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Towards Successful Adaptation to Sea-Level Rise along Europe's Coasts

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ABSTRACT

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Adaptation is defined as the planned or unplanned, reactive or anticipatory, successful or unsuccessful response of a system to a change in its environment. This paper examines the current status of adaptation to sea-level rise and climate change in the context of European coasts. Adaptation can greatly reduce the impact of sea-level rise (and other coastal changes), although it requires adjustment of coastal management policies to changing circumstances. Consequently, adaptation is a social, political, and economic process, rather than just a technical exercise, as it is often conceived. The Synthesis and Upscaling of sea-level Rise Vulnerability Assessment Studies project has shown that adaptation to sea-level rise is widely divergent among European countries. Crudely, four groups of countries were identified:

1. Those that do not worry about accelerated sea-level rise and should not as their coasts are not susceptible
2. Those that do not worry as they have more urgent problems
3. Those that do not worry but probably should
4. Those that do worry and have started to adapt

At the European Union level, while coastal management is a focus, this effort is mainly targeted at today's problems. Hence, this paper suggests the need for a concerted effort to address adaptation in coastal zones across Europe. Sharing of experience among countries would facilitate this process.

ADDITIONAL INDEX WORDS: *Climate change, protection, accommodation, retreat, coastal management, vulnerability.*

INTRODUCTION

To date, the consideration of possible and likely adaptations by society in response to impacts of climate change has been limited in most studies that have aimed to assess the vulnerability of coastal zones to sea-level rise (SLR). Adaptation enables coastal communities to limit their vulnerability by averting or reducing potentially negative consequences of SLR while benefiting from potentially positive consequences. It is intuitive that people will not just sit back and watch their land and property being eroded and flooded by the sea—as the historic response to coastal hazards demonstrates (see VAN KONINGSVELD *et al.,* 2008; STERR, 2008). However, the process by which adaptation takes place and reduces the vulnerability of coastal zones to SLR is a new issue on which systematic studies are only beginning. It is also still unclear how adaptation to SLR relates to and would fit in with current coastal management practices, although these linkages are widely acknowledged (BIJLSMA *et al.,* 1996; KAY and ADLER, 2005; TOL *et al.,* 1996; WORLD COAST CONFERENCE '93 STAFF, 1994). Humans have been adapting to changes in the coastal zone and sea-level variability ever since they moved there. (Accelerated) SLR and climatic change usually modify existing problems rather than create new ones, so this historic experience is meaningful and useful.

Few of the large number of coastal vulnerability studies currently available in the scientific literature (DARWIN and TOL, 2001; FANKHAUSER, 1995; KLEIN *et al.,* 2001; TOL, 2002a, 2002b; TURNER and ADGER, 1996; TURNER, DOKTOR, and ADGER, 1995; WEST, SMALL, and DOWLATABADI, 2001; YOHE *et al.,* 1996; YOHE and NEUMANN, 1997) analyse with some degree of sophistication how societies would and should respond to SLR. As the other papers in this volume demonstrate, other studies have evaluated the technical feasibility

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of adaptation measures but have little or no assessment of the economic and other considerations affecting the implementation of these measures. This limited consideration of adaptation in climate change vulnerability studies is partially explained by the standard methodologies for such studies, such as the Intergovernmental Panel on Climate Change (IPCC) Common Methodology (IPCC, Coastal Zone Management Subgroup Staff, 1992), the IPCC Technical Guidelines (Carter *et al.,* 1994), and the United Nations Environment Programme Handbook (Feenstra *et al.,* 1998), which emphasise a stepwise approach, starting with scenario development and followed by a primary impact assessment, and postpone adaptation assessment to the end of the study, when time and money have typically run out (Downing, Olsthoorn, and Tol, 1998; Klein and Nicholls, 1999). Another part of the explanation is the predominant role of natural scientists in vulnerability studies. Adaptation is very much a social, political, and economic process, and any assessment therefore requires the involvement of social scientists, including economists.

Since the important knowledge gaps have become widely apparent, research on adaptation is booming. Most current literature is still conceptual in nature (see Smith *et al.,* 2000, for an overview), but there are some notable exceptions that focus more strongly on empirical analysis, particularly in relation to water resource management (Cohen *et al.,* 2000; Frederick, 1997; Frederick, Major, and Stakhiv, 1997; Mendelsohn and Bennett, 1997; Miller, Rhodes, and MacDonnell, 1997; Tol and Langen, 2000; Tol *et al.,* 2003) and agriculture (Mendelsohn, Nordhaus, and Shaw, 1994, 1996; Reilly and Schimmelpfennig, 1999; Smit, McNabb, and Smithers, 1996; Smithers and Smit, 1997; Solow *et al.,* 1998).

