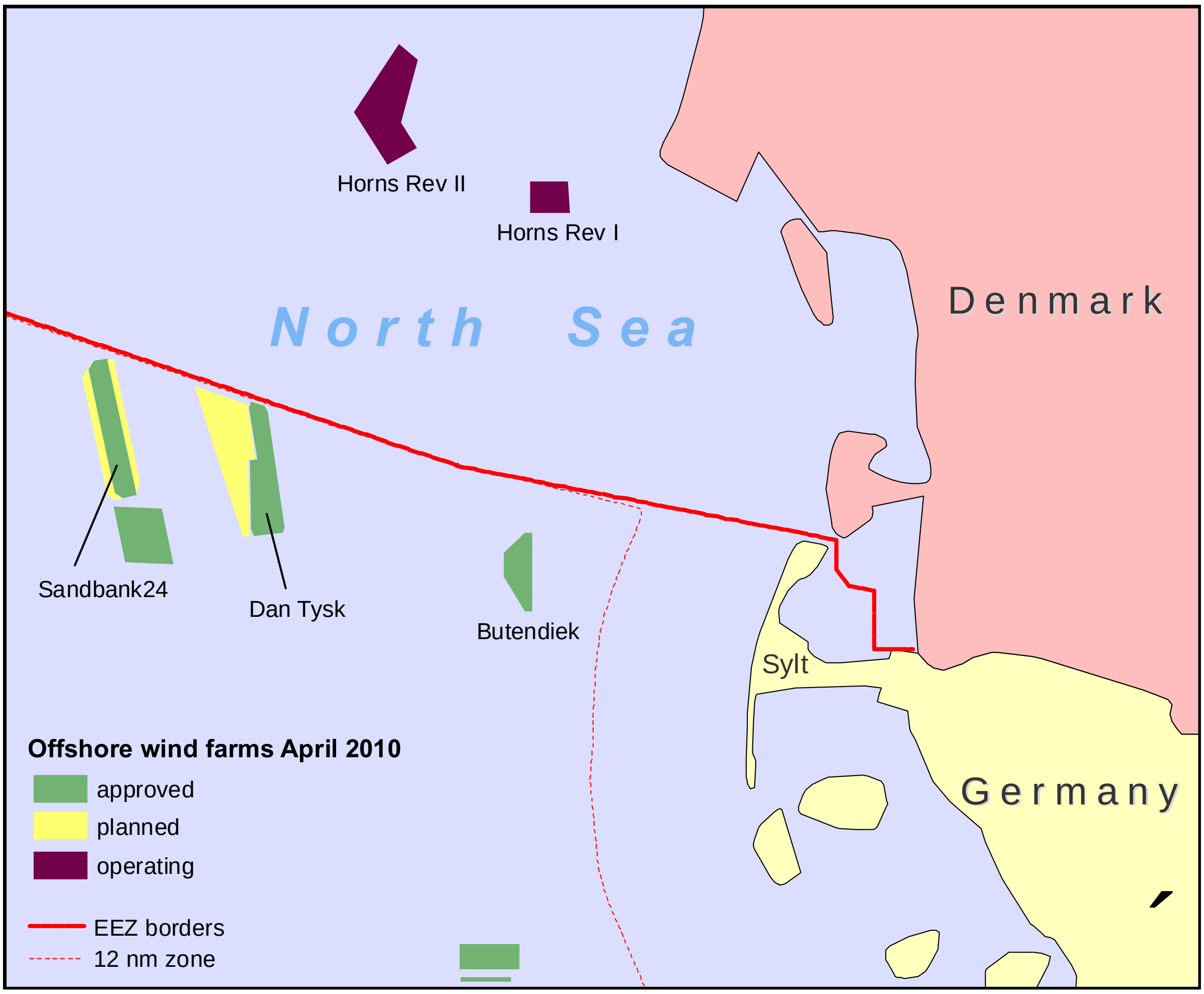


***Fig. 5.3:** Overview about the investigation area (data sources: project data and BSH).*

In the OWF scenario, a total of 144 piles were placed into this bathymetry with a distance of 1.000 m apart from each other. A single pile has a diameter of 20 m in relation to the grid size, corresponds to the installation of monopiles, which is expected to be used as a foundation.

Since a pile with a diameter of 20 m is an extremely large foundation a model with a higher resolution was constructed. In order to resolve finer structures around a single pile, a model for a 'Single Pile scenario' was created where the pile has a diameter of 8 m. This area has a grid space of 1x1 m and a 600x600 m extension with a water depth of -25 m, still representing the shallowest point measured in the vicinity of the OWF DanTsyk.

Both models were run for a real time period of 14 days (14.12.-28.12.2005). The modeled time step was 60 seconds. For the 28 tidal periods the forcing was extracted in the following way.

Modeling

A pile with a diameter of 20 m is an extreme large foundation. Therefore a secondary model was created. This area has a grid space of 1x1 m and an extension of 600x600 m with a water depth of -25 m as measured as shallowest point in DanTsyk.

Modeling with wave influence showed that there is no influence by the waves to current and topography. The proportion between wave high and water depth is to low so that the wave has no appreciable influence to current and sediment transport. Instead of time series extreme values were taken into account to reduce the calculation times.

The modeling could start after preparation, plausibility check and adaptation of extern input data were finished. In the first step the 20x20 m grid was calculated. The 20x20 m grid size was a compromise between calculation time and resolution. 144 piles were situated in this area with a distance of 1.000 m.

A parameter study was carried out to identify the sensitivity of additional parameters which were not measured in nature.

As basis for the modeling of sediment transport and extension of the suspended matter during erection two different hydrodynamic models (HD) were established: one for the complete area and one for the 600x600 m area.

Forcing parameters

There were no hydrological parameters available of the DanTysk area directly. The nearest measurement point is the gauge 10 km west of Sylt Island in a water depth of 13 m. This gauge was build in 1986 and delivers data continuously. Hydrological data were taken from this gauge.

Wave data are registered every 2 hours at the gauge of Sylt Island. During storm events the registering interval is increased to 20 minutes. An influence on the wave parameters between DanTysk and Sylt Island was neglected, because the water depth of 25 to 35 m and resp. 13 m is too high to have a significant influence on the registered data.

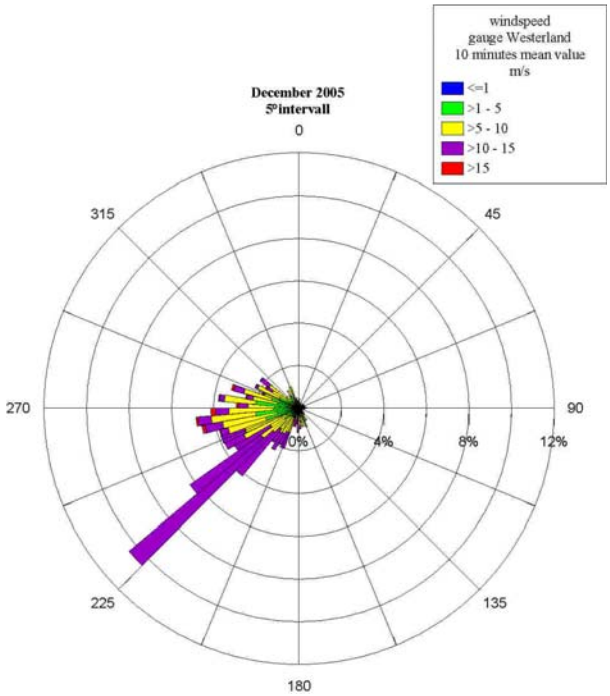


Fig. 5.4: *Wind rose from the gauge 10 kilometers westerly Sylt Island for December 2005.*

The tidal parameters are assumed to be more or less the same in DanTysk and Sylt Island and were therefore taken directly from the gauge data. The important wind parameters (Figure 5.4) were also taken from the gauge of Sylt Island, because there is no influence on the wind between DanTysk and Sylt Island. The wind-field in December 2005 was measured without any gaps and represents a w-s-w direction which is typical for this time of the year. Easterly wind did not occur. The mean wind speed was between 10-15 m/s.

Sediments

High resolution sediment data were not available for that area. The map from Figge (1981) gives an overview of the sediment distribution in that area. In the area's centre, sediment data were available from the EIA mapping, kindly offered by the former developer GEO. This information where combined to generate a sediment map for the numerical model MIKE21

Wave influence modelling showed that there is no influence of the waves on currents and topography. The proportion between wave height and water depth is too low to have a significant influence on currents and sediment transport. Instead of time series, extreme values were taken into account reducing the calculation times.

A parameter study was carried out to identify the sensitivity of additional parameters not measured in nature, e.g. bottom roughness manning number.

Suspended matter

Based on the hydro-dynamical model, a particle transport model was carried out using the model MIKE21/3 PA. An assumption was that during 6 hours the total sediment dredged for the foundation of a mono pile was spilled into the water column. This corresponds with the volume of a mono pile penetrating the sea floor. The worst case would be spilling the sediments in the upper 2 m of the water column. The settling velocity was taken from the sediment data, e.g. of silt.

From the 144 piles at DanTysk in the OWF scenario, it was assumed that 2 piles were penetrated into the seafloor at the same time. The averaged and the instantaneous concentration were calculated in kg/m^3.

Directly at the spill source concentrations of 5 mg/l were calculated. In a distance of 150 m the concentration is already reduced to 2 mg/l (Figure 5.5). The spill cloud can still be detected up to 7 km away, yet with minimal concentrations of less then 0.5 mg/l. The width of the suspension cloud is 40-80 m.

In the Single Pile scenario the suspension cloud in the area with the 1x1m grid shows dispersion in east to north-east. In the lee of the pile concentrations of 2.000 mg/l can be detected. In 100 m distance the concentrations are reduced to 140 to 280 mg/l (Figure 5.6). In 300 m distance the concentration is less than 2 mg/l.

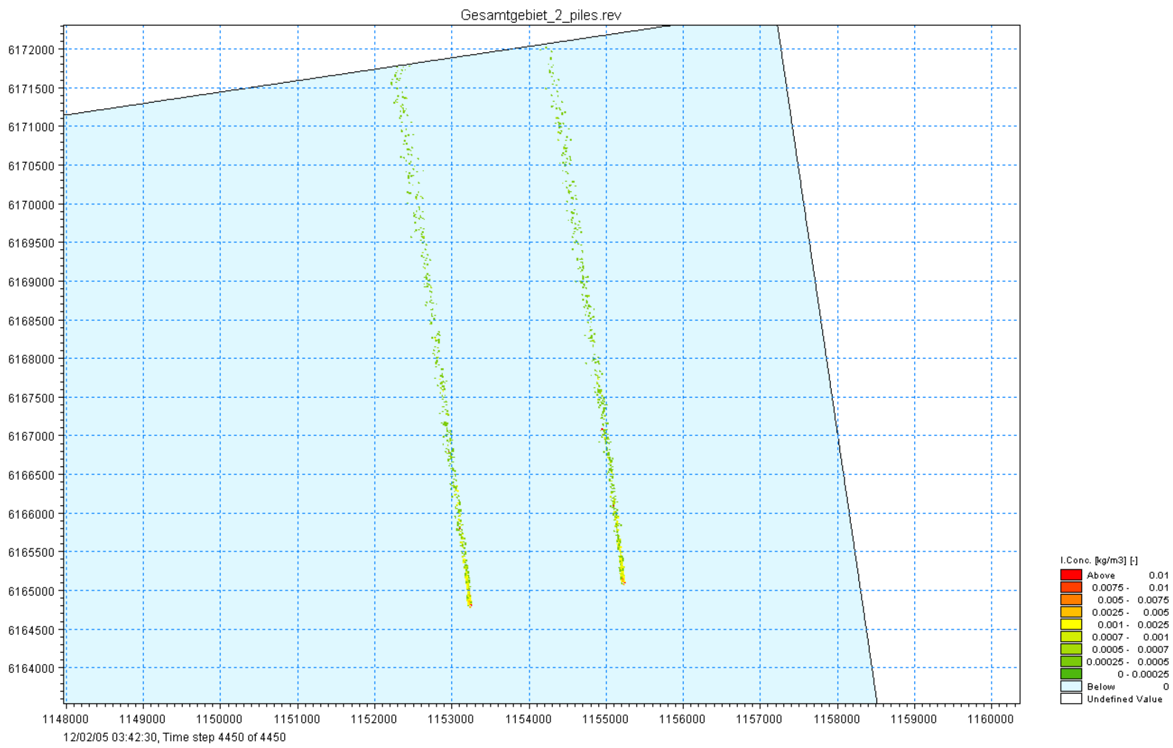


Fig. 5.5: *Suspension (kg/m^3) behind two piles during erection.*

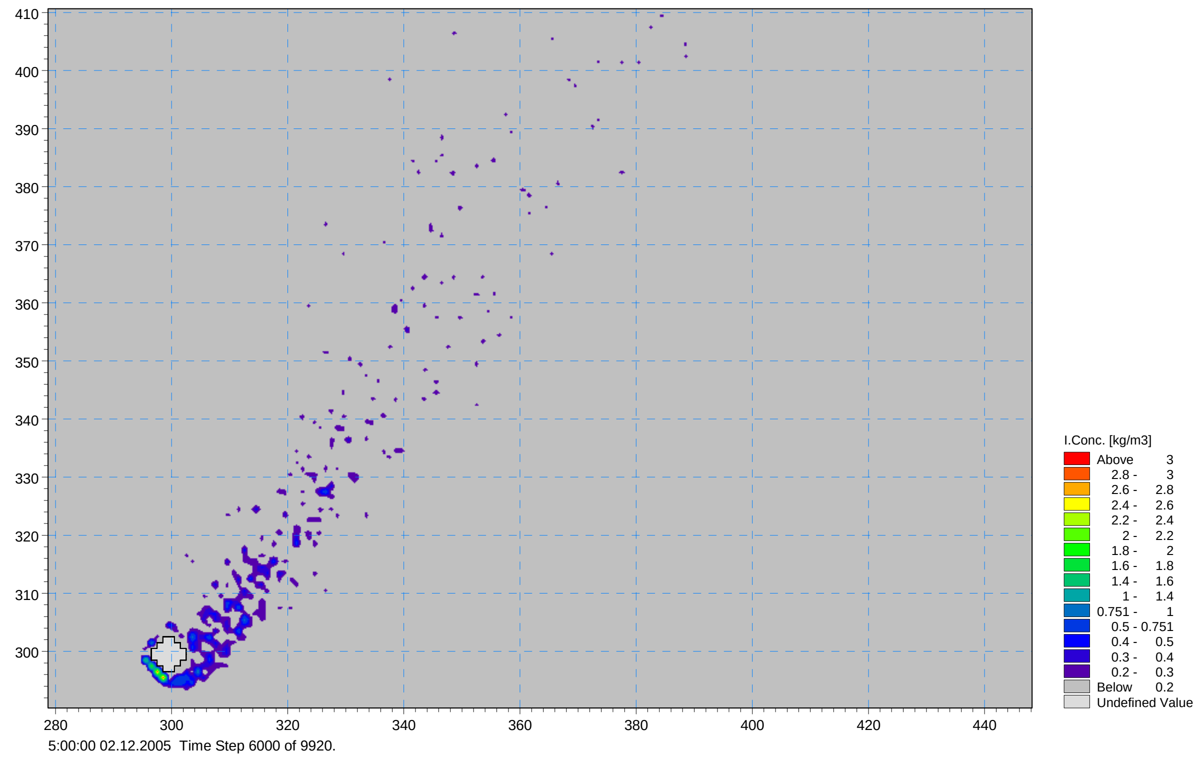


***Fig. 5.6:** Suspension (kg/m³) behind a pile with a resolution of 1x1 meter.*

Sediment transport

Erosion and sedimentation analysis was carried out with the help of the MIKE21 ST model. MIKE 21 offers different sediment transport formulas for calculation. A sensitivity study, using different parameters in combination with different transport formulas showed differences in calculated erosion ranging from 1 cm to 7 cm, computed with the same forcing data. The formula of Engelund & Hansen (1976) with 7 cm erosion was chosen to calculate the maximum erosion depth based on different formulas.

The maximum (vertical) erosion of 3 m occurred in the north-western part of the investigation field directly behind a pile. Erosion can be detected up to 80 m surround a pile with depth of 10-20 cm. Sporadic sedimentation up to 1.5 m occurred. The changes have only values in the order of decimeters. During a theoretical storm (with a wind speed of 50 m/s) erosion and accumulation did not increase significantly. Additional erosion compared to the run without piles could not be observed within the OWF area.

In the single pile scenario changes in the sedimentation depths around a single pile occurred in the scale of just some centimeters and can not be detected some meters away from the pile. Topographic changes do not occur or are not relevant.

During a theoretical storm with a wind speed of 50 m/s the erosion is limited to 3 m around the pile with maximum erosion depths of 2.2 m. In a distance of 6 m the erosion depth is less than 10 cm (Figure 5.7).

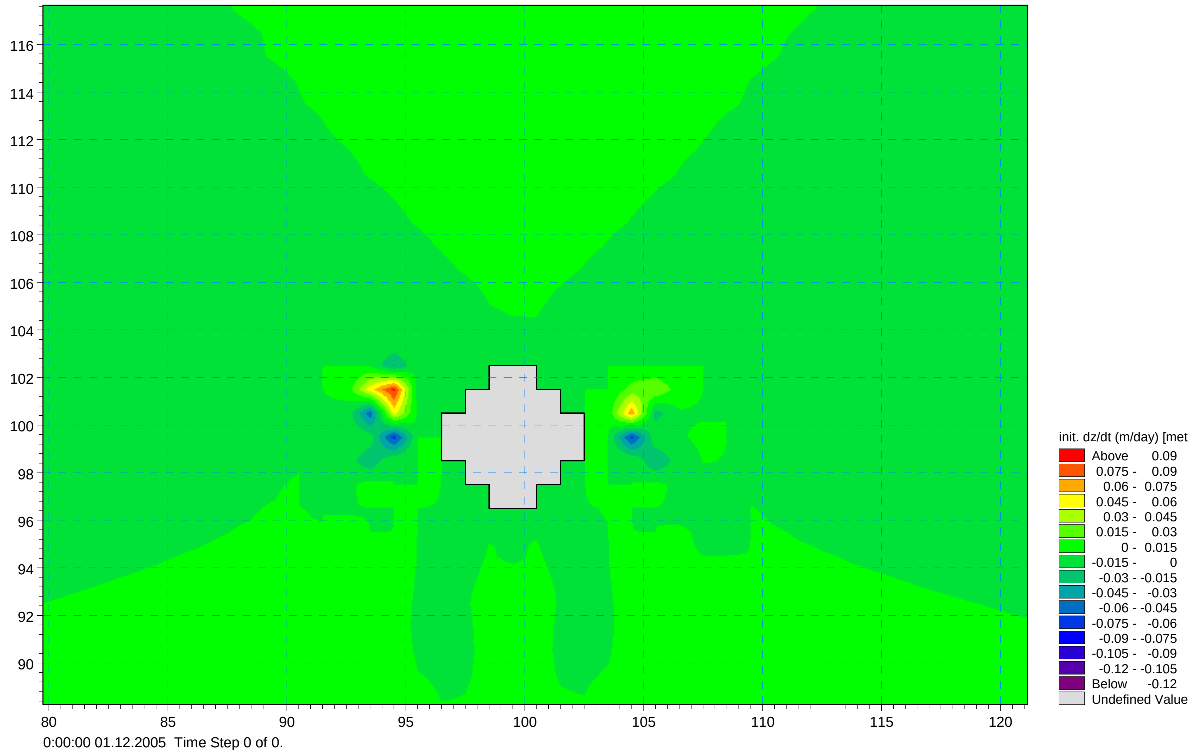


Fig. 5.7: *Topography changes (m/day) behind a pile with a resolution of 1x1 meter.*

Current

The U (west-east direction) and the V (south-north direction) current vector components were calculated with MIKE21 HD. Without piles, maximum current velocities (V) of 1.28 m/s in north direction were identified. This current occurred in the area with the shallowest water depth of -23 m. For the simulation with the piles of the OWF introduced into the model domain values of 0.124 m/s were calculated in the same area. The maximum current velocity occurred during the lateral circulation around the pile. In comparison to neighboring regions, an increase of 1.2 cm/s was calculated. Directly behind the pile, a reduced current velocity of 0.1 m/s was recorded.

The main current velocity in the single pile scenario in the 1x1 m grid is more or less about 0.1 m/s. During the lateral circulation of a pile, the current velocity increased to 0.2 m/s. Behind the pile, turbulences occurred with current velocities between -0.1 and 0.025 m/s (Figure 5.8).

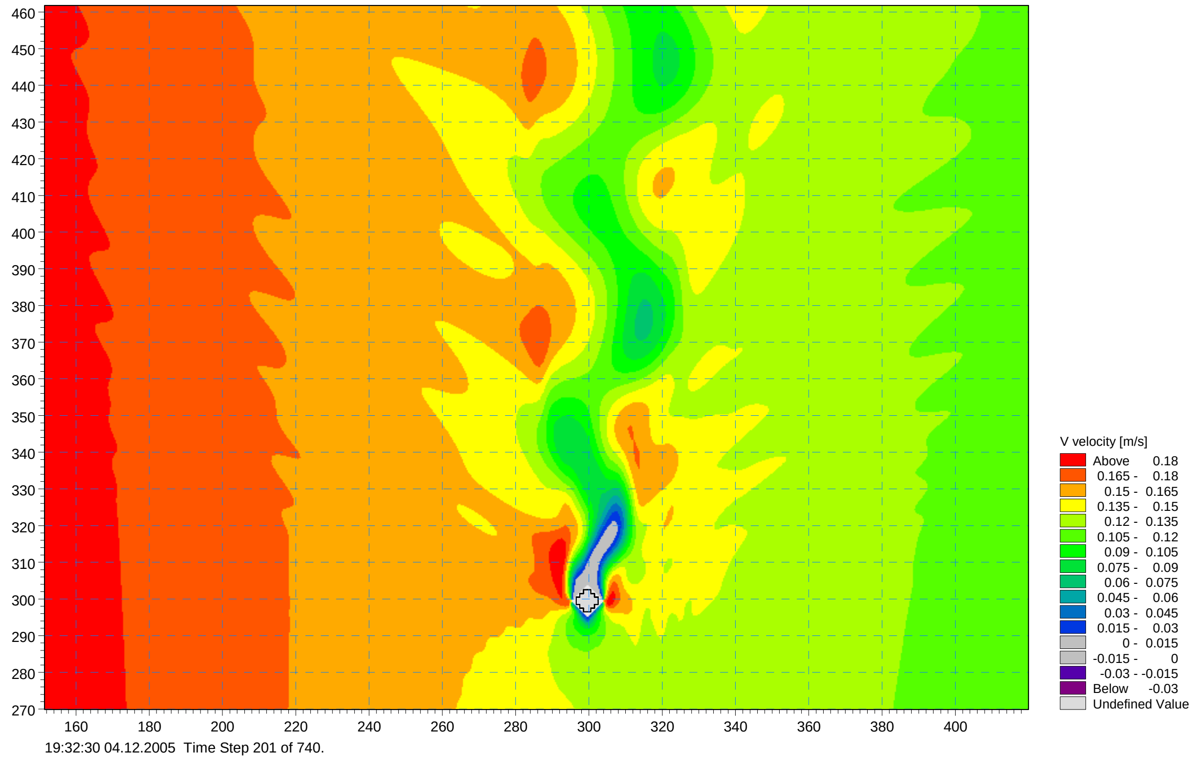


Fig. 5.8: *Current component V (m/s) behind a pile with a resolution of 1x 1 meter.*

Conclusion

The presented model studies showed that there are no relevant influences expected from the mono piles on sediment structure and morphology as well as on current velocity fields. Cumulative effects or rather influences between single piles do not exist. Local erosions around the pile only have little impact on the abiotic system. From a geological-sedimentological point of view, there are no concerns regarding the construction of offshore wind farms under the modern climatic conditions in this area.

The suspended matter cloud is restricted in time and space. The simulation agrees with the findings from a DHI study (DHI 1999), where the changes in the suspended sediment concentration due to dredging does not exceed 2 mg/l for more than 10 % of the time. Therefore this value was selected as a useful threshold for the assessment on the installation of offshore wind mills, which is then added on the natural background concentration for SPM.

5.2 Ecological impact during the construction of offshore wind farms

Wilfried Kühn, Hermann Lenhart

During the construction of OWFs increased suspended matter concentrations occur as a result of the mechanical disturbance of the sea bed (see previous chapter 5.1). This increase in the concentration of suspended matter (SPM) in the water column can lead to light limitation during the photosynthesis of algae and to modification in the nutrient cycling within the ecosystem. Previous studies with the ecosystem model ERSEM (Nunneri et al. 2008) showed a clear impact of the changes in the SPM concentration on the net primary production and the associated nutrient cycling. Since this study was not able to resolve the vertical structure of the water column, the present study is based on the three-dimensional ecosystem model ECOHAM (Ecological Model Hamburg).

The coupled physical-biogeochemical or ecosystem model ECOHAM has been used to calculate nitrogen and carbon budgets in relation to varying NAO conditions (Pätsch & Kühn 2008, Kühn et al. subm.). The physical part is based on the hydrodynamic model HAMSOM (Hamburg Shelf Ocean Model, Pohlmann 1996). The biogeochemical part represents the pelagic and benthic cycles of carbon, nitrogen, phosphorus, silicon and oxygen. The state variables included are: diatoms and flagellates, micro- and mesozooplankton, slowly and fast sinking detritus, labile and semi-labile dissolved organic matter, and bacteria, dissolved inorganic carbon (DIC) and oxygen, as well as the nutrients NH_4, NO_3, PO_4, SiO_4. In shallow areas, phytoplankton growth is limited due to self-shading and light attenuation by silt. To include the latter effect, daily silt data from Heath et al. (2002) were interpolated to the grid and prescribed at each grid point. The ECOHAM model has been used to assess the impact of riverine nutrient reduction scenarios (Lenhart et al. 2010) in the frame of OSPAR ICG-EMO (Intersessional Correspondence Group on Eutrophication Modelling).

In order to assess the impact of the construction phase of OWF on the ecology within a water column, simulation with the ecosystem model ECOHAM were carried out for the OWF DanTysk (see Figure 5.3) with increased SPM concentration based on the studies in the previous chapter 5.1. To represent a realistic SPM scenario, it was assumed that the construction can only be carried out during the calm summer period. Therefore, an additional SPM load of 2 mg/l was added onto the background concentrations during the construction period, starting from the beginning of May until the end of September, with a decline toward the background concentration for one more month (Figure 5.9). Since the OWF site DanTysk has a depth of only 28 m and the water is well mixed in this part of the North Sea, the increased SPM concentration is applied to the whole water column.

The changes associated with this increased SPM concentration from the SPM scenario are analyzed in comparison with an ECOHAM standard run, which represents an undisturbed ecosystem with respect to OWF construction. The comparison of the time series of the phytoplankton concentration (Figure 5.10) obtained from the standard run and from the SPM scenario, respectively, shows an enhanced phytoplankton concentration during the period when the SPM concentration is increased in the SPM run (day 100 to day 300). This indicates that light limitation for this period as result of the increase of the SPM concentration in the SPM run is not the dominant mechanism.

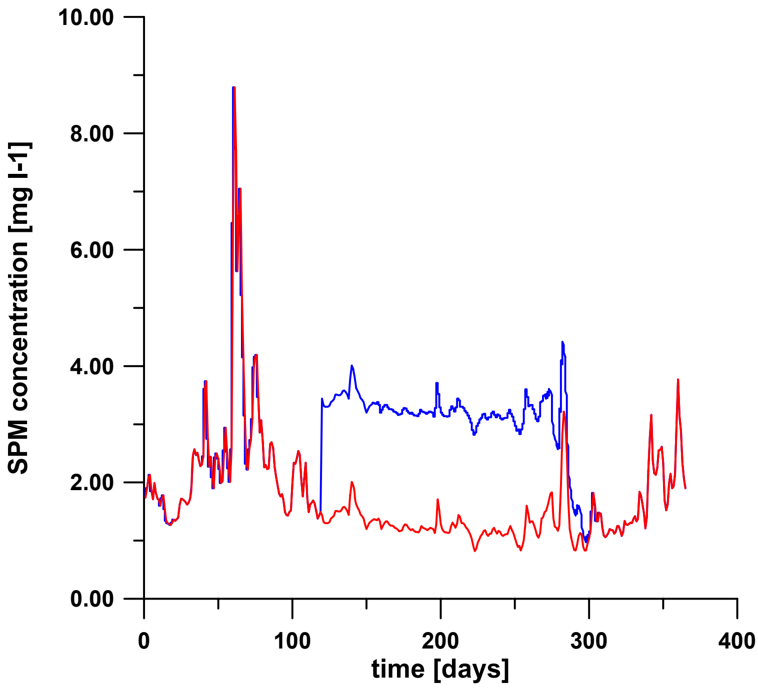


Fig. 5.9: *Background SPM concentration (in red) and enhanced concentration (in blue)*

There is a difference between the phytoplankton time series which starts in the middle of the spring bloom and lasts for the whole summer period. However, the result does not match the expectation, since the SPM scenario exhibits higher phytoplankton concentration than the standard run. At the end of the period with increased SPM concentration the phytoplankton concentration match again and show the same concentration till the end of the year.

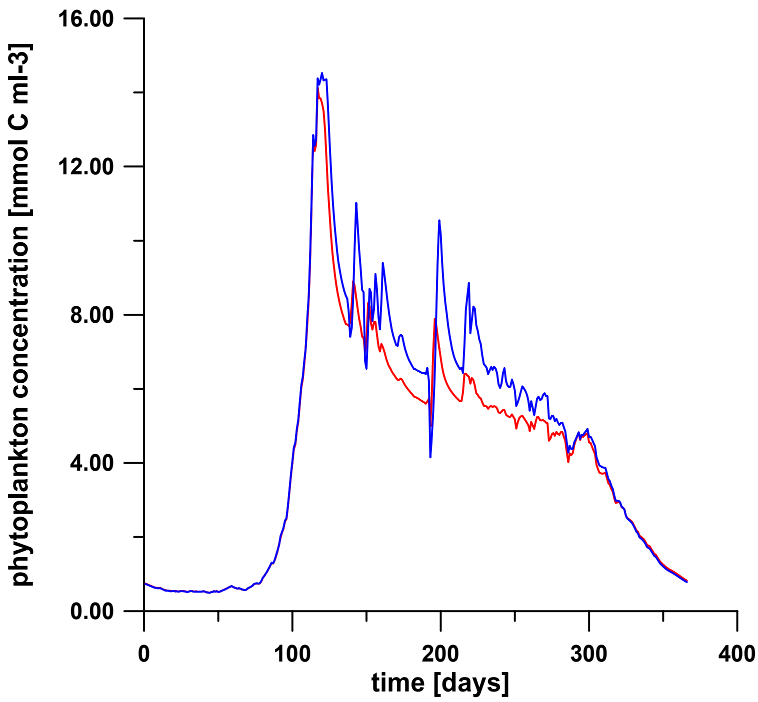


Fig. 5.10: *Phytoplankton concentration. Standard run: red; SPM scenario: blue.*

The differences in the actual light climate among the two simulations are presented in Figure 5.11 in form of the ratio between the incoming light at the surface and the biologically available light for the primary production in the first layer (at a depth of 5 m). One can see a continuous reduction in the available light available for the primary production in that layer during the time of the increased SPM concentration between day 100 and 300. However, considering the peak in the SPM concentration in spring (Figure 5.9), probably induced by a storm event, it is interesting to note that this natural event has a higher impact on the primary production than the increased SPM concentration as a result of the OWF construction (Figure 5.11, blue line), however for a much shorter period of time.

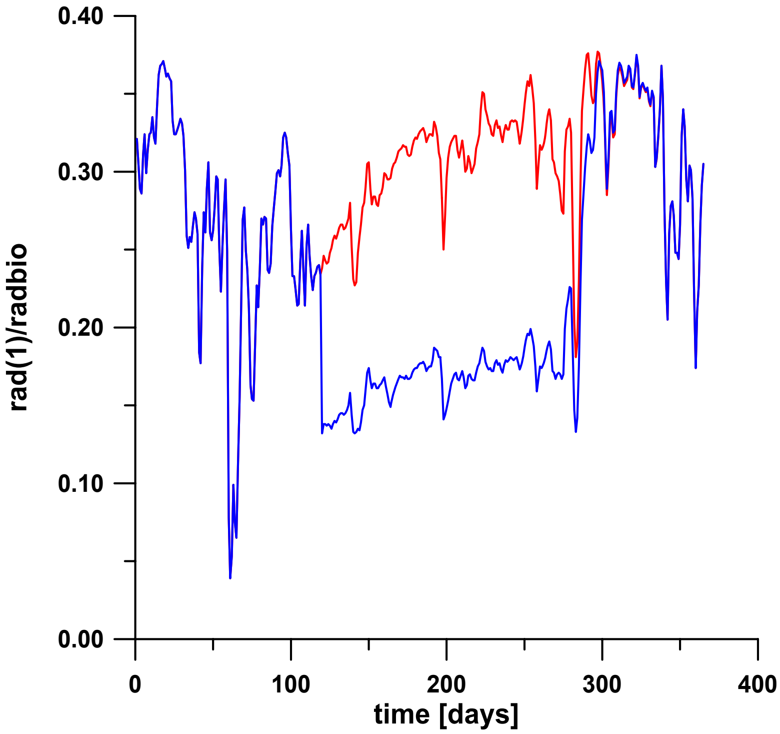
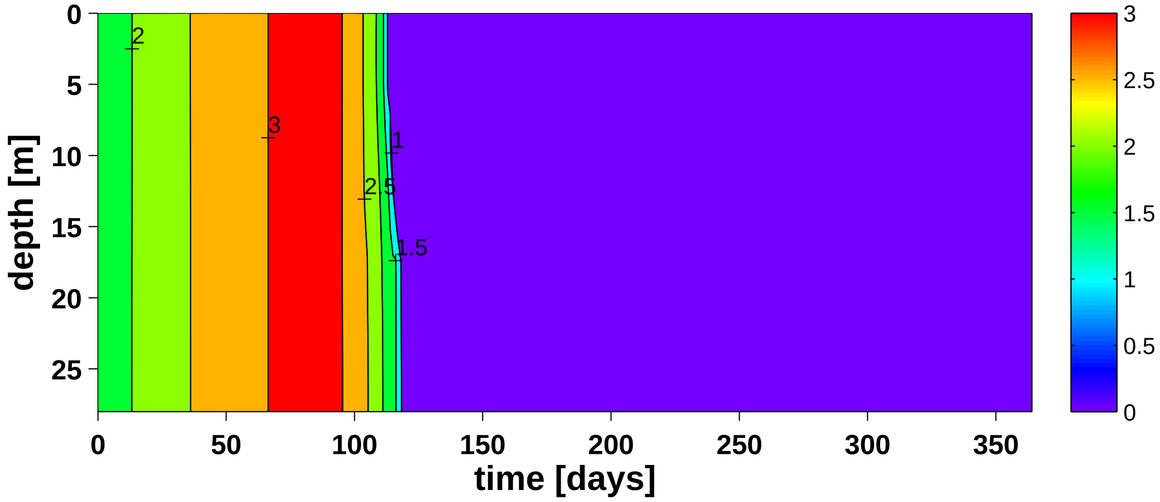


***Fig. 5.11:** Ratio between the light at 5 m depth rad(1) and the incoming light at the surface radbio*

So the light climate does not explain the higher phytoplankton concentration in the SPM scenario in comparison to the standard run for the time of increased SPM concentration. Therefore it is necessary to have a look at the nutrient cycle. In the standard run the phytoplankton growth is nitrate-limited during the time after the spring bloom. This can be seen in the vertical distribution of the nitrate concentration over the year for the standard run (Figure 5.12, upper figure) where nitrate is totally diminished for most of the year. In contrast, there are events of higher nitrate concentration in the SPM scenario (Figure 5.12, lower figure) with values of 0.5 mmol N/m^3 near the bottom, e.g. before and after day 200. In the dark part of the water column near the bottom ammonium (not shown here) is transferred into nitrate by nitrification. This process is light-limited and increases at reduced light intensity.



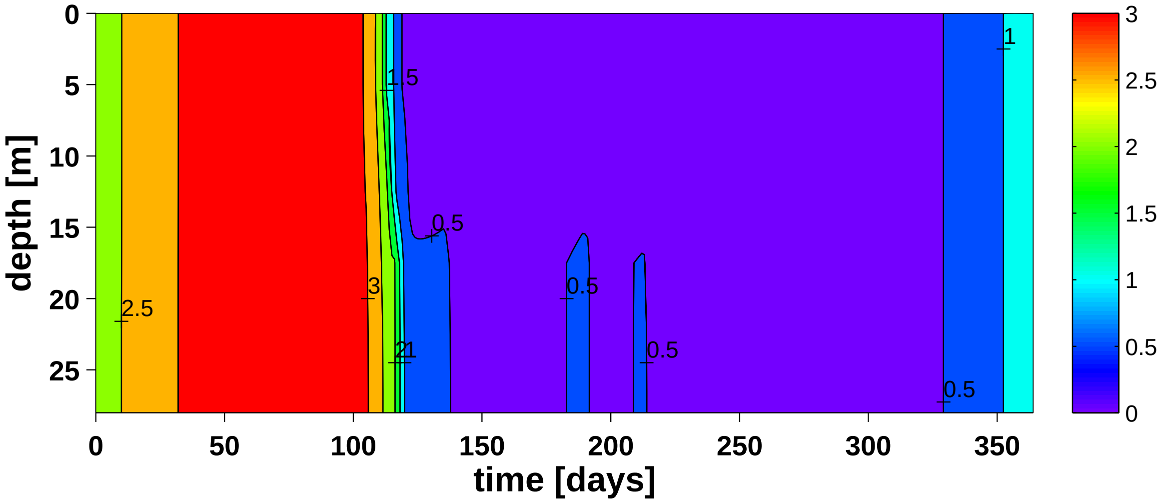


Fig. 5.12: Vertical distribution of nitrate concentrations (mmol N/ m³) for the standard run (upper) and the SPM scenario (lower).

During the time with increased SPM concentration, reflecting the OWF construction period, larger parts of the lower water column have less light in comparison to the standard run. In these deeper areas nitrification takes place which allows to overcome the nitrate limitation at the surface, where there is still enough light for primary production. This is the mechanism by which the phytoplankton production can be intensified in the SPM scenario, even though there is less light available. Figure 5.13 shows the vertical distribution of the phytoplankton concentration for the standard run (Figure 5.13, upper figure) and the SPM scenario (Figure 5.13, lower figure). After the spring bloom, one can see that at times when the nitrate distribution near the bottom shows values of 0.5 mmol N/ m^3, there are periods of higher phytoplankton concentration (about 8 mmol C/ m^3, marked in red) in the SPM scenario (Figure 5.12, lower figure) in comparison to the standard run (Figure 5.13, upper figure).

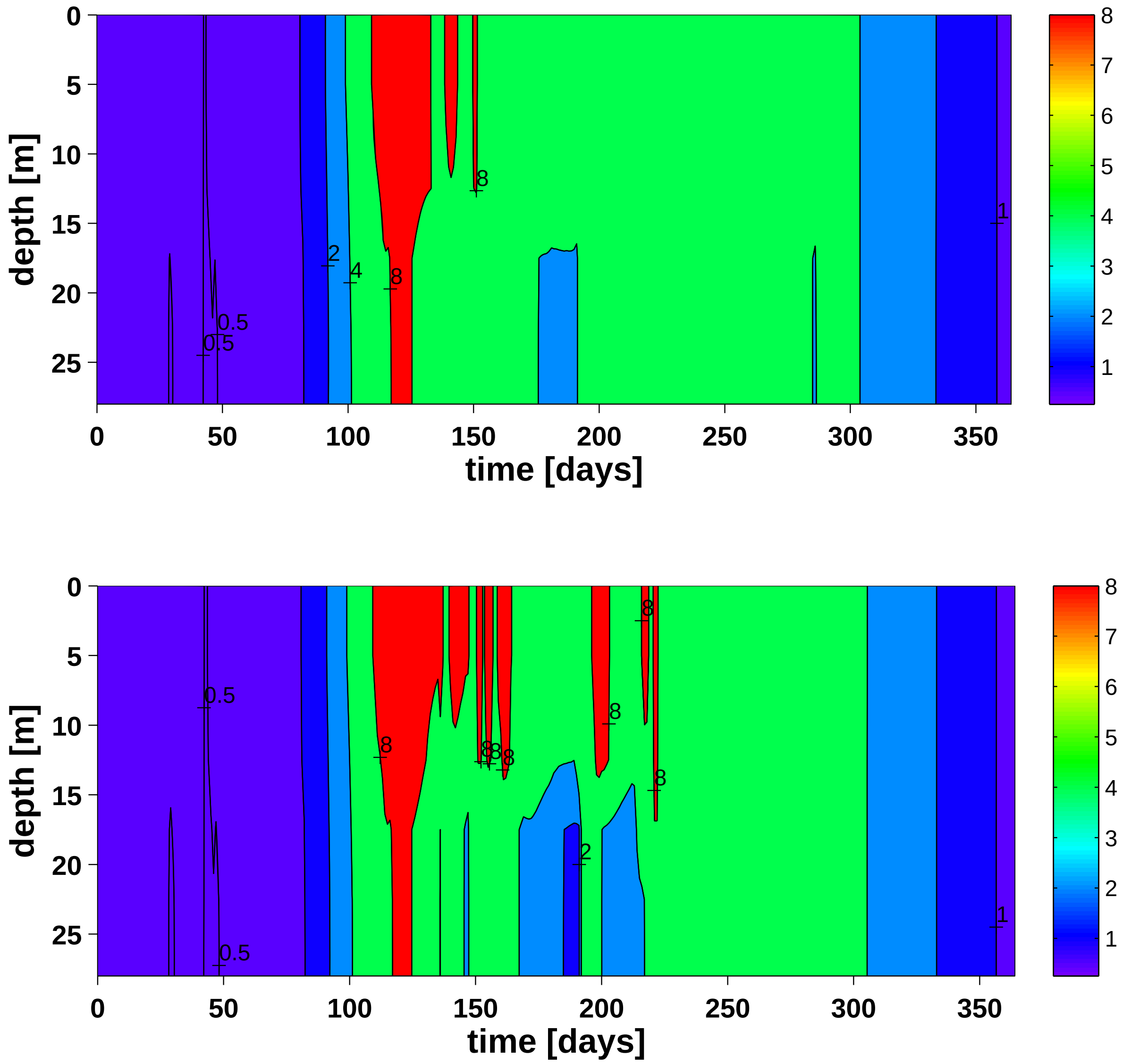


Fig. 5.13: Vertical distribution of phytoplankton concentrations (mmol C/ m³) for the standard run (upper) and the SPM scenario (lower).

This dynamical interaction between increased nitrification in the deeper parts of the water column in combination with generally nitrate-limited summer growth period in this region of the North Sea explains this surprising result of increased primary production during the construction period. During the time with increased SPM concentration large parts of the lower water column have less light, which fosters the nitrification process, which in turn overcomes the light limitation of the production, at least in the upper parts of the water column. Therefore it is indeed important to analyze the impact which the construction of the OWF has on the marine ecosystem site specifically, as it was done in this present study for the OWF DanTysk in the southern North Sea.

5.3 Wake Effects

Petra Nerge, Hermann Lenhart

A first impression on the far reaching impact of the rotating propellers of the OWFs on the ocean wind field, which affects a downstream area that can be bigger than the wind farm itself, can be taken from the satellite pictures by Christiansen & Hasager (2005). One ERS-2 pictures shows the SAR derived wind speed over the North Sea near the Danish wind farm Horns Rev, with a long tunnel of low wind speed downstream of the wind farm as a result of the wake effect. The calculated length for the area with reduced wind speed varied between 5 km under stable and up to 20 km for near-neutral meteorological conditions.

From these pictures and calculations the question arises if these distortions in the ocean wind fields may lead to changes within the upper ocean itself, e.g. differences in the strength or the duration of the themocline. In this way changes in the physical environment could impose effects on the ecosystem, since the development of a thermocline is an important factor for the structure of the spring bloom or the occurrence of oxygen deficit in autumn. The basis for the present study on the impact of the wake effect on the marine environment is the HAMSOM for the North Sea (Backhaus 1985, Pohlmann 1996, 2006) in the version with the horizontal grid resolution of 3 km. In the vertical the layer thickness is 5 m down to 50 m. The model is driven by a 6-hourly meteorological forcing by NCEP.

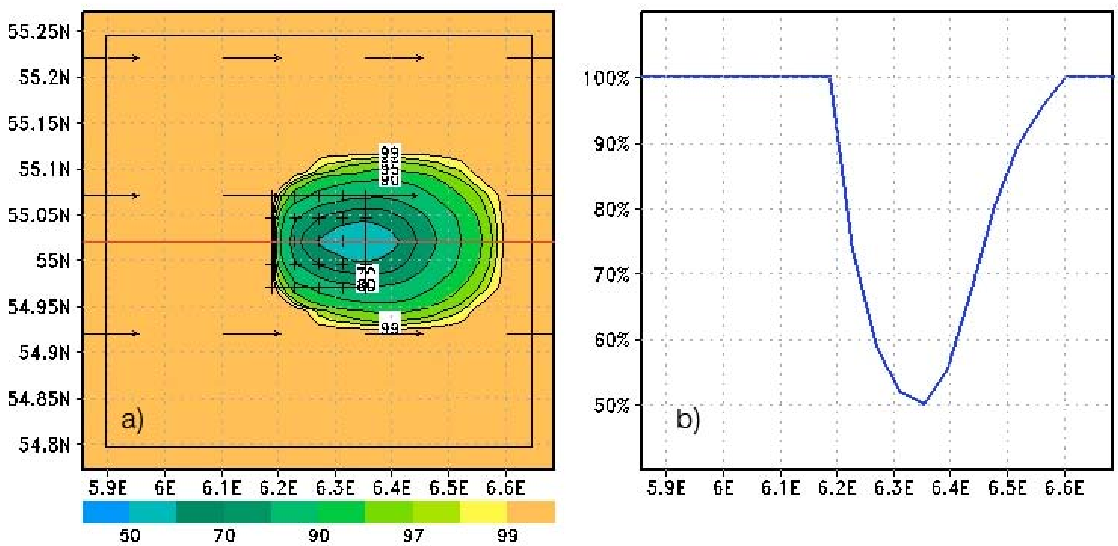


Fig. 5.14: Wake effect represented as reduced wind stress in percent for an offshore wind farm a) in the horizontal and b) on an east-west transect through the wind farm after Broström (2008).

Since model derived changes on the wind field representing the wake effect are at present not available, the assessment was based on a theoretical study by Broström (2008). In this study the wake effect is applied to the ocean in form of changes in the wind stress. The assumption is, that there is no deficit in the wind stress before the wind farm, a maximum reduction about 50 % on the wind stress is applied at the end of the wind farm and further downstream the wind adapts to the ambient wind stress with a characteristical length scale L, which is only depending on the extension of the wind farm. For our present study the test wind farm has an extension in east-west direction of 12 km and the relate length scale for the wake is set to 20 km. In Figure 5.14a the reduced wind stress reflecting the wake effect for this study is presented for a westerly wind directed to the x-axis of the wind farm. It should be added that a 50 % reduction in the wind stress is related to a 30 % reduction in the corresponding wind speed. In Figure 5.14b the reduction of the wind stress is presented for an East-West section through the centre of the wind farm (red line in Figure 5.14a).

