Reg Environ Change (2014) 14:2105–2114
DOI 10.1007/s10113-012-0338-x

ORIGINAL STUDY

Integrating regional perceptions into climate change adaptation: a transdisciplinary case study from Germany's North Sea Coast

Anke Schmidt · Meinfried Striegnitz · Katina Kuhn

Received: 28 February 2012 / Accepted: 25 July 2012 / Published online: 7 August 2012

Abstract Coastal protection strategies increasingly have to take into account the effects of climate change. At present, engineering and natural science models that assess the impact of global climatic transformations on regional coastal zones and their protection structures remain rather detached from the knowledge and insights of regional practitioners. The main thesis of this contribution, using a case study from the North Sea Coast of Germany, is that innovative coastal protection requires not only interdisciplinary research but transdisciplinary collaboration in order to develop a viable adaptation strategy. The investigation of the social dimension of climate change and coastal protection strategies, using qualitative interviews with organized regional stakeholders, climate researchers and coastal engineers, as well as a representative public survey, contributes to a comprehensive understanding of regional perceptions with respect to climate change and coastal protection.

Keywords Adaptation strategies · Transdisciplinarity · Coastal zone · Climate change · Perception

This paper contributed to the LOICZ Open Science Conference (OSC) on "Coastal Systems, Global Change and Sustainability," September 12–15, 2011, in Yantai, China.

A. Schmidt (✉) · M. Striegnitz · K. Kuhn
Institute for Environmental and Sustainability Communication, Leuphana University Lüneburg, Scharnhorststr. 1, 21335 Lüneburg, Germany
e-mail: Anke.Schmidt@uni.leuphana.de

Introduction

Global climate change is a serious problem, particularly for low-lying coastal areas, coastal communities, and their economic basis. Coastal zones are highly vulnerable to the projected impacts of a changing climate, such as accelerated sea-level rise and enhanced storm surges (Nicholls et al. 2007). In response to such threats, adaptation research has sought to address changing risks and secure improved protection within coastal zones (Burton et al. 2002; Cheong 2010; Smit et al. 1999).

Uncertainty and complexity, arising from the interplay of climatic as well as demographic developments and regional economic conditions, shape the overall discussion on climate change as it influences not only the natural coastal system but also almost every societal action taking place in coastal zones (Patt et al. 2005; Lorenzoni and Pidgeon 2006). Decision-makers and stakeholders are faced with uncertainty and a lack of scientific consensus on climate change and divergent public perceptions of the implications of various scenarios (Jones 2000; Webster et al. 2003).

Consequently, adaptation decisions (e.g., protection, accommodation, retreat—following IPCC CZMS 1990) have to integrate the various interests and needs of all actors involved in the sector where adaptation measures are to be taken. In the past, the integration of local, non-scientific knowledge and social sciences has been largely neglected, and as a result, natural science- or engineering-based strategies have remained rather detached from their societal anchoring. In terms of coastal protection, this means that adaptation to climate change, along with diverse societal and economic claims, needs to be integrated into regional spatial planning policies.

Against this backdrop, this article focuses primarily on the transdisciplinary integration of non-scientific, local

knowledge, and values into research and adaptation strategy development processes. By examining different perspectives on climate change and regional coastal defense, knowledge asymmetries between science and society will be identified as prerequisite and starting point for an integrative strategy development process.

The jigsaw of transdisciplinarity as means to foster climate adaptation

In this section, we first elaborate briefly on transdisciplinarity as a fruitful research approach for integrating diverse actors into strategy development. Having set this research frame, we briefly introduce the project, the transdisciplinary context, and methodologies from which our empirical results were derived (see "Changes in the coastal climate: a transdisciplinary approach"). "Results" section focuses on empirical findings, which we then compare and discuss in the section "Comparative analysis and discussion."

Transdisciplinarity as a research approach

Addressing climate change in general, and adaptation to a changing climate more specifically, is no longer academic issues exclusively. Climate change is defined as a life-world problem requiring a solution process that transgresses the boundaries between different scientific disciplines on the one hand, and the boundaries of science itself, by integrating practical and societal knowledge on the other. Transdisciplinarity is a form of research that emanated from the discrepancy between scientific disciplines and life-world problems, and the challenge to solve problems of "… what is perceived to be the common good." (Hirsch Hadorn et al. 2008:19). In contrast to the traditional linear production of scientific knowledge, the practice-oriented character of transdisciplinarity links abstract scientific knowledge with case specific, practical knowledge in an iterative and reflexive procedure. Additionally, moral concepts and local values can be integrated (Defila and Di Giulio 2001; Gibbons et al. 1994; Hirsch Hadorn et al. 2008). Reflexivity is a core element in dealing with uncertainty "… and the outer boundaries of knowledge resulting from transdisciplinary endeavors" (Wiesmann et al. 2008:10). Thus, conceptual and methodological reflexivity is an integral part of knowledge production in transdisciplinary research.