This paper first reviews the conceptual literature on adaptation and then adds illustrations from the empirical literature that would also pertain to coastal zone management. It then continues with an assessment of adaptation planning and practice to SLR along Europe's coasts. The present assessment draws on the papers contained in this special issue, other materials presented at the European workshop for which these papers were originally prepared (de la Vega-Leinert, Nicholls, and Tol, 2000), and the many discussions at that workshop.

WHAT IS ADAPTATION?

What is adaptation to climate change and SLR? The glossary of the IPCC Third Assessment Report (McCarthy *et al.,* 2001, p. 982) provides the following definition:

> Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

This suggests that adaptation is a very broad process, which can be categorised into components according to who or what adapts, the timing of adaptation, its motive, and many other factors (Smit *et al.,* 2001).

To illustrate adaptation, consider a sandy beach on a sunny day. The beach is filled with sunbathers. Most people lie with their heads a few centimetres above the level of the sea. If the sea were 50 cm higher, they would all drown![1] That is, unless they adapt. There is little reason to doubt sunbathers will adapt. Sunbathers have eyes and ears and reasons to avoid drowning. It takes about 10 seconds for people to get on their feet, hours for the tide to rise, and decades for mean sea level to rise. While this example is deliberately simplistic and of little practical significance, it illustrates the general point that adaptation is of little concern in systems that change rapidly (relative to climate change), monitor their surroundings, and have incentives and abilities to avoid potentially negative consequences of change.

On the other hand, adaptation is potentially problematic in systems that have long turnover times and therefore change slowly, such as dikes and seawalls, drainage and sewage systems, harbours, and cities. These structures or systems could face considerable climate change during their long lifetime. Adaptation would imply making them more robust or more flexible to anticipated changes.

The Thames Barrier in London is an example of making infrastructure more robust. It includes a 1-m/century allowance based on the observed rise in high water levels in the Thames before the barrier being built (Gilbert and Horner, 1984; Kelly, 1991) This translates into a 0.5-m high-water-level rise allowance from 1980 to 2030. Consideration of secular SLR and water level change has been a part of engineering design in the United Kingdom for decades, preceding concerns about human-induced climate change. Other examples of increasing robustness of infrastructure include a sewerage system in Boston (United States), which was raised about 50 cm; reclamations in Hong Kong, which include an allowance for SLR; higher new dikes in the Netherlands, England, and Wales; and the new Northumberland Bridge between Prince Edward's Island and Canada's mainland of New Brunswick, all of which were built to account for a 1-m SLR (de la Vega-Leinert and Nicholls, 2008; Nicholls and Leatherman, 1995; von Koningsveld *et al.,* 2008). In addition, offshore oil platforms are being built higher, but this is mainly to withstand expectation of a more severe wind and wave climate.

In Egypt and elsewhere, family houses provide examples of flexibility in infrastructure, or rather, infrastructure that is easily upgraded. House foundations are built to anticipate additional storeys so the building can be readily extended upwards if the need arises (*e.g.,* a son is getting married) or if the economic situation allows it. Similar flexibility can be designed into piers, groins, seawalls, and much other coastal infrastructure.[2] Many coastal lowlands are subject to relative

[1] This example comes from Howard Gruenspecht.

[2] Flexibility is common for infrastructure that is meant to cope with sea-level variability (*i.e.,* floods). Examples include moveable barriers, ranging from the large Thames and Eastern Scheldt barriers to the hand-operated barriers for individual houses in Spain and the quay doors in Hamburg Harbour. In the context of SLR, flexibility means that the infrastructure can be readily upgraded to a higher design standard or that freeboard is included in the design.

SLR (due to subsidence) and flood defence structures, for example, in Malaysia and the United Kingdom, are designed to be easily raised if so required. Note that flexibility is more than structural design. In the Netherlands, for instance, it is occasionally hard to raise a dike because houses are very close to, and sometimes even partially on, the dike (Tol *et al.,* 2003). Similar issues are emerging as the upgrade of London's flood defences is planned (Lavery and Donovan, 2005).

The assumption underlying these types of adaptation is that retrofitting existing infrastructure is considerably more expensive than designing it to be more flexible or more robust in the first place, additional adaptation costs being negligible in terms of initial building costs. This implies that for all new, long-life (decades or longer) coastal infrastructure, adaptation to SLR and climate change should be considered at the design stage. Generally, anticipatory adaptation of these long-life systems will be cheaper than reactive adaptation.

While the process of adaptation is easiest to illustrate with solid infrastructure, other, "softer" aspects of coastal management such as land use, education, and institutions may be just as hard to change. However, the same general principle holds: the longer it takes to change a system, the earlier adaptation should start. For instance, land-use measures and building setbacks on the coast are more effective if implemented today than in 50 years, when much more of the coast may have been developed.