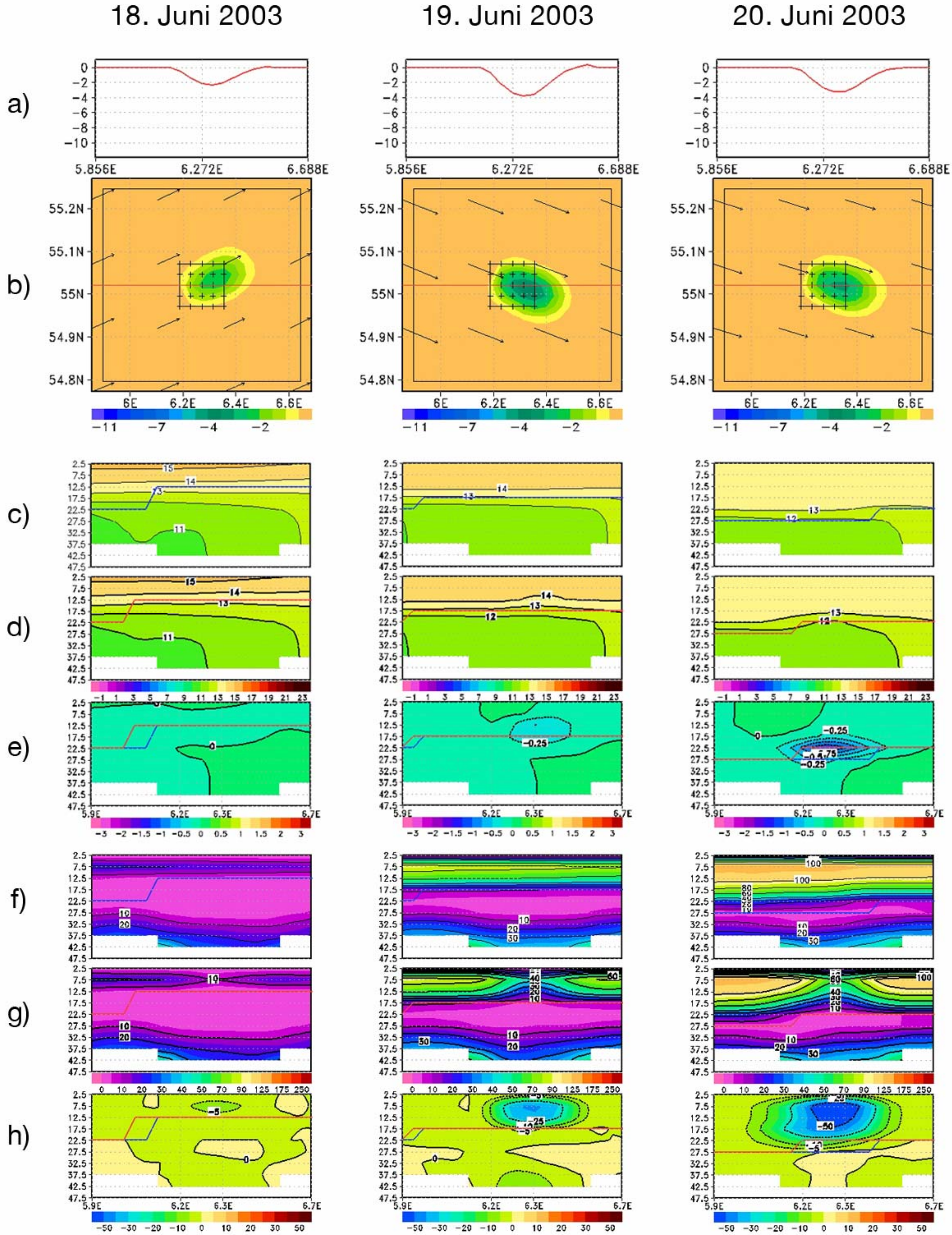


Fig. 5.15: *Overview on wake modification for the wind a) on the central east-west transect and b) the horizontal overview for the wind farm. The results are presented for the standard run, the wake scenario and the difference between the runs for temperature (°C) c-e) and vertical exchange (cm²/s) f-h) for three selected days.*

The test wind farm is represented by a pile height of 100 m. Taking the distance between the piles for 4x4 grids within the hydrodynamical model, the total number of piles accounts for 150 piles, which represents a big size offshore wind farm (double size of Horns Rev). This theoretical approach is applied to the HAMSOM model with the center of the test wind farm located at 6° 16' E, 55° 1' N, a region which is still located in the German Exclusive Zone where a thermocline occurs regularly in summer.

The impact of the wake effect on the regular forcing is displayed for 3 days, from 18th to the 20th June 2003 in Figure 5.15. The wake is expressed as difference in the wind forcing, in its horizontal distribution over the OWF (Figure 5.15b), while the upper picture gives the difference on the east west transect (Figure 5.15a) through the center of the test OWF. Between the 18th and the 20th June 2003, one can see the development of a temperature difference of up to 1 K between the two runs. Therefore the wake run (Figure 5.15d) results in a lower temperature near thermocline than the standard run (Figure 5.15c). On the 18th June the thermal stratification in both runs is located nearly identical between 13 and 14 °C at a depth of 12.5 m. The stratification is calculated as the maximum temperature gradient over the water column. The difference plot (Figure 5.15e) between the two runs shows small deviation in the western part of the transect, which is related to a south westerly mean wind speed of 7 m/s (Figure 5.15b) at the first day of our assessment. On the 19th June the mean wind speed with 11 m/s comes from a north westerly direction and applies a much stronger differences in the wind forcing between the standard and the wake run. Now the 13 degree isoline shows a small doming upward, which results in a temperature difference of 0,25 K near the thermocline. Still there is no difference in the calculation of the temperature gradient between the two runs. With 13 m/s the mean wind speed at the 20th June (Figure 5.15b), still in the same direction, further applies a strong impact in the wake run. Now the 13 °C isoline is doming up over a great part of the transect (Figure 5.15d) and also the 12 °C isoline follows in the central part of the wake affected area. The resulting difference in the temperature distribution (Figure 5.15e) between the two runs shows an area which stretches over the whole OWF with differences in the temperature of up to 1 K near the thermocline. This results also in a difference in the depth of the thermocline between the two runs of about 5 m, which is the thickness of the vertical layer within HAMSOM.

Up to now the result of the wake effect on the temperature distribution was described for the three days under consideration as a result of the differences in the wind forcing. In order to understand the processes leading to this change in the temperature, with the resulting difference in the depth of the thermocline, one has to look at the vertical exchange (Figure 5.15f-h) since this process is responsible for the heat transfer into the water column. For the 18th June one can see in the standard run (Figure 5.15f) the typical distribution of the vertical exchange, with one band of high values at the top and one at the bottom of the water column. The region of higher vertical exchange at the bottom results from the bottom friction due to tidal mixing, while the upper one is the effect of the wind forcing at the surface. The wind induced mixing at the upper layer of the water column reaches down to the depth of thermocline, while directly below the thermocline there is no mixing. In the wake run (Figure 5.15g) there is a small change in the vertical mixing near the surface in the region of the wind farm, which does not show a strong effect in the difference plot between the two runs. On the 19th June, the vertical mixing is stronger than the day before with values of up to 80 cm^2/s at the surface with a rapid decline towards the depth of the thermocline. In contrast, in the wake run there is a local reduction of this exchange with values of 40 cm^2/s or less. Therefore the difference plot exhibits values of

40 cm^2/s in the depth region between 8 to 13 m, just above the region of the maximal temperature difference at that day. Even though the mean wind speed is less at the 20th June, the vertical exchange is stronger with maximum values of up to 100 cm^2/s in the standard run. Again the wake run revields a reduced vertical exchange with about 60 cm^2/s. With the deepening of the thermocline also the area of maximum differences in the exchange rates between the two runs extends down to 17 m, while the maximum temperature difference is situated at a depth of about 23 m in the wake run. Therefore the differences in the temperature and the thermocline depth (Figure 5.15e) at that day are clearly linked to the difference in the vertical exchange (Figure 5.15h) as a result of the wake effect in the wind forcing.

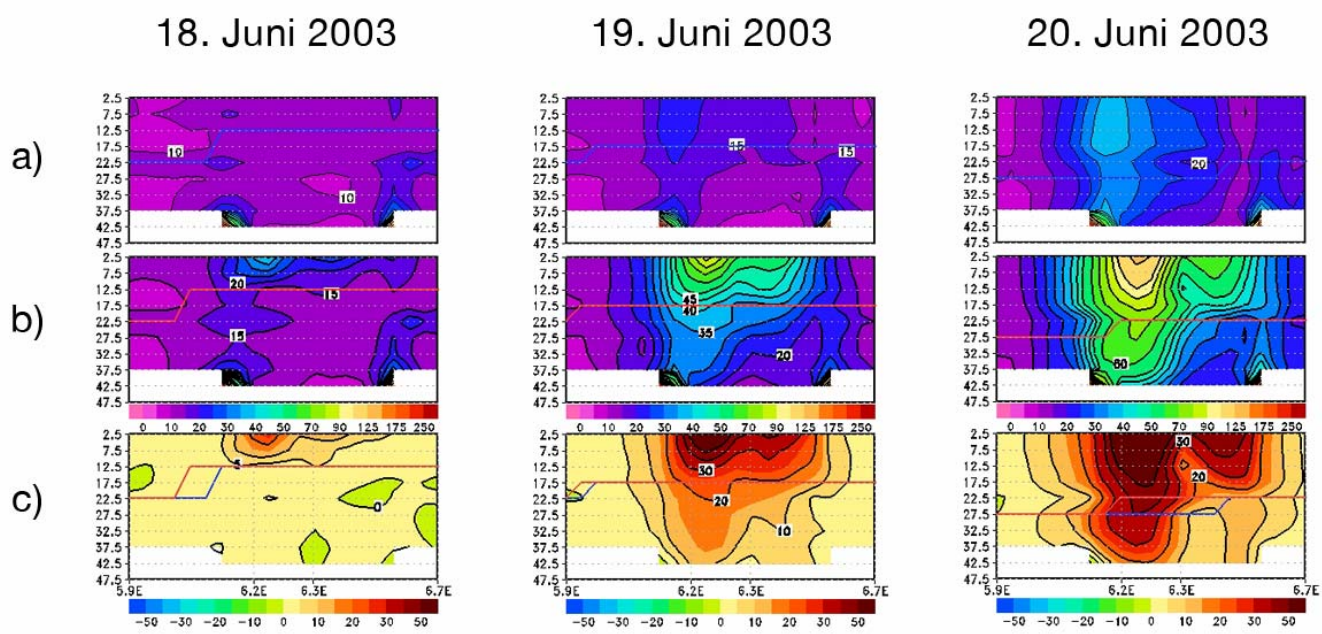


Fig. 5.16: Transect information on the horizontal exchange (m²/s) for a) the standard run, b) the wake scenario and c) the differences between the runs for three selected days.

The change in the temperature distribution (Figure 5.15e) which extends along the thermocline over a large part of the OWF also implies a strong impact on the horizontal exchange. In Figure 5.16a-c the development of the horizontal exchange is presented for the wake run (Figure 5.16b) and its difference (Figure 5.16c) to the standard run (Figure 5.16a) for the 3 days of our assessment in June 2003. One can see differences up to 20 m^2/s, but in contrast to the vertical exchange the impact is not only related to the upper layer above the thermocline. The differences in the horizontal exchange can be seen through the entire water column. Considering the position of the wind farm in an area where fronts occur quite often, this impact of the wake effect could also results in changes in the development of the biologically important fronts. Also Broström (2008) postulated the impact of the wake effect not only on the hydrodynamics but also the follow up consequences for the ecosystem. The process in the focus of his discussion was the upwelling of water masses. He calculated an upwelling of up to 1 m/day, based on a wind speed between 5 - 10 m/s. This upwelling would lead to net primary production and therefore to a change in the local ecosystem.

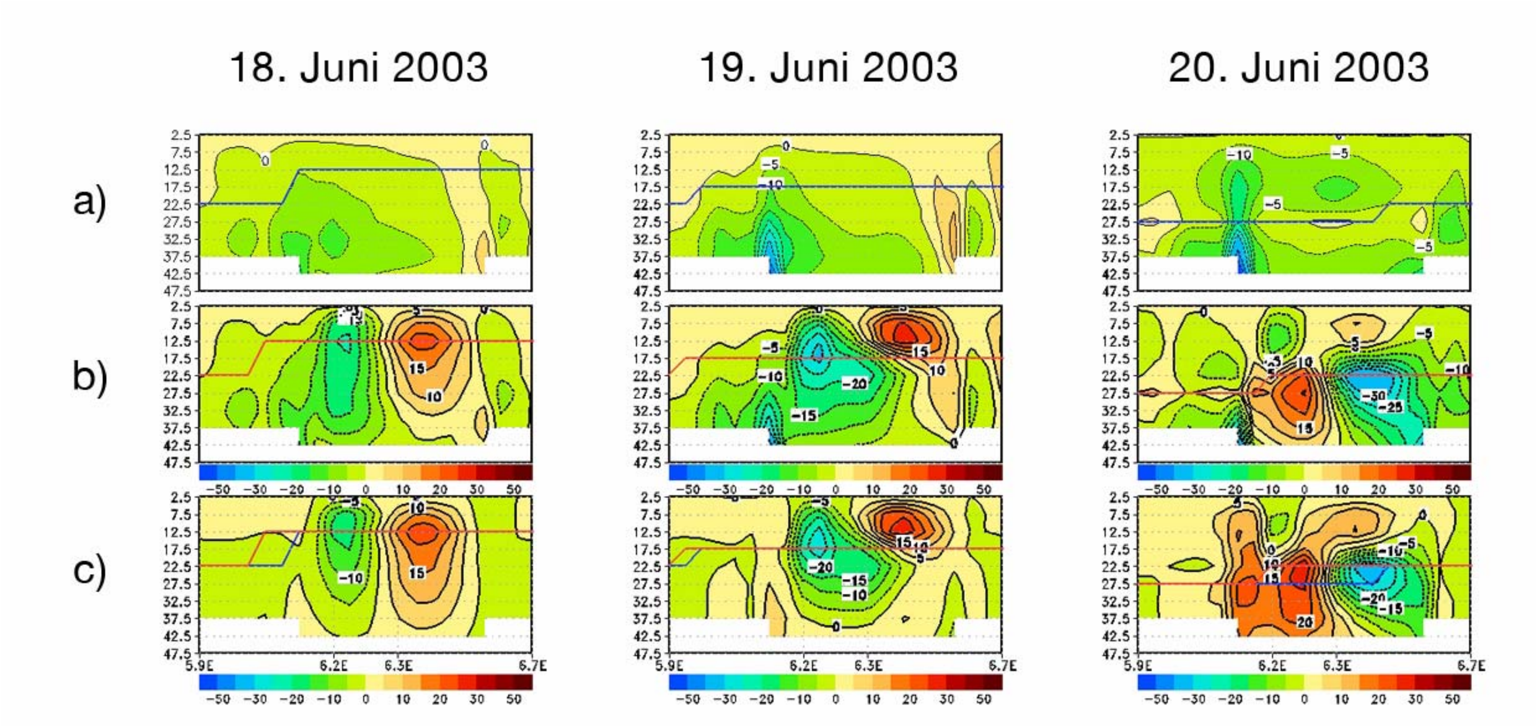


Fig. 5.17: *Transect information on the vertical velocity (µm/s) for a) the standard run, b) the wake scenario and c) the differences between the runs for three selected days.*

Looking at the vertical velocity in the present study (Figure 5.17a-c) the results give a clear indication of upwelling as a consequence of the wake effect. Taking a value of 10 µm/s for the vertical velocity the upwelling can reach the magnitude of 1 m/day as postulated by Broström (2008). However, it is worth to mention that the wake simulation shows upwelling (positive values) as well as downwelling (negative values), according to the balance between the geostrophic and wind driven flow. Therefore there is the potential that the wake effect might have an influence on the ecosystem of the North Sea via its physical features introduced by the wake effect, however this can only be examined by combining the hydrodynamical model with an ecosystem model like ECOHAM. The present study with the HAMSOM model has proven, that the effects postulated by Broström (2008) do also appear in a realistic simulation based on a high variable wind forcing with NCEP data. In addition it could be shown that the introduction of the wake effect as a result of the installation of an offshore wind farms will generally lead to a more complex hydrodynamical system which affects an area much wider than the extension of the wind farm itself.

5.4 Artificial reef - increase in mussel

Silvia Opitz

Marine anthropogenic hard substrates such as artificial reefs, oil and gas platforms, navigation marks, bridges and wrecks provide suitable habitats for hard bottom communities (Joschko et al. 2008). A variety of sessile filter and suspension feeders are competing for space. A strong competitor for space on hard substrates in the North Sea is the blue mussel *Mytilus edulis*. In the North Sea *M. edulis* is one of the dominant species close to the surface on underwater sections of hard substrates while other epibenthic filter and suspension feeders are more dominant in the lower sections. Thus, it was hypothesized that the new structures from offshore wind farm installations may offer suitable additional substrate for epifaunal macrobenthos in particular sessile filter / suspension feeders.

For an analysis of the impact on structure and flow of the trophic network at the potential wind farm site Butendiek (Figure 5.3) from additionally available hard substrate on piles and scour protection of future wind craft installations a series of trophic network models was produced reflecting the trophic situation before, during, and after construction of the wind farm.

Material and methods

The trophic network models simulating the situation before and during construction of the wind farm were produced in the first phase of the *Zukunft Küste - Coastal Futures* project. The models were produced using the software package Ecopath with Ecosim (EwE), version 4.0 (Christensen et al. 2000).

For the analysis of possible impacts from biomass accumulated on hard substrate of wind farm installations on structure and flows of the trophic network during the operational phase III an updated model was prepared with the EwE 4.0 software package. Outputs for lower trophic levels were derived from an ECOHAM (Pätsch & Kühn 2008, short ECOHAM description in chapter 5.2) run for the area. Inputs for benthos and fish were extracted from environmental impact analyses for Butendiek kindly provided by DHI (German Institute of Hydrography) in Hamburg, from data published in the literature (e.g. Opitz 1995, Carrer & Opitz 1999, Christensen 1995) and from publicly accessible data bases, e.g. FishBase (www.fishbase.org, Froese & Pauly 2000). A detailed description of the models for phase I and II, where the input for the lower trophic levels was derived by the ERSEM model in a less site specific model version, may be found in Opitz (2007, 2008). Furthermore, biomass and diet inputs for birds and mammals were updated with new and more precise data kindly provided by colleagues from FTZ Büsum.

Colonization data from the research platform FINO1 provided in Joschko et al. (2008) were used to model a set of so-called 'FINO1' scenarios. The first scenario is based on additional biomass values for several macrobenthos groups of the hard bottom community on the platform from July 2004. A series of 3 sub-scenarios deals with the impressing increase of blue mussel (*M. edulis*) biomass in the upper parts of the platform from July 2004 to July 2005. A further modeling scenario is based on biomass accumulation data from the Danish wind farm Horns Rev sampled in March and September 2003, 7 and 13 months after deployment, respectively, to consider seasonal and local variations. An overview on the scenarios for the present studies is given in Table 5.1 below.

***Tab. 5.1:** Model scenarios used for an analysis of possible impacts from biomass accumulated on hardsubstrate of wind farm installations on structure and flows of the trophic network during the operational phase.*

No.	Scenario	Description	Data source
1	FINO1July04	based on biomass accumulation data of several macrobenthos groups of the hard bottom community on the FINO1 platform from autumn 2003 (platform installation) until July 2004.	Joschko et al. (2008)
2	FINO1MytilusJuly04	based on increase of blue mussel (*Mytilus edu lis*) biomass in the upper parts of the platform from autumn 2003 until July 2004.	Joschko et al. (2008)
3	FINO1MytilusApril05	based on increase of blue mussel (*Mytilus edu lis*) biomass in the upper parts of the platform from autumn 2003 until April 2005.	Joschko et al. (2008)
4	FINO1MytilusJuly05	based on increase of blue mussel (*Mytilus edu lis*) biomass in the upper parts of the platform from autumn 2003 until July 2005.	Joschko et al. (2008)
5	*Horns Rev*	based on biomass accumulation data from the Danish wind farm Horns Rev sampled in March and September 2003, 7 and 13 months after deployment.	adopted from Figure 38 in Ulrich (2006)

An estimate of additional hard substrate area of 0,325 % corresponding to 260.208 m^2 available to epibenthic mainly sessile filter and suspension feeders after wind farm construction was calculated based on indications in Ulrich (2006). Values of biomass of functional groups accumulated on hard structures at FINO1 and Horns Rev were read off Figures 37 and 38 in Ulrich (2006) and transformed in such a way that the respective amounts could be expressed in mgC m^{-2} of horizontal wind farm area (values in Figures 37 and 38 in Ulrich 2006 were given in kgWW m^{-2} installation surface). Depth at Butendiek is 18 m.

The resulting values were added to the original biomass of each affected functional group. New model runs were made using the new biomass values for the respective functional groups and original biomass values for all other functional groups in the system. All other parameters and ratios were not modified.

Running a 'mixed trophic impact' routine with EwE was supposed to identify positive and negative and impacts on predator groups - in particular mammals, birds and fish - originating from an accumulation of biomass of macrobenthic organisms on the underwater section of piles and scour protection of the wind turbines.

An estimate of the potential increase of annual biomass production of predator groups from additional biomass production of prey groups for different scenarios was obtained from model outputs by calculating an average P/Q ratio for all groups preying on the respective prey groups. This ratio was used to calculate additional biomass production of predator groups from additional production of prey groups and was subsequently transformed into a percentage value of the original biomass production of the predator groups.

Results

The results of the Ecopath models simulating the situation of the ecosystem before and during construction of the wind farm did not show remarkable differences in food web structure. Relative biomasses (in mgC m^{-2}) differed only slightly for groups at lower trophic levels and did not impact relative biomass of groups at higher trophic levels. This may in part be attributed to the fact that the same diet composition was applied to both scenarios. Ecosystem indicators for the food web showed an ascendancy value (measure for the level of organization in a system, depends strongly on the relationship between throughput and number of pathways between elements of a system) of 28 % of total system capacity before and 32 % during construction. This increase can be attributed to the fact that primary production was slightly reduced due to a higher concentration of suspended matter in the water column while the system's structure and was kept unchanged (see chapter 5.7 also).

Figure 5.18 gives an overview on functional groups used for all scenarios, and their respective position in the food web. Trophic level values for functional groups are extracted from the updated standard model (phase I) (Opitz, 2008) produced with ECOHAM outputs for lower trophic level inputs. Trophic level values for functional groups higher in the food web, particularly birds and mammals differ to some extent from the results of the models produced with outputs from previous ERSEM model runs (Opitz 2008). This may be attributed to the fact that biomass and diet inputs for these groups were updated with new and more precise data kindly provided by colleagues from FTZ Büsum.

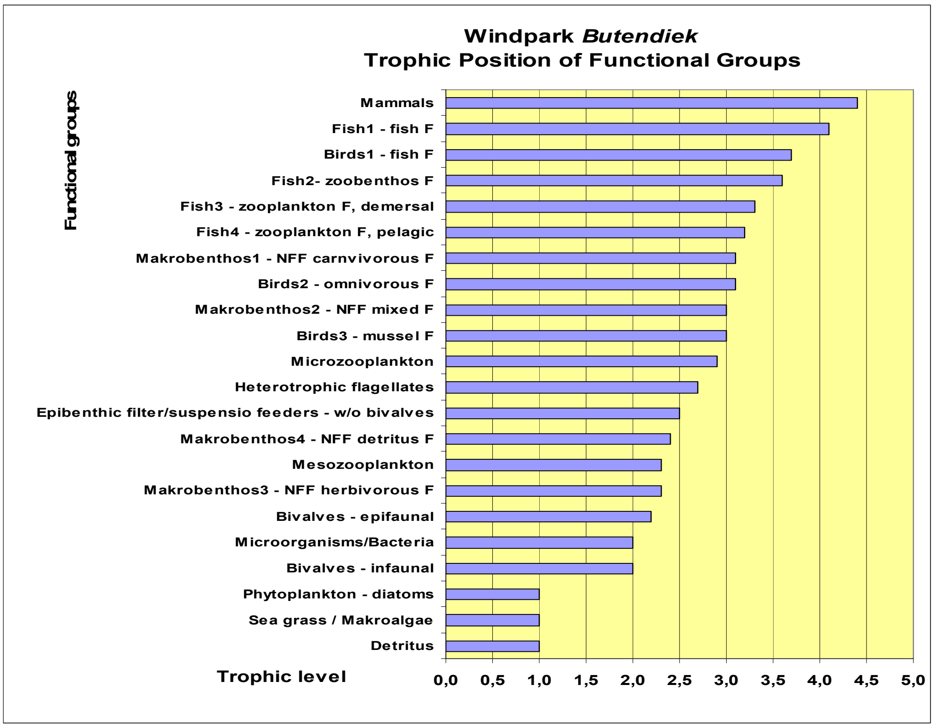


Fig. 5.18: *Functional groups at the potential wind farm Butendiek and their respective position in the food web.*

With a trophic level of 4.4 and 4.1 respectively, mammals and fish feeding fish play the role of top predators in the food web at Butendiek. Only a negligible downshift of trophic level for several functional groups could be observed during construction of the wind farm, the most pronounced being a downshift from 2.5 to 2.2 for epibenthic filter / suspension feeders. This shift could be attributed to the fact that during the construction phase primary production was reduced as a consequence of an increased concentration of suspended matter in the water column, and thus, the percentage of detritus in the diet of this group had to be raised to compensate for the lack of phytoplankton and zooplankton as food items.

To demonstrate the increase of relative system biomass (in mgC m^{-2}) at Butendiek when adding accumulated biomass values of hard bottom communities from FINO1 and Horns Rev the cumulative biomass levels for all scenarios were assembled in Figure 5.19 below.

Ecotrophic efficiency (EE) for a functional group in an EwE model is a test measure for the percentage of the production of a prey group that is consumed by predators. Values above 1 can normally not be tolerated as this would imply that the amount consumed in the system is higher than the production of a group. In dynamic systems such as the Southern North Sea with high amounts of import and export of living and dead matter between adjacent areas a certain amount of matter being imported or exported to and from the modeled part of the system can be assumed (if not known). Nevertheless, the EEs for functional groups in the different scenarios showed that - if import is disregarded - the carrying capacity particularly of detritus for more consumption by filtering organisms is restricted.

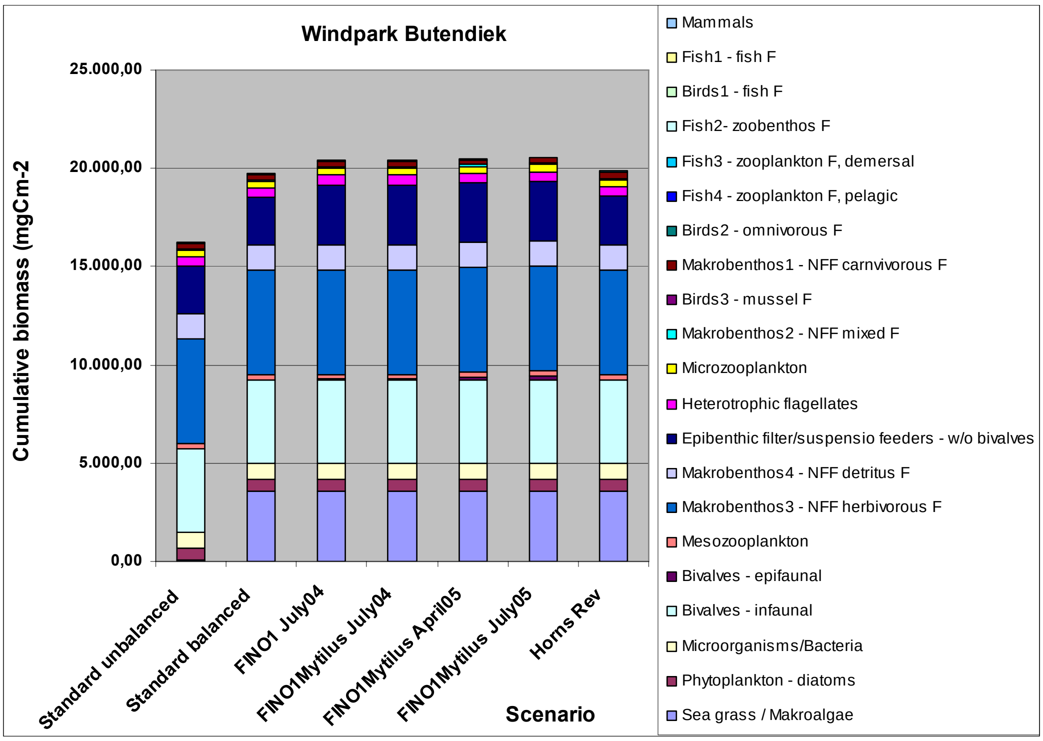


Fig. 5.19: *Cumulative biomass for different scenarios at the potential wind farm site Butendiek. Functional groups are vertically organized by trophic level ranking with lowest trophic levels at the bottom of the columns. Detritus was excluded from the Figure due to its high biomass value of 14.173 mgC m^{-2}.*

In the case of scenario Horns Rev, the pressure from additional organismic biomass growing on subsurface wind farm installations becomes visible with respect to increased feeding pressure on prey groups of carnivorous macrobenthos. Since this group encompasses all kinds of carnivorous predators it can be assumed that they will not eat what is not available (e.g. fish) but switch to resources that are more easily at hand such as e.g. blue mussels. Reducing the (small) share of fish in the diet of carnivorous macrobenthos by raising the share of epifaunal mussels in its diet, the EEs of the fish groups in the model went down immediately to about 80 % instead of 101 % (of production consumed by predators).

Due to the comparatively small biomass modifications on a relative basis resulting EE values did not show pronounced changes. Thus, it was concluded that the additional substrate from piles available to sessile organisms after the construction of the wind farm would not have a significant quantitative impact on structure and flow pattern of the trophic web at Butendiek.

Results of a mixed trophic impact routine are given below in relative quantities for scenarios FINO1 and Horns Rev. Objective of running such a routine was to show what positive direct and indirect impacts on their predators an increase of prey groups on hard substrate of wind farm installation would have.

FINO1 scenarios suggest that an increase of the blue mussel Mytilus edulis on hard substrate would very positively impact herbivorous non-filter feeding macrobenthos, followed by zoobenthos feeding fish and to a very mall extent by zooplankton feeding fish and mussel feeding birds.

An increase of the other prey groups shown in Figure 5.20 and impacts on their predators can be interpreted in the same way.

Scenario Horns Rev (Figure 5.21 below) indicates that principal winner of additional biomass from organisms on hard substrate of wind farm installations is the group of herbivorous non-filter feeding macrobenthos. The diet of this group consists of 65 % plants and of 35 % other food items. Apart of this, additional biomass of blue mussel would positively impact the biomass production of zoobenthos feeding fish, non-filter-feeding carnivorous macrobenthos, fish feeding birds, and to a very small extent that of fish feeding fish as well as zooplankton feeding fish.

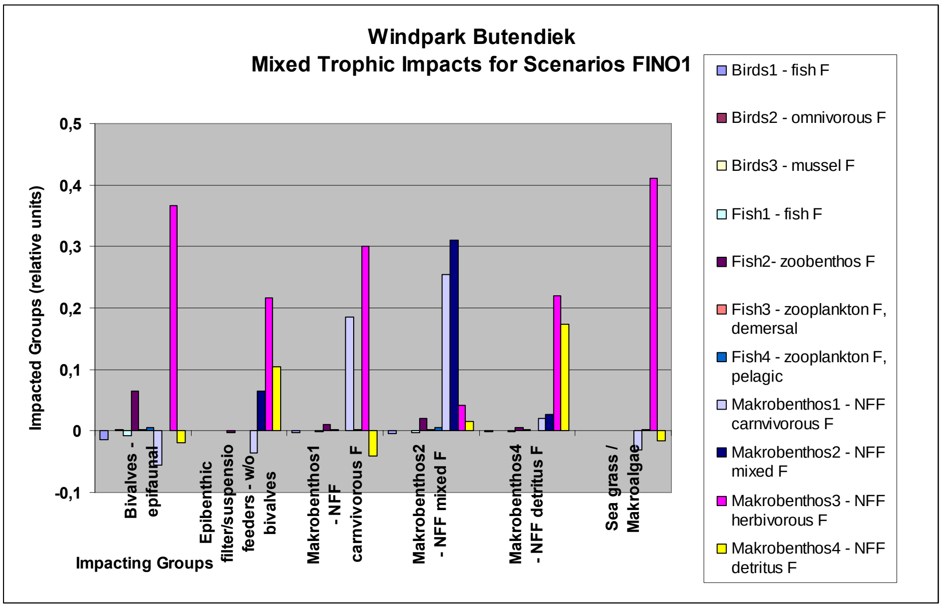


Fig. 5.20: *Direct and indirect trophic impacts for Scenarios FINO1 on functional groups with increased biomass levels on hard substrates of subsurface wind farm installations.*

An increase in hard substrate of 260.208 m^2 at Butendiek available to organisms such as epifaunal bivalves (mainly blue mussels), other epibenthic filter/suspension feeders, non-filter/suspension feeding macrobenthos, and macroalgae after construction of the wind farm would theoretically increase the original biomass of the trophic web (33.914,776 mgC m^{-2}) by maximally 2,4 % according to the results from the scenarios as shown in Table 5.2 below.

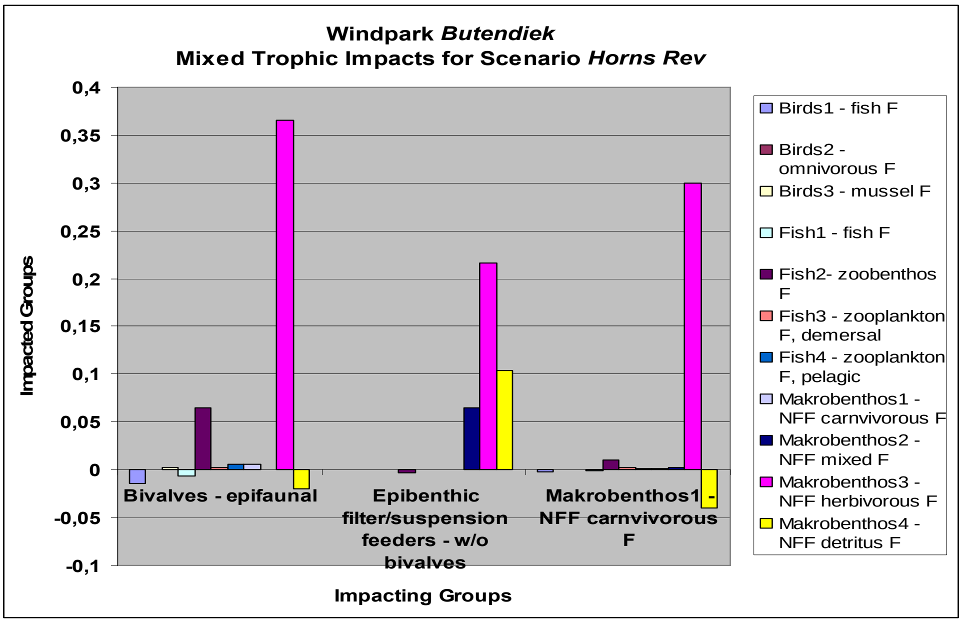


Fig. 5.21: *Direct and indirect trophic impacts for Scenario Horns Rev on functional groups with increased biomass levels on hard substrates of subsurface wind farm installations.*

***Tab. 5.2:** Additional biomass of functional groups on research platform (FINO1) and on underwater structures of wind farm installations (Horns Rev).*

Scenario	Additional biomass Mytilus	Additional biomass other groups	Additional B / Original B	Total new biomass / total system biomass
	mgCm-2	mgCm-2	%	%
FINO1July04	3,60	640,15	8,40	1,90
FINO1MytilusJuly04	4,71	640,15	14,56	1,90
FINO1MytilusApril05	117,75	640,15	363,88	2,33
FINO1MytilusJuly05	188,4	640,15	582,20	2,44
Horns Rev	0,87	126,81	4,74	0,38

A biomass increase of macrobenthic organisms on piles and scour protection of wind farm installations as derived from results of the FINO1 research platform and from the Danish wind farm Horns Rev suggests a potential increase of annual biomass production of the beneficiaries of 0,28 % (Scenario Horns Rev) to 1,20 % (Scenario FINO1MytilusJuly05). Results for all scenarios may be found in Table 5.3.

***Tab. 5.3:** Potential increase of annual biomass production of predator groups from additional biomass production of prey organisms for different scenarios.*

Scenario	Additional biomass production of prey groups (mgCm-2year-1)	Production / Consumption ratio of predator groups (%)	Additional biomass production of predator groups (mgCm-2year-1)	Additional biomass production of predator groups (%)	Additional biomass production of predator groups for total wind farm *Butendiek** (kgCyear-1)
FINO1July04	841,30	6,58	55,36	0,93	74,4
FINO1MytilusJuly04	842,74	6,58	55,45	0,93	74,4
FINO1MytilusApril05	989,69	6,58	65,12	1,10	88,0
FINO1MytilusJuly05	1.081,54	6,58	71,17	1,20	96,0
Horns Rev	249,28	6,58	16,40	0,28	22,4

*80 000 000 m2

Discussion

When considering a single wind farm area consisting of 80 turbines in an area of 30 km^2 (Borkum Riffgrund West), accumulated mussels on wind farm installations would add 10 % to the local macrofaunal biomass and consume 1,4 % of the annual primary production according to Joschko et al. (2008). These findings are based on an accumulated biomass load of *M. edulis* of 39 kgWW m^{-2} corresponding to 1,2 kgC m^{-2} on the upper parts of the underwater structure of the wind turbines, an assimilation rate of seven times their own biomass per year with an assimilation efficiency of 70 % and an average macrofaunal biomass in the North Sea of 7 gAFDM m^{-2}.

In contrast to Joschko et al. (2008), model results suggest that total accumulated biomass from mussels and other functional groups would add only 6 % to the local macrofaunal biomass. Accumulated biomass of mussels alone would not exceed 1.4 % of macrofaunal biomass. For scenario Horns Rev accumulated biomass of all functional groups adds scarcely 1 % to the local macrofaunal biomass. Annual primary production necessary to maintain the additionally accumulated biomass would be between 9,5 % for scenario FINO1MytilusJuly05 and 3,7 % for scenario Horns Rev when assuming the same annual primary production per area as in Joschko et al. (2008). These differences could be attributed to the fact that not only mussels, feeding low in the food web, but functional groups at higher trophic levels are contributing to the accumulation of additional biomass. Joschko et al. (2008) do not provide figures for other epibenthic organisms accumulating on the wind farm installations, therefore, results cannot be compared directly.

Based on the accumulated biomass data from Horns Rev and FINO1, model results suggest a potential increase of annual biomass production of the beneficiaries (predators) of 0,28 % to 1,20 % respectively. These values seem very low but nevertheless could have a considerable impact on predator groups foraging on specific prey groups as for example the eider duck feeding on blue mussels. Standard biomass of blue mussels at Butendiek is rather low and so is consumption of mussels by eider ducks in the area suggesting that the ducks 'don´t go there to feed'. Eider ducks - represented in the group 'mussel feeding birds' could strongly profit from additional biomass of epifaunal bivalves on piles since blue mussels preferable fix themselves on the piles in the upper 3 to 5 m below the water surface (Ulrich 2006, results from Horns Rev) and thus become easily available to birds while feeding competition from aquatic organisms is reduced. Theoretically, particularly macrobenthos feeding fish could also be attracted and their standing stock biomass benefit to a higher extent from the biomass accumulated on the hard structures than the average figures of 0,28 to 1,20 % would suggest. Their standing stock biomass is rather small compared to that of some groups of other predators such as e.g. carnivorous macrobenthos. Additional prey consumed would thus have a relatively higher impact on standing stock biomass of macrobenthos feeding fish than on populations of e.g. carnivorous macrobenthos.

The system´s potential for accumulation of biomass on hard substrates of wind farm installations cannot only stimulate an increase of predator populations such as birds and fish but may have relevance for potential future aquaculture activities in the wind farms of organisms low in the food web such as mussels, oysters and algae.

5.5 Impacts on the North Sea fish community

Dominik Gloe

More than 200 fish species with widely differing ecological characteristics are known to occur in the North Sea. A study from the World Wide Fund for Nature (WWF) in 2009 has shown that despite the recovering of several North Sea fish stocks, the stocks remain still at risk (http://scotland.wwf.org.uk). The species composition is underlying large annual variations, due to natural fluctuations in recruitment success of the individual species (ICES 2008). It is distinguished between 3 main fish assemblages (Daan et al. 1990). In the study 'Impacts of Offshore wind farming on the provision of Ecosystem Services in the North Sea' (Gloe 2009), impacts of OWFs on the southeastern fish community were evaluated. Offshore constructions like oil platforms have the characteristic to attract fish species (Løkkeborg et al. 2002). This is known as artificial reef effect. Furthermore, the protection of an area from fishing activities could have widely studied benefits for the fish community (BfN 2004). In this context it is important to discuss the potentials of OWF's for the southeastern fish community of the North Sea. For the evaluations in this study, data from the Dutch Nearshore Wind Farm (NSW) project was analyzed. The NSW is located 10 km off the coast near Egmond an Zee in a water depth of 19 to 22 m. The NSW contains 36 turbines with an overall capacity of 100 MW (www.nordzeewind.nl).

Material and methods

To evaluate possible impacts of OWF constructions on the southeastern fish community in the North Sea, different data sets from the Dutch NSW project were analyzed. The project is divided into two subprojects, a pelagic and a demersal part. These data were kindly provided by the Institute for Marine Resources and Ecosystem Studies (IMARES) in Ijmuiden/Netherlands, belonging to Wageningen University. During the monitoring program, the NSW area and two additional reference areas with similar characteristics were observed. This enabled a direct comparison of the areas and a transfer of possible impacts.

The pelagic fish data included acoustic data (Nautical Area Backscattering Coefficient - NASC per nautical mile; describes the fish density along transect lines) and trawl data (Catch per Unit Effort - CPUE in kg). The trawls were performed in areas with high fish densities for species identification (species compositions and appertaining length distributions). The data were available for April and May 2003, and April 2007, describing the situation before and one year after the construction of the NSW.

The demersal data included Bottom Trawl Survey (BTS) catches (CPUE in numbers) in the monitored area. Due to the beam trawl survey design, two trawl stations were performed at every position. The data were available for June and July 2003, January and February 2004, June and July 2007, and for January and February 2008.

Furthermore, GIS data provided by the *Zukunft Küste - Coastal Futures* project and IMARES was used for the evaluations.

Results

Effects of the NSW construction on the fish abundance and the fish diversity between the different areas (NSW and reference areas) and years (before and after the construction) were examined. For this purpose, different statistical models were used and the Shannon-Wiener Index was calculated to compare the different situations.

The fish abundance from the pelagic surveys showed a significant increase after the construction of the NSW in 2007. Mainly responsible for this increase was the sandeel with very high abundances in all investigated areas. Similar results were obtained from the demersal surveys. The fish abundance was highest after the construction of the NSW in all areas (NSW and reference areas).

No effects were found for the diversity of the pelagic fish species. Also no clear trend was found for the demersal surveys. The diversity was expressed as Shannon-Wiener Index. In general, a higher diversity was found in the summertime, while diversity showed a clear decrease in the wintertime. This result was also indicated by the statistical models. Part of the variance can be explained by the season. No effect of the different areas on the diversity was observed.

In summary, small effects on the fish community could be found. The fish abundance was higher after the construction of the NSW, while no clear effect was found for the diversity in the investigation areas.

Discussion

Fish abundance

Even if no attraction of fish was expected to occur, a high fish density was found in the NSW and in the reference areas during the pelagic survey. Sandeel was mainly responsible for the high fish densities after the construction. This was an unexpected result, because it was discussed in the literature that the offshore constructions could have a negative impact on sandeel, because this species depends strongly on the sediment (Muus & Nielsen 1994). A similar result was found in the Danish OWF Horns Rev. Sandeels were the most abundant species during the monitoring in 2004 (Horns Rev 2005). The authors concluded that sandeel abundance could be used as an indicator for sediment changes. This result supports the assumption that no significant impacts on the sediment in the OWFs in the German EEZ will occur. Overall, no avoidance behavior of the pelagic fish species was found.

The results from the demersal surveys showed the same trend as the pelagic surveys. There is evidence that no avoidance of the demersal fish species appeared.

In contradiction to the pelagic results, almost the same species were caught during the demersal surveys, while the catch rates differed. An explanation could be the higher faithfulness of demersal species to their habitat. A significant difference of the catch rates was found for the year 2008. A seasonal effect of the CPUE was also discovered. Due to the small underlying data set, no further conclusions can be drawn. Nevertheless, the seasonal effect seemed to be an important factor.

In summary, more fish was caught after the construction of the NSW in all areas. No avoidance occurred. It is imaginable that an attraction of fish could have appeared, at least to a small degree, even if one year after the construction probably no artificial reef effect took place. Unfortunately, no fouling data from the piles were available. But it can be assumed that an accumulation of biomass occurred so far. Additionally, no fishing activities took place in the NSW. Both effects could have led to an attraction of fish species. This effect will probably get more important in the future and will be monitored in the next phase of the NSW project.

Biodiversity

The results obtained for the diversity of fish must be interpreted carefully. The Shannon-Wiener Index is a measurement of biodiversity, including the number of occurring species and the species abundance in an area. The diversity of the pelagic fish species was calculated only to get an impression of prevailing trends in the NSW and for a comparison with the diversity of the demersal surveys. The design of acoustic surveys is not suitable for the calculation of diversity indices. Additionally, the distribution of pelagic fish species in the coastal zone is highly variable. For that reasons, the results will not be discussed at this point.

The demersal survey is more convenient to evaluate the diversity. A higher number of random samplings were taken in the whole study area. The statistical test showed no clear effect. Due to the insufficient data base for the statistical model, it cannot be explained, which factor affected the biodiversity the most. It is known from bottom trawl surveys (BTS) in the German Bight, that the average demersal species number in wintertime is slightly smaller than in summer (pers. comm. Sell 2009). This could be evidence of a particular season having an important effect on the diversity in the area. This would underline the results of this study and also the fish abundance results for the demersal species. The areas seemed to play no role in this context as no differences between the areas were found. This again is evidence of no avoidance of the NSW taking place. No negative impacts on the biodiversity after the construction of the NSW were found. Maybe more conclusions can be drawn in the next phase of the NSW monitoring.

Capabilities of OWFs in the German EEZ

The OWFs in the German EEZ could fulfill the requirements of artificial reefs. Even if the turbines in the OWFs will probably have a distance of 500 m to each other, due to safety regulations, an attraction of species will probably occur. An artificial reef effect for North Sea oil platforms was proved with benefiting effects especially for the fisheries on a small-scale (Løkkeborg et al. 2002). It can be assumed that the same effect could appear in OWFs because of the similar characteristics of both types of underwater structures. The construction of OWFs will introduce hard structures which will provide additional habitats, accumulate biomass and enhance the productivity of the area. The meaning of OWFs as artificial reefs could further be enhanced through cautious design. It was shown that the biomass and diversity in the OWF areas are, at least partly, controlled by the material used and its roughness (Petersen & Malm 2006). For example, the use of different types of scour protections in the wind farm or the use of additional polypropylene fronds could increase the heterogeneity. This would provide additional habitats that could act as shelter and reduce predation pressure. This effect depends strongly on the species preferences. Sherman et al. (2002) highlighted the importance of structural complexity in artificial reefs designed to enhance fish recruitment, aggregation and diversity.

Destructive trawl net fishing will be forbidden within OWFs and there will be 500 m safety zones around OWFs. Thus, OWFs could act as a kind of marine protected areas (MPAs). A MPA is an area of seabed and overlying waters dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (after ANZECC 1998). Different types of MPAs are known, depending on the applied restrictions. The approved OWFs in the German EEZ of the North Sea will have a share of 3 % (~880 km²) of the total EEZ's area. The German Federal Government had plans to use a share of 12 % (~3.500 km²) of the German EEZ to achieve the 20 % target of CO_2 reduction set by the European Union by 2020. Such a network of OWFs acting as MPAs could have benefits for the southeastern fish community. It is difficult to make assumptions which species of the fish community would benefit. But in general, the areas could be used as spawning areas, as refuge or for feeding purposes (Ehrich 2001). Again, this strongly depends on the biology of the different species. Several North Sea fish species are known to utilize rocky substrates at some life stages (Muus & Nielsen 1994). It is imaginable that a provable effect on the recruitment of some commercially important species could develop. This could lead to benefits for the fishery sector and to an increase of the profits. But no quantities or assumptions will be given in this context.