Transdisciplinarity and climate adaptation

By using global scenarios, such as IPCC's scenarios, climate change is often presented and projected at the global level, whereas impacts on coastal zones are as diverse as coastal areas are worldwide (Paavola and Adger 2006).

Due to these regional differences a spatial and, if possible, temporal concretization of climate parameters is required in order to develop viable adaptation strategies that meet regional economic, political, and societal interests and demands. Accordingly, these requirements link scientific and non-scientific knowledge in a transdisciplinary manner. The transdisciplinary pieces that are to be assembled in a jigsaw are:

- natural and engineering scientists who are increasingly able to substantiate the vague public debate with "hard" climate data based on numerical models;
- regional authorities and communities that are in the best position to understand local and regional specifics, and incorporate prevailing societal values and interests;
- social scientists, assessing the publics concerns and perceptions and supporting reflexive and discursive interactions, are an integral part of knowledge production.

Ideally, the result of such transdisciplinary cooperation is that policy implementation in terms of adapting to a changing climate is based on sound climate research as well as on regional values and acceptance.

Changes in the coastal climate: a transdisciplinary approach

The main objective of this paper is to explore different regional perspectives on climate change and adaption responses, representing the social science jigsaw piece, in order to contribute to the transdisciplinary strategy development process. The different perspectives incorporated are those of scientists, stakeholders, and finally those of the affected public.

The findings result from the transdisciplinary research project A-KÜST "Changes in the Coastal Climate—Evaluation of Alternative Strategies in Coastal Protection", which aims to create a regional database for the hydrodynamic loads resulting from climate change, and provide a basis for viable future coastal protection measures and strategies.

The A-KÜST project links up three major perspectives: first, a natural scientific and engineering perspective, second a socio-scientific one, and third the social perspective of an accompanying advisory board, which comprises a range of representatives from regional institutions and organizations that are directly or indirectly related to coastal protection. The board can be seen as representative according to all actors relevant in regional decision-making practice in coastal protection. It consists of nearly actors or institutions assigned to, or affected by, coastal protection:

- the heads of four dike associations, organizing Lower Saxony's coastal defense in a subsidiary manner.

These associations are self-governing bodies under public law, responsible for construction and maintenance of coastal defense structures (Striegnitz 2006);
- representatives from the lower coastal protection administration as supervising authorities for the dike associations;
- regional authorities responsible for spatial planning, coastal defense, waterways, and nature conservation, covering cross-sectoral linkages;
- representatives of the chamber of industry and commerce and the economic sector in general, such as the ship and harbor industry and construction industry. These members represent mostly economic interests.

In contrast to the general term "stakeholder" that comprises all actors having a stake or an interest in a given issue, we conceptualize stakeholders relatively narrowly in this paper to describe this advisory group, as opposed to the general public and scientists. To clarify this distinction, we use the acronym ABM (Advisory Board Member) when we refer to organized regional stakeholders.

It is assumed that these regional actors, who participate actively in the A-KÜST project by giving advice, contribute to an effective, feasible, and socially accepted adaptation strategy in coastal protection.

Acceptance on the part of those who will be affected by future measures is a basic prerequisite for successful implementation. Lorenzoni and Pidgeon (2006) consider policy implementation as problematic when the adaptation policy is misunderstood or neglected by the public due to different frames of reference.

It should be noted briefly that the transdisciplinary approach makes sense in this case because coastal protection has a long history in this area, going back to approximately 1000 A.D. when people in the North Sea region cooperatively built and maintained dikes. This long association with coastal protection activities means that there is a great deal of local knowledge about the coast and its climate as well as the viability of adaptation strategies.

The aim of this paper is to examine and analyze a multifaceted landscape of perceptions around regional climate change and adaptation in coastal defense. We highlight diverse knowledge, knowledge gaps, and prevailing uncertainty among organized stakeholders and the public, and finally present a vision of a forward-looking planning process.

The Ems-Dollard region in Lower Saxony, Germany

Before expanding on the scientific research process and initial results, we will briefly introduce the project and case study region upon which this paper is based.