As indicated in the introduction of this paper, adaptation is closely related to the notion of vulnerability, which is defined as follows in the glossary of the IPCC Third Assessment Report (McCarthy *et al.,* 2001, p. 995):

> The degree to which a system is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Thus, reducing vulnerability is an important goal of anticipatory adaptation. In general, vulnerability can be reduced by the following five anticipatory adaptation strategies (Klein and Tol, 1997):

- Increasing robustness of infrastructural designs and long-term investments—for example, by extending the range of sea levels a coastal system can withstand without failure and/or changing the tolerance of loss or failure (*e.g.,* by increasing economic reserves or insurance)
- Increasing flexibility of vulnerable managed systems—for example, by allowing midterm adjustments (including change of activities or location) and/or reducing economic lifetimes (including increasing depreciation)
- Enhancing adaptability of vulnerable natural systems—for example, by reducing other (nonclimatic) stresses and/or removing barriers to migration (including managed retreat and realignment)
- Reversing trends that increase vulnerability (which is termed "maladaptation")—for example, by introducing setbacks for development in vulnerable areas such as coastal floodplains and landwards of eroding cliffs
- Improving societal awareness and preparedness—for example, by informing the public of the risks and possible consequences of SLR and/or setting up early-warning systems (*e.g.,* for coastal floods due to storm surges)

		Anticipatory	Reactive
Natural Systems			Changes in length of growing season Changes in ecosystem composition Wetland accretion and migration
Human Systems	Private	Purchase of insurance Raising of houses on pilings/stilts Redesign of oil rigs	Changes in coastal tourism Changes in insurance premiums Installation of individual flood doors
	Public	Early-warning systems New building codes and design standards Land use planning and incentives for relocation Shoreline management planning	Compensatory payments and subsidies Disaster relief Shoreline defence

Figure 1. Matrix showing the five types of adaptation prevalent to sea-level rise and climate change, including examples relevant to coastal areas (adapted from Smit *et al.,* 2001).

Anticipatory adaptation is implemented before impacts of climate change are observed, while reactive adaptation takes place in response to impacts. In natural systems adaptation is always reactive, whereas in human systems both reactive and anticipatory adaptation are observed. The goal of reactive adaptation is to minimise damage or maximise opportunities, as well as to prepare for a future similar event. Note that anticipatory adaptation, although future oriented, is typically in reaction to an event (*e.g.,* an adverse projection). Thus, the distinction between anticipatory and reactive adaptation is not always as clear as the definitions would suggest.

Within human systems, we can make a further distinction based on whether adaptation is motivated by private or public interests. Private decision makers include both individual households and commercial companies, while public interests are served by governments at all levels. Figure 1 shows examples of adaptation activities for each of the five types of adaptation that have thus been defined.

Another useful distinction is often made between planned and autonomous adaptation (Carter *et al.,* 1994). Planned adaptation is the result of a deliberate policy decision based on an awareness that conditions have or are about to change and action is required to return to, maintain, or achieve a desired state. Anticipatory planned adaptation, aimed at reducing vulnerability, would apply to one or a combination of the five adaptation strategies listed previously. Autonomous adaptation, on the other hand, involves the "spontaneous" changes that natural and most human systems undergo in response to changing conditions, irrespective of any policy plan or decision. In human systems, this adaptation can be triggered by market or welfare changes related to climate change and hence is incorporated into routine operations in coastal zone management. Improving the capacity for autonomous adaptation, for example, by allowing natural processes to operate to the maximum degree possible or by introducing markets, can be considered an additional form of planned adaptation.

ADAPTATION IN COASTAL ZONES

The vulnerability of coastal communities to SLR depends on their exposure to climatic hazards such as storms, floods and cyclones, erosion, ecosystem changes, and saltwater intrusion. These types of events are likely to become more frequent and intense as sea level rises. There are three basic strategies to reduce society's vulnerability to these events, and for each strategy a range of adaptation options is available (Bijlsma *et al.,* 1996; IPCC, CZMS Staff, 1990; Klein *et al.,* 2001). The three basic strategies are as follows:

- "Protect" to reduce the risk of the event by decreasing its probability of occurrence
- "Retreat" to reduce the risk of the event by limiting its potential effects
- "Accommodate" to increase society's ability to cope with the effects of the event

To identify the most appropriate coastal adaptation strategy, we must consider the full context in which the impacts of climate change arise and realise that the three aforementioned strategies happen within a broader policy process, which includes consideration of numerous nonclimate issues (*e.g.,* Harvey, Clouston, and Carvalhio, 1999; Kay and Adler, 2005). Within this process, increasing resilience by reducing nonclimate stresses could be an important option to reduce coastal vulnerability to climate change. This could be part of an integrated coastal policy aimed at addressing both climate and nonclimate issues (van Koningsveld *et al.,* 2008). Such nonclimate stresses include overexploitation of resources, pollution, increasing nutrient fluxes, decreasing freshwater availability, sediment starvation, and urbanisation (Klein and Nicholls, 1998; Nicholls and Klein, 2005).