Despite the fact, that OWFs will be an intrusion in a natural system, the preliminary monitoring results from the Dutch NSW have shown that positive effects on fish could be expected from wind farm constructions in the North Sea. Similar effects for corresponding species could be expected for OWF constructions in the German EEZ. However, the comparability of the results will depend on the fact how the extension and the design of the offshore wind farms will match the environmental conditions in the German EEZ.

5.6 Cumulative effects of anthropogenic activities on seabirds in the North Sea: Methodology and first results

Stefan Garthe, Bettina Mendel

The North Sea and its adjacent waters are an area of world-wide importance for seabirds. This holds true for both birds breeding along all coasts and birds using the area during migration and wintering. Number during as well as outside the breeding period are of international importance (Skov et al. 1995). Within the German sector of the North Sea, 28 species occur regularly with on average more than 50 ind. The most numerous species in the EEZ are northern fulmar (*Fulmarus glacialis*), lesser black-backed gull (*Larus fuscus*) and black-legged kittiwake (*Rissa tridactyla*) in summer and common guillemot (*Uria aalge*), herring gull (*Larus argentatus*) and black-legged kittiwake in winter (Garthe et al. 2007). The two diver species red-throated diver (*Gavia stellata*) and black-throated diver (*Gavia arctica*) have recently received particular attention. This is because of the following reasons: (1) Their distribution within the North Sea concentrates during spring in the southeastern North Sea (Skov et al. 1995, Figure 5.22); (2) they are listed on Annex I (species of particular conservation concern) of the EU Wild Birds Directive; (3) their occurrence has been essential in designating a Special Protection Area in the eastern German Bight (Garthe 2006); and (4) their distribution overlaps substantially with wind farm planning in German EEZ waters (Mendel & Garthe 2010).

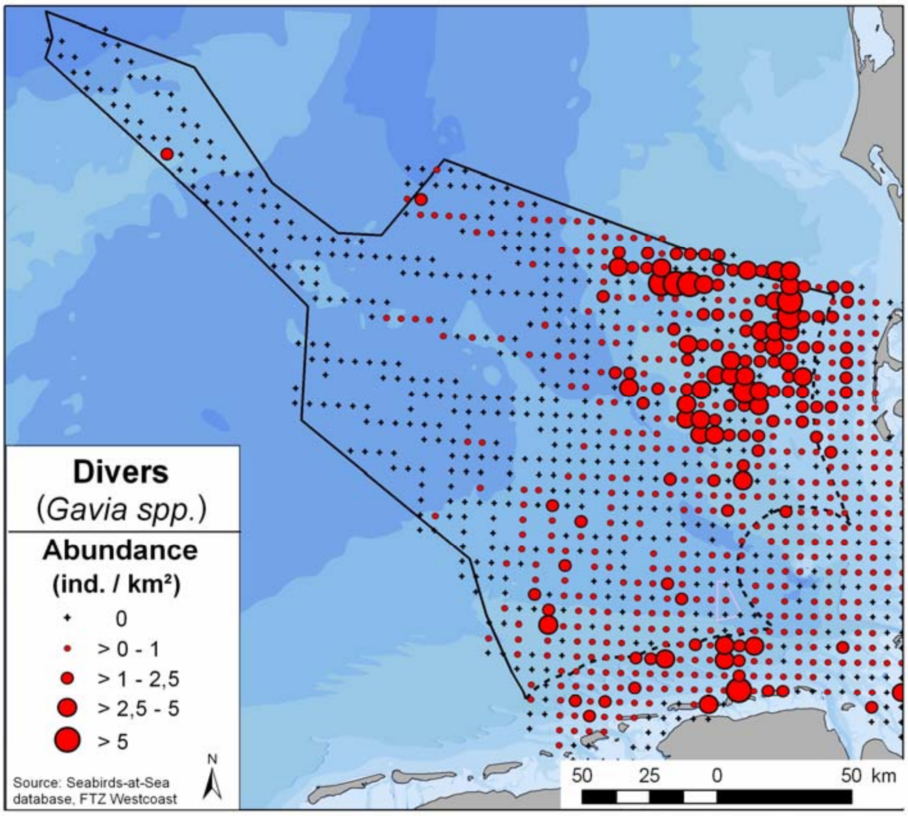


Fig. 5.22: Distribution of red-throated and black-throated divers in the German North Sea in spring. Data originate from aerial surveys conducted between 1 March and 15 May in the years 2002-2008.

Multiple anthropogenic activities at sea

In the North Sea, various anthropogenic activities take place (chapter 2). They act over large areas under, on and above the sea surface. Figure 5.23 illustrates those activities that are currently judged to be most important with regard to seabirds. Some of these factors act directly on the birds by affecting their condition or health, others have a more indirect causality.

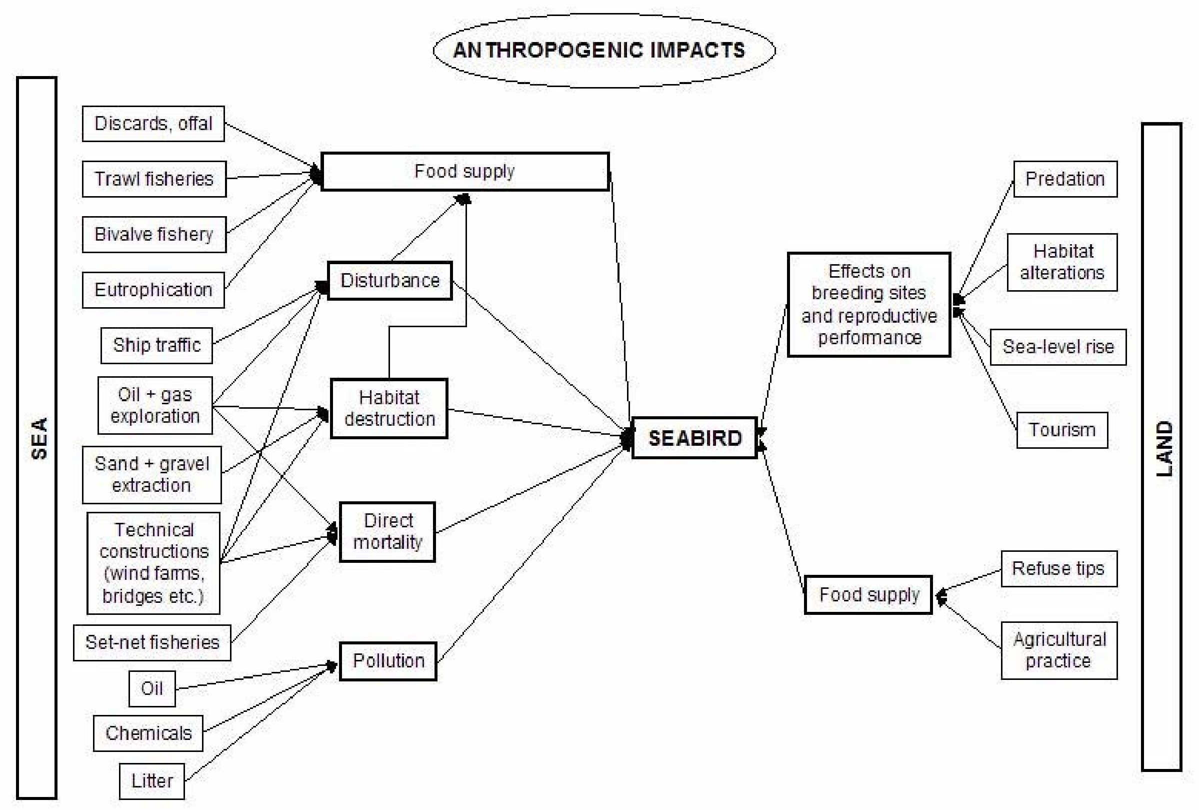


Fig. 5.23: Most important anthropogenic impacts influencing seabird behaviour and life history in the German North Sea (from Garthe 2004).

In addition to these seabound sources there are more activities that originate from terrestrial source and which affect seabirds mostly in the coastal zone of the North Sea. Usually, fishing has been judged as being of strong if not most relevance of all factors (Jennings et al. 2001, Garthe 2004) but large-scale constructions at sea could become another major factor especially in the EEZ.

Effects of offshore wind farms

Although plans for offshore wind farms have been established since the turn of the last century and licenses were given to several projects in the North Sea, experiences from operating wind farms are still relatively scarce and many aspects remain unclear so far. Generally, seabirds might be affected by offshore wind farms in four different ways (e.g. Dierschke & Garthe 2006):

(1) Collision: Birds may collide with the wind turbine and are likely killed in such situations.

(2) Barrier effect: Birds may avoid the wind farm by flying around it (horizontal escape) or over it (vertical escape). Such escape movements involve additional energy costs for the birds due to the detour and additional flying activities.

(3) Habitat loss: Resting and foraging seabirds may avoid wind farms because of the disturbance by the technical structures.

(4) Attraction: Birds may be attracted by the 'irregularity' of the sea surface, and also by potentially increased food availability due to a ban of fishing activities.

From a review of the literature on studies at operating wind farms it was found that at least six seabird species clearly avoided the wind farm areas. Such behavior was very obvious in the two diver species and included not only the wind farm area itself but also a buffer zone of at least 2 km around the site. It is thus to be expected that all birds that stay in areas where wind farms will be constructed will loose their habitat. Even after five and six years, respectively, of wind farm operation could no habituation of divers be observed; still, these species avoid these areas (Petersen & Fox 2007, Petersen et al. 2008).

Cumulative impacts by different uses

Not only offshore wind farms affect sensitive seabird species in the German North Sea but also a variety of other activities (see above). Ship traffic may act similarly to offshore wind farms on sensitive species by causing habitat loss as has been indicated by regular escape movements of sea ducks, divers and some other species when approaching with a ship (Bellebaum et al. 2006, FTZ unpubl. data). In an attempt to quantify possible habitat loss for red-throated and black-throated divers both from wind farms and from shipping traffic, the following assumptions were made (Mendel & Garthe 2010): 1. Wind farms: Divers avoid the wind farm areas as well as a buffer zone of 2 km around the sites completely but are not affected at larger distances. 2. Shipping: Permanent ship traffic causes strongly reduced abundances. Diffuse ship traffic has a large-scale negative effect on divers, too, as the abundances are reduced in areas used frequently by ships (e.g. fishing vessels). From this, an estimated habitat loss for 50 % of the birds is assumed for the main shipping lanes and shipping preference areas.

The habitat loss of divers due to wind farms in German North Sea waters as of August 2009 (Figure 5.24) would affect 1.450 individuals, that of ship traffic 2.700 ind. In a cumulative approach the total number of divers affected would thus be more than 4.100 ind. as wind farms and shipping would exclude each other spatially (except for maintenance of wind farms which is not accounted for here).

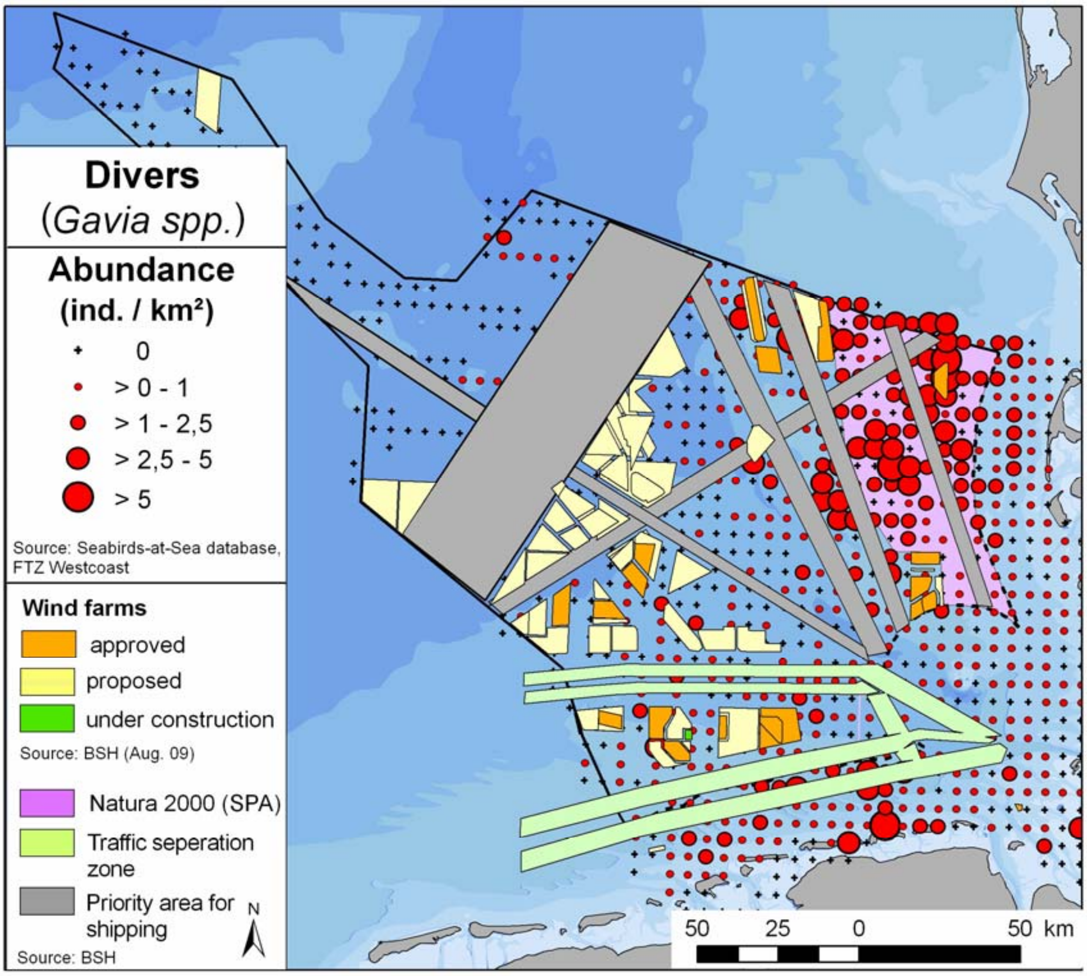


Fig. 5.24: Distribution of red- throated and black-throated divers in the German North Sea in spring (see Fig. 5.22), overlaid with licensed and applied wind farm sites and shipping area.

To refer these numbers to a wider context, two possible reference populations are: (1) The national average number for spring is for both diver species 18.500 ind. (Garthe et al. 2007); habitat loss due to wind farms alone would thus be 7.8 % and for both uses 22.5 %. (2) The northwest European population size is estimated at 110.000 ind. (Skov et al. 1995); habitat loss due to wind farms alone would thus be 1.3 % and for both uses 3.8 %.

Conclusions

The fact that both the construction of wind farms and the occurrence of intense ship traffic lead to a partial or complete loss of habitat for sensitive seabird species demonstrates that this issue needs further attention in the near future. There is an increasing demand of marine resource use by humans due to the generation of energy by renewable and fossil sources, due to increasing ship traffic, but also due to still existing strong pressures by fishing activities and other uses. All these activities will constrain the survival of seabirds during all times of the year, likely further challenged by the expected climate change.

5.7 Ecosystem integrity synthesis

Benjamin Burkhard

The assessment of large scale offshore wind farms' impacts on the marine and coastal ecosystems of the North Sea demonstrated that ecological integrity is an appropriate guideline for ecosystem-oriented analyses. Ecological integrity means the support and preservation of those processes and structures which are essential prerequisites of the ecological ability for self-organization (Barkmann et al. 2001). Hence, the focus of the analyses was not individual species or elements but structures, processes, their interplay and emergent properties. For the first time, different models and data sets have been combined and linked in order to provide more realistic simulations of real conditions in marine ecosystems and to exploit the capacities of the individual models (Burkhard et al. 2009).

The indicators which were utilized to quantify changes have been developed and applied in a broad range of projects (Müller 2005, Müller & Burkhard 2007) including a marine case study dealing with eutrophication in the German North Sea (Windhorst et al. 2005, Nunneri et al. 2008). The indicators are related to the energy budget of the system (exergy capture, entropy production), the matter balance of the system (nutrient cycling, nutrient loss, storage capacity), structural components (biotic diversity, abiotic heterogeneity) and the system's stage of organization. For a more detailed description of the indicators and their quantification in marine ecosystems see Burkhard et al. (2009) or Windhorst et al. (2005).

The ecosystem dynamics which can be triggered by the installation of huge offshore wind farms have the potential to alter the ecosystems' ability for self-organization and thus, their integrity. Whether there will be a system shift towards artificial reef ecosystems (see introduction of chapter 5), towards degraded ecosystems or whether there will be a high degree of resilience, was analyzed by modeling a) a reference state (the German North Sea without any offshore wind farm), b) the offshore wind farms' construction phase, and c) the following offshore wind farms' operating phase.

Reference state - the North Sea without offshore wind farm

One of the main challenges in the analyses of human impacts on the environment is the lack of suitable reference states. In an optimum case, this reference state should describe 'pristine' or 'natural' conditions, not yet affected by human activities. In the case of offshore wind farms we were in the favorable situation that this is a very new form of human sea use. Thus, the situation without any offshore wind farm, as it was the case in the German part of the North Sea until the year 2009, represents an appropriate reference state. Nevertheless it has to be considered that the North Sea is under high pressure by manifold other forms of human activities such as eutrophication, fishery, waste disposal, oil spills, raw material extraction or shipping (see chapter 2). Hence, the North Sea cannot be regarded as undisturbed system at all but, impacts of offshore wind farms have not been present before. Therefore, results from monitoring, modeling and measurements covering the years before 2009 could be applied in order to evaluate systems' alterations following the installation of offshore wind farms. For example, comprehensive material from environmental impact assessments, which had to be carried out for each wind farm approval (e.g. BSH 2002), as well as data and experience from the comprehensive Seabirds at Sea (SAS) monitoring program (Garthe & Hüppop 2004) were analyzed.

For the marine nutrient and energy cycling the input data were derived from an ERSEM simulations representing the year 1995 as reference conditions (Nunneri et al. 2008, Lenhart et al. 2006).

Construction phase

One of the main impacts which is expected to take place in relation to the construction of OWFs is the increase of suspended particulate matter (SPM) in the water column (Lenhart et al. 2006). Further material allocations will take place during the scavenging of cables for grid connection within the wind farms and to the mainland. These impacts were simulated with ERSEM. As the results showed, a temporary increase in SPM affects the net primary production and subsequent processes. Due to construction-related noise and disturbances, impacts on sea birds and marine mammals (Garthe & Hüppop 2004, Gilles et al. 2009) are to expect. These analyzes of these impacts showed that considerable numbers of animals have their habitats at locations where offshore wind farms are planned. The construction of offshore wind farms will take place during summer seasons where there are less strong weather conditions. Even under favorable conditions, the erection of all turbines in a wind farm takes several months. Nevertheless, impacts occurring during the construction phase are not permanent. Thus, on a longer temporal scale, they have to be regarded as rather short-term disturbances.

Operating phase

As there is no long-term experience with large offshore wind farms only little is known so far about impacts occurring during the operation phase. On the one hand, there are temporary disturbances due to maintenance activities like helicopter flights, boat traffic or accidents. On the other hand, there are continuous impacts due to the permanent insertion of hard structures into the sea bottom and related to the above-water rotation of the turbine blades. The insertion of hard structures might trigger the development of new habitats which can lead to the settlement and migration of certain species. This might lead to the development of artificial reef ecosystems or to a deterioration of ecosystem functions. Above water, the permanent rotation of the wind turbines might cause changes in the wind field which are analyzed as wake effects. The results showed that alterations in the physical environment up to 20 km away from the source (the individual wind turbines) are possible. At local scale, decreased vertical water diffusion was shown. This means a decreased heat transport and a downwards movement of the thermocline. Moreover, an increase of horizontal diffusion was modeled throughout the whole water column. Both effects are affecting temperature-depending processes, e.g. the primary productivity of algae, nutrient cycling and species distribution - all important components of ecological integrity.

The simulations of the food web with Ecopath showed that two years after wind turbine construction, an increase in biomass (e.g. of blue mussels) and first changes in predator-prey relations become obvious. Other processes like respiration which were disturbed during the construction phase came back to the reference state conditions during the simulated operation phase. Ecopath simulated slight increases for ascendancy which can be interpreted as a first sign of the emergence of a more complex system. The ERSEM simulations showed that alterations in e.g. net primary production and matter budget due to increased SPM mainly are limited to the year where the wind farm construction took place (Nunneri et al. 2008). The simulation of current and sediment dynamics with MIKE 21 revealed that effects are limited to a very local scale, i.e. in the very near surrounding of turbine piles. In combination with the wake effects, small variations can be expected for the abiotic heterogeneity.

The GIS analysis of sea bird abundance data showed, that considerable parts of selected bird species' populations will be affected by the offshore development. This would cause a change in bird species distribution in the research area. The results from the Dutch Nearshore Wind farm (NSW) project concerning the abundance of fish species showed a very slight increase in fish biomass in the wind farm area but no significant changes in species distribution were found yet (Gloe 2009). Table 5.4 gives an overview of the integration of ecological modeling results within the assessment of ecological integrity. The results of this assessment are shown in Figure 5.25.

Tab. 5.4: *Ecological integrity groups and indicators, parameters and data sources applied for their quantification (modified from Burkhard et al. 2009).*

Orientor groups	Indicator	Parameter	Data source
Energy budget	Exergy capture	net primary production	ERSEM
	Entropy production	C / year from respiration	Ecopath
Matter budget	Storage capacity	C stored in biomass	Ecopath
	Nutrient cycling	winter turnover of nutrients	ERSEM
	Nutrient loss	transport loss of nutrients	ERSEM
Structures	Biotic diversity	Diversity sea birds	GIS data
		Diversity fishes	Data NSW
	Abiotic heterogeneity	turbidity + wake effects	MIKE21, ECOHAM
	Organization	Ascendancy	Ecopath

Discussion and conclusion

The ecological modeling showed an increase of complex structures in the marine ecosystem due to the installation of offshore wind farms. The results presented in Figure 5.25 show that some of the selected indicators are sensitive to the impacts of the disturbances of the construction phase. During the operation phase, most of the parameter values indicated a resilient system behavior, i.e. processes and structures return to a state comparable to the reference conditions. Exceptions are storage capacity, abiotic heterogeneity, organization and nutrient cycling which increase slightly. This could be taken as a first indication for the emergence of a more complex (artificial reef) ecosystem. Unfortunately, the model simulations did not cover time periods long enough to sufficiently illustrate long-term dynamics. The Ecopath calculations for example do not represent the final stage of development potential. In spite of this, the main exception of the analysis is bird species diversity. Here a permanent loss of habitats within the wind farm areas was assumed for selected species. This proves the argument that birds are of major concern in the context of offshore developments.

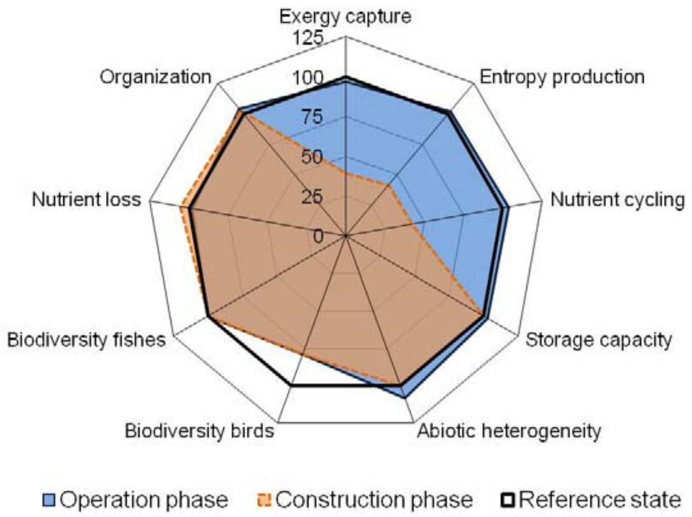


Fig. 5.25: *Synoptic overview of ecosystem development related to different phases of offshore wind farm installations in the German North Sea. The reference state (the German North Sea without offshore wind farms) is indicated by 100 %, alterations during construction and operation of wind farms are indicated by relative deviations (in %) from these reference values.*

One critical point in the assessment was the integration of different spatial and temporal scales. As the results showed, some effects take place on very local (individual turbine pile) scale only whereas other effects are relevant for the whole North Sea region. Therefore, Figure 5.25 should be regarded as a rather rough overview of possible systems developments. Differences on the particular spatial scales are shown in the ecological integrity assessment in the context of the ecosystem services analysis (chapter 8). With regard to ecosystem services, the development of artificial reef ecosystems would cause an increase in ecological integrity and thereby improve the provision of many marine ecosystem services. Nevertheless, the installation of huge offshore wind farms is a substantial change of marine and coastal systems. Therefore, their planning and monitoring should be carried out carefully and adaptive strategies are needed in order to harness benefits without jeopardizing the integrity of high value ecosystems. In future research projects, the coupling of models with data from monitoring programs, for example from the test offshore wind farm Alpha Ventus, will provide possibilities to further improve and to calibrate the simulations.

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6 Stakeholder Analysis in *Coastal Futures*

Kira Gee, Katharina Licht-Eggert

Although public support for renewables in Germany has generally been high (European Communities 2006) and the institutionalization of renewable energy generation proceeded apace (Byzio et al. 2005), the debate on whether large-scale offshore wind parks are a desirable feature of Germany's low carbon future and where the limits of development might lie is ongoing. From its first inception in the German context in the late 1990s opinions on offshore wind farming have ranged widely, leading to a multi-faceted and sometimes controversial debate across geographical scales and political orientations. Although there are other contributing factors such as technological feasibility and not least the costs of construction, the long and protracted process of siting offshore wind farms in the EEZ is the main reason that Germany lags behind in terms of actual construction (see also chapter 2). At the time of writing (November 2009) the first offshore wind farm (Alpha Ventus) has just been completed.

This paper refers to work carried out in the period 2004-2006, when the process of granting planning permission for offshore wind farms was still a relatively recent development. The first offshore wind farm in the EEZ of the German North sea was approved for construction in 2001. Approval was limited to 12 turbines to be built off the island of Borkum (Lower Saxony), about 45 km offshore at a water depth of 30 meters. A total of 13 parks had been approved for construction in the German North Sea and Baltic Sea (EEZ) by 2006, but none had actually been built (www.bsh.de). As a result, the offshore wind farm debate in Germany at the time was very much about potential impacts and expectations rather than actual fact, which has continued to be the case until late 2009.

6.1 Core issues surrounding offshore wind

At the time of analysis in 2006, core issues from a planning point of view were the sea cable connections to the mainland and the siting of the proposed offshore wind farms in the case study area. Beyond the planning issue, however, stood the fact that many of the short- and especially long-term impacts of offshore wind farms on ecological, economic and social systems were found to be difficult to predict (e.g. Kannen et al. 2004, Garthe & Hüppop 2004, Gill 2005). In the case study region, ecological concerns have largely focused on the Wadden Sea and wider North Sea ecosystem, where migratory birds, marine mammals or the marine environment in general enjoy protected status (see chapter 5). Socially, there were issues related to employment, new versus traditional sectors of work and general attitudes of local people to change in a rather traditional and structurally weak region (Ziesemer & Zahl 2005, Kannen 2005).

These concerns stood against a concerted regional and national drive to push for offshore wind farm development as part of the federal government's plans to increase the country's share of renewable energies. Wind industry and operating consortia constituted a strong lobby in favor of large-scale offshore wind farms. They had a - perhaps surprising - ally in national and international nature conservation organizations which also support offshore developments because of climate concerns. Greenpeace Germany went as far as saying there was no alternative to offshore wind energy, and the German Association of Nature Conservation Organizations (DNR) started a publicity campaign for wind farms together with the Federal Ministry for the Environment and the Federal Environmental Agency (DNR 2006, Greenpeace 2006).

Against this background, the overall goal of the *Coastal Futures* stakeholder analysis was to arrive at a better understanding of the prevailing opinions on offshore wind farm development in the case study area. What opportunities and risks do different stakeholders associate with offshore wind farms? How does this relate to the ecological and economic risk potential identified in *Coastal Future's* other work packages, and what does this mean for the future development of offshore wind?

6.2 Methodological background

Stakeholder expectations of the impacts of offshore wind farms have been studied in the US, the UK and Denmark, for example (Kempton et al. 2005, Firestone & Kempton 2007, Bishop & Miller 2007, Ladenburg 2008 and 2009), each of which has a particular stakeholder focus. The study presented here combines a range of different methods to bring together the views of all relevant stakeholders. A particular benefit is that it yields a clearer understanding of the key values that ultimately shape attitudes and concerns with regard to the marine environment. This has been instrumental in eliciting the specific cultural ecosystem services provided by the sea (see chapter 8). Primarily, though, it helps to identify stakeholder conflicts or convergences of interest. This in turn is useful for assessing the likely future trajectory of offshore wind farm development and for designing marine planning and management processes (see chapter 10).

Stakeholder analysis is a method used to identify and describe stakeholders on the basis of their attributes or interests in a system (Grimble & Wellard 1997, Ramirez 1999). As such it has served many purposes in many different contexts (e.g. Ellegard 1998, ODA 1995, Coastal Resource Centre 2005). Here we use it to identify positions, opinions, perceptions and values at the individual and group level (see also Lockie & Rockloff 2005 for a similar approach). The study was carried out with two specific aims: Firstly, to identify the relevant stakeholders and to map their prevailing attitudes to offshore wind farming on a scale from 'strongly in favor' to 'strongly against', and secondly to uncover the reasons behind these positions. Here we expected both material and immaterial gains and losses associated with offshore wind to play a role (see also chapter 8). Support for offshore wind farms, for example, could be based on expectations of direct economic gain, but could also be driven by purely emotional reactions or deeply held worldviews. The same could apply to opposition to offshore wind farms, where aesthetics and perception of the landscape could be key immaterial qualities with influence on attitudes. The aim was to draw up a range of comparisons between different stakeholders and stakeholder types.

For the purpose of the study, stakeholders were defined as 'individuals and formal or informal groups and organizations with an interest or involvement in offshore wind farming or its systems context, either because the person/group is itself influenced by offshore wind farming or because the person/group actively influences offshore wind farming or its systems context'. Group stakeholders represent institutions, organizations or networks; individual stakeholders represented selected local residents.

6.3 Methods

For the group stakeholders, the first task was to identify relevant institutions and organizations at four spatial levels of stakeholder activity: international, national (federal Germany), regional (the state of Schleswig-Holstein) and local (the districts of Dithmarschen and North Frisia). This was done through a literature search and consultation with regional contacts and yielded a total of 430. Each of these was assigned to a sector (e.g. 'nature conservation'); the respective organizational types (e.g. public authorities, NGO) were also noted. The result was an organizational matrix which could be analyzed by sector strength (e.g. the total number of stakeholders in each sector, number of local vs. national stakeholders per sector) and composition (e.g. public bodies versus NGOs, national vs. local organizations). For each of the 430 stakeholders, published documents (PD) such as position papers, information on the website or press releases were then searched for that indicated their positions vis-à-vis offshore wind farming. A total of 90 documents were found; one recent document was used per stakeholder.

For those same 430 institutions and organizations, statements were sought that would indicate their respective positions vis-à-vis the specific offshore wind farms Sandbank 24, DanTysk and Butendiek (subsequently labeled CD). This enabled some comparison of positions of principle (i.e. attitudes to offshore wind farming per se) and positions on specific wind parks in the German EEZ. It also provided some indication of representativeness in terms of the number and type of stakeholders included in the public consultation phase of offshore wind farm licensing. Out of the 430 with a stake in offshore wind farming, 79 turned out to be included in the public consultation procedures. 57 had provided written statements (see also Licht-Eggert et al. 2008). Table 6.1 summarizes the total number of stakeholders identified per sector and the number of documents that were found and subsequently used in the analysis (both PD and CD).

***Tab. 6.1:** Total number of stakeholders and publicly available documents found per sector (PD), compared to the number of stakeholders in the public consultation rounds for selected offshore wind farms and the number of statements actually given per sector (CD) (adapted from Licht-Eggert et al. 2008; see also for more detailed definitions of the sectors)*

Thematic sector	Total no. of stakeholders identified per sector	No. of documents (PD) analysed per sector*	No. of stakeholders involved in public consultation	No. of statements identified per sector (CD)*
Administration	107	9	35	28
Aviation	17	1	1	1
Culture	12	0	0	0
Economy	36	6	0	0
Electricity generation and energy provision	21	5	3	2
Fisheries, aqua- and mariculture	17	2	5	5
Harbours and shipping	27	2	7	2
Nature conservation	35	13	14	10
Oil and gas/pipelines	15	3	2	2

other	15	4	2	2
Politics	34	24	0	0
Research	8	0	1	1
Security and military use	10	0	1	1
Sport and leisure	5	1	2	2
Tourism	46	2	1	1
Wind energy	25	18	5	0
Total	**430**	**90**	**79**	**57**

** In the analysis only one document/statement was used per stakeholder. Numbers therefore also indicate the total number of stakeholders that actually voiced their position on offshore wind farming.*

In all, 147 text documents (PD and CD) were analyzed (for methods see Diekmann 2005). Key words or phrases were used to establish absolute stakeholder positions on offshore wind farming; qualitative analysis was used to typify the arguments used. Coding of arguments and typification was done in vivo using the program MaxQDA, adding new headings to the thematic groups of arguments as they became necessary.

Local residents were surveyed in October 2005 by means of a postal questionnaire (for methods see Gee 2010). 1095 questionnaires were sent to randomly selected households in 15 local municipalities. Although the survey itself was not statistically representative, the municipalities included represented a comprehensive cross-section of local conditions, including the North Frisian islands, coastal tourist destinations on the mainland, towns and small rural communities in the hinterland. The rate of return was around 22 %, with 237 responses included in the subsequent analysis.

6.4 Stakeholder matrix

The left hand column of Table 6.1 shows that in terms of sheer numbers of relevant institutions and organizations, some sectors are clearly dominant. Except for administration and tourism, where about half of the stakeholders listed are local groups (municipalities in Dithmarschen and North Frisia, local tourism associations), large sector size tends to indicate relatively equitable representation of stakeholders across the national, regional and local geographical scales. Nature conservation and politics are among the largest sectors, which is expected given the importance of the Wadden Sea and the high interest of conservation organizations in renewable energies. In terms of organizational types, there is an overall dominance of public bodies (again owed to the complex administrative system in Germany); most NGOs and other civil society organizations congregated in the nature conservation sector (not shown in the table).

The overall weight of a sector, however, does not equal interest or active 'stake' in offshore wind farming. Surprisingly few institutions and organizations actually have a clear public position on offshore wind farming, even if it is just articulating a neutral one. Relevant documents were only found for 90 out of 430 key stakeholders. Predictably, it is political stakeholders, nature conservation organizations and the wind energy sector that are most vociferous. Whilst this may be a question of resources, especially for small local organizations, it could also indicate that offshore wind farming is considered tangential, that the position is subsumed in another stakeholders' position (e.g. a local view taken up by a regional association), or a 'wait and see' type attitude where the stakeholder is unwilling or unable to take up a position based on the currently available information.

In the context of licensing specific offshore wind farms, it is interesting to take a closer look at the number and type of stakeholders that are actively engaged in the public consultation phase. Although there are constraints resulting from the consultation procedure itself - issues of remit for instance, also some local views can be assumed to be represented by larger regional organizations - it is particularly local stakeholders that are underrepresented in the (in any case limited) public consultation phase (Bruns & Gee 2009). Stakeholders from the economy and the wind energy sector do not appear to take part; also missing are stakeholders from the tourism sector, which after all constitutes an important segment of the local economy in the case study area. Naturally, not every organization listed as a stakeholder will wish to comment; some communal representatives for instance consider the planning documents too complex to deliver meaningful comments. Also, failure to become involved is not necessarily a failure of process, but may indicate unevenness of mobilization, a sense of futility ('why bother'), inability or unwillingness to comment or the simple fact that stakeholders do not feel affected by the proposed offshore wind farm. With communication playing a key role in this context, it is interesting to note that the local press mostly discusses offshore wind farming in a positive context and much less controversially than might be assumed (Licht-Eggert et al. 2008). As it stands, the public consultation process nevertheless falls short of delivering a key aspect of governance, which is broad involvement of stakeholders.

6.5 Stakeholder positions on offshore wind farming

Questions of representativeness become particularly relevant when linking involvement in the consent process to the opinions held on offshore wind farming. Table 6.2 provides an overview of the attitudes revealed by different methodological components.

***Tab. 6.2:** Positions on offshore wind farms: results of different elements of the stakeholder analysis.*

Methodological component	in favour of offshore wind farms ☺	neutral	against offshore wind farms ☹
Content analysis (PD), n = 90	83 %	8 %	9 %
Content analysis (CD), n = 52	17 %	58 %	25 %
Questionnaire survey of local residents, n = 237	45 %	11 %	44 %

Favorable attitudes to offshore wind farming were expressed in 83 % of all public documents assessed. Positive attitudes are found across all sectors and stakeholder types, with nature conservation organizations, regional governmental organizations, political parties, companies or federal ministries all arguing in support. This suggests broad organizational and institutional consensus on the general desirability of offshore wind farming. One of the reasons might be the convergence of different lines of argument, with offshore wind farming providing not only environmental benefits, but also incentives to the local economy and the German wind industry in general (BMWi 2008). Opposition to offshore wind farms in PDs mainly comes from local organizations, in particular those from island communities.

In contrast, only 17 % of the respective stakeholders state their explicit support for offshore wind farms in the public consultation documents; at 25 % the share of opponents is also significantly greater than in the PDs. Some of this difference may result from the fact that the consultation phase asks stakeholders to comment on specific offshore wind farms rather than offshore wind farming in general, which is why stakeholders giving a negative statement here may well have a positive attitude in the PDs. The high percentage of neutral statements in the CDs could suggest uncertainty, mask a more negative attitude or simply a 'take it or leave it' attitude. Again, stakeholders with negative attitudes to offshore wind parks are almost exclusively found at the local level (Licht-Eggert & Gee 2006), indicating greater caution the closer the proposed offshore wind farms are perceived to hit home. At the level of the local population, absolute opinions on offshore wind farms show no clear-cut preference. The sample is fairly evenly divided between those in favour of offshore wind farming and those against (45 % vs. 44 %), with 11 % professing no opinion on the issue.

6.6 Arguments raised

Document and questionnaire analysis show a wide range of arguments are raised in support and opposition to offshore wind farming. Table 6.3 compares results obtained through different methods. Figures indicate the percentage use of each argument type relative to the total number of arguments that were counted, which gives an estimate of the relative importance of each topic in the overall pattern of argumentation. Table 6.3 also indicates which perspectives are primarily drawn on to argue for and against offshore wind farming, and where acceptance of offshore wind farming is attached to certain conditions.

Tab. 6.3: Topics used to defend positions on offshore wind farming, with figures indicating the percentage of use of each argument relative to the total number of arguments used. ☺ = arguments in this category predominantly used in favor of offshore wind farms, ☹ = arguments predominately used in opposition to offshore wind farms ! = condition or demand for lending support to offshore wind farming. n.a. = not applicable on account of too small a percentage of mentions (from Licht-Eggert et al. 2008).

Argument thematic group	public documents		statements in public consultation procedure		local population	
Arguments mainly used to support offshore wind farms						
climate change	3.3	☺	0.2	☺	0.2	☺
energy	7.9	☺	2.1	☺	23.2	☺
port and harbour development	0.6	☺	0.2	☺	n.a.	n.a.
local economy and jobs	9.0	☺	0.2	☺	5.2	☺
Arguments mainly used to object to offshore wind farms						
nature conservation	13.0	☹	20.2	☹	15.1	☹
aesthetic qualities of the landscape	1.5	☹	5.3	☹	21.8	☹
fisheries	0.3	n.a.	6.3	☹	n.a.	n.a.
shipping safety	6.1	!	19.4	☹!	3.6	☹
tourism	2.5	☹!	1.3	☹	n.a.	n.a.
Demands raised to qualify support for offshore wind farms						
legal issues	1.3	!	1.3	!	n.a.	n.a.
planning procedure and process	14.1	!	24.8	!	n.a.	n.a.
feasibility/technology/financing	18.0	!	15.8	!	4.4	☹☺
economic viability	7.5	!	2.1	!	4.6	☹
policy	3.0	!	n.a.	n.a.	0.4	☹
science	7.0	!	0.2	!	n.a.	n.a.
other	4.7	!	0.6	!	0.6	n.a.

Out of the above table some interesting differences emerge, suggesting different priorities and viewpoints taken by different stakeholders. The first aspect to note is that comparatively few arguments are actually fielded in clear support of offshore wind. As far as PDs and CDs are concerned, a greater proportion of the respective total of arguments is raised in opposition, suggesting that stakeholders can readily think of problems but are pushed to offer explicit reasons why offshore wind should go ahead. This seems to contradict the high degree of support lent to offshore wind farming in the PDs. A simple interpretation is that stakeholders consider the advantages of offshore wind to be apparent and do not see the need to re-iterate them. Another is that the high overall institutional support expressed for offshore wind farming in the PDs may not indicate outright support, but rather the difficulty of finding convincing arguments against this technology and also the lack of a renewable alternative with equal potential (Gee 2006). Another is that institutional and organizational support in fact represents an opportunistic strategy that makes use of a particular set of circumstances to realize political and economic gains. Doubtlessly, the circumstances are ideal for developing offshore wind, with climate change representing an overall concern, high public support for renewables, no real opposition from the classic conservation interest groups, supportive EU policy, economic incentives in place (the EEG) and the sea as an available space (Gee 2010b). That said, there is also a considerable amount of qualified support given to offshore wind farms in the CDs. evidenced in the many different conditions and demands that stakeholders raise but not as insurmountable obstacles. Concerns mostly refer to technological feasibility or expense; for others the long-term economic feasibility is a concern. Much hope is also placed in an appropriate spatial planning framework in terms of reducing environmental impacts and providing greater planning security for investors.

In terms of the actual arguments fielded, nature conservation and shipping safety concerns are two main reasons for objecting to offshore wind farms. Shipping safety is a particular issue in the CDs and a predominantly local concern, whereas nature conservation has similar shares of the total number of arguments across all three categories. In this latter the level of detail in the arguments raised suggests good knowledge of the issues involved; numerous individual marine protected species and habitats were quoted as a specific concern (e.g. heightened risk of bird collisions. effects of noise and vibration on marine mammals). But nature conservation arguments are also emotionally driven, in particular where local residents are concerned (e.g. dangers to the Wadden Sea ecosystem or general degradation of nature). Some stakeholders, predominately those from a nature conservation background, did also raise potential opportunities such as artificial reefs or the use of offshore wind farms as nursery grounds for fish, but argued that this would depend on other factors such as restricting access to fishermen.

An interesting finding is the category 'aesthetic qualities of the landscape', which hardly features at all in the PDs. a little more in the CDs but very prominently in the category of local residents, where it represents the key reason for objecting to offshore wind farms. Although some of this objection can probably be put down to a combination of an onshore wind farm effect (where many do find wind turbines a visual nuisance) and lack of information - after all the proposed offshore wind farms will be almost invisible from the shore - more detailed analysis has shown that many residents are quite firm in their belief that the sea should not be marred by any 'industrial' type of use at all. This represents a line of argumentation that brings together aesthetic and moral sea values, with clear emphasis on mankind's duty to preserve the marine environment 'untouched', as a counterpoint to the 'despoilt' mainland and for its own sake, irrespective of any instrumental values that might be drawn from it (Gee 2010a). Whilst the visual aesthetic argument is at least raised in the CDs by some local stakeholders, the view of the sea as a 'last wilderness' that should not be wholly developed is not raised by any group stakeholder at all. Given the difficult trade-offs in the minds of local residents between the principle of renewable energy generation and preserving a particular notion of the North Sea, it is notable that two apparently essential concerns - the moral and visual aesthetic ones - are absent from the debating table both in the public consultation phase for offshore wind farms and in the wider public debate on the future of the North Sea.

Looking at arguments primarily fielded in support of offshore wind, the category 'energy' stands out, although the overall importance of this particular category differs considerably between group and individual stakeholders. 'Energy' comprises arguments such as clean/ green/ renewable energy or 'an alternative to nuclear and coal'; the specific argument 'environmentally friendly form of energy generation' makes up a significant 23 % of all arguments within the sample of the local population. Added questionnaire results have shown that local residents consider regenerative energies to be a moral issue, where the principle of renewables is considered good and becomes a main reason for supporting offshore wind farms. This then poses a moral dilemma for those who also consider the marine environment to be sacrosanct and place high intrinsic value on the sea itself (Gee 2010a), which might explain the sometimes ambivalent attitude of local residents to offshore wind. In contrast, the green energy argument only accounts for 7.9 % of all arguments raised in support in the PDs and 2.1 % in the CDs. indicating that this argument is less of an issue to group stakeholders.

Other opportunities put forward as a reason for supporting offshore wind also show differences between local and national and regional perspectives. Seen through PDs, opportunities associated with offshore wind farms seem to relate primarily to their impact on the local economy and potential to generate jobs. 9 % of all PD arguments name local economy and jobs as a reason to support offshore wind farms, as do 5.2 % of the local resident sample; this however is not matched by local opinions voiced in the CDs where the employment argument hardly features at all. The 'local job' argument does not match real opportunities on the ground; in the case study area recent development decisions have effectively prevented Dithmarschen and North Frisia from developing into an offshore wind farming servicing and infrastructure hub. Opportunities that may at one point have existed have therefore been lost locally.

6.7 Discussion

From the above analysis of stakeholder positions and attitudes to offshore wind farming, some notable differences in perception emerge between institutional stakeholders and local residents. Differences also exist between attitudes to offshore wind farming in general and specific wind farms planned in the German North Sea EEZ.

From the arguments used, three main stakeholder camps can be identified, two in favor and one in opposition to offshore wind farms. One small camp brings together local and regional stakeholders who argue offshore wind farms to be a key in securing economic advantages and possibly local jobs. Not surprisingly, these tend to be political organizations, stakeholders from industry, and also administrative institutions; it should also be pointed out that the arguments of national and regional stakeholders do not necessarily reflect the real potential of Schleswig-Holstein's West coast. The second, larger camp is led by nature conservation organizations who almost universally endorse offshore wind farming as an efficient alternative source of energy. The former red-green federal government supported this view, pointing to a triple win scenario consisting of climate benefits, economic growth and technological innovation. From these camps a strong coalition of interest emerges in favor of offshore wind farming which extends across sectors and scales and also draws in the more skeptical stakeholders as long as it is linked to appropriate siting, ecological monitoring and continued political support.

Whilst there seems to be high support for offshore wind farming in principle, greater caution appears to be exerted by those who could consider themselves more directly impacted. At the local level, stakeholders carefully weigh the potential advantages against the perceived disadvantages of offshore wind. Cultural ecosystem services are a useful way of framing their concerns, highlighting in particular the immaterial values many residents consider threatened by the large-scale expansion of offshore wind farming (Gee & Burkhard 2010). At the same time, the principle of renewable energy generation and the idea of a more universal cross-generational benefit does appear to count strongly, overriding some of the above concerns (Gee 2010b). Group stakeholders consider shipping accidents to be a major risk, with indirect consequences feared for the environment and hence tourism. Another opposing group are local residents concerned with the loss of essential marine qualities, which is rated higher than the principle of renewable energy generation. Their experience of the seascape is emotional, sometimes even spiritual and tends to focus on a sense of freedom, on the open, expansive horizon and the role of these in generating sense of place and identity. Opposition is therefore mostly local and likely to be less 'weighty' than the views of the coalition of interest described above.