The three large estuaries of the rivers Ems, Weser, and Elbe characterize Lower Saxony's coastal area. In total, this area covers approximately 6,600 km^2 and incorporates a population of 1.2 million people living in potentially flood-prone areas. These people depend on flood protection during storm surges and increased precipitation and in the face of continued sea-level rise.

The project region, which is shown in Fig. 1, is centered on the Ems-Dollard Estuary and encompasses a geographic area that exhibits typical elements of low-lying coastal morphology. For these coastal areas, increased storm surges and accelerated sea-level rise represent the major threat. Scientists and engineers assume that increased hydrodynamic loads resulting from climate change elevate the risk of severe damage to coastal protection structures and may cause hazardous flooding of the hinterland (Woth et al. 2006; Niemeyer et al. 2011; Weisse et al. 2011).

Methodology

The results presented in this paper focus on the description and analysis of lay people's perceptions of climate change and coastal protection, based on a representative survey. These results have been compared to the ABMs' and scientists' perceptions and evaluations, to identify differences or common perceptive cultures to substantiate the appropriateness of a transdisciplinary approach.

Whereas ABMs and scientists argue mostly from a professional point of view because they participate as representatives of their respective institutions, the responses of the surveyed public represent the lay perspectives of a coastal population living in a potentially flood-prone area.

Data were collected using two different methodical instruments. The regional public was questioned using a representative mail survey, which provides an adequate procedure to fulfill the pretension of a representative inquiry, and allows conclusions to be drawn about the general coastal population. Complementing this quantitative public survey, qualitative semi-standardized interviews were conducted with regional experts.

Representative public survey

Using the quantitative survey method, representative statements on public perception and evaluation of climate change impacts and regional coastal protection could be made for the general population living in the flood-prone area adjacent to the Ems-Dollard Estuary.

Questionnaire design The survey employed a standardized questionnaire, comprising nearly 40 open and closed questions mainly focusing on the following topics, and was distributed in the Ems-Dollard region:

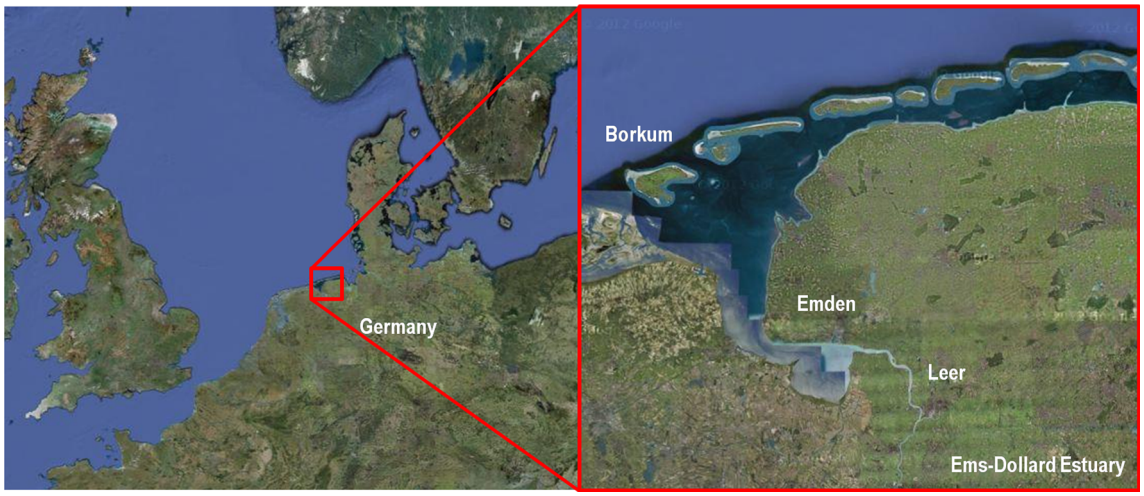

Fig. 1 Study area: the Ems-Dollard Estuary, Lower Saxony, Germany (Google 2012)

- How do people perceive climate change, and which implications do they recognize and anticipate?
- Do people perceive themselves and their living environment to be under threat?
- How does the public evaluate current coastal protection and do they have confidence in the responsible institutions?

The sample Approximately 6,500 questionnaires were distributed to a random sample of households in the project region. Residents living in the potentially flood-prone zone below 5 m above mean sea level—the area protected by coastal defense—represent the general population. The project region covers the mostly rural territories of the dike associations (matching the potential flood-prone area), the two cities Emden and Leer and the island Borkum. Within sampled households, the person whose birthday is next and who is older than 16 was supposed to answer the questionnaire.