Case studies in the Netherlands, the United Kingdom, and Japan (Klein, Nicholls, and Mimura, 1999) have shown that coastal adaptation to climate change can be considered a multistage and iterative process. In each of these countries, management approaches have been adjusted over the past decades to reflect new insights and priorities, including concerns about climate variability and, more recently, climate change. Four basic steps recur in each of the case studies (Klein, Nicholls, and Mimura, 1999):

- Information collection and awareness raising
- Planning and design
- Implementation
- Monitoring and evaluation

Adaptation to climate change in coastal zones has thus been conceptualised as a process that comprises more than merely the implementation of technologies to protect against, retreat from, or accommodate SLR (Klein *et al.,* 2001). Awareness that climate variability, climate change, or both—together with other stresses on the coastal environment brought about by existing management practices—can produce or is producing the impacts that trigger the adaptation cycle is crucial. Measures are planned and designed to reduce the vulnerability of coastal communities or ecosystems to these impacts—a process that is conditioned by policy criteria and coastal development objectives and interacts with existing management practices. Monitoring and evaluation of the performance of the implemented adaptation options is the preferred state under successful adaptation. This may also provide new information and insights leading to adjustments in the adaptation process, thus creating a new adaptation cycle. Lastly, changes in societal values or objectives may lead to changes in what is conceived as successful adaptation, as illustrated by the Delta Project in the Netherlands (van Koningsveld *et al.,* 2008).

It is increasingly argued that assessments of adaptation following currently available methodologies, such as the IPCC Technical Guidelines (Carter *et al.,* 1994), do not provide the kind of information that is useful to policymakers. Implicit in these assessments is the assumption that there are no constraints on implementing the adaptation options identified and analysed. The extent to which mechanisms are in place and technologies, expertise, and other resources are available to implement effective adaptation options is usually not assessed, although inclusion of these aspects is likely to give a more reliable picture of vulnerability to climate change. It is the capacity to adapt rather than the availability of adaptation options that, along with exposure to impacts, determines vulnerability.

ADAPTIVE CAPACITY

Rather than focusing only on the identification and appraisal of adaptation options, adaptation assessment must consider the full context in which adaptation takes place, including the factors that determine the capacity of the country or system to adapt. The IPCC Third Assessment Report of Working Group II uses the term "adaptive capacity" (Smit *et al.,* 2001). As stated earlier, it is one of the three determinants of vulnerability to climate change, along with sensitivity and exposure. Adaptive capacity is loosely defined as a system's ability to respond to changes in its natural environment, alleviate potentially negative effects, and amplify potentially positive effects. The glossary of the IPCC Third Assessment Report defines adaptive capacity as follows (McCarthy *et al.*, 2001, p. 982):

> The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

As such, adaptive capacity is not a one-dimensional concept that can be easily measured. The literature on adaptive capacity is still in its infancy but is growing rapidly (Alberini, Chiabai, and Muehlenbachs, 2006; Kelly and Adger, 2000; O'Brien, Sygna, and Haugen, 2004; Tol and Yohe, 2007; Yohe, 2000; Yohe and Tol, 2002). There is no concrete and agreed guidance as to how adaptive capacity can be assessed, although a range of indicators have been identified that are assumed to be useful predictors. These indicators relate to the determinants of adaptive capacity as listed in the preceding definition. One possible set of factors consists of the following:

- Technological options—Does a society have the technical wherewithal to do something about the problem?
- Resources and their distribution—Can a system afford to do something about the problem? Do the neediest have access to the required economic resources?
- Institutional structure—Are natural resources allocated by markets, by law, or by custom?
- Human capital—Is the population sufficiently educated to grasp future SLR and its potential consequences and to implement adaptation strategies?
- Social capital—Does a society have the trust, norms, and networks to facilitate collective action on adaptation to SLR?
- Risk spreading—Are losses carried by individuals or distributed throughout a larger population?
- Information management—Is information about potential SLR and climate change available to the relevant people?

The important point about the adaptive capacity concept is that successful adaptation requires all the necessary elements to be available to sufficient degrees. Hence, they cannot be substituted, and increasing technological options is not a substitute for faulty information management. Similarly, better education is no substitute for a lack of economic means. At the moment, the concept of adaptive capacity is very much at the conceptual stage, with various elements hypothesised to be important. These hypotheses are inspired by a large number of case studies but have not been tested in empirical studies or even meta-analysis. YOHE and TOL (2002) offer a first attempt to operationalise adaptive capacity, followed by ALBERINI, CHIABAI, and MUEHLENBACHS (2006) and TOL and YOHE (2007).