Some lessons can be drawn for shaping dialogue on the future of offshore wind in the case study area. An important consideration is that offshore wind seems widely acceptable in principle as long as wind farms are sensitively sited and open questions surrounding their economic and technological feasibility are resolved. From the analysis, and in the period considered, no clear lobby group could be identified with an interest in preventing offshore wind farming and no 'good reasons' are put forward against offshore wind that would prevent its development in principle. This, however, is conditional to the siting of offshore wind farms to minimize any potential visual aesthetic impacts, as well as the continued lack of any negative impacts on the marine ecology.

A concern that remains is the fact that current sea planning processes - and the public debate for that matter - fail to recognize the full multiplicity of sea use values, in particular intrinsic sea values such as those voiced by local residents. The fact that these views are not being heard may be due to the difficulty in eliciting them in the first place; also emotional concerns are rarely given credence as a valid argument. For political processes to be successful, however, decision-makers do need to satisfy the public that they are taking into account their concerns, and with these the underlying values, beliefs and feelings (Vining & Tyler 1999). Representativeness of processes must therefore be considered not only at the level of sectors or stakeholder numbers, but also in terms of the views that are brought to the debating table. Means must be found to identify the entire spectrum of sea use values (see chapter on cultural ecosystem services) in order to weigh up choices for future sea use based on a balanced assessment of values. Efforts must also be made to mobilize those stakeholders to take part in the debate whose values are not (yet) represented by any existing group.

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7 Analyzing potential Impacts of Offshore Wind Farms on regional Economic Development

Olav Hohmeyer, Andreas Kannen, Marcus Lange, Jörg Köhn

In regions with good wind energy potential such as Germany's North Sea coast, wind energy holds substantial promise of increased economic activity and employment. This has been a key argument for regional developers along coastal areas for supporting the development of offshore wind energy.

In order to analyse opportunities and possible pathways of regional development that could originate from offshore wind, the potential regional economic effects of offshore wind energy were analyzed by O. Hohmeyer based on a regional input-output model (see chapters 7.1 - 7.4). Another opportunity for regional development is provided by co-uses, e.g. combining offshore wind farming with marine aquaculture (see chapter 10 and Michler-Cieluch et al. 2009) or hydrogen production (see chapter 7.6). Either pathway could lead to impacts of offshore wind farming on the economic and social well-being in the region (see chapter 8).

The study focused on the German North Sea coast, in particular the administrative districts of Dithmarschen and Nordfriesland (North Frisia) in Schleswig-Holstein, one of the 16 federal states (Länder) in Germany. The input-output analysis compares the results for these local areas to those available for the national scale. An important aspect for interpreting national or regional data is that the urban federal states of Hamburg and Bremen are located in the vicinity of the coastal region, both of which have strong economic impact on the German North Sea region. Dithmarschen and Nordfriesland, in contrast, are predominately rural areas dominated by tourism (economically) and agriculture (in terms of land use). An exception is the southern part of Dithmarschen, where the chemical industry provides an industrial basis.

7.1 Regional input-output analysis

Positive economic effects of wind energy use can occur on different levels of the wind energy value chain. They may be found in very different regions depending on the actual location of the economic activities along the value chain. Whilst the use of wind energy induces positive economic impacts, the replacement of conventionally generated electricity by wind energy will have some negative economic effects due to reduced electricity production in conventional power plants. Due to the variable nature of wind energy and its low capacity credit, it temporally replaces the operation of conventional power plants but not the construction of such plants. As a result, negative economic effects are limited to the reduced operation of conventional power plants. In cases where wind energy has higher production costs than the substituted operation and fuel costs of conventional electricity generation, higher electricity costs result. The increased electricity bill of consumers reduces the money available to purchase other goods or services. Where demand is reduced as a result of the switch to wind energy, a lessening of economic activities will therefore result in other sectors of the economy.

To enable the analysis of the different levels of production and preproduction along the wind energy value chain, a comparative static input-output-analysis was used. The official input-output-table for Germany of the year 2000 was used as a basis, which disaggregates the German economy into 59 industries. As the German input-output-table is functionally aggregated, it is possible to interpret the input-vector of each industry as an aggregated production function of its mix of products. Functional aggregation allows the integration of additional production functions of single technologies as additional input vectors into the input-output-table (see e.g. Petersen 1976, Hohmeyer 1989). In this case, this would apply to the production of wind turbines, for example. Data for such production functions were gathered during the research project by structured interviews of producers, operators and planners of wind turbines and wind farms. These interviews covered internal production structures and the cost of intermediate products purchased as inputs to the respective production process. Over 20 different companies were interviewed. Data collected included the costs of the different primary inputs like labour and capital costs, as well as the actual number of working hours used in production. A number of prior analyses of the production function of different parts of the wind energy value chain were also drawn upon (DEWI 2001 & Fichtner 2001, Croll & Trittin 2002, Dibbern 2003, Niedersächsische Energieagentur et al. 2001, DEWI 1999, DEWI 2001, DEWI 2002).

Seventeen different production functions of different steps of the wind energy value chain were developed and integrated into the basic input-output-model as additional input vectors. Based on the representation of the direct input structures of the total of 76 industries of the enlarged input-output-model (the so-called A-matrix), the inverse of this input matrix was calculated. The resulting so-called Leontief-Inverse (I-A)-1 - named after the Nobel laureate Wassily Leontief - contains input coefficients which summarize all steps of induced preproduction, as the matrix inversion of the direct input coefficients of the A-matrix is the mathematical equivalent to summing up the geometric chains of all preproduction effects induced in a matrix of such summarizing coefficients. Multiplying the final demand for any given product with the Leontief-Inverse allows the calculation of all induced production effects along all steps of preproduction and the resulting employment effects.

As the income resulting from induced employment and invested capital leads to further consumption spending, a multiplier effect results, which includes production and employment as further economic effects. The model includes the analysis of induced multiplier effects based on the results of the input-output-analysis.

To analyze the final net economic effects based on all economic impacts, a net analysis is carried out that recognises the following effects:

- Effects of new demand for wind energy (+)
    - Investment in wind energy technology
    - Operation and maintenance of wind energy installations
    - All intermediate production induced along the wind energy value chain
    - Income multiplier effects of all wind energy induced economic activities
- Effects of replaced demand for conventional electricity production (-)
    - Operation and maintenance of conventional power plants
    - All intermediate production along the conventional power value chain
    - Income multiplier effects of conventional power induced economic activities
- Effects of increased or decreased spending on consumption due to changed electricity costs (-/+)

- Direct production effects of consumption goods and services
- All intermediate production along the consumption goods value chain
- Income multiplier effects of the production of consumption goods.

To analyze the economic effects of new demand for wind electricity replacing conventionally generated power, all the above need to be taken into account. Otherwise gross effects are calculated, which seriously overestimate the overall economic effects.

Only part of the original economic activity on the last step of the value chain, and an even smaller part of the production along the value chain, is induced in the coastal region under analysis. Regional effects thus have to be differentiated from the national effects induced. In order to achieve this, the analytical model is regionalized. It takes into account the location of the activities along the wind energy value chain and the share of the region in the overall production in Germany. As electricity generated offshore mostly replaces electricity not produced in the region, and as most of the negative effects of higher electricity costs are paid for by consumers outside the region, the production of wind energy and wind energy technology in the region will most certainly lead to positive economic net effects for the coastal region under analysis.

7.2 Scenarios for the economic analysis

The economic effects of offshore wind energy development on the entire German economy as well as the regional economy were analyzed based on three scenarios for offshore wind development in the German North Sea that had been defined for the entire research project (see chapter 4). For economic analysis, they assumed 2 GW of installed offshore capacity by 2030 ('Little Implementation'), 15 GW of installed capacity ('Modest Implementation'), and 25 GW of installed capacity ('High Implementation', see Table 7.1). The year 2030 was also set as a cut-off point for investment in wind energy for the purpose of economic modelling. Economic analysis includes investment in wind turbines as well as 20 years of operation following the initial investment. It was assumed that in the best case, it would be possible to attract one third of all offshore contracts to Schleswig-Holstein. Although there were tentative capacity assumptions for the year 2055 in the *Coastal Futures* scenarios, these were not subject to any further economic analysis. It was assumed that under each scenario one third of the installed capacity would be shipped through the North Sea ports of Schleswig-Holstein.

For the (gross) value added remaining in the region an important consideration is the share of the total production, operation and maintenance of wind turbines that can be kept in or attracted to the region. To analyze the impact of potentially differing shares of value added remaining in the region, each of the three scenarios was subdivided into four sub scenarios (A to D), ranging from a maximum share of the value chain being realised in the 'West Coast' region (the administrative districts Dithmarschen and Nordfriesland/North Frisia) of Schleswig-Holstein including rotor blade and tower production (A) to the absolute minimum share with no wind energy specific production, operation or maintenance in the 'West Coast' region (D). This subdivision results in twelve different scenarios analyzed. Table 7.1 provides the installed capacities under each major scenario for the years 2010, 2030 and 2055 for the entire German North Sea and the corresponding shares of the 'West Coast' region of Schleswig-Holstein. The figures for 2055 are only indicative and were not used in any further analysis.

Tab. 7.1: Scenarios analyzed for the development of offshore wind energy in the German part of the North Sea (The numbers indicate the installed offshore wind power capacities in MW)

Cumulated Capacity in MW	Germany (North Sea)			Share of the 'West Coast' region of Schleswig-Holstein		
Year analyzed	2010	2030	2055	2010	2030	2055
Scenario 'little implementation'	926	2,329	15,000	309	776	5,000
Scenario 'modest implementation'	2,329	15,000	55,000	776	5.000	18,333
Scenario 'high implementation'	2,239	25,000	90,000	776	8,333	30,000

Sub-scenarios analyzed:

- **A - Maximum share of the wind energy value chain attracted to the 'West Coast' region of Schleswig-Holstein**
- **B - Constant share of the wind energy value chain as of 2005**
- **C - Loss of parts of production and wind park construction**
- **D - Loss of all wind energy related economic activities from the 'West Coast' region of Schleswig-Holstein**

7.3 Results of modelling

Modelling was performed using the model WindRegio developed by O. Hohmeyer. Within the modelling exercise, specific focus was on analyzing the effects on added value and employment. Results are compared between national effects and regional effects, with regional effects covering the area of the 'West Coast' of Schleswig-Holstein, defined here to encompass the counties of Dithmarschen and North Frisia.

Effects on value added

Analysis of the (gross) value added effects of the different scenarios on the German economy show relatively large gross effects induced by the investment in and the operation and maintenance of offshore wind energy in the German part of the North Sea. They range from 10.6 billion Euros for the scenario 'weak implementation' to 89.4 billion Euros for the scenario 'strong implementation' for the entire period analyzed. These gross effects of wind energy on (gross) value added have to be compared to the lost value added due to the reduced production of conventionally generated electricity and the consumption losses due to higher electricity costs. The remaining net effects are relatively small increases in (gross) value added of 0.7 billion Euros in the scenario 'weak implementation' and 4.4 billion Euros in scenario 'strong implementation', which is far below 10 % of the gross effects calculated. Figure 7.1 shows the ratio between gross and net value added effects as well as the shares of the different parts of the changed final demand.

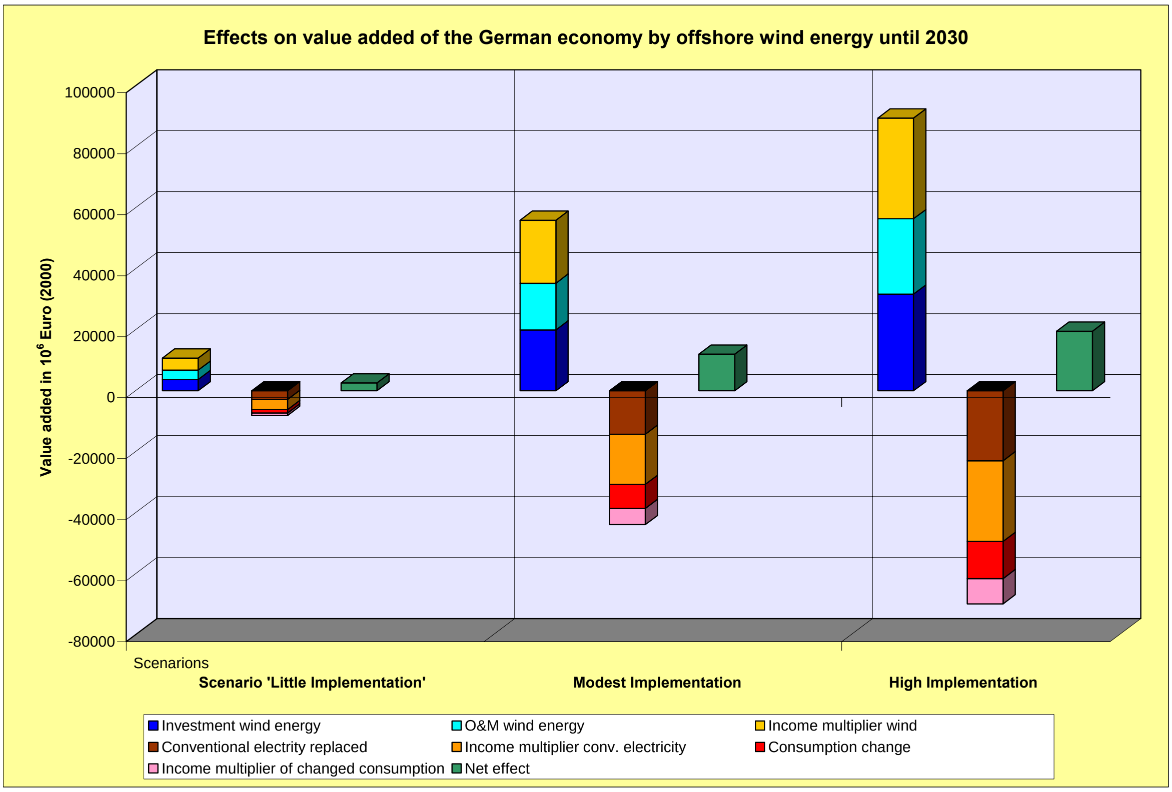

***Fig. 7.1:** Cumulated effects on gross v alue adde d in th e Germ an eco nomy d ue to the development o f offshore wind en ergy in the Ger man part of t he North Sea u ntil 2030 (tak ing int o account investments until 2 030 an d operation until 2050)*

Analyzing the structure of the gross value added effects of offshore wind energy on the economy of the region 'West Coast Schleswig-Holstein' demonstrates that negative effects have almost no impact on the region. Figure 7.2 shows this structure for sub scenarios A, which represent a very high share of the wind energy value chain being located within the region.

In this scenario, the region benefits most from the operation and maintenance for offshore wind energy. At the same time it experiences practically no losses in gross value added due to reduced conventional electricity production or due to reduced consumption as a result of higher electricity cost. This is due to the fact that all of the replaced conventional electricity production is located outside the 'West Coast' region. At the same time the additional costs for offshore wind energy production are levied on the average German electricity customer through a grid fee. Thus, more than 95 % of the reduced consumption due to increased electricity cost is induced outside the 'West Coast' region.

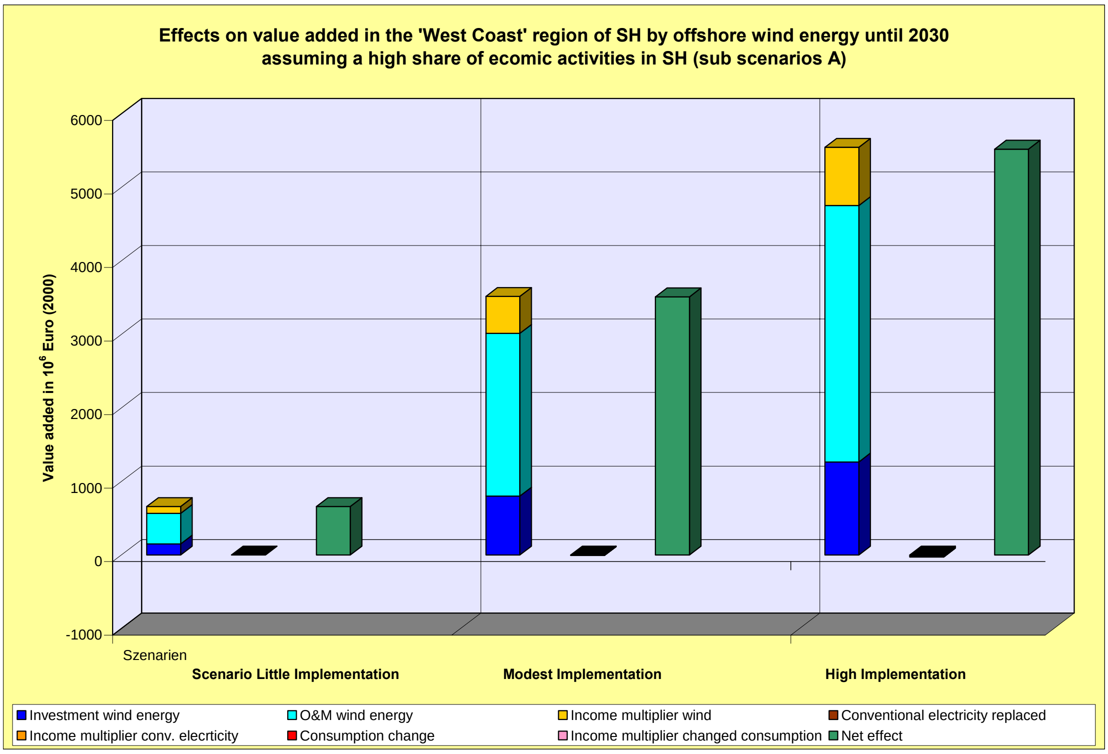

***Fig. 7.2:** Cumulated effects on gr oss value added in the region 'West Coast' due to th e development of offshore wind en ergy in the Ger man part of t he North Sea u ntil 2030 (tak ing int o account investments until 2 030 an d operation until 2050)*

Effects on employment

Induced employment effects are measured in person years, with a person year defined as full time employment for one person for one year. Effects shown are cumulated over the entire period to show the overall employment impact of offshore wind energy in the period analyzed. In the best case, the 'High Implementation' scenario, total net employment effects in Germany are just about 210,000 person years, while the gross effects of offshore wind energy are about 1.9 million person years. This effect has to be offset against the lost gross effects of replaced conventional electricity production and replaced consumption which amount to about 1.7 million person years. Figure 7.3 shows how the effects balance out.

A comparison of the net employment effects in Germany and in the region 'West Coast' as given in Figure 7.4 shows that it is possible to bring more than 50 % of the net employment generated (127.000 out of 214.000 person years) to the region if much of the wind energy value chain can be successfully concentrated in the region. To lose the parts of the wind energy value chain that already exist in the region would have a devastating result (1.100 out of 214.000 person years) in terms of economic development with practically no share of the net employment coming to the region. At the same time, the comparison of effects shown in Figure 7.4 underscores the importance of strong offshore wind energy development for the region: The difference in regional employment between the 'Little Implementation' and 'High Implementation' scenarios amounts to 110.000 person years.

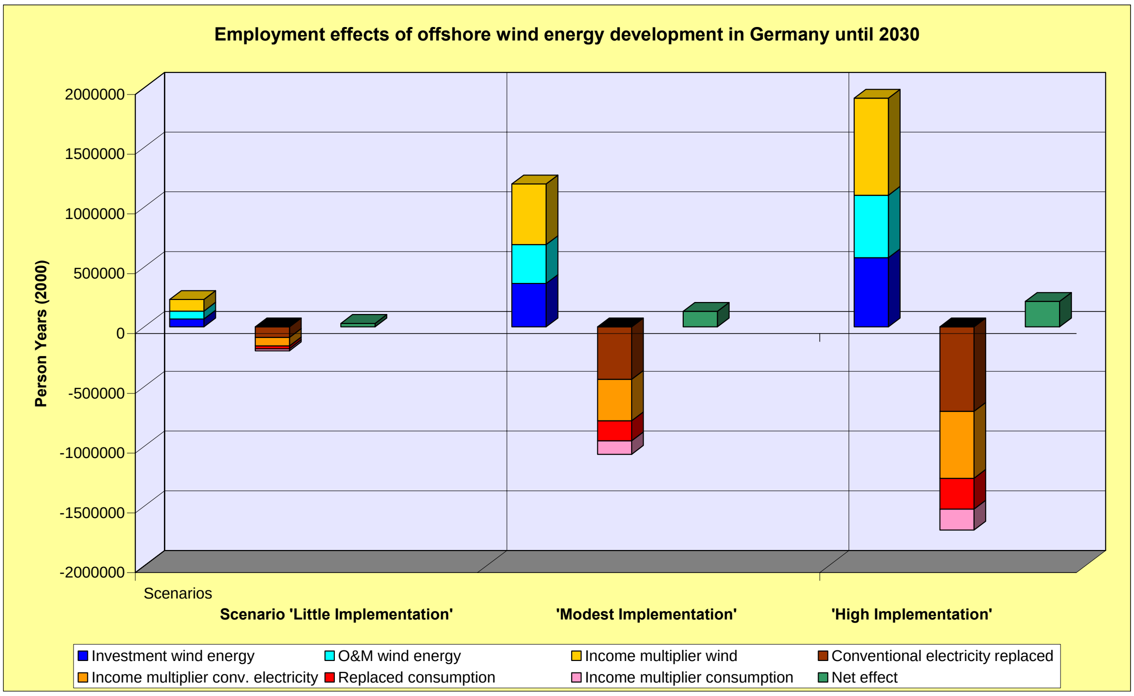

Fig. 7.3: *Cumulated employment effects in the German economy due to the development of offshore wind energy in the German part of the North Sea until 2030 (taking into account investments until 2030 and operation until 2050)*

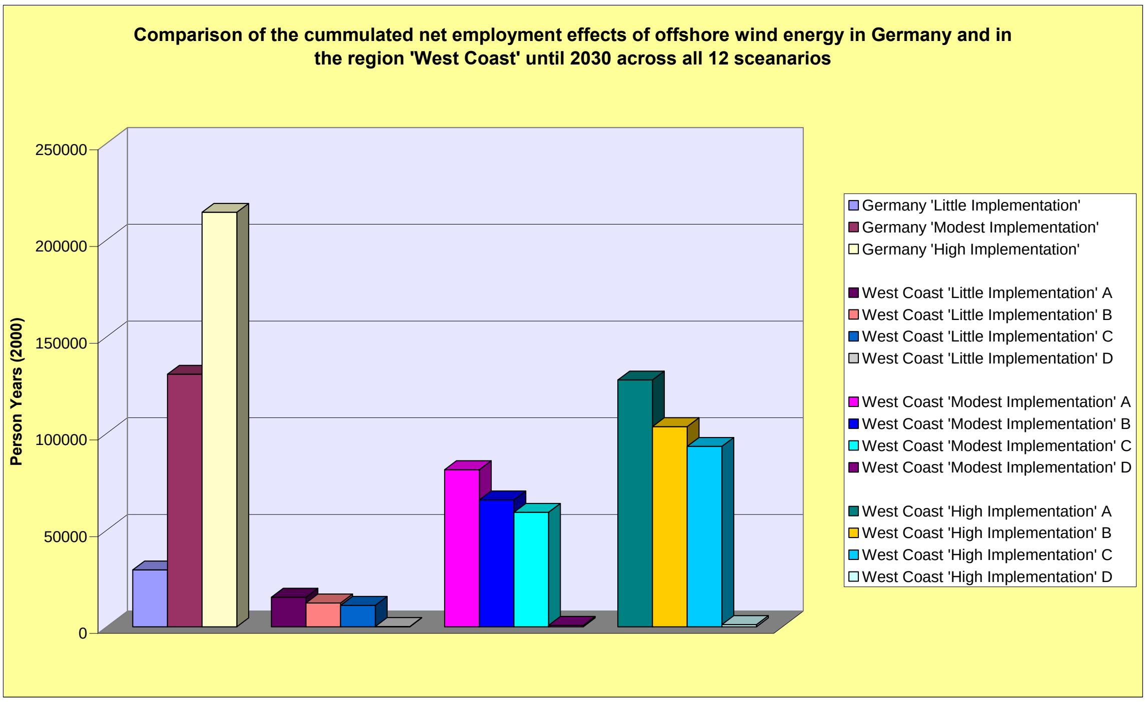

Fig. 7.4: *Comparison of the net employment effects in Germany and the region due to the development of offshore wind energy in the German part of the North Sea until 2030 across all twelve scenarios 2030 (taking into account investments until 2030 and operation until 2050)*

The comparatively high regional net employment effects are due to the high labour intensity of the operation and maintenance (O&M) of offshore wind turbines. Figure 7.5 shows the dominance of the O&M labour effects for wind energy in the region. As shown in Figure 7.2 for the net (gross) value added effects, the negative gross employment effects in the region are virtually zero. This leads to the surprisingly high share of net employment effects for the region compared to the total net employment effects in Germany.

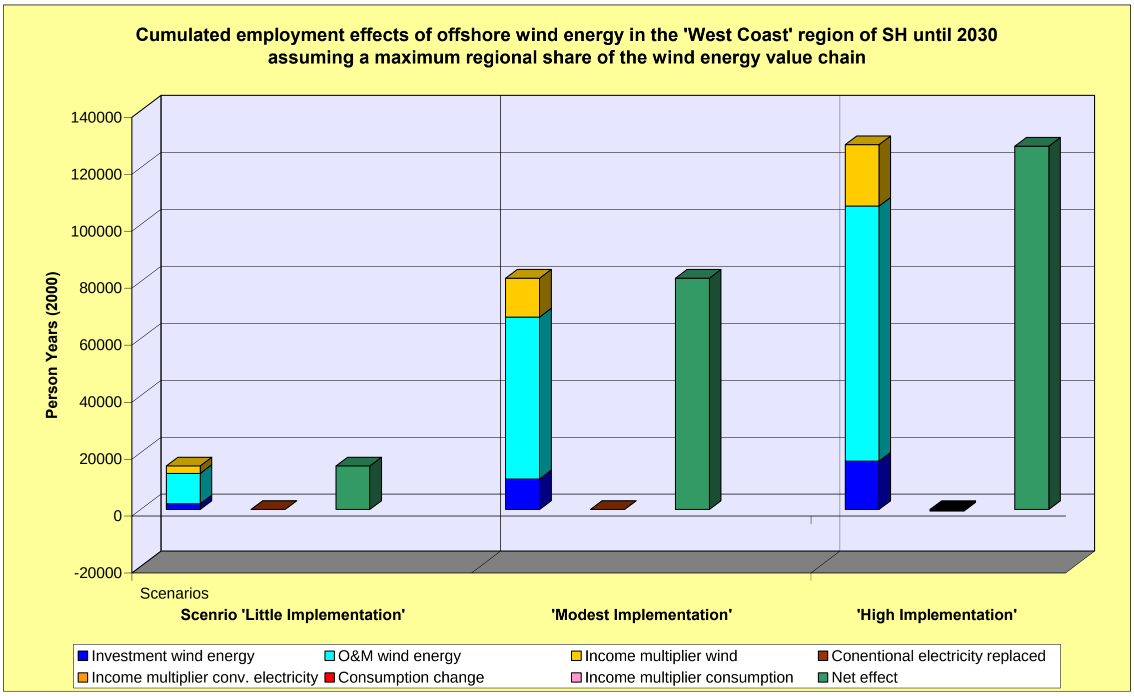

***Fig. 7.5:** Structure of the cumulated net employment effects in the region 'West Coast' due to the development of offshore wind energy in the German part of the North Sea until 2030 (investments till 2030 and resulting operation till 2050 taken into account)*

7.4 Discussion of results and limitations of the modelling approach

Offshore wind energy development in the North Sea can potentially become a major economic driver for employment in the 'West Coast' region of Schleswig-Holstein. In the economically optimal scenario more than 125.000 person years of employment can be created in a region with a relatively weak economy. During the period analyzed the average annual employment is about 3.000 person years. Nevertheless, it will be necessary to support the regional wind energy industry by active policies creating the necessary infrastructure (e.g. harbour facilities) for offshore development and attracting more companies in the wind energy value chain to the region. It is therefore in the region's economic interest to support strong offshore wind energy development in the German North Sea, as a very large share of the positive net employment effects can be realised in the region.

It should not be overlooked, however, that the analytical approach used here has some weaknesses and limitations. The main weakness is the static nature of all calculations due to the fixed input coefficients for all production functions of the input-output-model. This may lead to overestimation of the absolute gross effects of the different parts of final demand analyzed.

Asymmetrical development of the different industries can drastically change the resulting net effects. Due to the fact that the regional economic effects are almost exclusively positive, the regional net results will most likely be more stable than the net results for the entire German economy. Thus, although the modelling approach has some major shortcomings, the regional results seem to be rather robust.

Regional policy makers need to be aware of the fact that strong economic development in the region does not follow automatically from strong offshore wind energy development. If policy support in Schleswig-Holstein remains as weak as it has been during the last ten years, the region will most likely loose quite a share of the wind energy value chain presently established in Schleswig-Holstein, as other coastal regions are very actively trying to attract companies of the wind energy value chain by the establishment of a good infrastructure and strong political support for the industry.

7.5 The vision of hydrogen production as a co-industry for offshore wind energy

Andreas Kannen, Marcus Lange, Jörg Köhn

The results of the economic modelling demonstrate that a lively offshore wind industry can have strong effects on regional development in coastal areas along the German North Sea, with potentially significant impacts on societal well-being (see chapter 8). In rural areas, which currently strongly depend on non-industrial economic sectors such as tourism, offshore wind farming can also stimulate the investments necessary for strengthening the capital stock and modernity of the capital stock.

On the other hand, while providing a stimulus for regional development, investments in offshore wind energy might are expected to occur in the short to medium term. In order to strengthen regional development in the long term, German coastal areas would need to develop additional economic sectors.

Given the growing pressure of use on German sea areas, and given the resulting need for multifunctional concepts of use, (see chapter 2 and Gee et al. 2006a, 2006b), *Coastal Futures* investigated two options for potential co-use of offshore wind farms. The first option is mariculture, representing a promising avenue for producing fresh aquaculture products in offshore wind parks. Rather than technical or ecological barriers, it is social and economic barriers that need to be overcome for implementing it (Michler-Cieluch et al. 2009). This option is discussed in more detail in chapter 10 because it is strongly related to aspects of coastal governance. The second option is hydrogen production and storage, a visionary but possible form of co-use that would allow offshore wind energy to be stored and transported. Hydrogen, however, is more than a source of energy in that it is also a material resource used in many industrial processes. In this case, feasibility is primarily linked to market-driven arguments and technical aspects, including the question of how to link offshore production sites (wind farms) to land. Hydrogen production and storage is also an important option in the context of a potential future economy based on renewable energies.

Five workshops organised within *Coastal Futures* discussed the future prospects of linking offshore wind energy and hydrogen production. In total, 60 persons took part in the workshops representing industry, research bodies and federal and state authorities and institutions. Given the current lack of a mass market for hydrogen, this was a visionary exercise, aiming to place hydrogen in a wider context beyond a merely technological debate. Figure 7.6 outlines an initial scenario-like concept that was developed from the first two workshops. While the top arrow in Figure 7.6 represents the direct path of feeding offshore wind energy into the electricity grid, the arrows below describe the transformation of surplus wind energy into hydrogen (electrolysis). Hydrogen can then be transported onshore through pipelines or ships, where it is used for gasification and the production of synthetic fuels.

Although energy storage is still the primary use of hydrogen in this vision, there are many options for extending the concept further. In Figure 7.6, wind energy and other renewable energy sources are combined with hydrogen to allow for storage and electricity generation, but also the production of synthetic fuel. Another example would be to use hydrogen in the conversion of carbon dioxide into valuable industrial products such as methanol. The significance of this visionary concept is its potential for broadening the use of hydrogen: rather than using it only in electricity production, it could be combined with other renewable energy sources and used in various industrial processes.

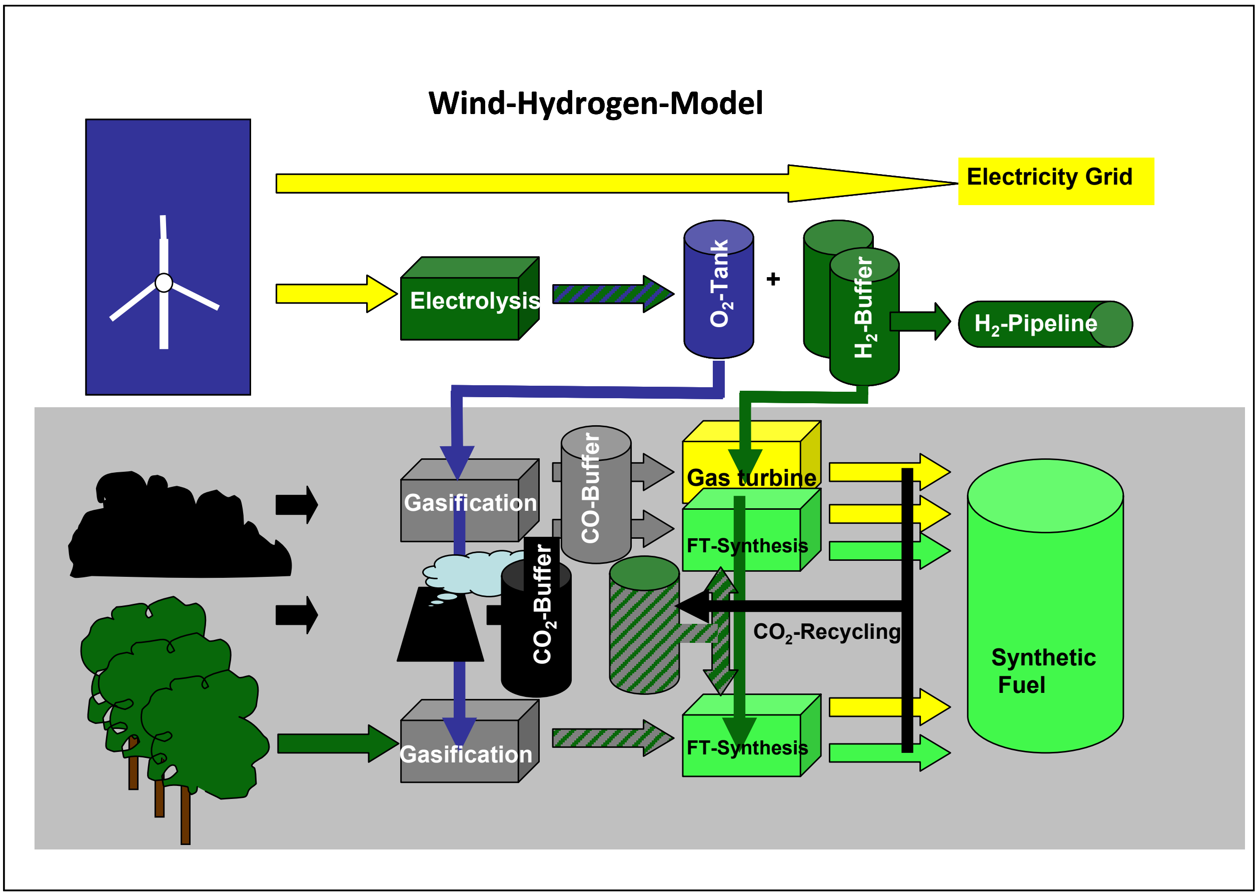

Fig. 7.6: *Conceptual model for integrating hydrogen production into wind farming (J. Köhn & O. Hohmeyer).*

Based on this model, workshop discussions then focused on different technical options for hydrogen storage, technologies of hydrogen production and market development. Most experts agreed that hydrogen could generally play an important role in future energy supply and the replacement of fossil fuels. Electricity and hydrogen were also seen as the two most promising avenues in the context of mobility. The particular advantages of using hydrogen technology were considered to be its potential for extraction from renewable energies, its ubiquitous availability and, with the exception of component production, zero CO_2 emissions (Institute of Vehicle Concepts of the DLR, http://www.dlr.de/fk/).

Hydrogen could also play a role in compensating for fluctuating wind energy production. It could act as an intermediate store for surplus electricity that cannot be fed into the grid.

In Northern Germany, and the town of Stade in particular, hydrogen is a by-product of the chemical industry. This has stimulated a broader debate in the region on the potential uses of hydrogen and the development of a market. Sites with port infrastructure, pipelines and storage facilities (e.g. salt caverns) could develop into centres for hydrogen-based industries. One of the main barriers to industry investment so far is the lack of a mass market for hydrogen. Nevertheless, one offshore wind farm within the German EEZ is set to produce hydrogen: an onshore demonstration project is currently under development by the company 'Wind-Projekt' (RH2-Werder/Kessin/Altentreptow, RH2-WKA, www.wind-projekt.de).

During the workshops, representatives from politics and government authorities frequently called for demonstration of the technical feasibility and economic viability of hydrogen-related concepts in test facilities. Many active researchers, however, pointed to successful existing approaches that are evidence for the principal economic and technical feasibility. Apart from industrial facilities in Switzerland, there is the technology and infrastructure design for a hydrogen grid in Texas, as well as two pipeline systems in Germany that serve the chemical industry. Further concepts for pilot projects were also presented and discussed during the workshops. One is a pilot project in the state of Mecklenburg-Vorpommern where a wind-hydrogen combination is currently being tested onshore. This facility can store electricity and produce hydrogen using an electrolyser.

The workshops concluded that technology was not the major obstacle in the development of a hydrogen-based industry and infrastructure. One difficulty is the lack of political will to support the development of a hydrogen mass market. Here, a fundamental political decision would need to be taken on the mid- to long-term future energy mix in Germany and the role of hydrogen within this mix. This decision is yet to be taken.

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8 Impacts of Offshore Wind Farms on the Provision of Ecosystem Services and Human Well-being

Malte Busch, Benjamin Burkhard, Marcus Lange, Kira Gee, Nico Stelljes

This chapter will name and evaluate large scale offshore wind farms' (OWFs) impacts on the provision of Ecosystem Services (ES) within the case study area. After a theoretical introduction to the ecosystem service approach and its project-specific transformation and application, the expected impacts on marine ecosystem services identified by our research will be presented and structured according to the four ES categories.

8.1 Conception and theory

Ecosystem services are defined as the benefits people obtain from ecosystems (MA 2005). In 2005, the Millennium Ecosystem Assessment, conducted by the United Nations Environment Programme (UNEP), imposed the ecosystem service approach. The central aim of the Millennium Ecosystem Assessment was to assess the consequences of anthropogenic causes of ecosystem changes and effects on human well-being. It aims at providing the scientific basis for activities needed to enforce the conservation and sustainable use of ecosystems and by that, ensuring their contribution to human well-being in terms of ecosystem goods and services. The idea behind a comprehensive view on ecosystems as a source of human well-being and a potential origin of management activities can be traced back to the year 1992, when de Groot's approach to 'Functions of Nature' was published. It named 37 environmental functions fulfilled by ecosystems and provided methods for establishing their socio-economic value. Contributions of Costanza et al. (1997), focusing on the monetary value of natural capital and ecosystem services, and Daily (1997), pointing out human dependency on earth's life-support system, e.g. the provision of ecosystem services, further shaped the development of an ecosystem-based research design.

The ecosystem service approach's basic innovation is its holistic and comprehensive characterization of ecosystem functions along four intersecting ES categories, constituting the preconditions of natural and material human demands. Supporting services, like nutrient cycling or primary production, form the initial point of all ES categories. Within the project *Zukunft Küste - Coastal Futures*, supporting services are measured using the concept of ecological integrity. They provide preconditions necessary for regulating services (e.g. climate regulation, water purification, sea bed control etc.), the provisioning services directly used by humans (e.g. food, water, energy etc.) and cultural services (e.g. beauty of landscape, inspiration etc.) (MA 2003). Man impacts these ES in various ways. Main impacts are changes in land use and cover and climate change, which are understood as pressures on ecosystem functions (see chapter 3 & 4). These pressures are a result of various drivers of change (e.g. demand for energy; see chapter 4). The final element of this conceptual approach constitutes human well-being, which is based on and shaped by ES and has complex reciprocal feedbacks with indirect drivers, i.e. the social processes that influence direct drivers of ecosystem change (Carpenter et al. 2006). Within the DPSIR framework applied in *Coastal Futures* the ES analysis constitutes the impact assessment. A detailed overview of the DPSIR concept is provided in chapters 3 and 4.

In the last few years, this quite new and open approach has attracted the attention of a broad scientific community of diverse disciplines, developing and shaping the approach in different ways according to discipline specific conceptions. Two main tendencies can be observed: on the one hand, the approach is applied as an evaluation and analysis tool used to depict interactions and changes within social-ecological systems. Thereby, threatening potentials and impacts of anthropogenic activities can be identified and addressed, indicating the direct consequences of human actions on their own welfare. Such knowledge and understanding is required in order to improve ecosystem-based approaches' recognition by decision-makers and implementation in institutions (Dailey & Matson 2008). On the other hand, the approach is understood as an instrument to combine ecological and economic perspectives. By estimating and mapping the monetary value of ES, appreciation of natural capital can be created and shared. Ascribing value to often unconsidered ecological services as being the foundation of every production chain could basically change economy's attitude towards ES and create monetary stimulation for a sustainable rationing of natural resources. Both attempts have potential and are relevant in terms of establishing adaptive ecosystem-based management practices by illustrating man's intrinsic and monetary dependency on productive, adaptable ecosystems as basis for human well-being.

While the *Coastal Futures* approach mainly follows the Millennium Ecosystem Assessment and its definitions of ES and its service categories (with the exception that supporting services were substituted by the concept of ecological integrity), there is an ongoing controversial scientific discussion concerning the definition of central terms of ecosystem service research. New publications tend to clearly separate between services and benefits while defining ES as aspects of ecosystems (actively or passively) utilized to produce human well-being (Fisher & Turner 2008, Boyd & Banzhaf 2007). In this understanding, services must be ecological phenomena that do not have to be utilized directly. Consequently, cultural services are understood as benefits and not services. Moreover, ES include ecosystem organization and structure as well as processes and functions, if they are consumed or utilized by mankind. Ecosystem functions and processes become services, if humans benefit from them, meaning without human beneficiaries they are not services.

8.2 Aims of the research

Zukunft Küste - Coastal Futures used the ecosystem service approach to analyze the potential impacts of offshore wind farming on the provision of ES under specific future scenario assumptions (see chapter 4). The idea was to evaluate the applicability and suitability of this large scaled approach in relation to a specific regional case study. The aim was to gain information on marine and coastal ES affected by the introduction of a new form of industrial use offshore. Offshore wind farming is understood as a potential pressure on the marine environment, initiating changes of local ES provision (Figure 8.2). The ecosystem service approach was tested as a tool to analyze the impacts caused by this single agent (OWFs) on marine ecosystems, or more abstract, the system's response to a new introduced pressure.

The following research questions were addressed:

1. Which ecosystem services are provided by North Sea marine and coastal ecosystems?
2. Which ecosystem services are impacted by the introduction of offshore wind farms and what process-enforcing respective process-diminishing impacts are expected?
3. How do those impacts vary across different spatial scales?

8.3 Methodology

Based on the Millennium Ecosystem Assessment's framework (MA 2003), the ecosystem service approach had to be adjusted to fit the project-specific requirements. The Millennium Ecosystem Assessment's global perspective focuses on marine as well as terrestrial ES and had to be made applicable to analyze changes within strictly coastal and marine ES, initiated by a single human activity.

Baseline and scenario

In order to compare future changes of ecosystem service provision, a baseline or reference point was needed. For our research, the current condition of the German North Sea without any offshore wind farm was defined as the reference state. The future developments include an OWF construction and an OWF operating state. The 'Energy Park' scenario (see chapter 4) with a maximum installation of OWFs until 2030 was chosen from a pool of scenarios developed within the project. This scenario follows the German Federal Government's idea and political aim to install an offshore wind power potential of approx. 25.000 megawatt until 2030 (Bundesregierung 2002: 7). In this chapter, the impacts during the operating stage of offshore wind farms are discussed exclusively. Nevertheless, ecological impacts (ecological integrity and regulating services) were assessed for the construction and for the operating stage (long term impacts) (see chapter 5.2). This is difficult for the categories provisioning and cultural services, because impacts mainly appear during the operating stage.

Apart from temporal scales, several spatial scales of interest were identified. They were chosen to range from a local up to an international scale in order to make potential impacts and changes in intensity traceable among a large geographic area. The scale definitions vary depending on the individual ES categories. While, for example 'local' in terms of ecological integrity or regulating and provisioning services is defined as the pile of a single wind turbine, in the case of cultural services it means 'islands and municipalities' (see chapter 4.2 also). Table 8.1 gives an overview of spatial scales and their definitions:

Tab. 8.1: Spatial scales of the ecosystem service assessment.

Spatial Scales	Ecological Integrity	Regulating Services	Provisioning Services	Cultural Services
local	pile	pile	pile	islands and municipalities
regional	OWF	OWF	OWF	West Coast SH
EEZ	German EEZ	German EEZ	closer surrounding of OWF	German EEZ
southern North Sea	southern North Sea	southern North Sea	southern North Sea, German EEZ	southern North Sea

Project-specific interpretation and implementation of the ES approach

To realize the research aims and to get an insight into expected future developments under the chosen scenario, the following analytical steps were performed:

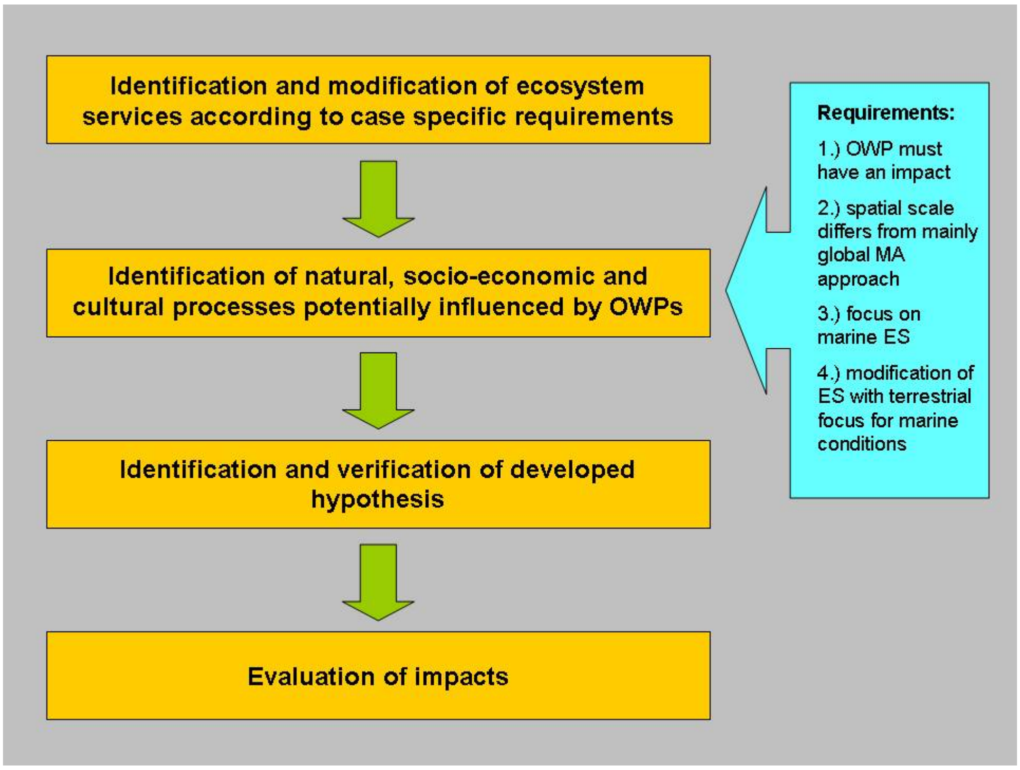

Fig. 8.1: Project specific modification of the ES approach.