Quantitative, descriptive, statistical analysis was carried out by means of the statistical package SPSS. The results presented in the following section are predominantly based on the descriptive statistical analysis of the questionnaires.

Qualitative expert interviews

Aside from the ABMs, who represent the full range of organized regional stakeholders involved in and affected by coastal protection, the project's researchers—namely natural and engineering scientists—were also interviewed. Their primary role is to perform a downscaling of global climate variables to a regional scale and assess hydrodynamic parameters.

In total, 20 qualitative interviews—of which 15 interviewees pertained to the ABM group and five to the group of scientists—were conducted on the basis of a semi-structured interview guide focusing on principles and strategies of regional coastal protection and on climate change. Interviews covered the following themes:

- Knowledge and evaluation of present coastal protection principles and strategy in the German Federal State of Lower Saxony.
- Evaluation of alternative adaptation strategies: retreat, hold, or advance the line, accommodation.
- Evaluation of adaptation strategies according to three time horizons: mid-term (2030), long term (2100), and very long term (far beyond 2100).
- Significance of climate change and possible effects on the Ems-Dollard region.

Interviewees were invited to discuss other aspects if these seemed important. In this way, regional characteristics, institutional specificities, and other particularities were captured. All interviews were recorded digitally and transcribed for comprehensive qualitative content analysis (Mayring 2008). The coding scheme comprised both theoretically and empirically derived codes.

Results

Public perception of climate change and coastal protection of the Ems-Dollard region

In this section, we elaborate on the specific findings resulting from the representative survey and the interviews. A comparison of the two studies is given in the section "Comparative analysis and discussion."

Of the 6,500 questionnaires distributed, 829 were returned. This is a response rate of about 13 %.

Sample characteristics The unbalanced gender ratio of 66 % male and 34 % female respondents does not mirror the demographic situation and implies that the topic of coastal protection and climate change is rather dominated by men. A similarly unbalanced picture emerges by analyzing the age structure of the respondents: Nearly half of the respondents are aged over 60. Younger people were less likely to answer the questionnaire. Only 6 % are aged between 16 and 29.

Over 90 % of respondents take climate change for granted and assume that its impacts will affect the coastal region they live in. The majority attributes climate change mainly (27 %) or likely (53 %) to anthropogenic causes.

Confidence in regional coastal protection

Confidence in the regional institutions involved in coastal protection is high. Table 1 shows the confidence in institutions entrusted with coastal protection on a Likert-type scale from 1 (very high confidence) to 4 (no confidence). As it shows, people trust the dike associations the most (mean = 1.49), followed by the Lower Saxony Water Management, Coastal Defense and Nature Conservation Agency (NLWKN) (mean = 1.73), and the Coastal Research Station of the NLWKN (mean = 1.89). Reasons for these institutions being more trusted than the Federal Ministries (mean = 2.89), the European Union (mean = 3.07) and the political parties and Parliament (mean = 3.20) may be their direct connection to regional coastal protection and their higher regional visibility. Obviously, people relate the satisfactory protection to the regional institutions that are responsible.

In contrast to other German regions, especially Hamburg in 1962, regional coastal defenses have protected the coastal area of the Ems-Dollard region reliably for decades (von Storch et al. 2008). Due to this fact, people feel safe and evaluate the reliability of current coastal protection as good for the next 20 years, as shown in Table 2 (Question: "How do you assess current coastal protection for the next 20 years"). Whereas 60 % of the respondents assessed regional coastal protection as fully sufficient (30 %) and partially sufficient (30 %) for the coming 20 years, only 22 % assessed current coastal protection as likely insufficient (10 %) and insufficient (12 %). In contrast to this reasonable period of time, respondents became uncertain when evaluating future coastal protection. We asked them to assess the reliability of today's coastal protection in 20–60 years from now, in order to compare the perception of reliability over different periods. As shown in Table 2, only 40 % evaluated coastal protection as fully sufficient (13 %) and partially sufficient (27 %). The proportion who evaluated coastal protection in the future as insufficient increased to 37 %, of which 14 % described it as likely insufficient and 23 % as insufficient.