Based on the papers in this volume and in DE LA VEGA-LEINERT, NICHOLLS, and TOL, 2000, a number of different situations in Europe can be identified. For instance, Norway has a low vulnerability to SLR, with a few notable exceptions. The perception of an invulnerable Norway means that SLR is ignored, even in the areas where it is a real issue. In countries such as Cyprus and Spain, the notion of coastal zone management is fairly recent. Decision makers are occupied with institutionalising this new mandate and combating the current problems for which it was created (largely managing coastal tourism and issues such as coastal erosion). As a result, SLR is neglected, although it is a real issue and decisions are being made that will have long-term consequences. In many of the countries of the Baltic and Black Sea, current political, social, and economic hardships override most concerns for the distant future, and it is interesting that Sweden did not participate in the Synthesis and Upscaling of sea-level Rise Vulnerability Assessment Studies (SURVAS) project. Poland and Germany are exceptions, and coastal plans for SLR are being formulated. These examples illustrate that adaptation to SLR can be a low priority for decision makers for a wide range of reasons and thus will influence adaptive capacity to SLR.

In general, land use in some countries is determined by land zonation and spatial development plans, while in others it is set by market forces. Markets respond rapidly and autonomously to changes in supply and demand, which are in turn influenced by erosion, salinity, and flood risk. In contrast, regulations do not change rapidly—so it is important that the implications of climate change and SLR are integrated into regulations now.

In the Netherlands, the coastal strip is public property and the national government is responsible for coastal defence. In Germany, state governments are responsible for the coast, so the coasts of Lower Saxony, Bremen, Hamburg, and Schleswig-Holstein have different levels of protection against floods. In Ireland, counties are responsible.[3] The European Union plays only a limited role in coastal zone management *per se* (COMMISSION OF THE EUROPEAN COMMUNITIES STAFF, 2000b, 2000a),[4] but it does regulate certain aspects, such as public health (*e.g.,* the Coastal Bathing Water Directive) and nature (*e.g.,* the Habitats Directive), and has recently investigated coastal erosion across the European Union (EUROSION STAFF, 2004). In general, lower levels of government are more responsive to local needs than are higher levels of government, but they have also less resources and access to professional management and advice. Local democracies also have more of a tendency to emphasise short-term needs over long-term solutions, with potential adverse consequences for the planning for SLR and climate change.

Private individuals make decisions in a different manner than do governments and will tend to focus on a narrower self-centred basis—for instance an individual is less concerned about adverse consequences for neighbours. There are also substantial externalities in coastal management. It makes little sense to build a sea defence if your neighbours do not.[5] Governments are much better at handling externalities than are private individuals, and coastal areas are widely perceived as public goods with a high expectation that governments will "protect" coastal residents (KLEIN *et al.,* 2001).

Hence, we have looked at three levels of coastal decision making: national government, local government, and private individuals. They illustrate how different institutions have different ways of adapting to SLR. We cannot say which institutional arrangement is best for adaptation. In some cases, the speed of unregulated markets is needed. In other cases, government intervention is required to regulate externalities or to provide public goods. Under certain circumstances, decentralised management works better, whereas centralisation is best under other conditions. Further research is required to better structure our view of the most appropriate adaptation in the context of the decision-making framework.

ADAPTATION AND DECISION MAKING

In some cases, authorities should take action to encourage adaptation. In other cases, the authorities themselves should

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[3] We are not aware of a review of coastal zone management responsibilities for Europe's coasts that is tailored to the discussion in this paper. Neither the Hamburg workshop (DE LA VEGA-LEINERT, NICHOLLS, and TOL, 2000) nor this special issue provide sufficient information to fill this gap. General reviews can be found in BURBRIDGE and HUMPHREY (2003) and EUCC STAFF (2006).

[4] Interestingly, these recent official EU publications on integrated coastal zone management do not mention SLR or climate change.

[5] Unless you surround your property with a dike!

adapt. Coastal zones are frequently managed by a patchwork of regional, national, and international authorities looking after specific aspects (flooding, drinking water, water quality, transport, land use, nature conservation, *etc.*). Each management decision affects other aspects and other authorities' mandates. There are no well-established rules for solving potential conflicts (GREEN and PENNING-ROWSELL, 1999). Many decisions require lengthy public hearings. In such systems, it has proven very hard to make and implement far-reaching decisions. Only gradual improvements are possible. Such an incremental approach may not be enough to cope with accelerated sea-level rise (ASLR) and other climatic changes.