As a first step, there was the need to identify relevant ES, for their provision might be changed in intensity by the development of offshore wind farms. The ES defined within the Millennium Ecosystem Assessment served as a starting point and were modified according to the following case study-specific requirements (see Figure 8.1): (1.) Offshore wind power must have a potential process-reducing or process-enforcing impact on the ES. (2.) The global perspective of the Millennium Ecosystem Assessment had to be adjusted to a project-specific one. Since few impacts of wind farms within the German Bight bear international impact potential, the main focus was on local and regional impacts. (3.) Another important and project-specific aspect is its exclusive concentration on marine ES, which distinguishes this approach strongly from the Millennium Ecosystem Assessment's more terrestrial viewpoint. ES listed within the Millennium Ecosystem Assessment were discussed according to their marine dimension and partly specified in respect of their marine environment, e.g. the ES 'erosion control' of the Millennium Ecosystem Assessment became 'sea bed control' within the framework of *Coastal Futures*.

The next step was the identification of ecological, socio-economic and cultural processes influenced by OWFs and to group them. For example, newly introduced structures can serve as habitats for various marine organisms and function as an artificial reef (DONG Energy et al. 2006, ELSAM Engineering & Energy E2 2004). This was relevant for ecological integrity and regulating services. Thus, 'biotic diversity' and 'abiotic heterogeneity', both components of ecological integrity, as well as 'water purification', presenting a regulating service, are affected. The introduction of vertical hard structures in offshore waters represents additional space available for marine aquaculture as a potential co-use of offshore wind farms. This changes the provisioning service 'food'. Moreover, 'inspiration' is affected, for man-made structures alter previously undisturbed seascape.

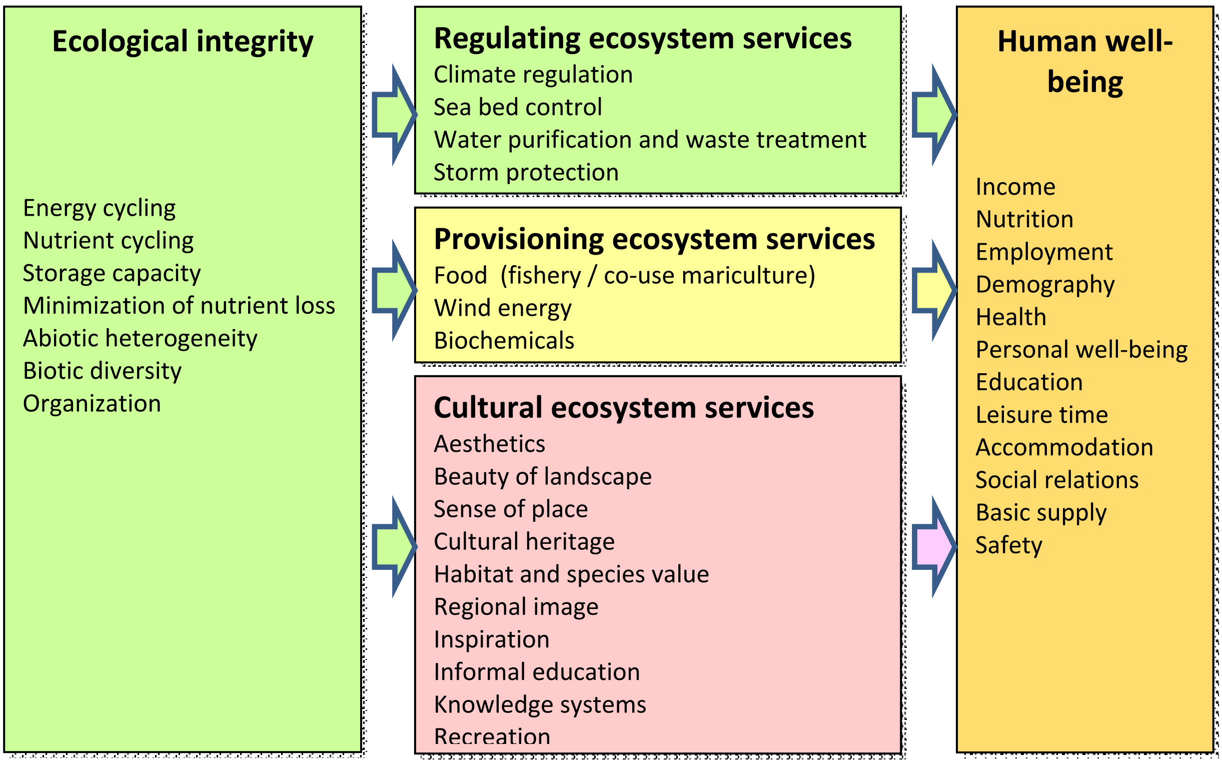

Fig. 8.2: *Overview on ecosystem services analyzed in the project Zukunft Küste - Coastal Futures.*

To identify and verify these ***hypotheses***, available information, for example through already existing offshore farms in countries like Denmark, was collected and studies were performed. For the ecological ES categories (ecological integrity and regulating services) computer-based modeling was performed (see chapter 5.2 and Burkhard et al. 2009). Document analyses and economic input-output analyses were used for the provisioning services, while a survey identified trends concerning the coastal inhabitants' perception of OWFs, which gathered information on affected cultural services (Gee 2010).

Subsequently, the single ES were rated to make them traceable and comparable. An exact valuation or measurement of relevant ES is difficult and there is an ongoing discussion about monetizing ES (Nelson et al. 2009). A qualitative rating ranging from -2 to +2 was performed to express the expected trends of development (see Table 8.2). It must be mentioned that X (= no effect) ratings are visualized as '0' within the later diagrams.

Tab. 8.2: *Rating values for the evaluation of potential impacts of OWFs*

Rating Value	Definition
+2	OWFs expected to have a strong increasing (respective process-enforcing) impact on the specific ES.
+1	OWFs expected to have a slight increasing (respective process-enforcing) impact on the specific ES.
0	Neutral effect of OWFs on the specific ES is expected. Both components interact.
X	No effect. No interrelation between OWFs and the specific ES is expected.
-1	OWFs expected to have a slight decreasing (respective process-diminishing) impact on the specific ES.
-2	OWFs expected to have a strong decreasing (respective process-diminishing) impact on the specific ES.

The final rating is the result of experts' estimations, based on information and discussions generated during project workshops. The rating was supported by model results, comprehensive literature research and workshops with experts.

The information, questions and results generated were structured and documented with the help of a comprehensive and detailed matrix, aiming at making the processes influencing ES of all categories both understandable and replicable for colleagues of different scientific background working within the interdisciplinary project *Zukunft Küste - Coastal Futures*.

8.4 Results supporting services - ecological integrity

The following chapters present the ecosystem service-based impact assessment's findings carried out in order to identify and weight the changes and risks of introducing OWFs on ES at the west coast of Schleswig-Holstein.

Within the project, basic ecosystem functions (or supporting services) are described by the concept of ecological integrity, defined by Barkmann et al. (2001: 99) as "the political target for the preservation against non-specific ecological risks that are general disturbances of the self-organizing capacity of ecological systems." Müller & Burkhard (2007) developed a set of indicators which were applied to analyze impacts on ecological integrity. These indicators describe the most relevant ecosystem processes and structures for ecosystem self-organization. Processes are related to energy budgets of ecosystems (indicated by primary production e.g.), the nutrient budget (e.g. nutrient uptake, nutrient turnover and exchange between adjacent systems) and structures (ES 'biotic diversity' indicated e.g. by species diversity indexes and ES 'abiotic heterogeneity' indicated by physical parameters such as temperature or salinity). An overview of ecological integrity components and respective impacts of OWFs agreed on within the project is provided in Table 8.3.

Tab. 8.3: *Impacts of OWF on ecological integrity (for lack of space, the spatial scale 'southern North Sea' within the column 'Perceived impacts of offshore wind farms' is shortened to 'North Sea')*

Category	Impact description	Relevance for case study on offshore wind farms	Perceived impact of offshore wind farms
Energy cycling	1.) **Wake effect**: the operation of wind turbines alters the wind field within and around the OWF. This effect can impact water currents, temperature layering and subsequently influence biological processes and structures.	Wind turbines produce/cause wake effects. Further effects on water currents and layering are expected to be induced by global climatic change.	pile: +1 ↑ OWF: +1 ↑ EEZ: 0 ↔ North Sea: 0 ↔
	2.) **Net primary production**: the insertion of hard structures and substrates into the sea might cause the development of artificial reefs around turbine piles and scour protections. These systems have a higher productivity than today.	Without the insertion of artificial hard structures into the sea, no artificial reef systems would develop and the changes described would not take place.	under the assumption of artificial reef formation: pile: +2 ↑↑ OWF: +1 ↑ EEZ: 0 ↔ North Sea: 0 ↔
	3.) **Food web**: Assuming artificial reefs emerge around the turbine piles and scour protections, the food web would become more complex with higher turnover rates.	Without the insertion of artificial hard structures into the sea, no artificial reef systems would develop and the changes described would not take place. At the same time, commercial fishery has by far the strongest impact on the marine food web accompanied by important human-induced factors like water pollution and euthrophication.	pile: +1 ↑ OWF: +1 ↑ EEZ: 0 ↔ North Sea: 0 ↔
	4.) **Entropy export minimization**: Assuming artificial reefs emerge around the turbine piles and scour protection, internal energy use would become more efficient (the gross primary production/net primary production ratio would change) and thus, entropy export decreases.	Without the insertion of artificial hard structures into the sea, no artificial reef systems would develop and the changes described would not take place.	pile: +1 ↑ OWF:+1 ↑ EEZ: 0 ↔ North Sea: 0 ↔

Nutrient cycling	5.) Assuming artificial reefs emerge around the turbine piles and scour protections, nutrient turnover rates around the piles will become higher. Additional effects are expected due to wake effects and the settlement of benthic organisms.	Without the insertion of artificial hard structures into the sea, no artificial reef systems would develop and the changes described would not take place.	pile: +1 ↑ OWF: 0 ↔ EEZ: 0 ↔ North Sea: 0 ↔
Storage capacity	6.) Assuming artificial reefs emerge around the turbine piles and scour protections, organic carbon stored in the organisms would increase.	Without the insertion of artificial hard structures into the sea, no artificial reef systems would develop and the changes described would not take place.	pile: +2 ↑↑ OWF: +1 ↑ EEZ: 0 ↔ North Sea: 0 ↔
Minimization of nutrient loss (Nutrient loss $^{-1}$)	7.) Assuming artificial reefs emerge around the turbine piles and scour protections, nutrient cycling would become more efficient and thereby, nutrient losses in the surrounding of the OWFs would be minimized.	Without the insertion of artificial hard structures into the sea, no artificial reef systems would develop and the changes described would not take place.	pile: +2 ↑↑ OWF: +1 ↑ EEZ: 0 ↔ North Sea: 0 ↔
Abiotic heterogeneity	8.) The insertion of hard structures and substrates in the form of wind turbine piles and scour protections provides new and more heterogeneous habitats for the settlement of e.g benthic organisms.	Without the insertion of artificial hard structures into the sea, no artificial reef systems would develop and the changes described would not take place.	pile: +2 ↑↑ OWF: +1 ↑ EEZ: 0 ↔ North Sea: 0 ↔
	9.) Water currents and sediment dynamics are locally influenced at wind turbine piles and scour protections.	Without the insertion of artificial hard structures into the sea, the changes described would not take place.	pile: +1 ↑ OWF: +1 ↑ EEZ: 0 ↔ North Sea: 0 ↔
Biotic diversity	10.) Assuming artificial reefs emerge around the turbine piles and scour protections, under water species diversity would increase. Nevertheless, negative impacts on above water species (migrating and resting birds) diversity and impacts on marine mammals are expected.	Without the insertion of artificial hard structures into the sea, no artificial reef systems would develop and the changes described would not take place.	under water: pile: +2 ↑↑ OWF: +1 ↑ EEZ: 0 ↔ North Sea: 0 ↔ above water: pile: -2 ↓↓ OWF: -1 ↓ EEZ: -1 ↓ North Sea: -1 ↓
	11.) As commercial fishery is not allowed within OWFs due to shipping safety reasons, species diversity will increase.	The ban of fisheries is an indirect effect of OWFs.	pile: +1 ↑ OWF: +1 ↑

			EEZ: 0 ↔ North Sea: 0 ↔
Organization	12.) Assuming artificial reefs emerge around the turbine piles and scour protections, ecosystems would become more complex with regard to matter, information and energy fluxes.	Without the insertion of artificial hard structures into the sea, no artificial reef systems would develop and the changes described would not take place.	pile: +1 ↑ OWF: +1 ↑ EEZ: 0 ↔ North Sea: 0 ↔

Table 8.3 identifies the most relevant impacts and their underlying ecological processes, the relevance of OWF as an additional stimulus for changes in comparison to already existing pressures influencing the specific ES, and the impact rating across scales of interest.

The ES 'energy cycling', 'abiotic heterogeneity' and 'biotic diversity' are influenced by more than one effect varying in force and direction of impact. For example, 'energy cycling' is affected by the wake-effect (see chapter 5.2), changes of net primary production, changes within the food web and the export of entropy out of the system. These ES are good examples for complex responses in marine ecosystems to OWF installations in various ways. Furthermore, they indicate how difficult it is to aggregate ecological processes into one single ES without getting too unspecific.

The diagrams in Figure 8.3 give a first impression of overall assessed trends concerning impacts on ecological integrity which will be discussed in detail afterwards.

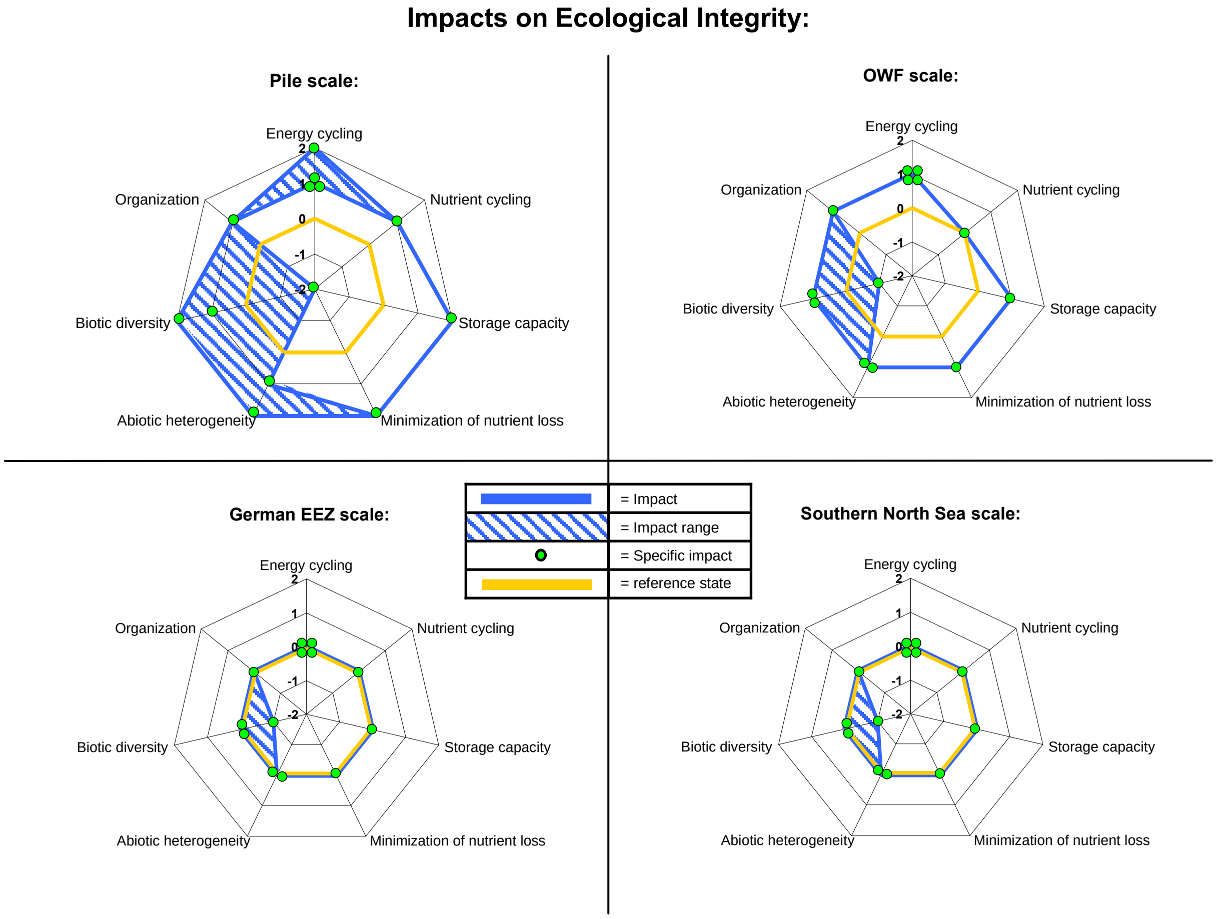

Fig. 8.3: Impacts of OWFs on the ecological integrity visualized across spatial scales. Relevant integrity parameters are located on the edges of the diagrams. The single blue lines visualize the rating values (-2 to +2) connecting the impact ratings of every ES, while the hatched areas visualize the impact range, showing if an ES is affected by several factors as described in the text. To indicate these variations and to provide a sophisticated description, the individual rating values are marked by green spots. The reference state (actual condition, the North Sea without OWFs) is displayed in orange and set to '0'.

The predominant number of ES shows a slight or even strong enforcement of ecological processes on a pile and an OWF-scale, while the intensity of impacts decreases on the larger spatial scales, showing typical dilution processes. On the scale of the German EEZ and southern North Sea, the expected impacts are the same. Here, the only negative impact is on above water biotic diversity, i.e. sea birds.

Two central ecological changes in response to OWF installation were identified: The first and by far most recognizable aspect is the introduction of artificial structures into the marine ecosystem. The wind mills themselves and the hard substrates inserted for scour protection represent a strong habitat change under water as well as above water. The second aspect addresses changes of current and sediment dynamics corresponding with several ecological processes.

The introduction of manmade structures to a naturally homogenous offshore habitat, consisting of open water and free sky accompanied by sandy and muddy sea bottom, is expected to have a process-enforcing impact on various ecological functions under water. The additional structures are assumed to provide ecological functions of an artificial reef, allowing sessile organisms to colonize. This corresponds with various cycling functions (DONG Energy 2006). The under water habitat will become more diverse ('abiotic heterogeneity') and will consequently attract an increased amount of species ('biotic diversity') like mollusks, fishes, benthic organisms and algae. The net primary production, the production of biomass by primary producers (e.g. blue-green algae), is expected to increase in a more diverse habitat. More habitat and biomass simultaneously supports the food web which is assumed to respond with increased cycling activities ('energy cycling' and 'nutrient cycling'). By assimilating nutrients, organisms minimize the loss of potentially available nutrients within a certain area ('minimization of nutrient loss') and enforce the structures and matter flows within the ecosystem ('organization'). At the same time, a larger amount of organisms accumulate more biomass and raise the capacity of the system to store matter ('storage capacity'). The species recruitment, as a precondition for an enforcement of ecological functions associated with the introduction of artificial sub-littoral structures, is expected to be governed by tidal and residual currents. This inscribes larvae and juveniles from the surrounding natural habitats. In relation to these processes, the production of entropy, the non-convertible energy fraction and product of exergy degradation, is assumed to decrease slightly due to a more efficient use of energy. This indicates a further system development where a higher share of exergy is used for the maintenance of the system ('energy cycling') (Burkhard et al. 2009).

Changes of water current and sediment dynamics were identified as a second main regime change caused by OWF introduction. This interrelation is described by the wake effect. The conversion of wind energy via wind turbines leads to wind speed and current changes as less energy is available to foster them. Currents, on there part, interact with the layering of different temperate water bodies ('energy cycling'). Expected impacts on biological processes are assumed to be process-enforcing. First simulations show, that the wake effect will lead to a more dynamic hydrological system which affects an area much wider than the OWF itself. This includes changes in the temperature distribution, stability of the thermocline as well as possible upwelling events. The upwelling has the potential to increase the local primary production by introducing further nutrients form deeper water layers (see chapter 5.2). Moreover, these physical changes are assumed to impact the 'abiotic heterogeneity' within OWFs, but modeling indicates, that these developments are less relevant than the assumed direct habitat changes through hard substrate insertion (see chapter 5).

Apart form these process-enforcements within a majority of ecological integrity components, marine mammals might be negatively influenced. While there is no doubt about negative impacts during the construction phase (see chapter 5.2), further research is needed for the operational stage (Gilles et al. 2009). Noise (vibrations) emitted by piles as well as potential electrical oscillations radiated by submarine cables connecting OWFs with the mainland could scare away seals and porpoises and thereby, negatively impact 'biotic diversity'.

'Biotic diversity' inflicts impacts on the diversity above and under water as well as the diversity of the marine food web. This component of ecological integrity was identified to be the most heterogeneously affected ES. The ES shows an enormous impact range across the complete rating scale, indicating a strong negative impact up to an international scale. While the diversity under water, due to the increase of abiotic heterogeneity named before, will provide suitable habitats for a larger amount of species (pile +2, OWF scale +1) the trends of bird diversity, as indicators for diversity above water, are moving in an opposite direction. Sea birds are affected in several and seasonally differing way. During migration, the risk of direct collision impacts different bird species. Species using potential OWF areas as feeding grounds will avoid these areas because of large vertical structures mismatching their habitat demands (Dierschke & Garthe 2006). This results in a rating of -2 on a pile scale and -1 for OWF, EEZ and southern North Sea scale for the diversity above water (see chapter 5.3). The diversity of the marine food web again seems to benefit from the OWF construction: more diverse habitat structures attract more species communities. This increases marine food web diversity, rated with +1 on a pile scale and an OWF-scale, becoming neutral with greater distance.

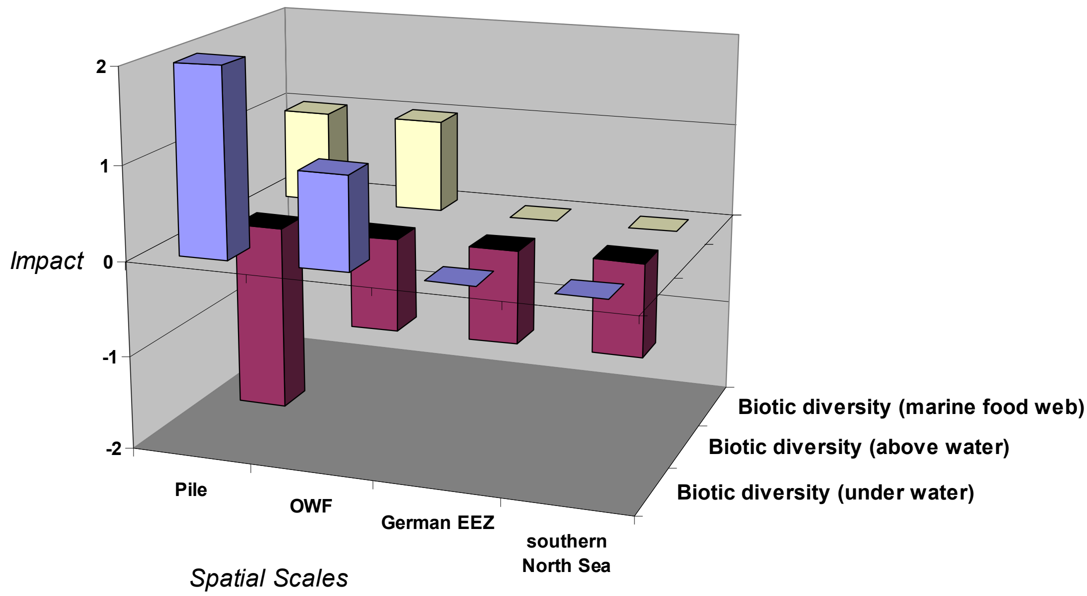

***Fig. 8.4:** Impacts on the 'biotic diversity', divided into the three components investigated across varying spatial scales.*

Discussion ecological integrity

In case the assumed artificial reef effect observed for example at Danish wind farms becomes true (DONG Energy 2006), an increase of ecological integrity is likely to occure. Nevertheless, negative impacts on sea birds, as the strongest process-diminishing consequence assessed here, must be taken into account. The emergence of artificial reefs enforcing ecological structures and processes under water would identify OWFs not just as a climate but also environmentally friendly way of energy conversion.

To classify these results more objectively in a discussion about the pros and cons of OWFs, it is important to take into account that, on the one hand, the positive development of most ecological integrity parameters has to be seen in relative terms as the introduction of OWFs still remains a massive change of natural conditions. On the other hand, the negative effects on for example sea birds have to be understood as a crucial point as it represents an effect influencing a larger spatial scale. While the argument whether it is possible to trade one ES against another necessitates further discussion, the spatial scale (extension) of an impact clearly determines its importance. With this in mind, the mainly positive impacts on a pile scale and an OWF-scale must be seen in relative terms. Process-enforcement within OWFs (small scale) is disproportionate to a large scale dilution.

Summary

The results concerning ecological integrity show that the majority of identified impacts is expected to enforce ecological processes on a lower spatial scale (pile, OWF), while impacts might disappear on a larger scale (EEZ, southern North Sea). 'Biotic diversity' is an exception in which negative trends are expected for example for sea birds. The results demonstrate that trade-offs between ES seem to be difficult to avoid when it comes to an enforced installation of OWFs. It is conceivable that the degree of impacts on seabirds could be mitigated by appropriate siting of OWFs to avoid their construction on core bird migration routes and feeding grounds.

8.5 Results concerning regulating services

Four regulating services were identified as being potentially affected by the introduction of offshore wind parks to the German North Sea: global 'climate regulation' (understood as CO_2 emission reduction), 'sea bed control', 'water purification and waste treatment' and 'storm protection'.

To measure impacts on these ES, physical (e.g. the 'ripple rate' (specific sediment structure of the sea bottom), sediment mobility, changes of water depths, roughness factor of habitat colonized by mussels) as well as chemical (e.g. mitigated CO_2 emissions) and biological parameters (e.g. filtration rate of mussels) are necessary.

Table 8.4 gives an overview of the information gathered according to impacts of OWFs on regulating services.

Tab. 8.4: Impacts of OWFs on regulating services (for lack of space, the spatial scale 'southern North Sea' within the column 'Perceived impacts of offshore wind farms' is shortened to 'North Sea').

Category	Impact description	Relevance for case study on offshore wind farms	Perceived impact of offshore wind farms
Climate regulation - CO_2 emission reduction	1.) OWFs provide alternative renewable energy and help to mitigate green house gas emissions. Thus, they have an indirect impact on global climatic change.	Depending on the amount of OWFs installed, the contribution is higher or lower. Further influencing factors are the current energy policy, energy consumption rates, share of other renewable energies.	pile: 0 ↔ OWF: 0 ↔ EEZ: +1 ↑ North Sea: +1 ↑
Sea bed control	2.) The insertion of hard structures can have negative impacts on seabed stability by causing lee erosion and the creation of pile scour.	Without the insertion of artificial hard structures into the sea, no lee erosion and piles scour would occur.	pile: -1 ↓ OWF: -1 ↓ EEZ: 0 ↔ global: 0 ↔
	3.) Assuming mussel beds and further benthic communities settle around the turbine piles and scour protections, seabed stability will increase.	Without the insertion of artificial hard structures into the sea, no mussel beds and new benthic communities would develop and the changes described would not take place.	pile: +1 ↑ OWF: 0 ↔ EEZ: 0 ↔ North Sea: 0 ↔
Water purification and waste treatment	4.) Assuming mussel beds and further benthic communities settle around the turbine piles and scour protections, water quality will be improved by filtering activities.	Without the insertion of artificial hard structures into the sea, no mussel beds and new benthic communities would develop and they could not filter water. Nevertheless, changes in water pollution schemes, temperature rise and changing matter deposition will have higher impacts on water quality than OWFs.	pile: +2 ↑↑ OWF: +1 ↑ EEZ: 0 ↔ North Sea: 0 ↔
Storm protection	5.) Hard structures can function as breakwater.	Global climatic change and the related increase of storm intensities and quantities will have higher impacts than effects of OWFs acting as breakwaters.	pile: 0 ↔ OWF: 0 ↔ EEZ: 0 ↔ North Sea: 0 ↔

The diagrams in Figure 8.5 visualize the force and direction of process changes across the investigated spatial scales.

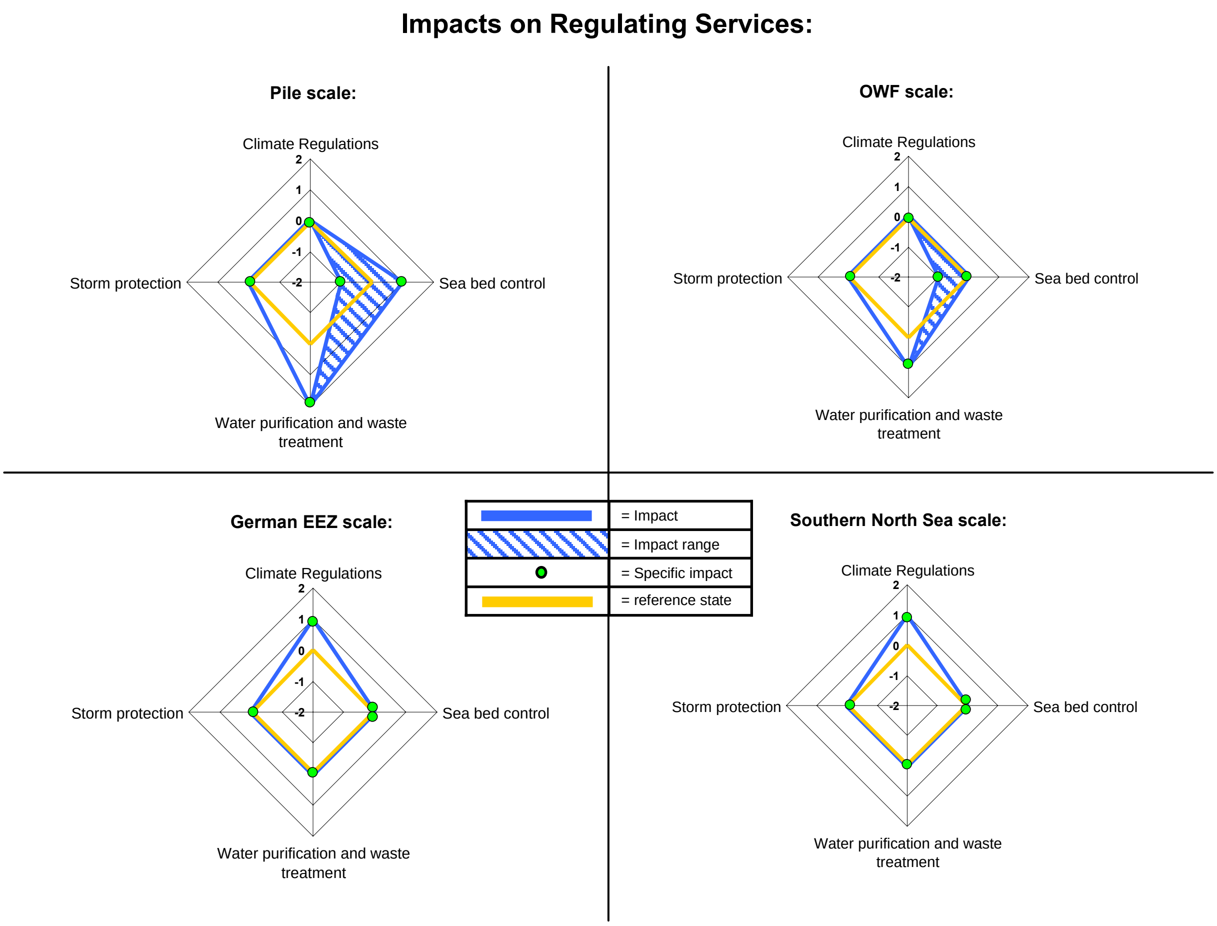

Fig. 8.5: Impacts of OWFs on regulating services visualized across spatial scales. Relevant regulating services are located on the edges of the diagrams. The single blue lines visualize the rating values (-2 to + 2) connecting the impact ratings of every ES, while the hatched areas visualize the impact range, showing if an ES is affected by several factors as already described. To indicate these variations and to provide a sophisticated description, the individual rating values are marked by green spots. The reference condition (actual condition, the North Sea without OWFs) is displayed in orange and set to '0'.

The diagrams demonstrate that the strongest and most multiple impacts are assumed for a pile scale. They decline slowly on an OWF-scale, combining process-enforcing and -diminishing effects. On a German EEZ and southern North Sea scale (actually up to a global scale), no changes are expected. One exception is the ES 'climate regulation'. As the CO_2 mitigation potential of offshore wind energy provides benefits for the global community, impacts on this regulating service occur explicitly on larger scales.

As for supporting services, the central factor influencing regulating services is the insertion of hard structures into the marine system. On the one hand, the insertion of turbine piles and scour protections disturb and change the natural sea bottom in terms of sediment consistency and the type of bottom cover. Negative impacts on sea bottom stability are expected to be caused by lee erosion. On the other hand, the assumed development of artificial reefs (e.g. mussel beds, enforced benthic community) would contribute positively to sea bed stability. This would improve water quality recognizably by enhanced filtering activities and by decomposing organic waste (‘water purification and waste treatment’). While the emergence of mussel beds might compensate negative impacts on sea bottom stability on a pile scale, negative impacts of erosion are assumed to dominate on an OWF-scale (‘sea bed control’). Nevertheless, turbine piles could function as breakwaters. However, taking the long distances of OWFs from the coastline and the assumed increased storm intensities in relation to climate change into account, this effect is not expected to be of relevance (‘storm protection’).

The second point of interest concerning changes within the ecosystems’ regulating functions is addressed by the ES ‘climate regulation’: It is expected that OWFs will not significantly impact the local climate. Therefore, the focus is on possible regulating impacts on the global climate, which is influenced by ecosystems sequestering or emitting greenhouse gases. The use of offshore wind energy enhances the climate regulation potential due to the reductions of CO_2 emissions for electricity generation. This mitigation potential, provided by 25.000 megawatt of planned wind electricity until 2030, will benefit the global climate.

Discussion regulating services

The results demonstrate that negative impacts on regulating services are assumed to be minimal and spatially limited. Next to local improvements of water quality (higher filtration rates) the central benefit of OWF, i.e. its climate change mitigating potential for electricity production, becomes visible. Nevertheless, it must be mentioned that some scientists suspect strong cumulative impacts of large scale wind energy use due to the reduction of moisture-laden ocean-to-land winds by offshore wind farms. This supposedly undermines the water cycle on land. It is stated, that in this effect the use of wind power is equivalent to deforestation (Makarieva et al. 2008).

Summary

Under the chosen scenario, offshore wind power does not seem to have a high impacting potential on large scale regulating ecosystem services. Although scour protections might have a slightly negative impact on sea bed stability, regulating ES do not show relevant changes related to offshore wind power introduction. The nutrient filtration rate is expected to increase due to larger populations of filtrating mussels on a local scale. The main effect is the reduction of CO_2 emissions for electricity generation, which is supposed to slightly slow down the current process of climate change and therefore contributes to targets of climate politics.

8.6 Results concerning provisioning services

Provisioning services relate to the more economic dimension of ES. While supporting and regulating services clearly focus on ecological processes, provisioning services focus on resources and products extracted from ecosystems. In many cases, they possess market values. In relation to the installation of offshore wind farms, ES dealing with the provision of energy, food and the use of biochemical resources become relevant. They describe the availability of consumable biomass provided by ecosystems and wind as a ‘resource’. The use of wind for energy conversion forms the ecosystem service itself. Further services might be used indirectly, e.g. through co-uses like marine aquaculture or hydrogen production.

Parameters suggested to measure impacts on relevant provisioning services refer to economic values, e.g. fishing and the amount of generated electricity. Mussels and algae are expected to be produced by mariculture within offshore wind farms. The space occupied by wind farms might exclude other marine uses.

Table 8.5 gives a detailed description of the relevant ES and their rating.

***Tab. 8.5:** Impacts of OWFs on provisioning services ('closer surrounding' is shortened to 'surrounding')*

Category	Impact description	Relevance for case study offshore wind farms	Perceived impact of offshore wind farms
Food - Fishery (fish accessible for commercial fisheries)	1.) OWFs seem attractive to several fish species because of 1.) food access (e.g. small fishes) and 2.) habitat (e.g. scour protection etc.) in the direct surrounding of the piles, which has an impact on fishery. These are two different important processes. Effects of point 2 might be stronger.	Depends on legal framework, e.g. ban of fishery due to restrictions on access to wind farm areas for shipping including fish trawlers (legal decision to ban fishery leads in practice to fish protection within the OWF). Consequently, this fish is not available for fisheries anymore. (overfishing might have a much larger negative impact on fishery than a ban on fishing in wind farm areas)	pile: X — OWF: -2 ↓↓ surrounding: +1 ↑ EEZ: 0 ↔
Food - potential opportunities / space for marine aquaculture as co-use (potential space to generate resources (mussels))	2.) Through inserting vertical structures (piles), the following effects arise creation of: 1.) new habitats and 2.) the possibility to install equipment needed for aquaculture, which require solid structures	Existence of OWF is the basic precondition of the ES aquaculture in this offshore area.	pile: X — OWF: +2 ↑↑ surrounding: X — EEZ: X —
Wind energy - available for electricity production (resource wind interpreted as energy)	3.) Use of wind energy to produce electricity through wind farms	The German federal government states that offshore wind power is of high importance to the national future energy supply concept. Yet, there is an open political debate and lobbying for nuclear power and CCS technologies for coal power plants. In the *Coastal Futures* project, we assume the German government's offshore wind farm strategy of 2002 to become real.	pile: +2 ↑↑ OWF: +2 ↑↑ surrounding: X — EEZ: +2 ↑↑
Biochemicals, natural medicines, pharmaceuticals (e.g. algae produced within marine aquacultures)	4.) Algae have the potential to enrich medical, cosmetic and food products. In coastal areas, companies produce health care products from algae and salt water. In relation to offshore wind farms, the potential production within offshore wind farms is important (similar to mussel aquaculture).	OWFs would be the basic precondition of the ES aquaculture at this point. (see ecosystem service 'potential opportunities for marine aquaculture')	pile: X — OWF: +2 ↑↑ surrounding: X — EEZ: X —

According to the specific potential impact scales of relevant provisioning services, the spatial scales selected for this service category differ from the ones used before (see Table 8.1). The ‘closer surrounding of OWFs’ is introduced as a specific scale, while the German EEZ and southern North Sea are united.

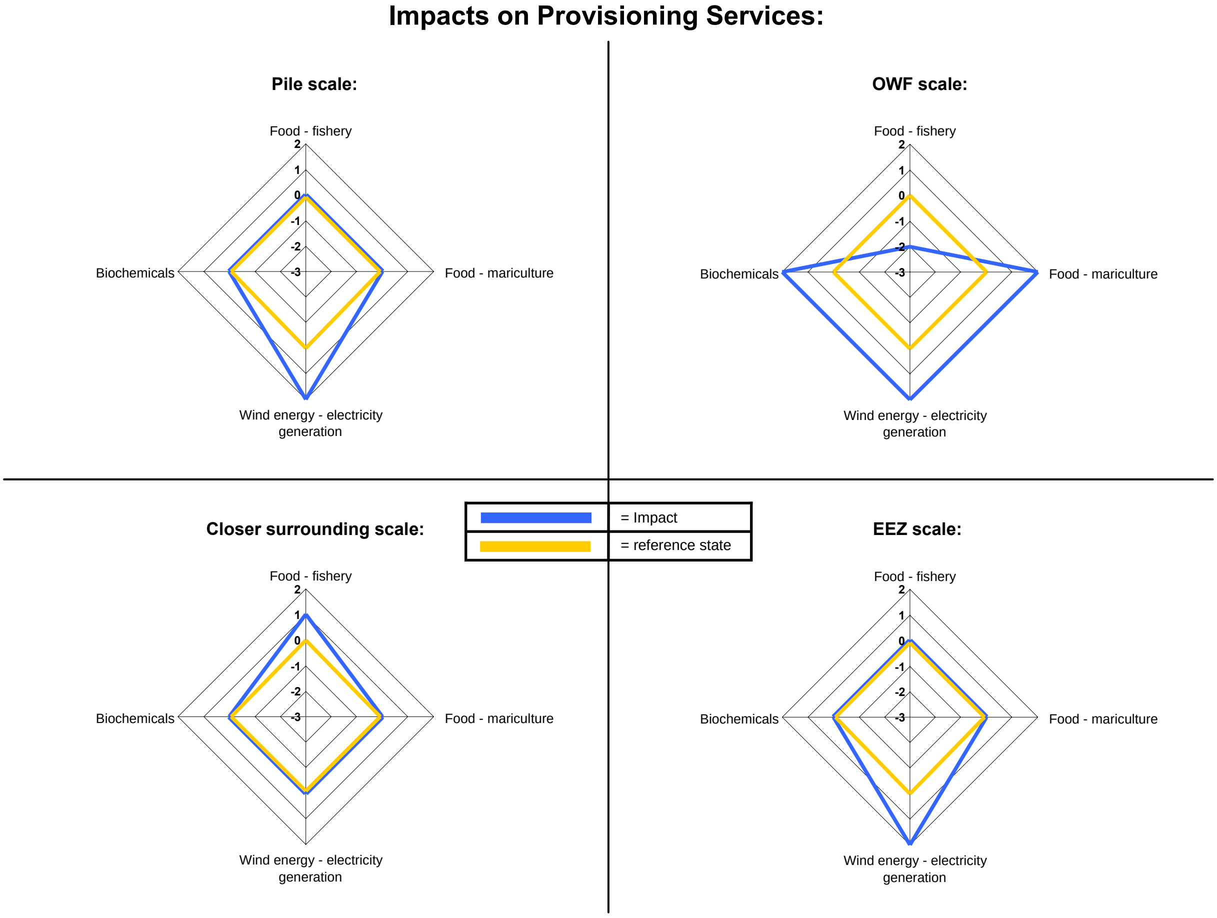

Fig. 8.6: Impacts of OWFs on provisioning services visualized across spatial scales. Relevant provisioning services are located on the edges of the diagrams. The single blue lines visualize the rating values (-2 to + 2) connecting the impact ratings of every ES. The reference state (actual condition, the North Sea without OWFs) is displayed in orange and set to ‘0’.

The amoeba diagrams in Figure 8.6 visualize a very heterogeneous behavior assumed across the defined spatial scales. The impacts of OWFs on provisioning services can be grouped into two main components: on the one hand there are changes concerning the accessibility of marine areas as well as new options related to the ES ‘food’, and on the other hand the provision of electricity.

Impacts concerning the topic ‘food’ focus on changes within the fisheries sector and the potential option to introduce co-uses benefiting from offshore wind farm installations. The fisheries sector will be affected due to legal obligations in relation to OWFs. The legal framework is supposed to prohibit fishing within OWFs due to security regulations. A 500 meters clearance distance is currently discussed, allowing only service boats to enter an offshore wind farm

(BMVBS 2009). In practice, this would lead to areas protected from fisheries and could make OWFs to recovery areas for commercially used species. Taking the large spatial dimension of offshore wind farms under the chosen scenario into account, catches might rise in the closer surrounding of OWFs due to fish population recovery and animal migration out of OWFs ('food - fish available for commercial fishery'). However, it is assumed that this effect might not be measurable at a North Sea-scale.

An antithetic behavior between several spatial scales is expected for the provision of food and other marine goods produced within mariculture. On an OWF-scale, and exclusively on this spatial scale, a strong enhancement is assumed, because the installation of OWFs creates huge areas for a potential co-use as mariculture sites. In the case of food production, blue mussels ('food - mariculture') could be the potential target species accompanied by the option to cultivate algae to be used for pharmaceuticals or as binding agent within food production ('biochemicals'). The piles would then provide vertical structures as prerequisites for installing long lines for mussel cultivation, for example. Research accomplished by the AWI (Michler-Cieluch et al. 2008) verified these co-use potentials. Realization depends on challenges in terms of communication and cooperation between actors from fisheries and wind energy, rather than the solution of technical problems. Moreover, experiences from Denmark proved the high potential of long line cultivation in inner waters. A Danish expert stated a harvest amount of at least 300 tons mussels annually on a 250 x 770 meters unit (Petersen, Managing Director, The Danish Shellfish Centre, 2009 pers. comm.). Figure 8.7 visualizes the presumed antithetic development of changes concerning food provision from fisheries and mariculture in relation to OWF installations.

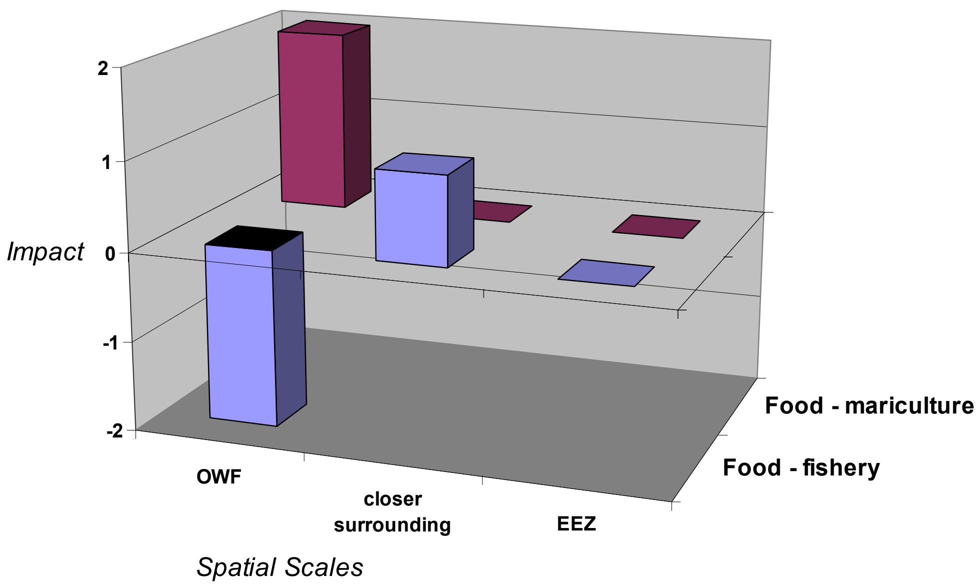

Fig. 8.7: Impacts of offshore wind farming on two food related provisioning ecosystem services across the investigated spatial scales.

The second component addresses energy and focuses on the ES 'wind energy - available for electricity production'. Through technical developments, wind has become a resource for low emission electricity generation, making the available wind to an ES. Strong process-enforcement in terms of wind electricity generation is expected, expressed by the rating +2. Under the chosen scenario, about 1/4 of the German North Sea EEZ would be covered by wind parks. The cumulative effect of all planned OWFs, having a capacity of about 25.000 MW, illustrates the huge importance of this service.

Discussion provisioning services

While scale-based assessments of ecological processes often generates information about dilution effects or identifies dominance of local effects, products of ecosystems or provisioning services partly appeared to be not scalable in case of offshore wind farming. For example, the existence of OWFs is the explicit precondition for aquaculture co-uses. Consequently, impacts on the provision of the ES 'food - potential space for aquaculture' exclusively occur on an OWF-scale. Unlike ecological processes occurring within the entire North Sea and being affected by OWFs in different ways on different scales, some provisioning services have no relation to spatial scales with the exception of the OWF they are attached to. The frequent occurrence of rating impacts with X (= no effect) on various scales expresses this misfit.