Confidence can be seen to decline with increasing time horizons. This, as well as the increased number of "do not know" responses, can be explained by widespread uncertainty regarding the temporal and spatial distribution of regional climate change impacts. Respondents who anticipated negative developments were asked to specify the grounds for expecting future deficits in coastal defense. Table 3 shows that a considerable proportion associates the expected failure with climate change. Interestingly, in comparing the two time horizons, respondents expect failure due to uncertain climatic development to increase, while failure due to the state of construction is expected to decrease for the time horizon 2030–2070. This may be linked to people's confidence in technological progress.

Table 1 Question: Regarding regional coastal protection: how strong is your confidence in the following institutions?

Institutions	*N*	Mean	SD
Dike Associations	764	1.49	.628
Lower Saxony Water Management, Coastal Defense and Nature Conservation Agency (NLWKN)	738	1.73	.661
Coastal Research Station of the NLWKN	680	1.89	.741
Local Authorities	715	2.16	.803
Federal Waterways and Shipping Administration (WSD, WSA)	679	2.20	.729
Federal Waterways and Engineering Research Institute (BAW)	651	2.22	.730
State Ministries	676	2.43	.761
Universities and Research Institutes	653	2.45	.838
Federal Ministries	680	2.89	.703
European Union	662	3.07	.693
Political parties and parliament	686	3.20	.690

Likert-scale from 1 (very high confidence) to 4 (no confidence): mean and standard deviation (SD)

Table 2 Question: How do you evaluate the reliability of recent coastal protection regarding the future time horizons of 2010–2030 and 2030–2070?

	Percent of responses	
	Today's coastal protection in 2010–2030	Today's coastal protection in 2030–2070
Fully sufficient	30 %	13 %
Partially sufficient	30 %	27 %
Likely insufficient	10 %	14 %
Insufficient	12 %	23 %
Do not know	18 %	23 %
Total	100 % ($N = 813$)	100 % ($N = 815$)

Table 3 Grounds for expecting that current coastal protection structures will not protect the region adequately in respect of the two future time horizons of 2010–2030 and 2030–2070

	Percent of responses (multiple answers possible)	
	Today's coastal protection in 2010–2030	Today's coastal protection in 2030–2070
The present state of construction will not be adequate	54 %	46 %
Climate change will lead to changing conditions	13 %	24 %
The effects of climate change are not predictable	8 %	17 %
Anthropogenic interferences will lead to changing conditions	5 %	5 %
Miscellaneous	24 %	15 %
Total	104 % ($N = 294$)	107 % ($N = 256$)

The majority of respondents think technological progress will lead most likely (25 %) or quite likely (48 %) to new solutions and advanced defense structures (on a Likert-scale from most likely (1) to most unlikely (4)). This can be traced to spatiotemporal uncertainty of climate change scenarios and the fact that present protection structures may turn out to be insufficient.

Temporal framing of climate change implications for coastal protection

Currently, 10 % of the respondents feel threatened by climate change, but 66 % indicate that they may feel threatened in the near future. These findings are congruent with the confidence we found in the existing coastal protection structures and the institutions responsible for them. Nevertheless, we sketched the existing uncertainty of climate change implications in the Ems-Dollard region. Respondents were asked to anticipate climate change impacts over time by indicating whether the existing coastline would have to be relocated inland. Nearly one-third considered a retreat of the coastline a possibility and gave a temporal distinction as shown in Fig. 2.

In contrast to the less widely held view of a potential need for relocation of the coastline, 61 % agree that the villages on the East Frisian Islands could not be defended and would have to be resettled in the future. The majority of those anticipate this within the next 20 (26 %) to 60 (50 %) years (see Fig. 3).

Both the need to relocate the coastline and to resettle the island villages appear to be recognized and expected in a relatively short-term time frame.

State of knowledge and information needs

Survey data analysis revealed that respondents are highly interested in climate change and coastal protection. Nevertheless, the state of knowledge on these topics varies among the respondents.

The feeling of uncertainty concerning the implications of climate change appears to be high. This is not least because of the diverse or even contradictory statements of scientists and academics, (mis)communicated by mass media, concerning climate change. This is reflected in the comparatively large number of "do not know" responses.

In addition, we wanted to know whether people, living in a potentially flood-prone area, know that current and projected accelerated sea-level rise has been and will be considered in determining coastal protection measures. In Lower Saxony, Germany, coastal defense dikes are designed on the basis of a deterministic approach, which means that for the dimensioning of the dikes single values (e.g., mean high water, surge, and sea-level rise) are summarized to the maximum water level of a storm surge that has not yet occurred (NLWKN 2007). Currently, this single value approach results in a reinforcement of the dikes by 25 cm for the next one hundred years. Additionally, the projected climate-driven sea-level rise is taken into account by adding another 25 cm.