Some examples of anticipatory adaptation to SLR and climate change have already been listed. Some countries have started with regulation for adaptation. In Canada, all new major infrastructure has to be able to withstand a middle-of-the-road projection of climate change. That is why the Northumberland Bridge was raised. Similarly, shoreline defences in England and Wales must be designed for, or at least be easily upgradeable to, a set ASLR: regional allowances are given in MINISTRY OF AGRICULTURE, FISHERIES AND FOOD STAFF (1999). Irish standards are generally derived from British ones. A one-size-fits-all regulation is easy to enforce but could lead to a series of suboptimal investments as it ignores the large uncertainties about future sea level and climate. More generally, England and Wales has widespread awareness building via the United Kingdom Climate Impacts Programme (http://www.ukcip.org.uk/). In the Netherlands and the United States, regulation is absent but awareness building is widespread. The assumption is that informed, responsible designers of infrastructure would take climate change into account if they knew about it; indeed, due care (otherwise unspecified) is often a legal requirement. Moreover, adaptation decisions would be made, on a case-by-case basis, by the people who know most about the project. In some cases, this works. For example, the Boston sewerage system was upgraded using the discretionary powers of the senior design engineer. Similar cases are known for the Netherlands but are not documented. In other cases, it does not work. For example, this paper and the one by DE LA VEGA-LEINERT, NICHOLLS, and TOL (2000) show that SLR is widely ignored in the design of coastal defences around the Mediterranean (and elsewhere), even though long-term records show a secular rise in sea level and forecasts of more rapid future change have been available for a decade or more (NICHOLLS and HOOZEMANS, 1996; KARACA and NICHOLLS, 2008).

The main agents in coastal adaptation are the managers of climate-sensitive resources in the coastal zone. Knowing most about the system and its sensitivities, they know best about maintaining or improving its performance under SLR and climate change. However, local managers may not be in the position to be able to adapt. They may lack a mandate, information, or resources; they may be restricted by regulations; they may lack the incentives to adapt; or they may depend on other managers' adaptations. In those cases, higher authorities need to act as enablers, regulators, or arbiters to create the appropriate environment for adaptation to occur. Appropriate public participation is also important and can operate in different ways. Political support of the notion of adaptation and the need to adapt is essential to promote compliance. However, such participation can delay or distort actions, especially as short-term issues may rise to the fore at the expense of long-term strategic adaptation. Clearly a balance needs to be found. The details of future SLR and climate change, which matter a great deal to adaptation, are highly uncertain. Decision making about adaptation needs to take account of this uncertainty. One method by which the uncertainties and risks associated with climate change can be integrated into the decision-making process at the policy, programme, and project spatial scales is through an adaptive management approach (CONNELL and WILLOWS, 2003; NATIONAL RESEARCH COUNCIL STAFF, 1995). Adaptive management is considered with the policy cycles discussed by KLEIN, NICHOLLS, and MIMURA (1999) and requires both institutional forms that are capable of "learning by doing" and a toolkit of techniques with which to act at the different levels of decision making.

Decisions can only be as good as the process by which they are taken. This has important implications for the institution involved. For an institution to practise adaptive management, it has to be permeable, absorbing concepts and views from outside and building partnerships with other stakeholders. Consequently, adaptive management requires the cooperation of different stakeholders in different institutions. Adaptive management also means a willingness to learn publicly from experience, even if this may result in what can in hindsight be seen as mistakes. Hence, ongoing monitoring is a fundamental element of adaptive management. Historically, monitoring and evaluation has been rather limited, although this is changing. Under aspirations for an integrated coastal zone management mandate, much more systematic monitoring is anticipated in the future (*e.g.,* BRADBURY, COPE, and DALTON, 2005).

Coastal management over the last 100 years has had a strong tendency to restrict the natural dynamics of coastal systems. The two critical management characteristics of resilient natural systems are that they need space to adapt and are dynamic. Thus, FRENCH (1997, 2001), among others, argues that coastal processes should be allowed enough space to change dynamically over time—which implies larger dynamic buffers between the sea and any human activity at the coast (*cf.* ROCHELLE-NEWALL *et al.,* 2005). It has been proposed that eroding coasts could be allowed to evolve freely between fixed artificial points (which, for economic or other reasons, it is necessary to protect). Similarly, low-lying coastal plains could be opened to tidal flows, creating new estuaries (BURGESS *et al.,* 2003). In Europe's densely populated coasts, there are a number of reasons we cannot walk away from the coast and it is not possible to allow natural coastal processes this full range of dynamic freedom (*e.g.,* RUPP and NICHOLLS, 2003). However, an appropriate compromise might be found that allows more dynamics. This is an interesting multidisciplinary problem that requires the engagement of engineers, natural scientists, and social scientists.