Another challenge compared to supporting and regulating services refers to the notion of 'space'. Nature offers space as a limited resource for human activities. This service was addressed in the former concept of 'Functions of Nature' (de Groot 1992) with the 'carrier functions'. In awareness of the ecosystem service approach and the importance of ES to generate and maintain human well-being, the central position of 'space' seems to be underestimated, specifically when marine areas are concerned. The provisioning services, related to OWFs are a good example for the space dependency of purely natural, in terms of not cultivated products of ecosystems (food/fish), and those produced under the precondition of man-made infrastructure (mariculture, wind energy generation). While the density of human activities can limit the accessible space to natural, uncultivated provisioning services (ban of fishery within OWFs) others completely depend on the availability of prepared space (mariculture).

Summary

The introduction of OWFs as a new human offshore activity, from a provisioning service point of view, conflicts with the traditional marine use fishery. But, a ban of fisheries within wind farms could enforce the recovery of commercially used fish populations and in the long term increase the catches in their surrounding. Nevertheless, until now, the fisheries sector mainly interprets offshore wind farming as a risk of its interests (Schubert 2009).

The potential of mariculture to produce blue mussels and algae is of exceptional interest. Even a co-use with hydrogen production is currently being discussed. A coupling of both techniques could be a possibility to solve the problem of storing electricity during low demand periods (e.g. strong winds during the night), but also to produce hydrogen as a primary product for industrial processes. The short term available additional wind energy could be used for hydrogen production, which can be stored easily (see chapter 11).

It can be concluded that the assumed process-enforcements within provisioning services exceed the local negative developments of the ES 'food - fishery'. Under the chosen scenario's conditions, the products obtained by ES, especially as wind energy as additional ES becomes available, are expected to increase.

8.7 Cultural services

The cultural ecosystem services deal with the non-material benefits people obtain from ecosystems in terms of spiritual enrichment, cognitive development, recreation and aesthetic experiences (MA 2003: 58). This category focuses on the often intangible but profound dimension of ES, being hard to measure and quantify (Gee & Burkhard 2010). While ecological implications of OWFs are additionally discussed in chapter 5, cultural implications are elaborated exclusively within this chapter. This asks for a more detailed debate in context of this chapter.

While for all ES categories described so far a more or less objective observation based on natural scientific or economic values and parameters can provide information concerning ES developments, changes within cultural services show strong interdependencies on individual and subjective cognition and values. While one person dislikes OWFs and regards them as a form of destruction of the typical natural landscape, another one might see OWFs as aesthetically valuable or inspiring. This leads to wide impact ranges within the single ES, ranging form service enforcement to diminishing effects, depending on personal preferences (Gee 2010).

On a first level, these different positions are a result of an individual, subjective opinion, while on a second level they might be based on socialization processes, which depend on societal factors like demography or education. This example points out the complexity of the assertions on changes of cultural services.

The assessment of cultural services proved to be difficult. A wide range of context-specific parameters is needed to indicate changes within this ES category, ranging from purely social-scientific empirical data about personal preferences and feelings gathered with the help of questionnaires (e.g. ES 'beauty of the landscape') to using long term monitoring of land use changes and decision making processes (e.g. 'sense of place'). Species surveys (e.g. 'habitat and species value' for ethical reasons) could serve as biological parameters for biodiversity assessments. Moreover, document analysis of marketing material (e.g. 'regional image') and inventories of cultural activities could provide valuable information concerning the state and changes within cultural services. This information provides an impression of informal educational offers (e.g. 'informal education') or artistic activities within the region (e.g. 'inspiration'). It can be concluded that a collection/assemblage of methods structured along available data is needed. It is important to mention that the impact rating within this ES category is based on expert estimations which are not validated by empirical data.

Tab. 8.6: Impacts of OWFs on cultural services

Category	Impact description	Relevance for case study on offshore wind farms	Perceived impact of offshore wind farms
Aesthetics ('scenery')	1.) Question is whether OWFs will be visible from land or not. This would add a new element to the seascape. If located near the shore, OWFs affect the visual perception of the coast from the sea. When on water, OWFs can affect perception of the sea as wide empty expanse (open horizon).	No other infra-structure exists, therefore impossible to say; relevance for case study area still high due to expectations associated with OWFs	Southern North Sea: 0 ↔ German North Sea: 0 ↔ West Coast SH: 0 ↔ Islands / Municipalities: 0 ↔
Beauty of the landscape	2.) Can be positive or negative (you either think that OWFs make the landscape more beautiful, or dislike them because they deviate from an existing concept of beauty).	high relevance	Southern North Sea: 0 ↔ German North Sea: 0 ↔ West Coast SH: 0 ↔ Islands / Municipalities: 0 ↔
Sense of place ('Heimat')	3.) OWFs could have indirect impacts that are linked to aesthetics and cultural heritage. OWFs impact the desire to keep the sea 'free' of industrial structures. Aspects of control and decision-making processes could be important. Indirect impacts, e.g. helicopter flights, could detract from what are now considered essential elements of 'Heimat'. This challenges the traditional view of the landscape/area.	low relevance, except for situation where significant expansion is planned and decisions are taken very quickly (rapid change)	Southern North Sea: 0 ↔ German North Sea: 0 ↔ West Coast SH: 0 ↔ Islands / Municipalities: +1 or -1 ↑↓
Cultural heritage	4.) In the long term, OWFs could become an accepted element of the cultural seascape (depends on acceptance). Short-term impacts: destruction of archaeologically important sites (bad siting of OWFs).	Not relevant beyond perhaps some very localized impacts.	Southern North Sea: 0 ↔ German North Sea: 0 ↔ West Coast SH: 0 ↔ Islands / Municipalities: 0 ↔
Habitat and species value (for ethical reasons)	5.) High, because OWFs would fundamentally change the natural habitat. Whether this is considered good or bad is another question. Wind energy generation is perceived as an industrial activity, which is seen as a threat to the 'wholeness' of creation. Offshore wind power affects the spiritual experience of the sea and is also linked to the ethical sense of protecting creation.	Depends on personal preferences, but relevance is high	Southern North Sea: -2 ↓↓ German North Sea: -2 ↓↓ West Coast SH: -2 ↓↓ Islands / Municipalities: -2 ↓↓ OWFs are definitively a change to the natural environment both spatially (precludes MPAs) and for individual species (impact on birds and mammals).
Regional image (primarily tourism but	6.) OWFs could be positive, helping the region to develop a more up-to-date image (modernization), or could be	high relevance if integrated into regional image; high relevance if	Southern North Sea: 0 ↔ German North Sea: -1 or +1 ↑↓

not exclusively)	negative, if OWFs are seen to detract from the essential qualities mentioned left. This does not only depend on visibility, but is related to choices the region makes as to what it wants to be.	large-scale expansion of OWFs but maintenance of current tourist image (naturalness)	West Coast SH: +1 or -1 ↑↓ Islands / Municipalities: +1 or -1 ↑↓ depending on developments (e.g. if the region wants to present itself as an energy region or natural region)
Inspiration	7.) OWFs add a new element to the environment/landscape. They can act as a source of inspiration, but can also detract from previous sources of inspiration. The idea can be inspiring independent of location; In case of visibility, the local view of wind mills can create inspirations or detract from existing inspiring qualities	low	Southern North Sea: 0 ↔ German North Sea: 0 ↔ West Coast SH: +1 ↑ Islands / Municipalities: +1 ↑
Informal education	8.) Offshore wind power is already mentioned in informal education and represents a new topic that can (+1), but must not (0), be added to existing issues.	relevant in the sense that offshore wind power is a new issue for informal education (technology, climate change, conflicts)	Southern North Sea: 0 or +1 ↔↑ German North Sea: 0 or +1 ↔↑ West Coast SH: 0 or +1 ↔↑ Islands / Municipalities: 0 or +1 ↔↑
Knowledge systems	9.) Offshore wind power uses scientific knowledge and could add new local and scientific knowledge in the long term. (leads to technology transfer, more and different types of knowledge, could be locally relevant in terms of management/ICZM). Technological advance must be sustained. In the case of fisheries, local knowledge could become irrelevant, because the choice of fishing grounds is restricted. Generation of systemknowledge concerning the sea.	Only relevant if new knowledge is sited in the region (technological knowledge). Scientific know-ledge can be generated on account of bio-logical / socio-economic monitoring. Traditional know-ledge will not necessarily be lost (other factors are more important). Impacts on fisheries probably minimal because traditional fisheries are near the shore.	Southern North Sea: 0 or +1 ↔↑ German North Sea: 0 or +1 ↔↑ West Coast SH: +1 or -1 ↑↓ Islands / Municipalities: +1 or -1 ↑↓ (+1 = OWFs generate new knowledge, little is lost; -1 = if influx of new residents means that traditions are no longer valued/maintained. We mean technological (scientific) knowledge; +1 means net gain in diversity of knowledge; fisheries: no reason why OWFs should directly lead to loss of knowledge)
Recreational (activities)	10.) Positive impacts - new recreational activities such as trips to wind farms. No negative impacts since offshore wind power does not impinge on any of recreational activities as such (except sailing).	No impact on the activity as such, but benefit of activity (e.g. wide horizon) may not be given any more (but this is another category and relevant for cumulative impacts). Relevance therefore low.	If accessible: Southern North Sea: x — German North Sea: x — West Coast SH: +1 or -1 ↑↓ Islands / Municipalities: +1 or -1 ↑↓

Figure 8.8 shows the results concerning cultural ecosystem services for the expected developments on the chosen scales.

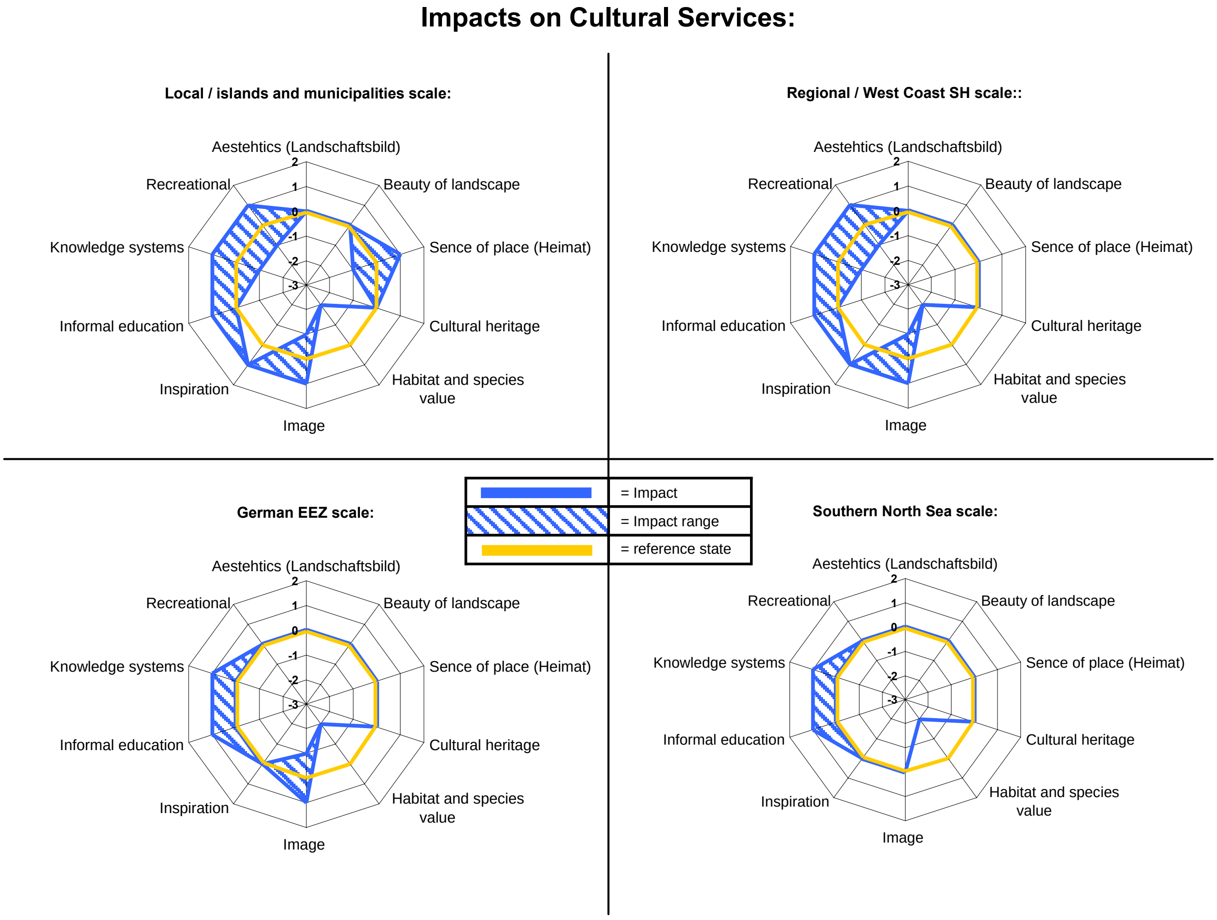

Fig. 8.8: Impacts of OWFs on cultural ecosystem services visualized across spatial scales. Relevant ES are located on the edges of the diagrams. The blue lines visualize the rating values (-2 to +2) connecting the impact ratings of every ES. The hatched areas visualize an impact range, as a result of the fact that impacts on cultural services, due to personal preferences, can be positive for one and negative for another person. The reference state (actual condition, the North Sea without OWFs highlighted in orange) is displayed and set to '0'. The diagrams are based on the assumption that OWFs are not visible from the coast.

The impact ranges shown in the diagrams are not a result of several components differing in rating, like it is with the components of ecological integrity or regulating services. As adduced, the impacts of OWFs on these ES vary according to the individual preferences concerning OWFs. This range of various ES clearly indicates expected trends. For example, focusing on a local scale, only four out of ten ES show impacts ranging from a positive (+1) to a negative (-1) rating due to individual and community preferences ('sense of place', 'image', 'knowledge systems', 'recreational'). For three services no changes are assumed on that scale ('aesthetics', 'beauty of landscape', 'cultural heritage'), while for three other ES there are obvious trends:

If the ES 'informal education' should be influenced, it is assumed that this can happen only in a positive way, as OWFs offers new, additional possibilities for the generation of informal knowledge concerning renewable energy. Whether the potential, as excursions to OWFs or the opening of information centers, will be used or not, can not be foreseen. It is irrelevant, whether OWFs are addressed as a positive or negative new development by informal education activities.

Both options would cause a process-enforcement of ”informal education” and as OWFs are not expected to displace other topics of informal education, a process-diminishing effect is presumed to be unlikely.

The ES ‘habitat and species value’ will be negatively affected, as from an ethical point of view, the industrialization of so far a natural (not build-up) area has a clearly negative impact on this ES. If individual species experience a negative effect (birds, marine mammals are displaced), then the existence/bequest value of the species is affected in this particular area. This is an ethical argument but also a legal one, if we consider national and EU legislation. The same goes for habitats which are also considered to have an intrinsic value (along with nature conservation as a moral imperative). If, on the other hand, environmental protection means protecting biodiversity, then the exclusion of other forms of use (e.g. fishing) could have a positive effect, if the wind farm acts as an artificial reef.

‘Inspiration’ is expected to slightly increase. According to the project internal definition, this ES can exclusively respond by process-enforcement triggered by OWF introduction. This rating results from the assumption, that OWFs are presumed to serve as a new source of inspiration. Whether this inspiration leads to positive or negative contention with offshore wind power is irrelevant and again depends on personal preferences, because in any case OWFs serve as a source of inspiration.

After this general introduction naming the specific aspects within this service category, the relevant ES identified will be discussed one by one.

The ES ‘aesthetics’ refers specifically to the case study area’s landscape (respective ‘seascape’) and its visual qualities. It does not focus on views of nature, like the view of the Wadden Sea ecosystem as a fragile system. Impacts on all spatial scales are assumed to be neutral. Changes within this ES depend exclusively on the visibility of offshore wind farms from the mainland, making visibility to a precondition of an impact. Under the chosen scenario, the planned wind farms within the German Bight do not fulfill the criteria of visibility, nearly all being planned more than 30 kilometers offshore (Köppel et al. 2004). Although influences on this cultural service seem to be irrelevant according to the specific scenario chosen for the ecosystem service analysis, wind farms fulfilling the visibility criteria are expected according to other scenarios (see chapter 4). A questionnaire survey identified aesthetic changes of a free horizon in the form of additional elements (OWFs) as a major fear of residents (Gee 2010), and therefore it must be stated that this ES is of high importance within public discussions.

A similar situation exists for the ES ‘beauty of landscape’. This ES refers to the meaningful and sublime dimension of the environment as being something higher and intangible, e.g. the experience of wilderness and the untamed force of nature. This ES does not focus on visual qualities of the seascape, but on a holistic experience of the environment with all senses (sound of waves, scent, migrating birds, etc.). The service as such is the sense of beauty people obtain by looking at a landscape which can be expressed by deep fulfillment or the meeting of the profound human need of being connected to the world at large (as a benefit). As changes of this ES again depend on the criteria of visibility, impacts are expected to be neutral. Nevertheless, it must be mentioned that apart from the visibility also the perception, the degree of acceptance and the general image of wind energy, might influence the appreciation of this ES.

The ES ‘sense of place’ is defined as physical man-made living space (strongly related to the German concept of ‘Heimat’), often created by ancestors. The service is the availability of space combined with the fact that it is influenced by local residents' decisions. Again a major factor related to this ES is the visibility of OWFs, but additional aspects could play a role, like the possibility to participate in decision-making processes concerning this newly introduced use of people's living space. Due to these criteria and the spatial limitation of individual living spaces, impacts might occur on a local scale of municipalities or islands. The rating ranges in relation to the personal attitude towards OWFs. While one person might wish to keep the sea free from industrial structures to maintain the traditional view of the living space, another might find a save job due to OWF introduction, making wind mills a typical component of his surrounding. On larger scales this ES is not expected to be impacted.

Another element of the cultural services is 'cultural heritage'. In terms of OWFs this ES mainly focuses on historically valuable elements or artifacts in the sea. Due to a low density of relevant sites for this ES no impacts are expected. A process-enforcement of this ES is not conceivable as new added structures can not directly serve as cultural heritage. A process-diminishing effect would be imaginable in case of OWF construction on a so far unknown cultural heritage site, e.g. a ship cemetery or former sunken settlement.

Strong impacts are expected for the ES 'habitat and species value'. The service itself is the provision of natural, as well as anthropogenic influenced habitats. But, whether a habitat will be protected with the help of environmental legislation depends on ethical aspects influencing this decision. Which habitat is worth protection? And how should the environment be managed? These questions illustrate the cultural dimension and relevance making this ES a cultural one. With the extent chosen in the scenario, OWFs will fundamentally change the natural environment both spatially and for individual species and assumingly lead to strong impacts on all spatial scales due to large scale changes of natural habitats. Whether these are considered positive or negative will be decided at a level of human well-being, when it comes to benefits obtained from ES.

The ES 'image' focuses on those elements of the environment used within the case study region to present itself to the public. This service is mainly related to touristic marketing and the region's advertisement as a good spot for a second, frequently visited, home. Image factors could be, for example, the wide horizon, the Wadden Sea as untamed nature, a traditional dialect or other elements of cultural heritage, but also OWFs as a symbol for modernization and sustainable development within the region. These examples point out that OWFs could have positive helping impacts on the region's image in terms of developing a more up-to-date image, as well as a negative influence, if OWFs are seen as threat for the essential tourism qualities mentioned above. How the ES develops does not solely depend on the visibility of OWFs, but is also related to active choices the region performs in shaping its image in a certain direction. This makes the presumed impact range understandable. On a southern North Sea scale, beyond tourism marketing activities, the ES is not expected to be altered.

Another ES of relevance is 'inspiration' defined as a tangible benefit related to any expression of spirituality or emotion derived from the local environment and landscape becoming conceivable in form or art, photography, literature or music. Within the project it was decided to focus on tangible benefits as these are measureable, not neglecting the existence and relevance of intangible ones. OWFs add a new element to the environment or landscape and could act as source of inspiration, but detract from previous sources of inspiration as well. Although the visibility is of importance for creating or detracting inspiring qualities, ideas can already be inspired knowing about the existence of OWFs independent of their location and visibility. For the local and regional spatial scale, process-enforcement is assumed. At the same time this does not define whether the enforcement is of positive or negative nature. On an EEZ and international scale, OWFs are presumed not to offer inspiring potential to a larger group of people.

The ES 'informal education' deals with the provision of educational activities beyond a formal scholastic context and specific target groups. The service itself is defined as the ecosystem's ability to provide the preconditions for activities such as guided walks, exhibitions or information centers. While these activities currently focus very much on the natural environment and the Wadden Sea ecosystem, OWFs could serve as an additional topic to be addressed within the context of renewable energies and climate change. An impact ranging across all spatial scales is expected. Future developments of this ES depend on the OWFs' use as an opportunity to widen the topics of informal education activities along the west coast of Schleswig-Holstein or if everything remains the same. Even on larger spatial scales, the use of offshore wind power for educational purposes is considered possible, thinking about the opportunity to offer boat trips to offshore wind farms. Process-diminishing impacts are not expected, like reducing the amount of topics currently discussed in the context of informal education.

A second ES dealing with educational issues is 'knowledge systems'. It examines the diversity of knowledge systems available in a particular environment. Within the case study this ES focuses on traditional knowledge, for example of fishermen and other local residents (e.g. local dialects). On the one hand, offshore wind power uses scientific know-how and could locally add new scientific knowledge to the region and, in the long term, generate new knowledge systems enforced by technology transfer. On the other hand, in the case of fishery, local knowledge could become irrelevant, because the choice of fishing grounds will be restricted due to security regulations within OWFs as mentioned earlier. At the same time, the discussed potential option of co-uses (OWFs - mariculture) could act as a displacement and generate new knowledge within the sector. Furthermore, it must be mentioned that ES changes basically depend on values stipulated by society on different types of knowledge. A good example might be the Frisian language. If the language is not longer valued and therefore not taught, it will disappear. Impacts are assumed to vary. An influx of new residents could mean that old traditions are not longer valued and maintained, but OWFs could as well generate new knowledge while little is lost. On larger spatial scales it seems to be likely that, if changes occur, offshore wind power will raise the net gain in knowledge diversity. Generally, it has to be mentioned that impact chains within this ES are very indirect and coincidentally OWFs would be just one potential driver in this context.

At last, the 'recreational' ES must be named. This ES focuses on outdoor activities related to the local environment or landscape including all types of sports, leisure and outdoor activities. OWFs could offer new recreational potential, such as boat trips. Under the chosen scenario, no direct negative impacts are assumed, as OWFs do not impinge on any recreational activity, except perhaps for sailing. Taking into account that OWFs might be visible from the mainland, according to other scenarios, the benefit obtained by outdoor activities could be impaired due to a loss of the wide horizon as a typical component of the coast's recreational value, although this depends on personal preferences, of course. Another slightly negative impact on these activities might be noisy helicopter flights for technical maintenance of offshore parks. Under the precondition of offshore wind farms' accessibility, the rating varied for local and regional scales where both new recreational activities and additional noise coincidentally could appear.

Discussion cultural services

The analysis of cultural services' response on OWF introduction identified several points demanding further discussion concerning the applicability of the ES approach for case studies like *Zukunft Küste - Coastal Futures*.

Within this service category it turned out to be difficult to clearly differentiate between an ES and its benefit, because some cultural services just emerge in the moment when it is recognized by a person, e.g. the ES 'inspiration'. Simultaneously, the person already benefits from the emerged service because of for example being inspired or touched by an aesthetic view. These examples point out the often smooth transition between service and benefit. Perhaps it could be helpful to define or understand cultural services as an offer of certain circumstances or resources by ecosystems, providing the opportunity for a human benefit. This can be for example a free view of the horizon, undisturbed landscape or silence. As soon as humans use these resources, the utilization itself must be understood as benefit. In terms of the ES 'inspiration' that would mean, inspiration itself is not an ES, but a benefit and the provision of the possibility of inspiration is the actual ecosystem service. A clear distinction between service (as a basis for benefits) and benefit (which can be direct or indirect, tangible or intangible) is of high relevance for communicating expected impacts. In the case of cultural services this is especially difficult as some ES are closely related to actual ecosystem functions, while for others individual cognition and interpretation layers lie between ES and ecosystem function. The current scientific discussion tends towards a clear separation of service and benefit (Fisher & Turner 2008, see chapter 8.1).

The relevance of space, as already discussed in connection with provisioning services, reappears within this ES category. The character and composition of space is the precondition for the generation and provision of cultural services. Whether e.g. a land- or seascape can offer this opportunity also depends on its size. To provide cultural services, which potentially could be affected by OWFs as already named (wide horizon etc.), large units of natural areas are needed. From this point of view it is also possible to argue that a specific composition of space is the actual ES while the single cultural services are the benefits.

This discussion shows that there are several approaches in interpreting the borderline between service and benefit. In the end a case-specific definition is needed to fit the approach to the specific requirements.

Another point important to stress is the role of visibility related to expected changes within a majority of cultural services. Although this factor is not relevant in the analyzed scenario, it appeared to be the major influencing component shaping personal opinions and attitudes towards OWFs. In the moment when wind power plants become visible from the mainland they really exist from a cognitive point of view. Exceptions are the ES 'habitat and species value', 'informal education' and 'knowledge systems'. In these cases threat ('habitat and species value'), additional educational potential ('informal education') and new know-how ('knowledge systems') will develop independent of visibility. The objective fact that OWFs will exist is the only precondition for potential changes within these ES, while all other cultural services are expected to interact to a greater or lesser extent with the factor of visibility.

Moreover the measurement of mainly intangible services could be identified as a big challenge concerning the assessment of cultural services. Not just because the cognition of changes within this ES clearly depend on subjective, individual issues, but because relevant data are not available or remain undetected in other contexts. This makes an evaluation extremely complex and asks for comprehensive resources which are not available in most cases.

Summary

Summarizing the chapter on cultural services it can be stated that the assumed impacts on this service category show a controversial behavior that is difficult to estimate due to the high relevancy of local residents' personal preferences. These circumstances lead to the presumed impact ranges for several ES varying between process-enforcement and -diminishment on a local and regional spatial scale (sense of place, image, knowledge systems, recreation) perceptible to coastal residents. OWFs proved to be a development some consider an opportunity and others a threat and has raised many arguments that are well suited for framing a conflict over cultural services. Visibility, or rather the fear that OWFs will be visible from the mainland, and accessibility were identified as further important factors shaping force and direction of impacts relevant on a local and regional spatial scale. On an EEZ and international scale impact estimations become more distinct, indicating trends for a slight enforcement of the ES 'knowledge systems' and 'informal education', while 'habitat and species value', like expected across all scales, shows a strong process-diminishing impact even on an international scale.

8.8 The relationship between ecosystem services and human well-being

So far, chapter 8 has set out which ecosystem services are likely to be affected by offshore wind farming and described the nature of these various impacts. Concluding this line of reasoning, and completing the last step of the Millennium Ecosystem Assessment (MA 2005) approach, this section focuses on how the potential changes to ecosystem services might affect human well-being.

Human well-being is a construct that has been variously termed "complex, controversial, and continually evolving" (Butler & Kosura 2006: 1). Lacking a universally acceptable definition, terms employed to describe it are numerous and competing, including "[….]quality of life, welfare, well-living, living standards, utility, life satisfaction, prosperity, needs fulfilment, development, empowerment, capability expansion, human development, poverty, human poverty, land and, more recently, happiness" (McGillivray & Clarke 2005: 3). As a result the linkages between human well-being and ecosystem services are equally diverse, with many still poorly understood and controversial (Fisher et al. 2009, Howarth & Farber 2002, Müller & Burkhard 2007). A major difficulty is that all ecosystem services can somehow be conceived to contribute to human well-being, be it directly or through some indirect route.

The MA (2005) assesses the link between changes in ecosystem services and human well-being at various scales. "The objective of the MA was to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being" (MA 2005: ii). But how to operationalise this link? Economic welfare is a key indicator of human well-being, offering ready links to a range of ES (e.g. Heal 2000, Turner et al. 2003, Plummer 2009). In the following we approach human well-being from the broader perspective of quality of life. The advantage of this concept is that it combines objective societal and subjective individual dimensions, each of which offers different access points to the ES - human well-being relationship.

Quality of life

Quality of life has come to represent a key indicator of social progress, expressed for instance in the yearly Human Development Reports published by the UNDP (www. http://hdr.undp.org/en/reports/). At the level of society, it is described by a wide range of factors, encompassing economic welfare but also the environment and social relations for example (e.g. Glatzer & Zapf 1984). Usually, societies define standards for each of these factors, supported by political objectives and measures designed to attain them. An indirect proxy for measuring the potential quality of life is the infrastructure that ensures a certain standard of living (Ruppert & Schaffer 1969, Fürntrapp-Klopp 1995). Spatial planning literature terms these infrastructural elements 'objective criteria for quality of life' or 'determinants of quality of life'. The comprise the economic status of a region (income and employment), infrastructural prerequisites for good living (housing, education, leisure, health and public transport) as well as the degree of satisfaction with living conditions, housing and employment amongst them (Licht-Eggert 2007, BBR 2005).

Quality of life, however, also has a subjective dimension in that societal standards for quality of life always come together with the subjective experience and rating of these (Majer 1984). Subjective well-being at each person's individual level is a time- and context-specific construct that is mediated by a wide range of factors. Material benefits are one aspect, but perception, past experience, personal value systems, life priorities and goals, as well as each person's social and economic situation all play a role (see also Cummins et al. 2002). For the purpose of describing human well-being, the above determinants of quality of life are therefore inherently limited. They tap the prerequisites that could allow individuals to attain a certain quality of life, but say little on whether individual well-being is actually achieved. Also, they only touch upon the non-material determinants of quality of life which the MA describes as important, such as good social relations and freedom and choice (see MA 2005).

Connecting ES and quality of life

To establish a workable connection between ES and quality of life, determinants of quality of life need to be selected that respond to ES benefits. In the case of societal determinants of quality of life, an example would be the direct link between provisioning services (e.g. fish, mussels) and the availability of local employment (e.g. fisheries). Extending the use of these provisioning services can lead to the creation of additional jobs, which could attract people to the region and might ultimately lead to increased demand for housing, education and public transport, for example. At this level of argument, impacts on quality of life refer to society generally and not to individuals who may or may not benefit from job creation. Impacts on public infrastructure also represent a rather indirect impact of utilising ES benefits.

To establish quality of life at the individual level, it can be helpful to consider hierarchies of human needs (e.g. Maslow 1954). The most basic level of human needs is the physiological level - the need for food, water, air - where links to ES can be established reasonably easily (provisioning and regulating ES as providers of food, clean water, air etc.). In the developed world, it is less the availability of these services per se but access to them that impact on quality of life, leading back to the crucial role of infrastructure. Beyond the physiological, however, and

"[….] once a material minimum is attained, human well-being is substantially experiential" (Butler & Kosura 2006: 1f.). Immaterial benefits play a particular role in this context (e.g. the pleasure of experiencing a beautiful landscape, or the satisfaction derived from knowing biodiversity exists; see also Gee 2010 and Gee & Burkhard 2010), as do emotions, value constellations, and perception as mediators of experience. Altogether, however, it is clear that individual well-being is influenced by a great variety of factors, many of which are not related to ES at all or only through an indirect causal chain.

The work described below forms part of the overall impact assessment of offshore wind farming (part of the DPSIR assessment, see chapters 3 and 4). Taking the human well-being terminology of the MA (2003) as starting point, we present a concept for assessing the impacts of changes in ecosystem services on objective determinants of quality of life and 'felt' well-being in our case study area. In this we only refer to changes in human well-being that could conceivably be ascribed to the impacts of offshore wind farming. Our primary aim was to develop a conceptual framework that would allow for these impacts to be captured and rated.

Conceptual premises and methods

We postulate that human well-being is strongly related to the ecological and socio-economic impacts of offshore wind farming. The strength of those impacts varies depending on the spatial and temporal scale that is chosen for assessment. Here the main focus was on the West coast of Schleswig-Holstein, a region characterised by a strong sense of identity, a historically close relationship to the sea (Gee & Burkhard 2010), extensive nature conservation areas (Wadden Sea), and tourism as a mainstay of the local economy. It is also a region that is structurally weak and in danger of negative demographic development (Licht-Eggert et al. 2007, Klein-Hitpaß & Bruns 2006). Apart from objective criteria such as economic welfare and the infrastructure to ensure good living conditions, immaterial factors can therefore expected to play a role in shaping subjective estimates of well-being in this region (e.g. attachment, home, social relations, feeling secure etc). In line with the scenario time steps of the project the year 2030 was chosen as a temporal horizon (see chapter 4). Aspects of offshore wind farming and ecosystem services that affect the national or international level were not considered.

Despite the particulars of the case study region, a decision was taken to mainly focus on objective determinants of quality of life (see above). We only touch upon subjective determinants of well-being, although this is due to the lack of data and no indication of their lack of importance. Reference to subjective determinants of human well-being is based on the results of a questionnaire survey of local residents (see chapter 5). The final assessment was carried out in an internal working group composed of *Coastal Futures* researchers with interdisciplinary scientific backgrounds.

The **first step** consisted of checking all four categories of ecosystem services (ecological integrity, regulating, provisioning and cultural ecosystem services, see chapter 8.2 for project-specific definitions) to determine whether a direct relationship could be constructed with objective determinants of quality of life or subjective well-being. Six ES emerged as particularly relevant in the case study area in the sense that offshore wind farming directly impacts on ES, which has a demonstrable impact on determinants of human well-being. These are global climate regulation, provision of food, provision of wind energy, aesthetics/beauty of landscape, image of the region/recreation, and species and habitat value. Elements of ecological integrity such as energy and nutrient cycling or storage capacity were still considered relevant, but only indirectly related to human well-being in that they act as enabling factors for others (see chapter 8.3 and Figure 8.2)

The **second step** consisted of a more precise definition and a selection of 12 determinants of human well-being. Particular reference was made to the objective determinants of quality of life used by the German Federal Statistical Offices (Statistisches Bundesamt 2008) and the Federal Spatial Development Report (BBR 2005) (see Licht-Eggert et al. 2007). Essentially, our assessment is restricted to the (infrastructural and material) prerequisites for a good life rather than the choices and views of individuals that might contribute to subjective quality of life. We thus consider health infrastructure rather than subjective health; or the availability and quality of regional seafood rather than the nutritional status of individuals, or the availability of leisure facilities rather than subjective enjoyment.

To properly assess and rate the selected determinants of human well-being a range of potential indicators were identified. Where possible existing sets of indicators were referred to (e.g. BBR 2005, Gehrlein 2004, McMahon 2002, Müller & Burkhard 2007; Licht-Eggert et al. 2007), statistical data (e.g. the regional statistical office 'Statistikamt Nord') and local survey results (Gee 2010). A set of indicators are thus suggested that are specific to the West coast of Schleswig-Holstein and sensitive to the case of offshore wind farming. These indicators can be used for future quantitative assessments. Table 8.7 gives a description of the various determinants and examples for potential indicators.

Tab. 8.7: *Determinants of human well-being, their project-specific definition and potential indicators*

Determinants of human well-being	Definition specific to the case study	Potential indicators
Economic welfare		
Income	Disposable income, i.e. the income available to individuals for meeting their respective needs. The material basis available to each individual for participating in social life.	- Average annual income per level of education - Disposable household income - Share of persons claiming benefits - Per capita GDP, by region/country
Employment	Diversity and security of available jobs within the region, linked to the overall regional employment/unemployment ratio. Employment is an important factor for maintaining social stability in the region.	- Regional employment rate - Regional unemployment rate - Share of the total workforce per sector
Housing	Availability of a range of different housing options (singles/families/retired persons/holiday homes), reflecting the need to plan new developments sensitively and sustainably (in keeping with local style) and with sea level rise in mind (vulnerability/security).	- regional demand for housing - living area per inhabitant - rent index per qm² - annual new land use

Infrastructure	As in other industrial countries basic infrastructure in the region is considered a public good. Here it means basic service infrastructure such as energy supply, transport, and telecommunication.	- public transport network, - km of roads - share of renewable energies in energy consumption (private households and industry/business)
Security	Security from sea-borne threats. Extreme events such as storm surges are included here as well as threats resulting from human uses, such as shipping accidents or accidents on oil platforms.	- Overall length and elevation of dykes - Number of shipping accidents - Annual public spending on sea defences
Personal well-being		
Personal well-being	Subjective determinants of quality of life.	- Personal satisfaction and happiness
Social well-being		
Nutrition	Defined here as the availability and quality of regional marine food such as fish and mussels.	- Suppliers of local produce in the region - Price index of local produce
Demography	Defined here as the dynamic changes of social structures and the overall social composition.	- Immigration/Emigration - Population structure - Birth and death rates - Share of foreign inhabitants
Health	Defined as access to health infrastructure and the overall status of health infrastructure within the case study area.	- GPs per inhabitants, - accessibility of hospitals (distance/time travelled); - hospital beds per inhabitant - average no. of sick days per person per year - cost of health insurance per inhabitant
Education	All forms of education and training. Formal education (e.g. in a schools context, formal vocational training) is set apart from informal education (voluntary participation in adult further education programmes, environmental interpretation, field visits etc).	- Pupil/-class ratio - Day care places per 100 children - No. of trainees/ apprentices per 1000 employees - Number of adult further education classes
Leisure	Individual leisure activities (in- and outdoor) and the provision of the infrastructure required to engage in these.	- Cultural and leisure (sport) facilities / programmes / courses
Social relations	Social stability resulting from social networking and interchange. The degree of self-organisation within society is considered an indicator of society's potential to regulate social conflicts.	- Number of citizen's initiatives - number of non-profit organizations and associations - volunteers / population - membership in associations

Scenario B1 (‘the North Sea primarily used as an energy park’; see chapter 4) was used as a baseline for the **third step,** which was to discuss the potential impacts of offshore wind farm-induced change on the selected determinants of human well-being. Essentially, this meant linking the six ES to the twelve determinants of human well-being assuming strong development of offshore wind farming. We emphasize that the aim of this step was merely to establish potential impacts in principle; no in-depth analysis of any connections was carried out. The above indicators were applied in a qualtitative way to determine impact strength. Hence, the method was rather simple: If a logical case could be made for a connection, this was indicated in a draft matrix using an arrow. The more obvious and direct the connection, the thicker the arrow. Thin arrows describe a more tenuous and possibly indirect link. Although this would clearly need to be supplemented by data, the strength of an arrow can be read as an indication of directness of impact. Connections were established based on intuition and reason and should therefore be considered a first step. Further research is needed to confirm the connections and to describe their nature in more detail.

Results

Figure 8.9 gives the relationship between the six selected ES and the twelve determinants of human well-being.

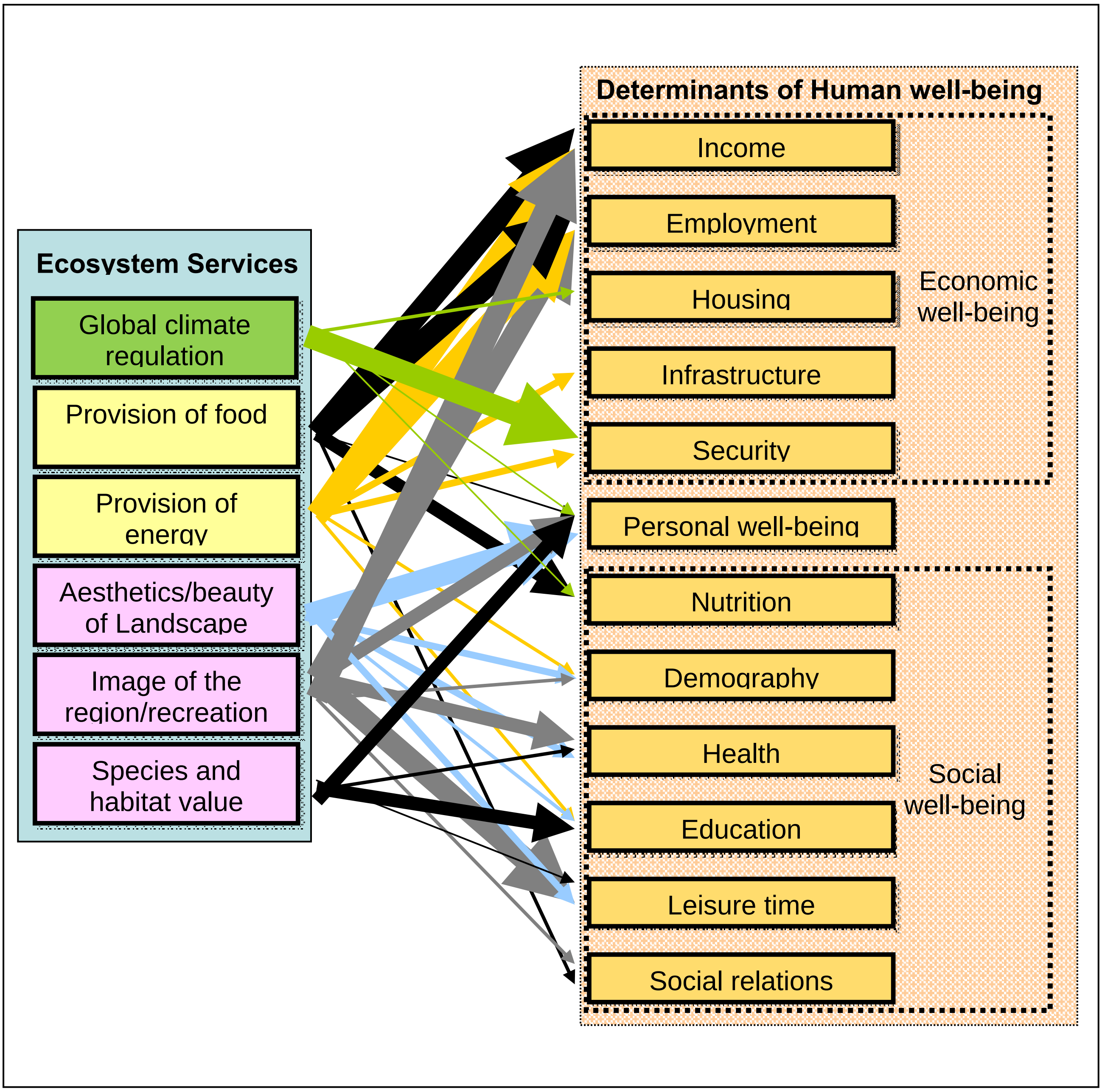

Fig. 8.9 : Linkages between ecosystem services and selected determinants of human well-being in the case study offshore wind farming in the German North Sea.

The ES 'global climate regulation' is directly linked to safety, defined in the case study area to mean safety from sea-borne threats. Many local residents assume that offshore wind farms will contribute to reducing the threat of global climate change, implying less of a threat from sea level rise or increased storminess. Lower vulnerability in turn has impacts on economic and social determinants of human well-being, such as the siting of regional infrastructure or decisions taken by industry to invest in a safe and stable region. The role of offshore wind farming in global climate mitigation, however, is probably minor at best.

The ES provision of 'food' clearly impacts on employment since fish and mussels constitute an important economic good. Offshore wind farms can serve as a nursery area for fish with potentially direct positive effects on local fisheries and employment (see chapter 5.5). If co-use of offshore wind farms with aquaculture becomes a reality, this link is strengthened even further. However, this interrelation is also strong because the fact that offshore wind farms restrict access to fishing grounds is seen as a negative impact by a majority of fishermen.

The provisioning service 'wind energy' is also linked to employment. Energy, here defined as the supply of renewable energy from offshore wind farming, is a wider societal benefit that can be obtained from wind resources and marine space. It is also a fundamental good which can support communities in generating economic and social well-being. Hohmeyer (2006) has shown that even if only parts of the offshore technology are being produced at the west coast of Schleswig-Holstein, a significant increase in employment could be expected (see chapter 7). This in turn could encourage an immigration of skilled persons seeking work, with corresponding impacts on infrastructure such as schools or transport.

Taking the economic determinants of human well-being separately, however, it has to be stated that the impact of offshore wind farming is likely to be minor compared to that of other human activities. Although 'employment' could be positively influenced by an expansion of offshore wind farming, this does not mean that these jobs will necessarily be created. National economic and social policy or the global economy as a whole are likely to exert a much stronger influence on employment options in the region, determining for instance whether a company chooses to invest in the region or not.

For the cultural ES 'aesthetics/beauty of landscape' the link to personal well-being is direct and obvious. Offshore wind farms directly impact on the perceived beauty of the seascape. Questionnaire results have confirmed that enjoyment of a beautiful seascape contributes to inner well-being, and that offshore wind farming threatens particular notions of seascape and the marine environment. Negative impacts on personal well-being are mentioned as an expected consequence (see for example Gee 2010). A similar link exists between image/recreation and leisure time in that a particular coastal and marine landscape can be important for personal enjoyment and spiritual satisfaction. Links can also be established at the societal level in the context of marketing the region for tourism. Here, offshore wind could be constructed as a positive impact - for instance, if the region chose to present itself as a sustainable energy region - or a negative impact if it were seen to detract from the essential natural environmental qualities the region. Impacts on employment in tourism could therefore be positive or negative.

Species and habitat value is another cultural ES affecting personal well-being depending on personal value orientations. Questionnaire results have confirmed that some local residents derive great satisfaction from knowing that marine species or biodiversity are abundant and protected. Species and habitat value is also linked to education, both in a formal and informal context (e.g. National Park informal education provision, school trips etc.)

Discussion

In the above we explored ways of operationalising the links between ecosystem services and human-well being within a specific case study. Although the assessment was mostly based on qualitative evaluations, links were shown to exist between offshore wind farming, changes in ecosystem services, and human well-being. It was also shown that impacts of offshore wind farming can affect human well-being through a multitude of routes, which can be made visible both at the level of objective conditions for quality of life and individuals' subjective sense of well-being. However, other developments may have much stronger impacts on human well-being, such as demographic change and the global economy. Future work will need to take this into account in overall ratings of impacts on human well-being. For the case study, future work will also be needed to determine whether there is a singular relationship between the ES shown in Table 8.9 and determinants of human well-being, or whether measurable impacts on human well-being only really result from a combination of the ES described.

Nevertheless, indicator-based assessments in interdisciplinary working groups are a method for arriving at well-founded assessment. A degree of subjectivity may well be an inherent feature of assessments of human well-being. Our study excluded potential indicators such as happiness in that it primarily focused on objective determinants of social well-being. Results will also be influenced by the scale chosen for assessment and the scenario used as a baseline. Here we only considered one scenario for offshore wind farm expansion and its impacts on the West coast of Schleswig-Holstein. This necessarily disregards any impacts that might be felt at other future developments or at other spatial (e.g. national or international) and temporal (decades, centuries) scales.

8.9 Conclusion

After this overview on all four ES categories it can be concluded that the ecosystem service approach served as a valuable instrument for analyzing and estimating expected impact of OWFs. Within all service categories changes and interesting trends were identified. At the same time the approach's difficulties (average values, weighting several components) and short-comings (distinction between ES and benefit) to deal with a strongly delimited subject became obvious and identified the need for further structural debate.

The majority of ecological integrity components showed surprising process-enforcements, especially on a pile and OWF scale, with the exception of the ES 'biotic diversity' indicating a strong negative impact on seabirds up to an international scale.

The mainly large scales' regulatory ecosystem processes grouped as regulating services are not expected to change significantly with OWF introduction. Most relevant ES just show slight and local reactions regarding OWFs. The reduction of CO_2 emissions for energy conversion can be named as the main effect to contribute to a deceleration of global climate change.

Concerning the provisioning services, today's fishery community mainly interprets OWFs as an endangerment. At the same time potential co-use opportunities for mariculture and hydrogen generation are assumed to enforce some provisioning services. Overall it can be stated that the process-enforcements exceed the local negative ES development concerning the ES 'food - fishery'.

To some extend, the cultural services showed a controversial picture caused by the high relevancy of personal preferences concerning the cognition of OWFs' impacts. Visibility and accessibility were identified as further important components influencing the development of this service category. On EEZ and international spatial scales less influenced by personal preferences, impact estimations became more distinct and indicated trends towards a slight enforcement of the ES 'knowledge systems' and 'informal education', while 'habitat and species value' was identified as strongly negatively impacted across all scales.