Nearly half of the respondents (45 %) were aware of this preventive measure. As shown in Fig. 4, the specific knowledge of those who affirm the reinforcement varies largely.

These two examples reflect a varying state of knowledge among the coastal population. We asked respondents about the extent to which they felt sufficiently informed concerning the protection of the coastal area and their individual safety: 38 % perceive themselves as likely

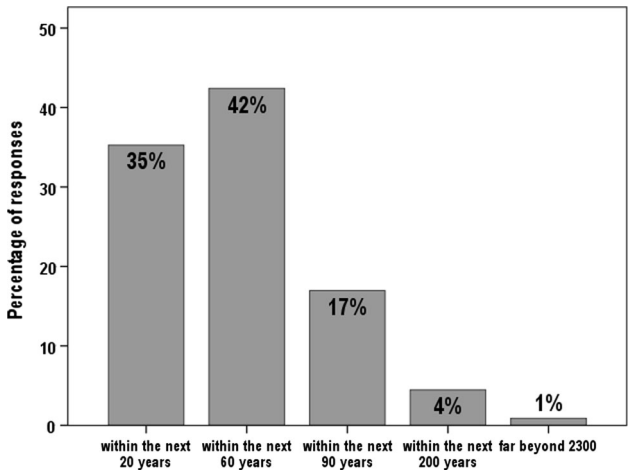

Fig. 2 Question: Do you think that the present dike line cannot be defeated in the future and has to be relocated? Please specify in terms of time ($N = 224$). Created with SPSS Software

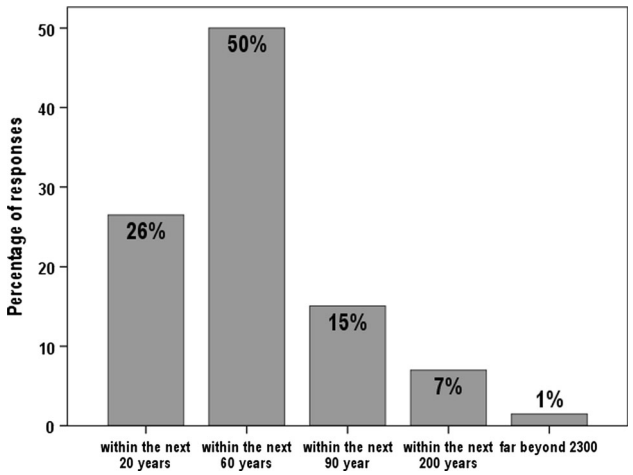

Fig. 3 Question: Do you think that the island villages cannot be protected adequately in the future and therefore have to be resettled? Please specify in terms of time ($N = 272$). Created with SPSS Software

insufficiently informed and 13 % as insufficiently informed.

Perceptions and orientations of organized regional stakeholders and scientists on climate change and coastal protection

In the following, we present the findings from the overall analysis of the qualitative interviews. We emphasize, as necessary, important differences within the interview-group.

Confidence in regional coastal protection

The analysis of the material shows an overwhelming consensus on fundamental issues of regional coastal protection among the ABMs and scientists. Nearly all ABMs and all natural and engineering scientists evaluate the current level of security as high. Linear coastal protection (e.g., a closed dike line) together with a uniform level of security for all citizens is favored. This means that the traditional and proven protection measures are clearly preferred for today's coastal protection.

Even though the ABMs state that there is no acute pressure to act, they consider a rethinking of long-term planning due to climate change as important and necessary.

Faith in technological advancement in coastal protection is also common to ABMs and scientists. But reliable scientific projections of regional climate change effects are required in order to evaluate the necessity of adaptation measures.

Temporal framing of climate change implications for coastal protection

The ABMs' statements concerning perceptions on the principles of coastal protection in the Ems-Dollard region are characterized by numerous references to a shared, collective past. These reference points, for example storm surges and other extreme events, draw through the past like pearls on a string.

