Tyndall Centre for Climate Change Research

Scaling adaptation: climate change response and coastal management in the UK

Roger Few, Katrina Brown
and Emma L. Tompkins

October 2004

Tyndall Centre for Climate Change Research Working Paper 60

Scaling adaptation:
climate change response and coastal management in the UK

Dr Roger Few
Overseas Development Group, University of East Anglia,
Norwich NR4 7TJ

Professor Katrina Brown
School of Development Studies, University of East Anglia,
Norwich NR4 7TJ

Dr Emma L. Tompkins
Tyndall Centre for Climate Change Research,
School of Environmental Sciences, University of East Anglia,
Norwich NR4 7TJ

Email: r.few@uea.ac.uk
k.brown@uea.ac.uk
e.tompkins@uea.ac.uk

Tyndall Centre Working Paper No.60

October 2004

This paper has been submitted to Environment and Planning A
(September 2004)

Tyndall working papers are "work in progress". Whilst they are commented on by Tyndall researchers, they have not been subject to a full peer review. The accuracy of this work and the conclusions reached are the responsibility of the author(s) alone and not the Tyndall Centre.

Summary

The focus of this paper is on scale dilemmas in environmental decision-making, particularly those dilemmas posed in space and time by the challenges of societal adaptation to climate change impacts. The analysis draws insights from a case study of strategic coastal management and decision-making at Christchurch Bay in southern England, where communities face long term threats of increased coastal erosion and coastal flooding.

In terms of spatial scale, the paper exposes a mismatch between the broad geographical scale at which strategic planning takes place in the UK and the narrower spatial scale of decision-making on coastal management interventions. In terms of temporal scale, it finds that the time horizons of coastal planning are generally too short to mandate consideration of climate change impacts. Both sets of scale issues inhibit anticipatory response capacity of institutions, and the barriers to adaptation are particularly evident at the local decision-making scale in the context of local political, financial and technical constraints. Together, they point to a 'problem of fit' between the climate change threat and local capacity to take advance action to address that threat, under conditions of long term change and scientific uncertainty.

1. Introduction

There is a growing body of work in geography, political ecology and related disciplines addressing the complexity of scale issues in environmental politics and decision-making. Recent contributions to this journal by Bridge and Jonas (2002) and Sneddon (2003), for example, have expressed the subtlety with which processes of power can weave through environmental negotiation by actors at different levels, shaping knowledge production, conflict and governance. Much revolves around the relative roles and discursive positioning of actors operating with different spatial perspectives and timeframes.

Here we bring this sensitivity to scale issues into a sphere of environmental discourse that has grown rapidly to international prominence, but which, we argue, has not benefited sufficiently to date from attention to the politics of scale: adaptation to climate change. Specifically, we look at decision-making processes regarding future coastal defence management in the UK in the face of potential future changes in sea level, rainfall and storm patterns.

In the case of climate change scale is thrown into particularly sharp relief, firstly because of the global scale of the phenomenon but local scale of impacts and potential action, and, secondly, because of the temporal scale of predicted impacts that may occur at an uncertain time in the future. It is these characteristics, we argue, that generate particular challenges for coastal management and decision-making. This paper first reviews ideas about scale in environmental governance: how scale has been understood and approached in different analyses, and why scale matters in discussions about climate change. It then discusses climate change and decision-making with reference to the management of coastal zones, before moving to the main case study material on future coastal defence management in Christchurch Bay in southern England. Through detailed empirical analysis, the paper illuminates technical and administrative aspects of spatial and temporal scale that currently inhibit response capacity of society to future coastal hazards.