Moreover the analysis of interrelations between environmental changes induced by OWFs and aspects of human well-being could be shown on a conceptual basis. It was shown, for example, that changes in the marine environment result in impacts at considerable distance, affecting system components not originally connected to the site of impact but still making use of the relevant ES.

The application of the ES approach generated a holistic picture regarding the pros and cons or chances and risks related to OWF introduction in the German North Sea. The results can serve as an initial estimate. Relevant aspects demanding further research as well as negative impacts which should be addressed in a precautionary manner before large scaled installation of OWFs take place could be identified.

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9 Capacity Building for Coastal Managers - Integrating traditional Coursework - ELearning and Coastal Wikis

Christiane Eschenbach, Wilhelm Windhorst

9.1 Coastal environmental challenges ...

The ecological state of coastal ecosystems and the level of ecosystem services provided in coastal zones is object of multiple spatio-temporal interactions. Large scale hinterland interactions driven for example by river basin processes (e.g. eutrophication or damming) and settlement (e.g. road systems), and broad scaled marine processes like circulation patterns or population dynamics of commercial fish species are relevant determinants for the state of coastal ecosystems. Local and highly dynamic processes and structures are interacting with each other and the broader scales to shape the coastal ecosystems. Of major ecological importance are resting areas for migrating birds, but also natural or manmade structures for coastal defense are of major relevance. Additionally, global processes like climate change - accompanied by sea level rise - and global economic integration fostering shipping and harbor development are determining the level of ecosystem services available to underpin human well being. Hence, coastal zones are areas where extensive conflicts between environmental, social and economic targets have to be expected in the future: The intensification of human activities along the coasts, their attractiveness for settlements and tourism, the steadily growing transport capacities will lead to several contrary land and sea use concepts in extremely vulnerable and valuable ecosystems and habitats. This has been widely acknowledged by national, regional and international governmental bodies fostering cross national activities in Integrated Coastal Zone Management (ICZM), developing overarching marine policies (e.g. OSPARCOM, HELCOM, Barcelona Convention, etc.) and promoting research and & development activities (e.g. IPCC, EEA, etc.). Hence an ongoing and growing demand for human resources to actively manage coastal zones in respect to such challenging complexity is expected. Lacking management capacity is one of the major barriers to implement best ICZM practices on a broad scale.

9.2 … are challenges for Capacity Building - the integrated approach to teach Integrated Coastal Zone Management at the Ecology Centre of Kiel University

Harnessing eLearning can be an promising option to improve the science/education and the science/practitioner interface in the field of ICZM. The term eLearning refers to various forms of electronically-supported learning - we use it for all computer-supported, internet-based forms of teaching and learning, including so-called 'blended-learning', in which online-lectures are combined with face-to-face courses and other standard instruction elements (e.g. reading of printed papers). ELearning may also include associated management issues, such as administration and examination arrangements, as well as the means of communication. All these elements are dealt with using special software, a so-called eLearning platform. As there are no time and space constraints, eLearning enables students to attend lectures from their own home and makes it ideal for international collaboration. On the other hand, universities can ease the pressure on their resources, and can in the same time expand their range of optional subjects, that means an increasing number of eLearning courses can be exchanged.

By integrating traditional and web-based teaching approaches competences are trained to improve the problem solving and self organizing capacity of learners as well as their communicative and cooperative skills. Hence, traditional 'Stockpiling Learning' can be upgraded to 'Lifelong Learning' by augmenting non formalized learning structures (e.g. Revermann 2006a).

Though the steadily growing accessibility of computers and increasing media competences should ease the broad use of eLearning, the intensive use of web based learning technologies is still mainly limited to academia (Arnold et al. 2004). According to Georgieff, Kempeler & Revermann (2005), the limited use of eLearning in job training and further education could be explained by i) reservations of stakeholders to trust in such approaches and ii) the limited competences of practitioners to use the new instruments in a self organized way.

The Ecology Centre at the Christian-Albrechts-University established in 2004 the International Master Program Environmental Management (www.ecology.uni-kiel.de/masters). In 2008 major parts of this program became part of the ERASMUS MUNDUS program 'EMAE-European Master in Applied Ecology' (www.master-emae.org). And from 2010 especially the courses at Kiel University dealing with coastal issues will contribute to the recently approved ERASMUS MUNDUS program 'MSc Ecohydrology' (www.ecohyd.com). Besides in hard skills like Systems Analysis, Statistics, Modeling, GIS, etc. the internationally recruited students with varying disciplinary backgrounds (ranging from natural sciences to social sciences) are trained in soft skills. Moreover, cross-cultural communication and cooperation are part of the student's daily life in all classes, as regularly more than ten nations from all over the world are enrolled at the Ecology Centre.

The major objective of the course 'Integrated Coastal Zone Management' is to offer potential 'Coastal Managers' profound science based background knowledge and to provide methods to utilize this for practical challenges in coastal management. Targets of the embedded web based components are i) to train the students self learning capacity and ii) to give them access to the active science community in coastal and marine sciences.

According to Schulmeister et al. (2008), methodological approaches in eLearning can be classified by the size of the learning group, the virtual level, the degree of media integration, the level of synchronization and the need for communication. At the Ecology Centre three types of eLearning application have been elaborated in the field of ICZM:

(1) Accompanying material to underpin the face-to-face teaching is made accessible for the students via the eLearning platform of the Ecology Centre (www.ecology.uni-kiel.de/ilias).

(2) ELearning based case studies covering ICZM topics of major international relevance have been elaborated.

(3) A co-operation with the ENCORA Network (EuropeaN platform for COastal ReseArch, www.encora.eu) has been established in order to interface students and coastal & marine scientists already at an early stage.

9.3 Methods

The development of an eLearning unit differs in many ways from the concept of conventional teaching. The conceptual considerations require special care as spontaneous reactions of eLearning teachers - especially small adaptations, corrections, etc. - are strongly limited. For the development of an eLearning unit Kerres (2001) indicates the following interdependent core elements: (1) target group, (2) specification of learning objectives & content, (3) didactical concept, (4) learning scenario and (5) employment of multimedia.

Target group

Quality and capability of the target group are the foundation of every pedagogical approach - in this case, postgraduates of the Ecology Centre equipped with varying Bachelor Degrees. Pre-knowledge, media competences and intellectual capacity of this group are well known from face-to-face lectures as the ICZM module is taught in the last teaching term of the respective Master programs.

Specification of learning objectives & content

One major challenge especially for the development of ICZM courses is to allow students access to best practice examples and recent research results. To achieve this i) case studies have been integrated and ii) a close co-operation with the Costal Wiki established by the ENCORA Network and maintained by the EUCC was established.

The case study concept: Four case studies each representing a different coastal use situation were elaborated up to now: (1) Offshore Wind Farming in the German EEZ, (2) Shrimp Aquaculture & Management of Mangrove Forests in Thailand, (3) (Eco-) Tourism in Honduras and (4) The JadeWeserPort: Potentials of informal processes to resolve land- and sea use conflicts.

Each case study reflects use and user driven conflicts, resulting consequences and approaches for problem solving. The science interface was represented by a close co-operation with the R&D project *Coastal Futures*. All case studies have been structured along the Driver-Pressure-State-Impact-Response (DPSIR) scheme to analyze man and environment interactions in a comparable manner (Eliot 2002, Burkhard & Müller 2008, see chapter 3).

The WIKI concept: The Network ENCORA provides a platform for scientists and professionals covering all facets of coastal research and management (www.coastalwiki.org). In order to stimulate the use of most recent activities in ICZM students were asked to write articles with a topic of their choice after consultation with the responsible lecturer.

Didactical concept

Three major didactical approaches can be differentiated in principle: behaviorism, cognitivism and constructivism (see for example http://arbeitsblaetter.stangl-taller.at). With each approach an altered role of the teacher and a distinguished involvement and active participation of students is required. While behaviorism addresses the students more as passive consumers of information and the teacher has the task to bring the knowledge, learning according to cognitivism is the result of acquiring information and the active processing of this information by the learner. Constructivism understands gaining of new knowledge as the result of individual construction framed by the existing experiences of the learner.

Accordingly, the material accompanying the face-to-face lectures realizes the behavioristic approach. As knowledge about certain situations is represented as a series of learning units, the case studies also have to be classified as conventional teaching and learning. The information is transported from the teachers to the students. However the content was in parts generated by students during their master thesis - thus, students partly take over the role of bringing the information. The second type (cognitivism) in our implementation is represented by the online module 'Introduction and Basic concept of ICZM', harnessing animated graphs, interactive elements (Figure 9.1) and short videos especially produced to support the anticipation by the learner (Lohmann 2006). Finally, the inclusion of the WIKI concept, e.g. the writing of WIKI articles, relates to the concept of constructivism and calls for most active participation of the students (learner- centred approach).

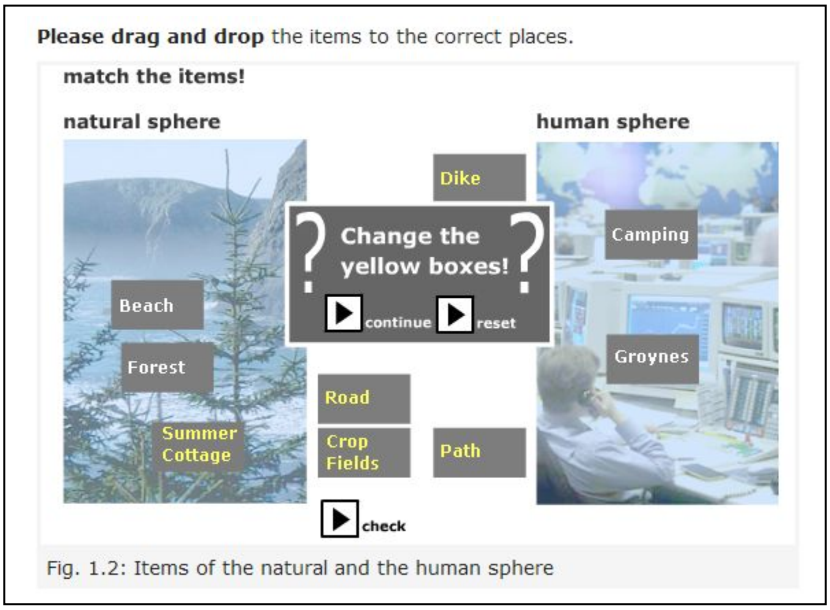
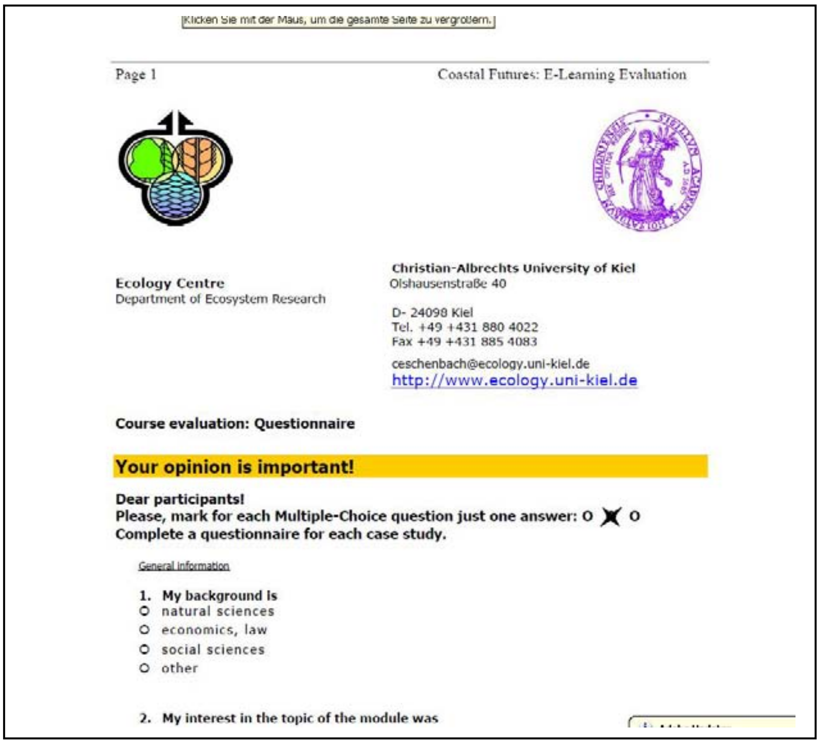


Fig. 9.1: Example of an interactive multimedia element of the online module 'Introduction and Basic concept of ICZM' (screenshot from ILIAS-platform of the Ecology Centre of the University of Kiel)

Implementation & evaluation

Case studies and online modules have been implemented at the Ecology Centre of Kiel University (http://www.ecology.uni-kiel.de/ilias) on the eLearning platform ILIAS (Integriertes Lern-, Informations- und ArbeitsSystem, www.ilias.de). ILIAS is an open source product developed by the University of Cologne and applying international exchange standards like SCORM, AICC or IMS. In order to promote the co-operation of students with the external ICZM-community the WIKI system developed by the EU-project 'ENCORA - EuropeaN platform for COastal ReseArch' (2001-2009) was used, which is now maintained by the German section of EUCC-D (European Union for Coastal Conservation). To receive regular feed back from students online-evaluation procedures have been elaborated (see Figure 9.2). The questionnaire addresses topics such as the overall impression of the module, usability of the platform, time required to work through the learning units, course topics, didactical concept, multimedia elements, and communication elements.



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Page 1 Coastal Futures: E-Learning Evaluation

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Course evaluation: Questionnaire

Your opinion is important!

Dear participants!
Please, mark for each Multiple-Choice question just one answer: O X O
Complete a questionnaire for each case study.

General information

1. My background is
- O natural sciences
- O economics, law
- O social sciences
- O other

2. My interest in the topic of the module was

Fig. 9.2: Evaluation of the eLearning units: Detail of the questionnaire.

9.4 Results

Case studies

Case study 1 'Integrative Impact Study on Offshore Wind Farming' comprises seven learning objects (LO). LO1 gives an introduction into ICZM: concept, components, socio-political conditions and historical development. In LO2 recent sea-uses in the southern North Sea like shipping, fishery, tourism, navy, mariculture, as well as oil, sand and gravel mining are described and reflect the multiple pressures on coastal zones. LO3 & LO4 (in prep.) will present technical, economical and possible ecological effects of offshore wind farms. LO5 (in prep.) will present an integrative ecological analysis of offshore wind farms elaborated within *Coastal Futures*. In LO6 the options and chances of participatory processes in respect to public decision processes on the spatial allocation of land- and sea-use rights are elucidated. LO7 illustrates stakeholder-mapping & analysis, in order to facilitate participatory and provides methods to identify the most relevant stakeholders in respect to a defined situation. Units 6 and 7 are based on results elaborated in the R&D project *Coastal Futures*.

Case study 2 deals with 'An ICZM Strategy for Tela Bay, Honduras'. Tourism is one of the most prosperous industrial branches worldwide and has the potential to yield multiple benefits not only to the investors but also to the local population. However, tourists and tourist infrastructure have also potential to threaten or even to destroy sensitive and valuable ecosystems. Hence, especially projects targeting to promote ecotourism have to be prepared and operated with special care. With the support of the Government Hondurian private investors are creating a new tourist resort located in the Caribbean Coast of Honduras on a water front stretch of land with

768.3 acres with beach, forest and lagoon access (http://www.losmicosresort.com). The specific social and ecological settings of Tela Bay as well as the legal constraints are forming the Learning Object 1 (LO1) of the case study 2. The project description plus stakeholder analysis and possible clashes of interest are displayed in LO2. In LO3 the situation is framed into an ICZM approach which is the basis for LO4 in which the multiple interactions are analyzed along the DPSIR approach. The integrated analysis is presented in LO5 where specific challenges like widespread poverty, lack of education, and others for the project are compiled. Furthermore, threats - like the poor level of natural resource management - are listed and, finally, recommendations to support responsible stakeholders are presented.

Case study 3 is on ‘Sustainable Mangrove Management in Eastern Thailand’. Mangrove forest is one of the most endangered coastal land-use (Figure 9.3). Though many ecosystem services are provided by them (firewood, food, nursery area for fish, coastal protection, etc.) large areas of mangrove forest are replaced by artificial structure, for example by ponds for aquaculture. The introductory LO1 elucidates the different ecosystem goods and services (see chapter 8) provided by mangrove forests and their relevance in general and exemplified by the development in Eastern Thailand since 1980. The specific quality of mangroves in Thailand and the study sites in Eastern Thailand are object of LO2. The suitability of alternative management approaches for mangrove forests, analyzed along the DPSIR approach, is accessible in LO3. Furthermore, in LO4 the weak points of recent mangrove management like lack of enforcement or deficits in education are identified. Finally the potential power of grass root movements to achieve a community based ICZM is presented. The presented successful case has the potential to be transferred to many other regions.

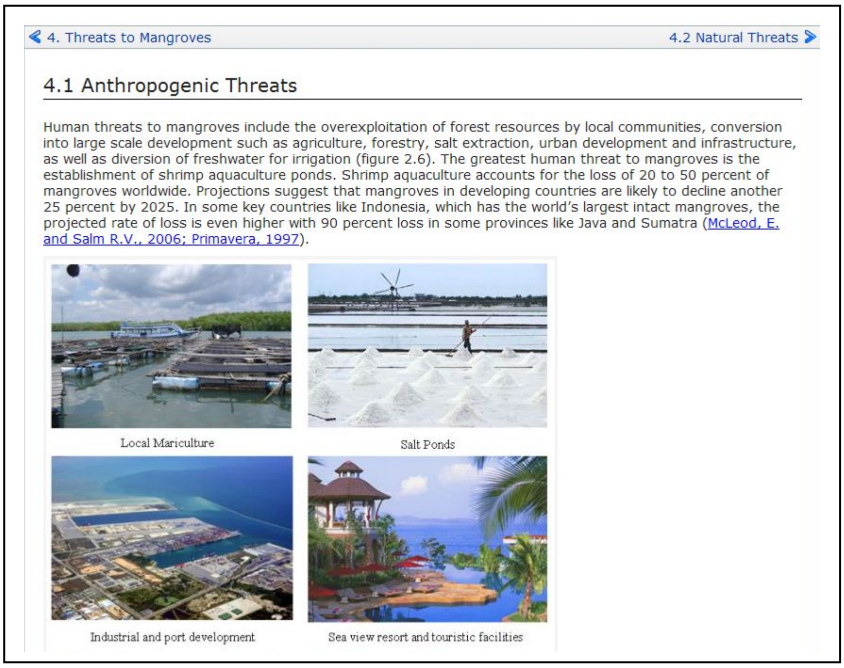


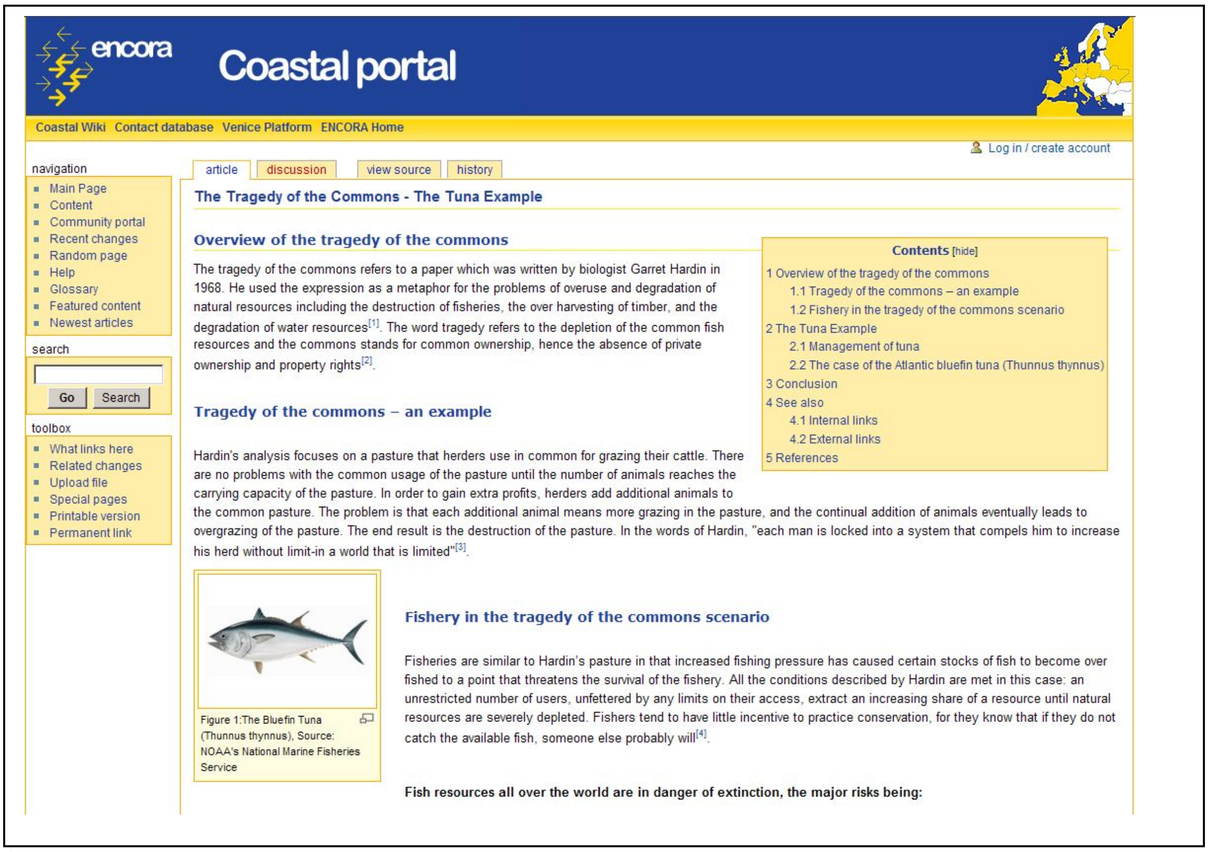
Fig. 9.3: *Exemplary page of the case study on Sustainable Mangrove Management in Eastern Thailand (screenshot from ILIAS-platform of the Ecology Centre of the University of Kiel).*

Case study 4 'Conflict management - JadeWeserPort' is in preparation and highlights a further perspective of ICZM. A case study (Busch et al. 2010) analyzed the question to which extent informative and co-operative methods are suitable to mitigate spatial land use conflicts. The efficiency of participative approaches could be shown provided personal and topical deviating views in the stakeholder community are made obvious at an early stage. The ILIAS case study will demonstrate which planning instruments and communication tools are available and how they can be combined to organize and accompany ICZM.

ENCORA Wiki

The articles written by the students for the Encora Wiki comprise a wide spectrum of scientific, political and management topics. For example, the articles dealt with OSPAR and Helsinki convention, with problems of erosion at Chinese rivers, nature conservation conflicts in Kenya, mariculture, and with the tragedy of the commons (Figure 9.4).

***Fig. 9.4:** Exemplary page of the ENCORA Wiki - detail of an article by a student of the Master program*



'Environmental Management' (screenshot).

9.5 Discussion and conclusion

Where we use eLearning it should be made sure, that it offers concrete benefits as compared to a face-to-face course. Therefore, the use of eLearning in academia and beyond has to answer the question whether it generates an added value in comparison to traditional teaching (Revermann 2006b). In its infancy many overshooting expectations dominated the discussion on eLearning features, elucidated by keywords like 'Information at your fingertips' or 'Education on demand'.

Though these expectations have been deceived eLearning nowadays is identified to enrich the range of didactical approaches (Wang 2002, Barth 2004, Eschenbach & Bischoff 2006). During the recent consolidation phase an intensified use of eLearning forms like interactive learning units, web based seminars or virtual laboratories can be monitored (Kleimann et al. 2008). While technical problems limited the spread of eLearning in its early stage recent barriers are rather insufficient didactical concepts or organizational problems (Eschenbach & Bischoff 2006). However, the full potential of eLearning has not been tapped, new promising phenomena are for example the developments of *social software*, *e-Portfolios*, and *eLearning 2*. These new concepts still move the focus from teaching to learning and foster the creative participation of learners and communication in learning groups and lecturers.

In this context, the presented eLearning implementation for ICZM as part of the curriculum 'Environmental Management' harnesses two distinct approaches. International case studies complement regular teaching and allow imparting usability and transferability of the learning content. Though implemented via new media this is a traditional approach inseminating knowledge directly via the lecturer to the learner. As the case studies base mostly on master thesis students contribute actively to the generation and propagation of understanding already on this level. The second main approach - to have students working with WIKIs as part of their studying - however, deviates noticeably from traditional models and is up to now rarely realized in eLearning (Schaffert et al. 2009). In this case the flow of information is complemented by net-based communication and co-operation with the goal to jointly create a new and broader knowledge base to be shared. Hence, learning includes the acquisition of soft skills urgently needed in teamwork to resolve complex problems in interdisciplinary structured groups, too. Furthermore, students get methods at hand to cope with the rapidly growing knowledge globally available as they get used to contribute with own case studies - and to refer - to globally available information sources.

As the final evaluation of eLearning-scenarios is challenging (Preussler & Baumgartner 2006, Schulmeister et al. 2008) the first response on the respective questionnaire is by far not representative. Nonetheless, the first feedbacks of the students were encouraging as they rated the quality of the eLearning units in general positive and their specific comments will be very supportive to improve the learning concept and the material itself. The efficiency of the courses was also proven by the overall good performance of the students during the oral examinations. We may conclude that integrating traditional coursework and eLearning, as shown in this study for the capacity building of future Coastal Managers, generates an added value in comparison to traditional teaching and learning approaches. This first positive impression is encouraging and will support the migration of the present system into the overall eLearning pool of Kiel Christian-Albrechts-University.

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10 Governance Aspects of Offshore Wind Energy and Maritime Development

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Several previous chapters of this synthesis report have demonstrated that the introduction of a new human activity such as offshore wind farming is accompanied by various impacts on a range of ecosystem services - in the sea as well as on land (see particularly chapter 8). Given the potential impacts on human well-being, and new options presenting themselves for regional development, several policy fields can be expected to react to this. In the DPSIR framework (see chapter 3) these reactions are covered by the category Response (R). For *Coastal Futures*, Response is defined as societal forms of response to systems change (see chapter 3). Central elements are management options, institutional responses and their respective framework conditions, as well as collective or individual changes of behavior. Response also includes changes to the existing legal framework, the introduction of monitoring systems, or investment decisions affecting the location of businesses. Response can therefore mean a range of different things - from small management adjustments to changes of legal structures or the development of new, more integrated approaches to planning and management.

The term 'governance' has become prominent in many settings where a fundamental rethinking of societal goals, structures and mores is deemed necessary. Like sustainability or biodiversity, governance is a contested term, subject to vague definitions, competing visions, extensive use, and application to nearly all spheres of life (Ratner 2003). According to the World Bank (1991) governance is in Webster's Unabridged Dictionary very generally defined as the exercise of political authority and the use of institutional resources to manage society's problems and affairs. The UN Commission for Global Governance has defined governance in a normative sense as "the sum of the many ways individuals and institutions, public and private, manage their common affairs. It is a continuing process through which conflicting or diverse interests may be accommodated and cooperative action may be taken. It includes formal institutions and regimes empowered to enforce compliance as well as informal arrangements that people and institutions either have agreed to or perceive to be in their interests" (Commission on Global Governance 1995). According to Juda & Hennessey (2001: 4), who applied the term in the context of coastal and marine ecosystems, governance includes the "formal and informal arrangements, institutions and mores that structure

- how resources or an environment are utilised,
- how problems and opportunities are evaluated and analysed,
- what behaviour is deemed acceptable or forbidden, and
- what rules and sanctions are applied to affect patterns of use".

Governance therefore addresses values, policies, laws and institutions, and probes the fundamental goals as well as the institutional processes and structures that form the basis for planning and decision-making. Management, in contrast, is the process by which human and material resources are harnessed to achieve a known goal within a known institutional structure (Olsen et al. 2009). Generally there are three key mechanisms for governance, the marketplace (e.g. through profit incentives), the government (e.g. through regulations) and non-governmental institutions and arrangements (Juda & Hennessey 2001, Olsen et al. 2006).

From a governance perspective, the category Response should therefore relate to the following questions: what response option is chosen for what reasons and based on what argumentation, by whom and through which type of process? Answering these questions demands the analysis of relevant actors, their beliefs and underpinning values, but also of decision making processes and their qualities such as openness and transparency. For the specific case of *Coastal Futures*, this calls for analysis of pressing issues and conflicts in space and ecosystem use (see chapter 2), analysis of actors and stakeholders and their respective interests (see chapter 6), analysis of approaches needed to deal with these, and analysis of governance mechanisms already applied or discussed in the German marine and coastal context (this chapter).

Coastal Futures looked at selected aspects of coastal and marine governance from several points of view. As a research project it was not involved in the many political processes and administrative developments in the different policy arenas and unable to analyse all aspects of the dynamic field of coastal and marine governance in Germany. The project therefore focused on selected structures and processes that enable decision-making in the context of the German North Sea regions at regional and national scales. Four key lines of research were pursued, covering selected issues of governance, policy development and planning:

- Analysis and reflections on the development and role of spatial patterns and trends concerning spatial use of coastal and marine waters (e.g. Gee et al. 2004, 2006a, 2006b, Glaeser et al. 2005, Kannen et al. 2004, 2008),
- Analysis of process related components like positions of institutional stakeholders (see chapter 6 and Licht-Eggert & Gee 2007, Licht-Eggert et al. 2008), values of local population (Gee 2006, Gee 2010a, 2010b, Bruns & Gee accepted), communication between actors for regional development (Zahl 2004, Zahl & Spiekermann 2005, Zahl et al. 2006, Grimm & Günther 2006) and framing of offshore wind energy in local newspapers (Fuchs 2006),
- Reflections on Integrated Coastal Zone Management (ICZM) and the evolvement of this concept in Germany and internationally (e.g. Kannen 2005, Kannen et al. 2004, 2005, 2008, Glaeser et al. 2005, 2007, Gee et al. 2006a, Bruns 2007a, 2010, Glavovic et al. 2008, Ahrendt 2009),
- Analysis of the development and role of non-statutory and informal mechanisms in planning and management (Bruns 2007b, 2010, Bruns & Gee accepted).

This paper builds on research carried out within *Coastal Futures* and is mainly based on publications and working papers written by members of the research team. Its purpose is to point towards some general conclusions and lessons in the context of governance in the case study area. Focus of the paper is on the spatial multiple use context into which offshore wind farm development is embedded (chapter 10.1), the challenges that have been associated with the development of integrated policies for coastal and marine areas over recent years (chapter 10.2) and specific examples that are developing in this context (chapter 10.3). Although *Coastal Futures* considered statutory as well as non-statutory processes, they were not directly compared in terms of their effectiveness.

10.1 The multiple use context of coastal and marine planning and management

Human activities in marine areas are increasing apace, and patterns of sea use are changing as a result of political, economic and societal developments. For the German North Sea, intensification of sea uses was assessed in a project carried out by *Coastal Futures* researchers and supported by additional funding from the Federal Ministry of Transport, Building and Urban Affairs and Federal Office for Building and Spatial Planning (Az: Z6 - 4.4 - 02.119) (Gee et al. 2006a, 2006b, see also chapter 2).

The challenges for planning and management arising from this multitude of human activities and interests of coastal and marine stakeholders are various. Given the limits of the German North Sea, one challenge is clearly spatial. How much can be fitted into the available space, how can spatial efficiency be increased, and how can spatial conflicts be addressed? Another related challenge is how to deal with many environmental pressures that arise from changing pattern of use, in particular cumulative impacts. Looking at the drivers behind these developments, it is clear that pressures on marine resources and space ultimately arise from particular constellations of interest and power. Coasts and seas bring together a multitude of stakeholders, each of whom is driven by a particular set of goals, beliefs, and value sets, and each of whom is subject to a particular range of social and economic demands and constraints. The third and possibly most important challenge is therefore to understand the various actor constellations (e.g. networks, alliances), their respective decision rules, as well as the essential social and economic argumentations that influence their decision-making.

Marine spatial planning as a solution?

Marine spatial planning (MSP) has emerged as a new instrument for managing the increasing diversity of marine uses. In Europe it is pushed by the EU Integrated Maritime Policy (IMP) and the EU Marine Strategy Framework Directive (MSFD). MSP is understood here as a normative approach to the development, ordering and securing of space (Douvere & Ehler 2009), which is concerned with "analyzing and allocating parts of the three-dimensional marine spaces to specific uses, to achieve ecological, economic, and social objectives that are usually set through the political process" (Douvere 2008: 766). As marine spatial planning goes beyond internal waters and territorial seas, international legal frameworks such as the UN Law of the Sea (UNCLOS), international conventions such as the Convention on Biological Diversity (CBD) and international policies, e.g. on fisheries also need to be considered (Maes 2008).

In Germany, MSP has so far been characterized by a direct transfer of terrestrial spatial planning paradigms to the sea, evident in the recently approved zoning concept for the German EEZ. The legal ordinances, together with the environmental reports, the justification for the zoning concept and maps, have been published online by the Federal Maritime and Hydrographic Agency (BSH, http://www.bsh.de/en/Marine_uses/Spatial_Planning_in_the_German_EEZ/index.jsp).
Triggered by the rapid emergence of offshore wind farming and the need to develop a licensing process for offshore wind farms, the zoning concept particularly focuses on the spatial conflict between shipping and offshore wind farms (Figure 10.1).

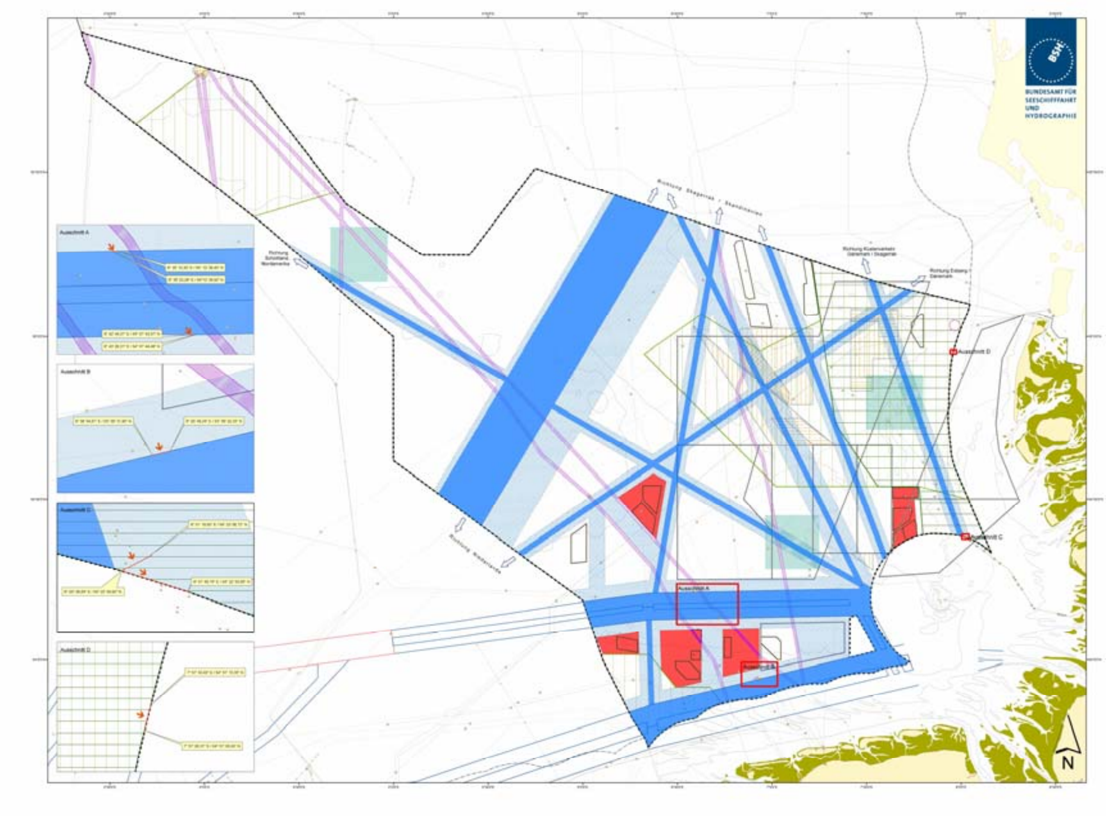

Fig. 10.1: *Spatial Plan for the German North Sea EEZ; blue areas mark priority areas for shipping, red areas as priority areas for offshore wind energy (BSH 2009, www.bsh.de/en/Marine_uses/Spatial_Planning_in_the_German_EEZ/index.jsp).*

Despite the inherently conciliatory nature of marine spatial planning, the finite nature of space as a resource means priorities need to be set. How should offshore wind farming be rated compared to other human activities, and when should it be given priority over other uses? In an attempt to achieve a balance between shipping, nature conservation and offshore wind farming, the plan only designates a small part of the EEZ as 'areas particularly suitable for wind farm development'. This allocates much less space to offshore wind than would be required if government targets of 20.000 to 25.000 megawatts by 2030 were to be achieved (see Figure 10.1).

Judging by the number of planning applications, demand by investors and developers for offshore wind farm space is already outstripping the amount of 25.000 megawatts even though investors start to adapt their plans to the spatial plan. After publication of a draft plan in summer 2008, contention quickly arose between the proponents of nature conservation and offshore wind farming, each claiming they had been allocated insufficient amounts of space. The ensuing debate led to an adjustment, allowing offshore wind farm developers to also apply for wind farm concessions outside the designated areas. The only constraint is that more stringent impact assessments have to be carried out than for applications within the designated priority areas. However, no wind farms will be approved within designated priority areas for shipping and already designated Natura-2000 sites.

What is demonstrated here is that concurrent growth in different policy fields (in this case shipping, nature conservation and renewable energy) may lead to an 'overbooking' of marine space. Shipping, nature conservation and offshore wind farming all lay claims to large parts of marine space, but they are not necessarily spatially compatible. This is exacerbated by the fact that renewable energy and nature conservation have to meet set policy targets (renewable energy policy targets and targets of the EU Habitats Directive), making it difficult for either sector to compromise.

Spatial planning is clearly relevant, as there is a real need for clarity and security of investment. The above case, however, demonstrates that some conflicts over the use of marine space - such as nature conservation vs. offshore wind farming - cannot be resolved by zoning alone. This is because the policy clashes outlined above go hand in hand with clashes of value, as fundamental differences exist between more anthropocentric and biocentric views of the marine environment. Greater integration of issues and processes can go some way towards resolving these, such as establishing closer links between MSP and ecosystem-based management (Laffoley et al. 2004). The existence of value clashes suggests that the current MSP process will need to be supplemented by a more fundamental debate on where future priorities for marine use should lie. In order to set priorities that are widely accepted, a broader 'sea debate' is needed within society and politics, not least on renewable energy generation in the sea. A specific task is also to establish clearer links between the combined political targets for different sectors, their impacts on a specific area or place and the natural and social qualities of that area. Overall, there is a clear demand for stronger links between MSP and other processes of marine governance.

An important question to be raised in this context is how 'marine space' is to be defined in a normative sense. MSP has so far concentrated on physical or 'usable' space; subjective conceptions of space such as symbolic interpretations of the sea, the sea as a landscape (or seascape, Döring 2009) or systems-oriented perspectives are missing. Approaches such as the cultural ecosystem service approach (see chapter 8) can help to increase the visibility of intangible sea values and identify possible trade-offs between different ecosystem services. 'Soft' and participative forms of marine management that could compensate for the limited range of values included in existing planning processes, however, are not currently employed. Given the diverging interests and the increasing potential for conflict in the sea, such concepts are urgently needed (Bruns & Gee accepted) and have been proposed e.g. in Glaeser et al. 2005 and Gee et al. 2006b (see also chapters 10.2 and 10.3).

In summary, *Coastal Futures* research shows the limits of the spatial planning approach in two lines of argument. Firstly, conceptual limits are identified in just taking a spatial view of the sea. Sea values identified (Gee 2010a) show that the sea is more than its uses. Comprehensive forms of 'sea management', as well as MSP and zoning, must therefore take account of multiple sea values (tangibles and intangibles) including optional value rather than limiting themselves to matching up existing demands in a sort of 'best fit' approach. This requires greater inclusiveness and a more pro-active role of any participatory processes that might accompany formal planning processes. Secondly, related to the first shortcoming, *Coastal Futures* research highlights limitations of process within MSP, for instance in terms of representativeness and transparency (Bruns & Gee 2009). Analysis of the hearings on the draft spatial plan for the German EEZ confirms that expectations may be placed on the statutory planning process it may not be able to meet.

Dealing with limited space

In a multiple use context, resolving the problem of spatial constraint is related to maximizing spatial efficiency. Specifically, this will require:

- new ways of combine different human demands, e.g. co-use of the same space by wind farms and mariculture (see Michler et al. 2009), and
- criteria and mechanisms to transparently define priorities for sea use, giving greater weight to some interests than others.

Coastal Futures research (e.g. Gee et al. 2004, 2006b, Glaeser et al. 2005) has identified three conceptual approaches that are interconnected and might help to deal with the problem of limited space:

- the concept of spatial compatibility,
- the concept of spatial co-use,
- participative visioning as a tool for early conflict identification, priority setting and deliberation.

Spatial compatibility

Spatial compatibility differentiates between spatially impacting and spatially non-impacting forms of resource use. In *Coastal Futures* it describes the ability of different sea uses to co-exist within the same or limited space without incurring a disadvantage to either. A tentative, subjective assessment of spatial compatibility was carried out on existing coastal and marine uses in the German North Sea (Figure 10.2).

The advantage of the concept lies in its ability to help move beyond the idea of exclusive priority areas. Rather than set and exclusive priority areas, it can help to look towards mechanisms that might support targeted forms of co-use or seasonal variations in the use of space. Spatial co-use in this context describes the co-existence of several forms of use in the same space (=multifunctional areas), for instance offshore wind farms and marine aquaculture or offshore wind farms and marine protected areas. Implementing this approach, however, requires methods of assessment that can measure the impacts of individual forms of use on other uses (thus evaluating their degree of compatibility), as well as measuring their cumulative impact on the marine ecosystem. The concept of multifunctional sea areas is therefore closely linked to a systems approach in planning. The *Coastal Futures* methodological approach (see chapter 3) is of benefit here in that it can help to identify individual and cumulative impacts of sea uses on ecosystem goods and services (see particularly chapter 8).

For offshore wind farming, it is clear that the scale of implementation in the German North Sea will depend on its spatial compatibility with other uses and its ecological compatibility. The limited nature of sea space has received particular attention because of the considerable spatial requirements of offshore wind: the German target of achieving 25.000 MW by 2030 is likely to translate into a sea area requirement of 2.000 to 4.000 square kilometres (BMU 2002). Although offshore wind is spatially incompatible with some uses (e.g. shipping), spatial efficiency could be increased by making the most of existing compatibilities or testing the potential for new forms of co-use (Gee et al. 2004, 2006b). Fishing is one example of a use that might draw indirect benefits from offshore wind farming, but the issue of compatibility might be perceived differently by different stakeholders and/or analysts. Due to shipping safety concerns, fishing boats are not allowed to enter offshore wind farms, which therefore provide automatic no-take zones and can potentially act as nurseries for certain fish species (Gloe 2009). This, however, is a position most fishermen will disagree with because they perceive wind farms as a restriction and therefore (as indicated in Figure 10.2) as incompatible with fisheries.

	Offshore wind farms	Marine protected areas	Fisheries	The sea as a public good	Cables	Tourism	Shipping routes	Hrabours and ports	Agriculture/run-off	Sand an gravel extraction	Oil and gas exploration	Dumping of dredged material	Aqua- and mariculture	coastal service centres	nature conservation	coastal protection	Military use
Offshore wind farms		**X**	**X**	**X**			**X**			**X**	**X**	**X**					**X**
Marine protected areas	**X**	**X**	**X**	x	**X**	x	**X**	x	**X**	**X**	**X**	**X**	**X**				**X**
Fisheries	**X**	**X**	**X**	x	x		**X**		x	x			**X**				**X**
The sea as a public good	**X**	x	x				x			**X**	**X**	**X**	**X**				**X**
Cables		**X**	x				x		x	**X**	**X**	**X**			**X**		
Tourism		x													x	x	**X**
Shipping and shipping routes	**X**	**X**	**X**	x	x					**X**	**X**	**X**	**X**				**X**
Harbour and ports		x											x		**X**		
Agriculture/run-off		**X**	x	x									x		**X**		
Sand and gravel extraction	**X**	**X**	x	**X**	**X**		**X**			**X**	**X**	**X**	**X**		**X**	x	
Oil and gas exploration	**X**	**X**		**X**	**X**		**X**			**X**	**X**	**X**	**X**				**X**
Dumping of dredging material	**X**	**X**		**X**	**X**		**X**			**X**	**X**	**X**	**X**				
Aqua- and mariculture		**X**	**X**	**X**			**X**	x	x	**X**	**X**	**X**	**X**		x		**X**
Coastal service centres															x		
Nature conservation					**X**	x		**X**	**X**	**X**			x	x		x	x
Coastal protection						x				x					x		x
Military use	**X**	**X**	**X**	**X**		**X**	**X**				**X**		**X**		x	x	

X = incompatible
X = conditionally compatible
Blank field = compatible

Fig. 10.2: *Estimates of compatibility of individual forms of use on coasts and seas (from Gee et al. 2006a, see also for earlier versions Gee et al. 2004 and Glaeser et al. 2004). For ease of analysis, the table only considers spatial compatibility and does not take account of social or aesthetic criteria. As such, incompatibility simply indicates that two forms of use cannot occupy the same coastal or marine space and does not exclude co-existence per se, for instance as 'peaceful neighbors'.*

Table 10.2 is a subjective assessment which does not differentiate between objective (measurable) and perceived spatial compatibility. Perceived compatibility, however, is at least as important as 'objective' compatibility, in particular where offshore wind farming is considered incompatible with core values held by the particular person or group. Essentially, core values are those that are non-negotiable, leading groups (and individuals) to do their best to defend them (Sabatier 1998).

Often, this takes place in a strongly emotional manner (Vining 1999). Core values are set apart from secondary values which are negotiable and leave room for dialogue (Sabatier 1998). In the case study area, there is evidence for value-laden conflict in that some local residents and also some stakeholder groups clearly perceived offshore wind farms to be incompatible with the aesthetic qualities of the land- and seascape (Gee 2010a). The vehemence of some of the comments suggests strong emotional attachment to the seascape, and readiness to defend particular aesthetic qualities as a strongly held value, although the precise nature of what is being defended is difficult to articulate. Other aspects where offshore wind farming might touch upon core values are the self-image of local communities, as well as traditional community structures and regional identity (Gee 2010a, 2010b, Bruns & Gee 2010). In the longer term, conflicts can also result from the disappearance of key visual elements such as working fishing boats, even though there are no direct causal links between this and offshore wind farming. The concept of spatial compatibility, and also of co-use, is therefore closely linked to issues of perception, as well as particular value sets and beliefs. 'Objective' estimates of spatial compatibility may therefore be quite different from stakeholder perceptions as to what the impacts of offshore wind farming are likely to be, which other uses it is deemed compatible with and whether this is acceptable.

Co-use with offshore wind farms - the case study of marine aquaculture

As discussed above, maximizing spatial efficiency by establishing multifunctional areas is one promising possibility for allocating the available sea space, although the cumulative ecological impacts on the marine environment have to be carefully considered and could place constraints on this approach. Mariculture was analyzed in *Coastal Futures* as an example for co-use, representing a potentially promising avenue for the German North Sea. Another possibility is to link electricity generation from offshore wind farms to hydrogen production, currently still a visionary long-term prospect (see chapter 7.5).