Concerning future developments, especially in coastal protection, these reference points are missing. The ABMs still perceive climate change in vague and incalculable terms. They largely avoided a temporal concretization of anticipated climate change impacts, because they can hardly imagine how climate change will affect the Ems-Dollard region. This perceived openness of long-term climatic changes collides with divergent, mostly short-term planning horizons. Regarding the perception of ABMs, we found that they estimate significant impacts on coastal

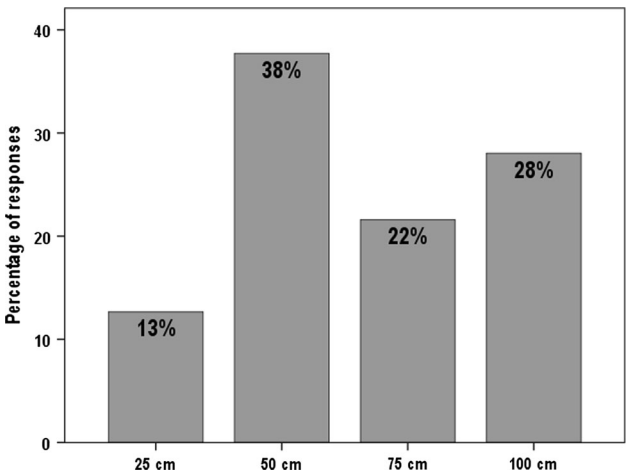

Fig. 4 Specification of the amount of the preventive dike reinforcement ($N = 403$). Created with SPSS Software

protection in a mid-term time frame, wherein adequate adaptation measures should be considered within the next 30–50 years.

Scientists, on the other hand, refer mainly to time perspectives that are rather long-term in comparison. Thus, time horizons in academic contexts are more extensive than those of practitioners. The project's natural science and engineering researchers professed that long-term perspectives are indispensable in developing a viable strategy for coastal protection. But the strategy discussion must also integrate a mid-term perspective in adapting to impending changes.

State of knowledge and information needs

All interviewees had problems in anticipating future developments in coastal protection. These problems emanate rather from being unable to anticipate technological advancement and social and economic developments than from uncertainty about the implications of climate change. Eisenack et al. (2007) gained similar insights, asserting that "… stakeholder intuitions are still very vague when it comes to local exposure units, while there is enough tacit knowledge and attention to formulate vulnerable sectors in an abstract way. In other words, there seems to be little concrete knowledge about whom or what is potentially affected by climate change" (p. 251).

Information needs are more substantial for the ABMs than for the natural scientists and engineers. In implementing coastal protection, they prefer clear and reliable scientific statements on the occurrence and characteristics of climate change in the Ems-Dollard region. ABMs feel insecure when handling the broad range of possible effects.

Comparative analysis and discussion

The two studies reported on in this paper produced a wealth of qualitative and quantitative data on perceptions of climate change and coastal protection among experts and lay people and highlighted the need for its integration in policy processes. Furthermore, we aim to outline the means by which to integrate different perspectives in a forward-looking planning process.

There is a wealth of national and international studies related to public perceptions of climate change that merely focus broadly on attitudes toward the seriousness of climate change (and mitigation) (cf. Bord et al. 1998; Dunlap 1998; Lorenzoni et al. 2006; Lorenzoni and Pidgeon 2006). Other studies, which are more related to coastal protection, focus merely on perceived possibilities of participation, neglecting climate change (Kaiser et al. 2004), or on risk perception and communication (Knolle et al. 2007).

The fact that both lay people and experts take (anthropogenic) climate change for granted is congruent with the results of previous surveys on public perceptions of climate change in Europe and the United States (cf. Bord et al. 1998; Dunlap 1998; Lorenzoni et al. 2006; Lorenzoni and Pidgeon 2006; Poortinga et al. 2006).

With respect to the public survey, the relatively low response rate may be traced back to the comprehensive and rather advanced questionnaire. This represents a certain self-selection and may partly explain the asymmetric gender and age ratio. Interestingly, similar surveys on risk perception in the North Sea region gained equivalent gender and age distributions among the respondents (Kaiser et al. 2004; Knolle et al. 2007).

The overall analysis of the two studies revealed that in certain respects the three groups—the public, ABMs, and researchers—could not be differentiated clearly by their perceptions. With regard to climate change effects on the region under study, the perceptions of natural scientists and engineers differ from those of the ABMs and the public. The two latter groups' perceptions are characterized by vast uncertainty of spatial and temporal consequences. Whereas researchers, relying on their academic knowledge, might easily put the given range of effects in perspective, lay people and the majority of ABMs did not have the knowledge to handle this specific issue to their satisfaction. Thus, they largely avoided statements on anticipated climate change effects.