Some systems have to be managed either because they are not dynamically adaptive on their own or because they are

Table 1. *Current status of adaptation to sea-level rise and climate change along Europe's coasts (derived from the papers in this volume; de la Vega-Leinert, Nicholls, and Tol, 2000; Paskoff, 2004).*

Country	Sensitivity	Awareness	Planned Adaptation	Implementation
Black Sea				
Bulgaria	Increases of erosion and flooding could be substantial, but significance unclear	Very low	None specifically related to sea-level rise	None
Romania	Potential increase of erosion	Very low	None specifically related to sea-level rise	None
Turkey	Some increase in cliff recession	Very low	None specifically related to sea-level rise	None
Ukraine	Potential increase of erosion and inundation; negative effects on tourism	Very low	None specifically related to sea-level rise	None
Mediterranean				
Croatia	Potentially large impacts in some significant localities	Very low	None	None
Cyprus	Potentially large impacts in some localities; overall low vulnerability	Low	None specifically related to sea-level rise	Monitoring of sea level, climate, and erosion
France	Enhanced erosion, flooding, and salt intrusion in some economically significant regions	Medium	None specifically related to sea-level rise; current practice deemed sufficent	Monitoring of sea level, climate, and erosion
Greece	Potentially lrge impacts in some localities; overall low vulnerability	Medium to low	None specifically related to sea-level rise	Monitoring of sea level, climate, and erosion
Italy	Large parts of coast susceptible to sea-level rise; socioeconomic implications unclear	Low to medium	None specifically related to sea-level rise	Monitoring of sea level, climate, and erosion
Malta	Enhanced erosion of economically important beaches	Low	None specifically related to sea-level rise	Monitoring of sea level, climate, and erosion
Spain	Enhanced erosion of economically important beaches; greater flood risks, particularly in deltas	Low	None specifically related to sea-level rise	Monitoring of sea level, climate, and erosion; anti-erosion programmes
Turkey	Some increase in cliff recession; greater flood risks for Istanbul; other coastal lowlands threatened	Very low	None specifically related to sea-level rise	None
Atlantic Coast				
France	Enhanced erosion, salt intrusion, and cliff receding in some regions	Medium	None specifically related to sea-level rise; current practice deemed sufficient	Monitoring of sea level, climate, and erosion
Ireland	Overall low vulnerability, with a few exceptions	Low	None specifically related to sea-level rise	Monitoring of sea level, climate, and erosion; development of coastal zone management plans
Portugal	Potentially large impacts on coastal morphology and ecosystems, with little impact on people and economy	Low	None specifically related to sea-level rise; current practice needs to be strengthened	Monitoring of sea level, climate, and erosion
North Sea				
Belgium	Potentially large impacts on coastal zone, with substantial consequences for country	Low	None specifically related to sea-level rise	Monitoring of sea level, climate, and erosion
Denmark	Potentially large impacts on coastal zone, with limited consequences for people and economy	Medium	None specifically related to sea-level rise; current practice deemed sufficient	Monitoring of sea level, climate, and erosion
Germany	Potentially large impacts on coastal zone, with limited consequences for people and economy	High	Current regulations under reconsideration	Monitoring of sea level, climate, and erosion; upgrading of new infrastructure
Netherlands	Potentially large impacts on coastal zone, with dramatic consequences for country	Very high	Maintenance of current safety and service standards	Monitoring of sea level, climate, and erosion; upgrading of new infrastructure
Norway	Potentially substantial impacts on coastal infrastructure; enhanced erosion in south-west, with substantial regional implications	Low	None	Monitoring of sea level, climate, and erosion
United Kingdom	Potentially substantial impacts on coastal zone, with substantial regional implications	Very high	Accelerated sea-level rise is part of current design standards	Upgrading of new infrastructure and coastal zone plans
Baltic Sea				
Estonia	Potentially large impacts on coastal ecosystems	Low	None	None
Germany	Potentially large impacts on coastal zone, with limited consequences for people and economy	High	Current regulations under reconsideration	Monitoring of sea level, climate, and erosion; upgrading of new infrastructure

Table 1. *Continued.*

Country	Sensitivity	Awareness	Planned Adaptation	Implementation
Finland	Large invulnerable	Very low	None	Monitoring of sea level and climate
Lithuania	Potential increases in erosion and flooding; negative impacts on harbours	Low	None specifically related to sea-level rise	Unclear
Poland	Potentially large impacts in coastal zone, with little significance to country	Low	National coastal plan (including SLR) being developed	Monitoring of sea level, climate, and erosion

so closely coupled to the socioeconomic system that their natural dynamic range is unacceptable or unobtainable, such as flooding in coastal urban areas. In managing such systems, the ideal system is one that degrades progressively rather than fails suddenly and one in which interventions are reversible. These ideals might be difficult to achieve in practise.