The combination of wind farms and aquaculture generally is a solution for increasing spatial efficiency in the offshore area as well as sharing stakeholder resources. Biological and technical studies in the German North Sea have demonstrated the feasibility of the approach (Buck 2002, Buck et al. 2004, Buck et al. 2006). The two species identified as most suitable for offshore cultivation are the blue mussel (*Mytilus edulis*) and sugar kelp (*Laminaria saccharina*). Despite the feasibility of the approach in the German North Sea (Buck 2002), complex socio-economic and technical challenges remain. As stakeholder attitudes towards wind farm-mariculture interaction are largely influenced by the general opinion towards offshore wind energy installations (Michler & Kodeih 2008), integration of the perspectives and demands of different user groups into the development of a multiple-use scheme is a very controversial issue (see the above issue of perception). Furthermore, disagreements exist with respect to the distribution of entitlements to socio-economic benefits. Whilst the wind farm developers are mostly concerned with wind farm operation and integrity, members of the mussel fishery society stress the economic and technical challenges related to the offshore cultivation of mussels (Michler & Kodeih 2008).

These competing concerns are an overriding theme in all conversations, leaving little room for discussing more specific views on potential management processes and solutions such as the collaborative development of an offshore co-management scheme for governing the shared use of ocean territory. Nonetheless, in-depth interviews with decision-makers and practitioners revealed that most of the respondents perceive the idea of combining both uses within the same ocean territory to be useful and something that should be followed up. However, the initial pioneer spirit has abated somewhat because compared to other European countries, offshore wind farm development in Germany is very much delayed (Michler & Kodeih 2008).

The study on wind farm - mariculture co-use confirms the essential role of values and beliefs, highlighting the importance of understanding stakeholder interests and values when it comes to implementing innovations. It also highlights the importance of communication processes, in this instance between mussel fishermen, wind farm operators and relevant authorities. Both aspects need time, and also need to take place before any formal processes such as MSP are instigated.

The need for visioning as an integrative process

In order to increase transparency and representativeness and create a sense of ownership for stakeholder-based coastal and marine planning and management, visioning exercises have been proposed as a tool for developing a widely accepted vision of long-term coastal and marine development (Glaeser et al. 2005, Gee et al. 2006). What coast would we as society like to see in 20 years time? Finding an answer to this question leads to an understanding of the kind of action required and the kind of targets that need to be set for ecology, economy, society and politics. Setting priorities and identifying potential co-uses based on assessments of compatibilities form part of such visions.

Visions in this form are essential tools for voicing what is often left unsaid, bringing together ideas in the form of an inspirational description. Such an approach could accompany and guide tools like MSP and mechanisms for Integrated Coastal Zone Management (ICZM) because it allows the incorporation of uncertain outcomes, beliefs and personal values and incomplete information into planning processes. However, visions cannot be developed by individual interest groups or institutions alone. This is a task that actively involves all administrative scales, relevant economic sectors and a wide range of groups within society.

Visions also link back to the scenario approach set out in chapter 4. A vision could conceivably act as a storyline, which can then be used to identify drivers, pressures and impacts and the responses necessary to achieve the desired outcome. This has the advantage of turning the vision into something more tangible, as well as posing the question of who needs to do what in order to achieve it.

10.2 Policy evolution and gaps in policy implementation

Initially *Coastal Futures* was developed around the evolvement of ICZM within the EU and the subsequent development of the German national ICZM strategy. Based on the 2002 EU recommendations (European Parliament and Council 2002) a national ICZM strategy was prepared in 2005 by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU 2006) (www.ikzm-strategie.de, German only). This strategy was then approved by federal cabinet in March 2006 and submitted to the EU Commission.

Multitude of policies

In recent years, ICZM has been overtaken by other coastal and marine policies. It is these that are currently receiving most of the attention of coastal and marine institutional actors in Europe. The increasing policy interest in the sea is driven by various factors, including the growing perception of marine areas as economic spaces, the political interest in utilizing marine resources, and the role of the maritime industry in regional development and regional economic growth (Kannen et al. 2008). Two major policy lines interact: One, the EU's Integrated Maritime Policy (IMP), which mainly focuses on the economic utilization of marine resources and the development of strong maritime industries, and two, the EU Marine Strategy Framework Directive (MSFD), which is the environmental pillar of the IMP and seeks to achieve Good Environmental Status (GEnS) for Europe's seas. In both policies, ICZM and MSP are specified as essential tools for implementation. As was the case with the Water Framework Directive (WFD), they also emphasize the need for stronger integration, demanding new and more interactive ways of stakeholder involvement in the respective implementation processes.

Their primary focus on economic and environmental objectives, respectively, puts the IMP and MSFD on a potential collision course. Whilst the conflicting targets may not come to the fore at the political and strategic level, problems will certainly arise when it comes to local implementation and the definition of priorities in MSP or regional development plans. Mechanisms typically associated with ICZM such as participation and communication are therefore needed, but so are visioning, political decisions and clearly articulated priorities.

A second relevant aspect is that implementation of EU policies, and the way in which tools such as MSP are applied, is the responsibility of the Members States. In many cases policies and mechanisms then trickle down from the national to the regional (e.g. Länder) level or even the level of districts and municipalities. MSP in the German North Sea is framed by national jurisdictions on the one hand (specifically within territorial waters, where MSP is the responsibility of the Länder) and EU Directives and international legislation on the other (e.g. UN Law of the Sea, IMO regulations for shipping) (see also Maes 2008). Transboundary issues are largely mediated by conventions at Regional Sea level, such as OSPAR for the North East Atlantic including the North Sea and HELCOM for the Baltic Sea.

The above makes clear that the North Sea is confronted by an increasingly complex web of policies, institutions and mechanisms that cut across a range of different spatial and jurisdictional scales. Nonetheless, it pays to consider the specific context in which this policy web is embedded, meaning that issues do need to be analyzed from the perspective of their respective political and administrative settings. This particularly includes the context of non-administrative decision makers such as investors and economic stakeholders (Kannen 2005) and the interests and values of local residents (Licht-Eggert et al. 2008). For processes such as ICZM, or for processes of decision-making more generally, the lesson is thus that local level activities are increasingly constrained by national and international legislation. At the same time, regional and local knowledge and conditions very much need to be taken into account if decisions are to be understood, accepted and enforced at the local level. If the different interests and targets for a particular marine area are to be truly integrated, policies such as IMP, legal requirements such as the MSFD, statutory planning tools such as MSP and non-statutory or even informal mechanisms all have to be brought together in multi-level and multi-sectoral governance architectures.

The institutional structures described above are not static, but bring about a range of governance processes. These in turn respond to emergent development paths and therefore time scales (see also chapter 3). Wind energy (and related institutions) for example developed over a period of more than 30 years, carried by growing public awareness of climate change, increasing prices for non-renewable energies, technological innovation and increasing political support. This development can be characterized by the Multiple Streams framework, which looks at policy changes through three relatively independent streams of actors and processes (Kingdon 1995, Zahariadis 2007): problems are recognized and framed in a problem stream, ideas to deal with a problem develop within a policy stream and if the problem becomes prominent, political support is gained through the political stream. If these converge over time, windows of opportunity open for entrepreneurs (see also Meijerink 2005 who used Dutch coastal flooding policy for an in-depth analysis of coastal policy change).

The need for a paradigm shift

All integrated approaches, be it ICZM or Ecosystem-Based-Management (EBM) as potential implementation tools, but also policies like the WFD, the MSFD or the IMP essentially describe a new philosophy and practice of coastal and marine governance. Aiming to overcome the shortcomings of traditional approaches, they demand a paradigm shift concerning how policies are formulated and implemented (Kannen 2002, Kannen & Burkhard 2009). A key element of the paradigm shift as described in Table 10.1 is its ability to take into account interactions at different scales, affecting both the institutional and social, and the ecological domains. (Organizational) learning and communication processes are listed as central tools to enable adaptation and understanding over time.

Tab. 10.1: *Paradigm Shift from traditional to integrated management (Kannen & Burkhard 2009, adapted from Lubchenco 1994 in Olsen and Nickerson 2003: 4)*

From	To
Individual activities (sectoral)	Use patterns (in space and time)
Individual species	Ecosystems
Individual spatial scales	Multiple nested scales
Short-term perspective	Multiple perspectives (short to long-term)
Humans independent of ecosystems	Humans as integral parts of ecosystems
Administrative hierarchies	Learning networks
Sectoral management agencies	Networks of institutions
Management separated from research and based on static plans, fixed for several years	Adaptive management based on monitoring and research and on continuous changes in plans according to new knowledge

Policies such as the IMP, MSFD and WFD already recognize this paradigm shift and request non-traditional ways of implementation (Douvere 2008, Meiner 2010), e.g. specifically asking for participation procedures (MSFD, WFD) or taking river catchments as boundaries (WFD). They also refer to the ecosystem approach to management as their underlying principle.

Nevertheless, concerning the practical application of integrative concepts such as ICZM and (EBM) an implementation gap is still observed (e.g. Shipman and Stojanovic 2007, McKenna et al. 2008, Glavovic 2008). In case of ICZM, “even when commitments to pursue sustainable coastal development through integrated coastal management are translated into policy and law, unsustainable practices persist” (Glavovic 2008: 130). To write commitments and vaguely defined concepts into policy documents, strategies or even legislation does not seem to be enough to ensure their implementation in daily practice.

Looking at ICZM in Germany, Glaeser et al. (2005) and Gee et al. (2006) propose that effective ICZM at a national level in Germany would particularly need adequate institutionalization, on- and offshore management, international engagement, and monitoring. Their suggestions (of which some were taken up in the national ICZM strategy from 2006) include the creation of a hierarchy of forums, tasked with networking between existing structures, facilitating horizontal and vertical communication, overcoming institutional barriers and achieving greater transparency at all levels. However, particularly these and similar process related suggestions from other experts were not taken up. Instead, what ensued can be counted as a case in point of the implementation gap. Progress in ICZM has remained fragmented and slow to this date. Also, despite the beginnings of MSP in the German EEZ and partly also in the territorial waters, the demand for more integrated and adaptive approaches is ongoing.

This arises from:

- the growing complexity of multi-level policies and their interactions,
- the challenges arising from lack of convergence of policies,
- the challenges arising from the multiple use context,
- the challenges from the shortcomings of MSP, e.g. dealing with multiple values and 'lack of fit' between values, and
- the challenges arising from the need to establish new structures.

Changes in planning and management in line with the above paradigm shift therefore continue to be required.

One simple reason for the implementation gap might be that it takes time for the practical demands of this paradigm shift to trickle down from the strategic level to bureaucratic routines. Also, in the perception of practitioners, lack of funding and available time (e.g. the timeline to come to a decision does not allow several rounds of communication with stakeholders) are often mentioned as constraints. The Multiple Streams framework may therefore need to be extended to include administrative implementation processes as an additional 'bureaucracy stream', describing the timeline from the initial political support to something becoming routine. As chapter 10.3 will demonstrate some examples for the successful creation of new routines already exist. It remains to be seen whether these can influence planning and management in similar fields in the future, such as the implementation of the MSFD.

10.3 Linking different modes of governance

Chapters 10.1 and 10.2 have demonstrated the strong link between structures, paradigms and processes and the implementation of integrated policies. None of these elements can sufficiently support integrated approaches in themselves. They need to be seen as necessary and interlocking elements of coastal and marine governance systems.

One of the most extensively debated issues in the context of governance processes is the relationship between non-statutory and statutory processes. How can successful non-statutory processes be set up and how should they relate to statutory planning and management? The latter was the subject of a study of selected governance elements, based on expert interviews, questionnaires and legal documents.

Two case studies where carried out to examine whether the Water Framework Directive (WFD) and Integrated Coastal Zone Management (ICZM) lead to changing modes of regional governance (see Bruns submitted for details). As mentioned before the term governance cannot be defined as a coherent theory. In these two case studies governance is conceptualized as a frame of reference for analyzing different modes of collective decision-making. Three modes can be distinguished: hierarchy, market and co-operation, where governance stands for their combination (Kooiman 2003). As such, it brings together established state-led policy-making with market regulation and the involvement of civil society in decision-making. The link between institutional conditions and collective action by actors is of particular interest. Empirical work (Bruns submitted) focused on the regional level on account of its particular importance for effectiveness of implementation. Both case studies represent distinctive modes of governance that exist at the same time in the same place. Both governance regimes go for an integrated management with a wider involvement of interested parties. But they evolve due to a specific set of drivers and preconditions that are listed in the following Table 10.2:

***Tab. 10.2:** Drivers for Governance at the West Coast of Schleswig-Holstein (Bruns submitted: 181).*

Drivers for distinctive governance regimes	
ICZM - Region Uthlande	RBM - Eider Catchment
▪ Vulnerability to environmental hazards ▪ Strengthen regional competitiveness ▪ Promoter on regional level ▪ Financial support through agricultural policy	▪ Legislation: Water Framework Directive ▪ Learning water administration ▪ Conflict: who is head of working groups ▪ Powerful water agencies

Governance Analysis for the implementation process of the WFD

The Water Framework Directive (WFD) came into force in 2000 and marks the beginning of a new water policy throughout the EU (e.g. Page & Kaika 2003). One of the major changes brought about by the WFD is that it establishes a coherent framework for integrated River Basin Management (RBM) which is linked to ambitious environmental objectives: Good ecological and chemical status is to be achieved for all water bodies by 2015. A second major innovation is that environmental management is to be based on hydrological systems (river basins) and no longer on administrative boundaries (see Moss 2004): To overcome the spatial misfit between environmental problems and collective action new governance space has to be created. In order to meet the environmental objectives, new principles, instruments, and methods were introduced, bringing with them significant changes to the way water resources are managed. One key concern of the WFD is the involvement of all interested parties (Newig 2005). The issue of participation is seen as a rationale that underpins the entire approach, as an appropriate instrument for achieving the objectives, and as a policy aim of the European Commission within the WFD.

As pointed out before the spatial and environmental planning system on national and sub-national level (Länder) has many shortcomings in terms of integration. To meet the requirements of the WFD, changes concerning the legislative basis, the organizational structure of the water sector and participation are needed. Analysis shows that organizational structures in the case study area of Schleswig-Holstein (with particular focus on the catchment of the Eider river) have changed as a result of the WFD. To ensure the exchange of information and to facilitate collaboration, Schleswig-Holstein established different boards. At the higher river basin district level, three advisory boards (one per district) were established, consisting of stakeholders from the nature conservation sectors, the national farmer's union or fishery organizations as well as agencies. Working groups (in total 34) represent the lower level of management, which is responsible for implementing the WFD.

Nevertheless, the progressive implementation process of the WFD is not only the result of a change of mind in the ministry but also a result of powerful Water Agencies and a strong agricultural lobby on a regional and local level (Bruns submitted). Figure 10.3 illustrates that decisions concerning the water quality are a combination between formal institutions and informal advisory boards: The process of deliberation takes place in the shadow of hierarchy. This pushes stakeholders to work together and solve problems jointly.

Overall the case study on the WFD demonstrates that the state of Schleswig-Holstein comprehensively implements the procedural principles of the Directive. The WFD has facilitated integrated river basin management across new spatial units and creates a new governance space. However, it is too early to see whether and how experience from this example will spread to other areas of planning and management.

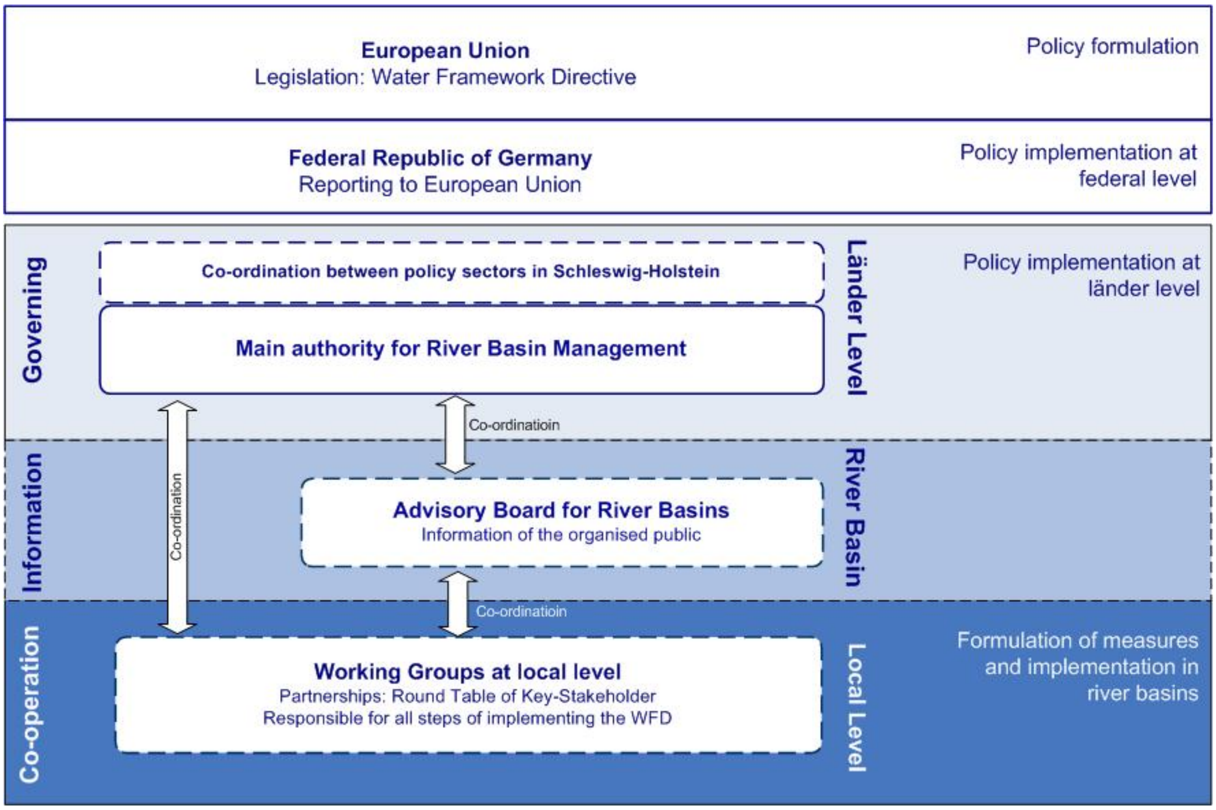

Fig. 10.3: *New organizations formed (dashed line) to implement the WFD in Schleswig-Holstein. (Antje Bruns).*

Governance analysis for ICZM at a regional level

Analysis of regional management processes in the region Uthlande (covering the North Frisian islands and Hallig islands) makes clear that neither the national ICZM strategy nor the Länder level provide any tangible impulses for ICZM in the investigation area. However, there is evidence for regional management processes which meet some core aspects of ICZM: spatial integration of sea and land plays a major role, sustainable development is the overall objective and decision-making processes are widened to include a broader public.

But what are reasons and conditions that facilitated the emergence of this regional management approach? Empirical analysis shows that strong bottom-up processes were important triggers. Actors with strong commitment to the region (promoters) are essential for building up self-organized forms of regional cooperation. Another issue was a shipping accident in the North Sea (the Pallas average in 1998) that led to greater (environmental) awareness and willingness of the North Sea islands to cooperate. As a result regional cooperation evolved and - triggered by top-down incentives provided through agricultural policy - a process of institutionalization began. However, the network of actors is unable to resolve conflicts of distribution and problems extending to multiple scales. But it is capable to represent interests and to coordinate action at a local and regional level.

One major finding of the analysis is thus the evolution of a new governance regime at a regional level. At the same time it is limited in its capacity to act because a suitable ICZM framework at a national and sub-national level is still lacking. The example therefore underpins the need for multi-level structures and mechanisms that can overcome horizontal barriers.

10.4 Conclusions

The foremost challenge for coastal and marine management is to govern a complex maritime system that is linked to several policy arenas. This system can be characterized by emergent non-linear behavior and high uncertainty as far as social and ecological impacts of human activities such as offshore wind farms are concerned.

Figure 10.4 provides a basic model, describing relevant interactions for the governance of social-ecological systems identified in *Coastal Futures*. Ecological systems provide ecosystem services (see chapter 8), which are used by individual actors or groups based on personal trade-offs. These include costs and benefits, but also beliefs, personal values, ethical considerations and individual perception of issue and area at stake. Through existing regulations, jurisdictions and planning restrictions their cumulative decisions affect patterns of use in the sea, resulting in environmental pressures and finally affecting the environmental status of the sea. In one way or another, all actors and stakeholders participate in and/or influence the governance system (as participants in discourses, lobbying, involvement in networks etc.). The response of the governance system in terms of planning and management is described here as a collective or institutional activity; individual activity or responses are not included. Collective activity will be based on similar calculations and trade-offs that are found at the level of individual actors. Within the governance system different forces can dominate the rules and the tools applied. These encompass regulations, market forces and civil society or any mix of these.

Figure 10.4 also illustrates that the development of structures is necessary, but just one element of successful integrated governance systems. Processes (who decides what and based on what rules) and involvement (who is involved when and how) are at least as important. Particularly power structures and power conflicts e.g. between different ministries or government authorities, might form a major constraint in the implementation of new approaches. Another constraint that is difficult to overcome without proper communication mechanisms is formed by different perceptions and value systems of the actors involved. As outlined in chapter 10.1 traditional approaches to planning are not particularly suited to deal with contradictory value sets and the potential value conflicts surrounding offshore wind farms. Contradictory policy targets are also difficult to overcome.

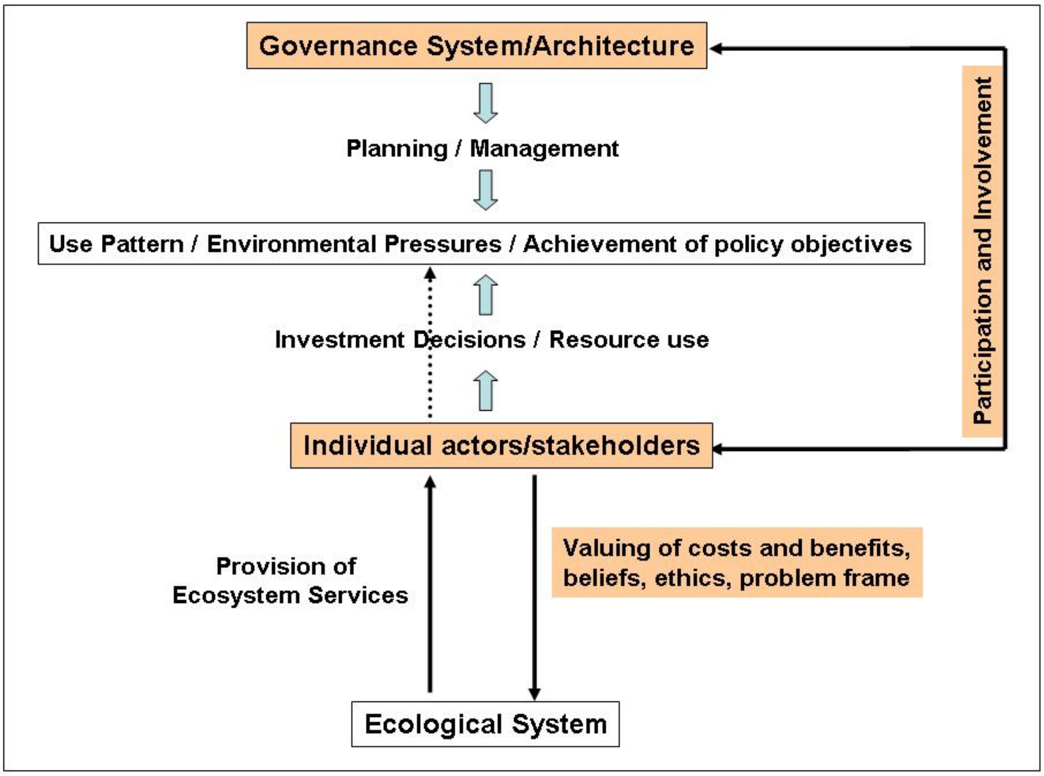

Fig. 10.4: A basic conceptual model describing relevant interactions for governance of social-ecological systems (Andreas Kannen)

Without question, MSP is needed to resolve the spatial dilemmas arising in the German EEZ. At the same time, a governance approach that exclusively relies on MSP or other statutory tools is found to be insufficient. Analyses carried out as part of *Coastal Futures* show that accompanying tools are required that go beyond the classic approaches of spatial planning such as zoning.

In Germany, development of the spatial plan for the EEZ was driven by the urgent need to develop a framework to guide offshore wind farm licensing. MSP could be seen as one (statutory and formal) tool within a broader ICZM concept. But typical elements of ICZM, particularly a clear and coherent strategy, a holistic vision and related goals for coastal and marine development, as well as non-statutory participatory mechanisms for strategic dialogues, are still missing from the current institutional context. *Coastal Futures* research has shown that statutory and non-statutory processes should be seen as useful complements within a broader governance system and that they are not necessarily a contradiction (see also Figure 10.4).

The research presented here documents the considerable challenges for spatial management in the sea. It also demonstrates that current policy changes such as the WFD stimulate the emergence of new governance regimes (chapter 10.2 and 10.3). These changes do not originate within a single sphere of coordination or at a single spatial level. On the contrary, they are the result of a wide range of interchanges between context-related, institutional and procedural factors. Local and regional calls for greater participation in (spatial) decision-making play a particular role. Concepts such as ICZM are never purely local or national, nor do they solely relate to planning or management. As stated in Kannen (2002), integrated management is best considered a philosophy that needs to trickle down into all fields of planning, policy formulation and policy implementation. It follows that any integrated approach needs to take into account multiple scales both at the spatial and administrative level. For ICZM, this was demonstrated clearly in the case study on the North Frisian Islands in chapter 10.3.

As illustrated in chapter 10.2, the transition from traditional to integrated approaches of planning and management implies a paradigm shift. This results in the need for new governance structures. In *Coastal Futures*, governance forms part of Response in the DPSIR framework in that actors/stakeholders, structures and processes of decision-making are considered. Within the context of multiple spatial and temporal scales, windows of opportunity are of particular importance because they permit shifts within the system. As illustrated by the recent evolvement of policies and legislations such as the MSFD and IMP the paradigm shift has moved into policy formulation, but in many cases it still lacks successful implementation at the level of planning and management where it demands changes in daily practice.

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11 Conclusions: The Usefulness of Applying a Multi-scale Systems Approach

Wilhelm Windhorst, Andreas Kannen, Kira Gee

Zukunft Küste - Coastal Futures set out to extend the knowledge base for Integrated Coastal Zone Management (ICZM) beyond the common buzzwords of participation or horizontal and vertical coherence of policies. Rather than supply a set of ready-made management recommendations, *Coastal Futures* sought to contribute to a better understanding of the dynamics and impacts of change, bridging the gap between research and practice and laying the ground for future debate as part of ICZM. It chose a systems perspective to do so, selecting offshore wind farm development in the German North Sea as an agent of change in a human-environmental coastal-marine system. The offshore wind farming perspective extends across various spatial scales and temporal horizons; consequently the systems perspective of *Coastal Futures* encompassed multiple scales, ranging from the local and immediate all the way to the global and long-term. This applied both to its definition of system elements and the interactions between them.

The challenges arising from this multi-level systems perspective are numerous. One is achieving a thorough description of 'the system' in the first place, bearing in mind that this is always an abstract entity composed of many conceptual and therefore spatial dimensions. In *Coastal Futures*, the understanding of the system as a social-ecological system with nested scales allowed local, regional, national as well as transboundary and global structures and processes to be identified from both a natural and social science perspective, including disciplines as diverse as geography, administration/policy, ecology, social sciences, economy, landscape and philosophy.

Given the system's inherent complexity (see e.g. Berkes & Folke 1998, Gunderson & Holling 2002), a key question is how it will respond to the arrival of offshore wind farming. *Coastal Futures* did not set out to assess the adaptive capacity of the entire system, but concentrated on selected impacts and factors that influence the system's ability to respond at different scales and points in time.

As with other social-ecological systems, a significant challenge is the multiple unknowns that could influence the system's development (cf. Walker et al. 2002). How many offshore wind farms will become operational in the next 50 years, and what will this depend on? This leads to other open questions: What interactions with the North Sea ecosystem are to be expected given different scenarios of wind farm expansion? Are offshore wind farms compatible with other sea uses? Who are the stakeholders affected and how does offshore wind farm development relate to the beliefs and values of coastal communities? How can existing governance structures deal with offshore wind farms and associated changes in patterns of sea use? How can participation of stakeholders and efficient implementation of recent EU policies like the Marine Strategy Framework Directive (MSFD) and the Integrated Maritime Policy (IMP) be ensured?

Below we summarize some key lessons learnt from attempting to answer these questions and applying a systems perspective in a setting characterized by multiple scales, dynamic interactions and uncertainties.

Bringing together different methods

The conceptual keystone of the project was the merger of the DPSIR framework and the ecosystem service approach similar to the concept applied by the Millennium Ecosystem Assessment (Figure 11.1, see also chapter 3, Figure 3.1). Similar approaches are implemented by few comparable projects (e.g. the RUBICODE project, Vanderwalle et al. 2009). The advantage of this approach is that it simplifies cause-and-effect chains and dynamics of offshore wind farm development (the DPSIR logic) whilst enabling connections to be established between sea use, the provision of ecosystem services, the resulting level of ecological integrity, the socio-economic system and human well-being

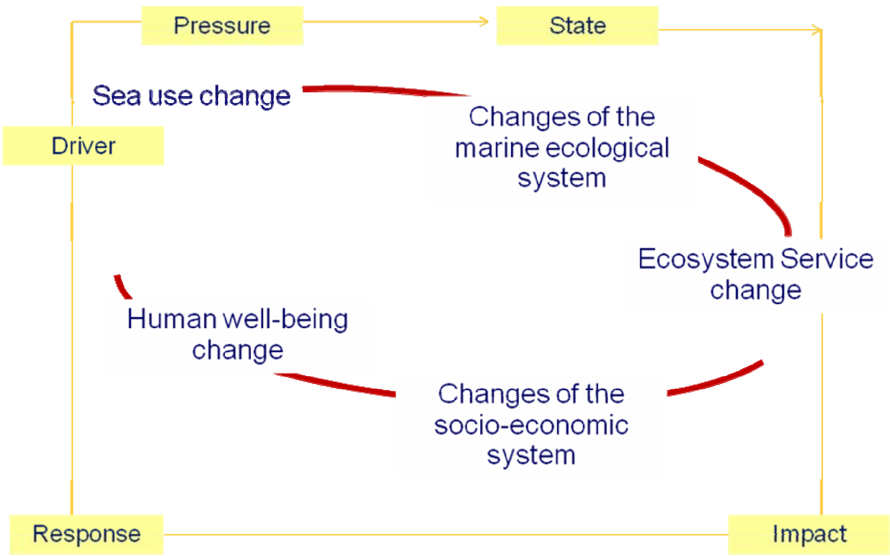

Fig. 11.1: *A stylized view of the combination of the DPSIR and the ecosystem service approach (Gee & Burkhard 2010)*

In keeping with the challenges outlined above, *Coastal Futures'* research methods were tailored to tackle different elements of this cycle from both disciplinary and interdisciplinary perspectives. They entailed: a) the discussion of future sea use patterns using a scenario approach, b) analysis and modeling of impacts of offshore wind energy on specific ecosystem services and assessment of socio-economic impacts at local and regional scale, and c) the analysis of stakeholder positions and their underlying values and beliefs, as well as related planning processes and policies. The specific benefits of this approach are outlined below.

How to deal with uncertainties?

Political targets for offshore wind farms in the context of the future energy mix are very ambitious, requiring large areas in the North Sea to be used for wind energy generation. As stated above, the degree to which these plans will be implemented is uncertain. Key aspects include political will and investor support, but also social acceptance and the constraints such development might place on other sea uses. Depending on the relative importance of these and other events at any one time, different system trajectories are conceivable, leading to potentially very different 'system futures'.

Coastal Future's multi-scale DPSIR approach paved the way for addressing uncertainty through scenarios, which represented plausible 'futures' of the North Sea and its hinterland. Whilst these cannot present a definitive version of the future, the advantage of the scenario-based approach is that it unveils contrasting, but equally possible developments of the system. Plausibility of the scenarios was achieved by identifying antagonistic and synergistic cross-scale interactions between existing sea and land uses, which could enhance or constrain the potential development of offshore wind farms. The DPSIR approach proved particularly useful here in that it allows the development of 'if… then…'-relationships across scales.

In order to subject them to ecological and economic evaluation, the scenarios were then translated into spatial offshore wind farming needs. For each scenario, the number of piles of the envisioned offshore wind farms was determined, their position in the North Sea, and the potential for electricity generation, either from existing plans or from expert information. This was then followed by more detailed modeling.

While this is clearly no forecast, the resulting scenarios and corresponding modeling outcomes do serve an important purpose as a structuring and communication tool. Not only do they highlight the economic and ecological consequences of different scales of offshore wind development, but also the influence of particular economic, political, social and ecological constellations on the ability and willingness of the system to respond. Although this was not pursued explicitly, the scenarios can be used to demonstrate the effects of path dependency (e.g. lock-in into a previously chosen development path, leading to resistance to change and failure to take up new development options, see e.g. Theuvsen 2004), or to show that misalignment of national and regional policy, for example in terms of investment priorities, can lead to de-coupling of national and regional development. They do, however, clearly show that internal local or regional developments are never isolated from external events such as global energy futures, or wider economic or societal trends, and that options for intervention at the local scale may therefore be limited in terms of achieving the desired effect.

An important lesson from the *Coastal Futures* scenario approach is thus that scenarios can help to translate multiple scales and uncertainty into visible connections and relationships, which is a valuable step when it comes to discussing management or development options as part of ICZM. At a more conceptual level, they also offer a way of clarifying the links between various system elements and the role of various agents in system dynamics. Although *Coastal Futures* only considered the case study of offshore wind farms in the North Sea, the overall approach has been thoroughly applied and documented (Burkhard et al. 2007) to ensure the transferability and applicability of the methodology to other regions or sea or land uses. From the perspective of the research team the approach chosen is useful in all situations that have to deal with a high degree of uncertainty, complex interactions between scales and path dependency of developments. Of course, specific models, relevant data and methods to gather necessary information always need to be adapted to the issue at hand and region specific needs.

Can direct and indirect impacts of offshore wind farming be detected?

An unprecedented range of data and models were harnessed to carry out an ecological impact analysis of offshore wind farming in the North Sea. Its strength lay in the fact that it was able to integrate multiple biotic and abiotic structures and processes at several scales, and that it could be coupled with the scenario framework and DPSIR structure to allow monitored data, model results and qualitative estimates to be brought together. A range of direct and indirect abiotic and biotic impacts of offshore wind farm construction could thus be detected in the marine environment. Direct projected impacts were also detected at the economic level by modeling regional economic and employment effects. Integration at the ecosystem level, achieved by linking the ecological impact assessment to the ecosystem service approach, thus served as a key interface between the ecological and socio-economic systems.

The ecosystem service approach proved to be a particularly valuable tool in *Coastal Futures* for analysing expected impacts of offshore wind farms on existing values. Conceptually at least, many interrelations could be shown between environmental change and aspects of human well-being, demonstrating that changes in the marine environment are closely connected to (sometimes unexpected) socio-economic impacts on land. This particularly refers to the various non-economic values held by local residents and other stakeholders, which are linked to perceptions of the local environment and landscape, rootedness in the region, or moral imperatives of what should and should not be. An important recognition is thus that land-sea interactions are much more than matter and energy flows from river catchments to the sea. Much is down to individual or group perception of the nature of the coastal and marine environment, and what is deemed acceptable change under which (social and economic) circumstances. Intangibles in particular merit further attention here as key factors in conceptualising the sea and with it (acceptable) sea use.

A significant drawback is that while the Millennium Ecosystem Assessment approach allows the construction of direct and indirect causal chains, only few of these can be sufficiently quantified. One reason is the influence of other factors on ecosystem services and determinants of human well-being. Employment, for example, and income in coastal regions are strongly influenced by demographic change and global economic conditions. Natural variability and climate change may lead to significant changes in the ecosystem. Although offshore wind farming might reinforce or lessen the changes resulting from such global trends, human uses such as this may therefore not represent the strongest force of change that acts on the system.

Furthermore, subjectivity is unavoidable in the design of any assessment of ecosystem change and human well-being. This applies to the initial framing of the system by the research team, and particularly the establishment of indirect links between ecosystem services and socio-economic system components. Despite these shortcomings, *Coastal Futures* has demonstrated the feasibility of using the DPSIR approach as a framework, within which socio-economic drivers, pressures and responses can be linked towards an integrated ecological impact assessment via the ecosystem service approach.

Despite these shortcomings, the merger of the DPSIR framework and the Ecosystem Services Approach is still important in that it allows different combinations of sea use to be considered and compared. Even though the results of *Coastal Futures* are subject to many uncertainties and therefore have mainly indicative character, they do highlight critical risks and opportunities associated with large scale offshore wind farm development. Applied more widely, such approaches have the potential to considerably strengthen the information base for decision making in the context of ICZM and Maritime Spatial Planning (MSP). At the same time the approach might serve as a blueprint for other integrative case studies. More specific investigations of particular sea and land uses may spring from its results.

Have cumulative impacts been detected?

In view of the ecological analysis a major applied result is that cumulative impacts are more relevant for ecosystem functioning than impacts resulting from one particular wind farm project. This implies that future assessments (and also planning and management) need to consider the cumulative impact of many wind farms rather than individual plans. Cumulative impact assessment will also need to take greater account of the overall sea use pattern. The ecological impact analysis of *Coastal Futures* had to merge data from different sites with varying quality and had to rely mainly on modeling. Due to the lack of long term monitoring data, validation was therefore limited. This can only be overcome with dedicated long term monitoring programs at different spatial and temporal scales.

In the case of some sea bird species the combined analysis of shipping areas and establishment of large scale offshore wind farm areas revealed mutually reinforcing trends. Divers for example avoid both areas intensively used by shipping and wind farms, which can potentially result in major loss of habitats for this species. Such effects usually remain undetected by impact analysis of single wind farms. Therefore, in this case both economic sectors - shipping and the generation of renewable energy - and their spatial arrangements are expected to form a major consideration in the context of habitat preservation, which is required by law. Other researchers have shown similar effects on fisheries, where access of fisheries to some commercially important species is heavily restricted when looking at all wind farm plans in the German North Sea. For other species this effect is negligible (Berkenhagen et al. 2009).

On the abiotic side a first hypothesis concerning the potential relevance of the wake effect of wind turbines has been confirmed by *Coastal Futures* research. The reduced wind stress downstream of one particular offshore wind farm placed in the southern North Sea and resulting changes in the vertical structure of the water column have been modeled with the HAMSOM model (Hamburg Shelf Ocean Model). For specific conditions new upwelling zones were shown to emerge, resulting from the reduced wind stress downstream of the modeled wind farm. Assuming that large areas of the North Sea will be used for offshore wind farming, significant changes could occur in the nutrient flows that currently foster or limit primary production. This in turn could have implications for the management strategies employed to implement the EU Water Framework Directive or the EU Marine Strategy Framework Directive, which aim at regulating nutrient emissions from catchments into the North Sea. Again, the impact only becomes relevant when looking at the cumulative effect of many wind farms. However, further analysis is needed concerning the biological effects that might arise from the wake effect.

Is spatial compatibility between sea uses relevant?

Coastal Futures linked the potential ecological impacts in the sea to envisioned economic effects in coastal areas and considered potential trade-offs between different ecosystem services. At a more pragmatic level, an added, highly topical perspective associated with offshore wind farms is that of spatial planning. Offshore wind farming enters a space where other human activities are already established and have long since claimed their own share of space. Given that sea space is limited, compatibility with other sea uses and sustainable use of marine resources is becoming an increasingly important criterion for spatial planners.

It is clear that some existing uses constrain future offshore wind farm development (e.g. shipping). Equally, offshore wind farming clearly places constraints on others (e.g. fishing). In cases that are not mutually exclusive, co-use is an option, maximizing spatial efficiency by combining offshore wind farming with other uses in the same space. *Coastal Futures* analyzed this potential from varying perspectives, with particular focus on offshore wind farming/open offshore aquaculture and the potential to enhance the economic effects of offshore wind farming by generating hydrogen. The scale effects demonstrated are essential background knowledge for comparing costs and benefits and risks and opportunities of different combinations of use at different spatio-temporal scales – with potentially useful implications for MSP.

In assessing the potential of offshore wind farming for co-use, the interplay between science-based information and subjective valuation emerged as a critical factor. Science can deliver important baseline information, such as whether the construction of a wind farm is likely to lead to the development of artificial reefs, what factors encourage the formation of a reef and the likely timescale of such developments. In contrast, it is a matter of attitude and preference at the individual level, or in case of organisations at the group level, whether offshore wind farms are seen as a barrier to fishing or potential recovery areas for endangered fish populations. The same applies to the case of open offshore aquaculture: its ability to evolve is not just a question of technical and ecological feasibility; acceptance and support by local stakeholders and both industries is at least of equal importance (Michler-Cieluch et al. 2009). Further evidence of the significance of subjective perception comes from a survey of local residents, which found that acceptance of offshore wind farms not only depends on objective information, such as the number of potential jobs created or purported environmental impact of the turbines, but also on subjective attitudes to renewable energies generally and held values and perceptions of the sea and the local seascape (Gee 2010). Subjective valuation also extends to the political level, where it has real impact in terms of infrastructure decisions for example: The fate of offshore hydrogen production depends on the political will at national and EU level to provide incentives that will allow exploration of the feasibility of a future hydrogen mass market. Tools like MSP therefore should not only refer to some of the analytical approaches used in *Coastal Futures* to take account of the dynamics of increasing human use of sea areas, but also consider the significance of subjectivities in determining acceptable levels and types of sea use.

What are the challenges for coastal and marine governance?

Globalization, climate change, technological progress, varying demographic developments as well as varying regional levels of affluence create a world with growing connectedness and additional pressure of use on natural resources. This undoubtedly results in new stakeholder constellations influencing and/or being influenced by new sea uses and the emergence of new coalitions of interest. At a practical level, the question is whether existing legal structures are capable of ensuring broadly acceptable decisions backed by sufficiently transparent and participatory processes. At a theoretical level, the question is whether complex coastal-marine systems such as offshore wind farming in the German North Sea can be governed at all, and what forms or modes of governance could enhance the adaptive capacity of the system in terms of enhanced self-organization and system learning.

An essential part of tackling the first question was to take a closer look at the structures and processes within the stakeholder community. Looking at the different scales in which different stakeholders are embedded, different perspectives and lines of argumentation pro and contra offshore wind farms were uncovered. Locally, aesthetic considerations and regional identity play an important role, at the regional level employment opportunities and regional development is seen as highly important and nationally, the debate centers around questions of energy policy and the future energy mix. These debates are further embedded in European contexts, focusing on centralized vs. decentralized energy markets, and global contexts such as climate change policies.

Despite the overall tendency to favour offshore wind farm develoment on the part of the stakeholders identified (or at least a lack of good arguments against it), and despite the generally coherent policy framework supporting it (recent EU Directives, national policy, regional policy), it is far from certain that coastal regions will be able to benefit from it. The nature of complex systems is such that even an apparently minor decision such as not constructing an offshore wind harbor can have wider system impacts down the line (e.g. by companies choosing to invest in another region), eventually precluding the system from choosing a particular development path (once the industry is settled elsewhere, it is doubly hard to attract it back). At the same time, the constellation of the system is such that stakeholders can take action to realize specific opportunities for regional development and human well-being. The economic analysis in *Coastal Futures* illustrates the potential of offshore wind farming to contribute to the economic prosperity of particular coastal areas. What is required is to turn the principal support of offshore wind farming into action on the ground and to do so early on, for instance by providing the necessary infrastructure.

Given the complexity of the stakeholder community, it was not possible to undertake a full and comprehensive analysis of all interactions at all scales. Nevertheless, the *Coastal Futures* stakeholder analysis is a transferable methodological approach that can enable coastal managers to identify the issues at stake and the scale as well as the level of involvement of the various stakeholders.

With respect to participation and transparency in decision-making, a major focus was the current offshore planning system. Since the current planning approval procedures focus on single offshore wind farms, they can neither address cumulative processes and indirect effects between multiple wind farms nor cultural settings and values associated with the sea. The increasing speed of coastal and marine developments, as well as the decreasing ability of local decisions to influence developments at other scales, pose new challenges to the principle of statutory regulation. Although frameworks and strategies have evolved to allow for greater local involvement in decision-making, the importance of externally driven trends and the constraints this places on local decision-making have to be recognized. Consequently the balance between statutory and non-statutory processes cannot be a static one.

Coastal Futures studied varying local, regional and national structures to allow and foster stakeholder participation. These studies have shown that statutory and non-statutory processes should be seen as useful complements within a broader governance system. Traditional approaches to planning are not particularly suited to deal with contradictory value sets and the potential value conflicts surrounding offshore wind farms. Similarly, contradictory policy targets are difficult to overcome by statutory means. The advantage of accompanying tools is that they can go beyond the classic planning approaches such as zoning, encouraging instead the development of holistic visions and coherent strategies for marine development. They also offer the possibility for encouraging greater flexibility of the socio-political system, enhancing its capacity to self-organize and to respond to changing circumstances. Targeted non-statutory participatory mechanisms also provide a means for engendering strategic dialogues across scales.

Lessons for governance can be learnt from current policy changes such as the Water Framework Directive (WFD), which stimulates the emergence of new governance regimes. Case studies have analyzed the implementation of participatory structures as part of the enforcement of the WFD in Schleswig-Holstein and the institutionalization of island development in the region Uthlande (covering the North Frisian islands and the Hallig islands). They show that the long-term viability of participatory structures is critically dependent on their statutory integration. In case of the WFD, decisions concerning water quality are taken by a combination between formal institutions and informal advisory boards. The process of deliberation thus takes place in the shadow of hierarchy, which pushes stakeholders to work together and solve problems jointly across different remits and spatial/administrative scales.

The development of new participatory multi-scale governance structures could benefit from the methods compiled and elaborated in *Coastal Futures.* These methods, imperfect though they are, support the devising and implementation of integrative management solutions that respond to local, regional, national and global social-ecological needs, hence assisting in ensuring the sustainable development of coastal and marine regions.

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12 Appendix

Project publications

Forthcoming publications

Bruns, A. & Gee, K. (accepted): Der Küsten- und Meeresraum zwischen traditionellen Küstenbildern und neuen Steuerungsformen für eine nachhaltige Entwicklung. Berichte zur deutschen Landeskunde. H.1./2010. Leipzig.

Bruns, A. (submitted): Governance im Küstenraum. Umweltpolitik im Wandel - Die Umsetzung des Integrierten Küstenzonenmanagements und der Wasserrahmenrichtlinie an der Westküste Schleswig-Holsteins. Dissertation. Faculty of Mathematics and Natural Sciences, Kiel University.

Burkhard, B.; Petrosillo, I. & Costanza, R. (eds.) (in press): Ecosystem services - bridging ecology, Economy and Social Sciences. Special Issue. Ecological Complexity.

Gee, K. & Burkhard, B. (accepted): Offshore wind farming on the West coast of Schleswig-Holstein: A shift towards a new cultural landscape? Paper für den internationalen Workshop 'Social-ecological resilience of cultural landscapes', Berlin-Brandenburgische Akademie der Wissenschaften, 15.-16. Juni 2010.

Glaeser, B. & Glaser, M. (in press): Global change and coastal threats: The Indonesian case. Human Ecology Review.

Ihme, K.; Burkhard, B. & Lorenzen, D. (submitted): Individual based modelling of bird migration in relation to offshore wind farms in the German North Sea. Environmental Software and Modelling.

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Project participants

Zukunft Küste - Coastal Futures

Photo: Project participants at the final project symposia in Hamburg, 4th March 2010.

From left to right: Malte Busch, Prof. Franciscus Colijn, Anke Schmidt, Matthis Münte, Antje Bruns, Kai Ahrendt, Kira Gee, Benjamin Burkhard, Petra Nerge, Hermann Lenhart, Christiane Eschenbach, Andreas Kannen, Nico Stelljes, Stefan Garthe, Marcus Lange.

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