Confidence in regional coastal protection

The public, ABMs, and researchers agreed on the high level of security and showed a high degree of confidence in the existing protection measures. Empirical studies conducted by Peters and Heinrichs (2005) in parts of Lower Saxony and Bremen showed that the coastal population largely trusted in the administration and protection against storm surges. We can corroborate this statement in light of the present survey, but differentiate between the confidence in institutions entrusted with coastal protection, and the protection structures per se. Whereas the public, as well as the ABMs and researchers, acknowledge the reliability of present coastal protection measures, nearly all interviewees and respondents had reservations concerning their reliability in the context of progressing climate change. Even if not specified, technological advancement plays an increasingly important role in future coastal protection.

The overall perception of mid-term pressure to consider adaptive measures within approximately 50–60 years is opposed by a small but considerable proportion of respondents (approximately 30 %), who anticipate a rather short-term time horizon of 20 years for initiating adaptation measures (see Figs. 2, 3).

Against this backdrop, effective coastal protection needs to be conceived as a long-term progressive project that has to address the requirements of a changing climate on a timescale in the order of a century.

Information needs

Information needs are mostly identified among the public and the ABMs, whereas the precise knowledge deficit varies. Analysis of questionnaire data revealed that the public perceives diverse information needs. The uncertainty regarding climate change is high, and the public is likely not very well informed about coastal protection in the Ems-Dollard region. A considerable proportion therefore requires more information on these two issues. By contrast, the ABMs, predominantly entrusted with coastal protection, were well informed about coastal protection issues. They require mainly scientifically sound information about exactly when and what climatic changes are to be expected. Additional scientific information about effective and viable adaptation options and their consequences is also potentially helpful. Based on this, they are able to evaluate different adaptation options, formulate strategy, and choose the proper window in time for implementation.

Conversely, coastal engineers in direct contact with coastal defense practitioners are able to take regional specifics into consideration at very early stages of modeling and knowledge production.

Transdisciplinarity: codeveloping adaptation strategies

As we have shown, diverse perspectives, states of knowledge, and information needs regarding climate change and coastal defense prevail among researchers, stakeholders, and the public. To profit from this diverse knowledge, ideally all parties have to come together in order to cooperatively analyze the current situation, the expected climatic implications, and the possibilities of adapting to climate change.

While climate researchers and coastal engineers contribute by providing basic scientific results, regional stakeholders, such as ABMs, are experts regarding regional specifics. They integrate local perspectives, and additionally, they are mouthpieces when it comes to communicating scientific results and strategic decisions to the affected public. Ideally, both groups communicate on a common ground and initiate a mutual learning process (Jahn et al. 2012).

Citing several authors, Jahn et al. (2012) argue that reflexivity is a prerequisite for accountability, which we assume is a focal point in developing and implementing adaptation strategies.

Concluding remarks

Sound adaptation strategies that meet the requirements of a given society need to be developed within the local context, and they need to be customized to the unique prevailing conditions by taking all relevant actors, their specific interests and perspectives into account (Klein et al. 2005; Tryhorn and Lynch 2010). Only by integrating the whole array of stakeholders can a new strategy to face climate change actually be socially accepted.

A vital prerequisite for joint strategy development is a common space where all relevant actors convene. Picking up the threads, this means that the three jigsaw pieces of transdisciplinarity, namely climate researchers and engineers, organized stakeholders, and social scientists, join together, initiating a consensus building dialog. Social scientists, assessing perceptions and evaluations, are in the best position to moderate a reflexive and iterative discussion (see Jahn et al. 2012), by reflecting stakeholders' as well as scientists' perspectives and incorporating public attitudes toward the issues to be discussed.

The findings presented in this paper are seen as a starting point to foster transdisciplinary communication by identifying information needs and finally closing the gap between the information that is required to act locally and the—mostly global—knowledge that is generated by academia. As we have shown, the overall impression is characterized by a likely similar perception of the current status and the future development of coastal protection. Considering the specific knowledge deficits discussed, the public and ABMs have to be informed according to their needs. We assume that this transparent and communicative research process will contribute to the societal acceptance of a viable adaptation strategy. The confidence of the coastal population in the institutions and, more importantly, in the protection measures, could be maintained and enhanced. Finally, this contributes to increasing people's sense of security regarding the future.

Acknowledgments The findings of the present study result from the social science sub-project "Perception & Cooperation" of the five-year research project A-KÜST. The project was launched in 2009 as part of Lower Saxony's Climate Impact Research Program (KLIFF) and is funded by the Lower Saxony State Ministry of Science and Culture. This financial support is gratefully acknowledged.

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