In designing such systems, it is necessary to consider how all conditions will be managed—not just those up to some indicative standard or level of service. This may need to include considering what will happen when the proposed project fails as the result of an event above the design standard. For instance, hard flood defences may lead to abrupt failure above their design range. Dikes that are resistant to breaching and only overtop when design levels are exceeded is one strategy for reducing this issue. Coupling defence with warning is another method of addressing this problem: this has attracted significant interest in the United Kingdom over the last 10 years. Ideally, a system should not make managing an event when it fails more difficult than managing that event had the system not existed. Likewise, because time to act is so important, it is preferable that failure should occur slowly and that the curve for the expected loss against the probability of the event causing that loss should not contain major discontinuities (such as breaching).

CURRENT ADAPTATION THINKING AND PRACTICE IN EUROPE

Table 1 compares the coastal countries of Europe with regard to their sensitivity to SLR, their awareness of that sensitivity, adaptation measures that are planned, and those that are (being) implemented.

The sensitivity of Europe's coasts differs dramatically from one place to the next. The extensive, low-lying coastal zones of Belgium, the Netherlands, Germany, and Poland are highly sensitive, and in Belgium and the Netherlands the coast is densely populated as well. Other countries, such as France and Norway, have regions that are highly sensitive, but overall sensitivity is low. Throughout the Mediterranean, the worries about SLR are its impacts on the highly valuable beaches and the low-lying deltas. In most places, coastal ecosystems are likely to come under additional pressure given ASLR.

Awareness of these problems varies as much as does sensitivity. Along the Black Sea Coast, perhaps highly sensitive, only a handful of people are aware of the problem. In the United Kingdom and the Netherlands, knowledge of SLR and its consequences are widespread, not only in the relevant scientific and management circles but also among the public. Other countries lie somewhere between. In the Mediterranean, awareness is largely limited to academics, while policymakers and the public have more immediate concerns about present coastal problems. In Denmark and France, current coastal zone management policies are deemed sufficient to cope with ASLR. In some countries, low awareness coincides with low susceptibility (*e.g.,* Ireland and Finland); in other countries, low awareness reflects false security (*e.g.,* Belgium and Denmark).

In some countries, awareness has already led to plans to adapt. These are particularly developed in Germany, the Netherlands, and the United Kingdom, although other countries, such as Poland, are planning future responses. The United Kingdom and the Netherlands have implemented countermeasures already. In other countries, current policies are thought to be sufficient (*e.g.,* Denmark and France). In yet other countries, the first priority is to get current coastal zone management policies to work (*e.g.,* Greece, Portugal, and Spain). The worst off are Turkey and the countries of Central Eastern Europe. These countries generally lack an adequate coastal monitoring programme, so changes go unnoticed and eventual policy formulation lacks a knowledge base.

DISCUSSION AND CONCLUSION

Adaptation has a great potential to reduce potential impacts of ASLR and climate change on the coastal areas of Europe (and elsewhere). Such adaptation builds on existing adaptation to climate variability and other coastal hazards, such as flood management around the southern North Sea. Although conceptual insights into adaptation are growing, the empirical knowledge is still lacking of how adaptation to SLR would work in reality, what the potential benefits and problems (including maladaptation) are, and how adaptation fits into current coastal zone management practices. These are important questions for future research, where European countries could benefit from one another's experience.

Our limited survey of current adaptation practices in Europe's coastal zones suggests that there are crudely four types of countries. First, there are countries that do not worry about ASLR, and should not as their coasts are not susceptible. Second, there are countries that do not worry because they have more urgent problems. Such countries should change their policies, perhaps with outside support, because small changes in current coastal zone management could make large differences to their coastal vulnerability in the future. Third, there are countries that do not worry but should, as their coasts are susceptible to SLR. In these cases, raising awareness is the appropriate response, and the academic community definitely has a role to play in this regard. Fourth, there are countries that do worry and have started to adapt. This last group of countries and their adjustments of their coastal zone management should form one of the empirical pillars of the future research suggested earlier.

The preceding is a snapshot of a dynamic situation, and it is our impression that awareness of the issues studied in this paper is increasing. However, it will take continued efforts to make a difference to the issue of adaptation in Europe. Given the scale of the problem, there is a need for a concerted effort to assess and promote appropriate adaptation to climate change and SLR in coastal zones across Europe. Appropriate proactive adaptation should be implemented within the wider context of coastal management, including explicit monitoring and learning. Building on the European Union's current review of the issue of adaptation to climate change across all sectors, it could play an important role in promoting research, sharing experience, and establishing appropriate methods for adaptation in coastal zones. Further development of pan-European perspectives, such as EUROSION, would also foster better understanding of how mitigation (to reduce climate change) and adaptation (to manage the impacts of climate change) might be combined (NICHOLLS and LOWE, 2004). This would also facilitate linking adaptation to wider coastal policy, which is presently lacking.

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