2. Why scale matters for environmental governance

Four major challenges are commonly identified in the literature identifying problems of scale in socio-ecological systems: the mismatch in scales between human systems and natural systems; the tendency to define issues at one scale; mismatch between scales of knowledge and management; and inattention to cross-scale interactions and linkages in human-environment systems. These issues have been characterised as 'problems of fit' (Pritchard et al, 1998). Problems of fit have been identified to explain the difficulties in designing appropriate institutions to manage complex multi-scalar environmental problems and reconciling multiple objectives and multiple actors and interests, such as conservation and development (for example, Brown, 2003; Brown and Rosendo, 2000). However, conventional analysis of environmental governance tends to approach 'levels' of decision-making as discrete or even independent from each other (Adger et al, 2003), although an emerging area of literature is concerned with the analysis of cross-scale institutions and environmental governance (Berkes, 2002). Indeed, Ostrom et al (1999) argue the need for institutional diversity to tackle complex environmental problems such as climate change and biodiversity loss.

The choice of scale is not politically neutral as the selection may intentionally or unintentionally privilege certain groups (Millennium Ecosystem Assessment, 2003). Cowell's analysis of environmental compensation schemes in Cardiff Bay (Cowell, 2003) exposes the politics of scale in revealing how relations of ecological and political scale frame the so-called 'decision space' within which debates and policy develops. The author argues that considerations of scale and the politics of scale are critical and are "centrally important in mediating the moral and political dilemmas that interpreting sustainability implies; whether that is the need to balance autonomy for particular social groups with more universal agendas or reconciling the claims of 'global' (scientific) and 'local' knowledge" (Cowell, 2003, page 343). Scale is not a given then, it is not pre-determined, and, as Cowell shows, environmental problems are re-scaled in terms of the decision-space and the objects of governance themselves. This reconfiguration and re-defining of the issue is a typical discursive strategy for those involved in environmental conflicts (Meadowcroft, 2002). This is particularly the case for climate change, a global phenomenon re-scaled to local impacts and adaptation and to governance at many different political scales.

In the existing climate change literature, scale has often been seen as an issue concerned with the resolution of integrated assessment models, or with the desire to bring national and sub-national policy interventions and regulations in line with international agreements. Yet, as Wilbanks (2002) suggests in a paper geared toward enhancing consideration of spatial and temporal scale in climate change modelling, there are wider ontological and epistemological issues that need to be addressed concerning cross-scale linkages between processes of change, scalar distinctions in the operation of agency and structure, and the need to examine complexities at the local scale to inform macro-scale understanding. The scale issues in environmental decision-making are multi-dimensional, and until now very little has been written on the political challenges these issues pose for responses to potential climate change impacts.

3. Climate change and coastal management

Information from climate science is providing an ever more sophisticated picture of possible climate alteration in future decades. In its Third Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) drew on a series of modelling approaches to estimate the global parameters of future change. These suggest that

over the next 100 years, a rise of between 1.4 ºC and 5.8 ºC might be expected in average near-surface temperatures, bringing a range of associated changes including increase in sea level and alterations in patterns of precipitation and storm events (IPCC, 2001).

The accumulating weight of scientific evidence is now pointing strongly to the prospect of human-induced changes in climate: the problem is knowing how fast the process of change will take place and precisely what might be its effects. Confident prediction of the speed, the magnitude and, in some cases, even the direction of change remains an elusive goal partly because of imprecision in scientific understanding of how climate systems function and partly because we do not know how effective climate change mitigation actions will be in the coming decades: whether global emissions of greenhouse gases will increase, stabilize or decrease (Hulme et al, 2002). Hence a high degree of uncertainty is inherent in any attempts to provide quantified predictions.

Yet, for coastal zones in particular, the potential consequences of climate change are a cause of mounting concern. Coastal areas are perceived as particularly vulnerable to the impacts of climate change because they are subject to changes both in the marine environment and in the terrestrial environment. They would be affected by sea level rise, and any changes in storm surges and wave heights, and they would also be affected by changes inland, including alterations in river flow regimes.

According to the UK Climate Impacts Programme, over the next century the UK is likely to experience a number of key changes, including higher tides, higher winter rainfall and possibly an increase in storm surges (Hulme et al, 2002). The 'Foresight Future Flooding' report raises the prospect of a 4-10 fold increase in coastal flood risk by the 2080s as a result of sea level rise alone (Evans et al, 2004). Indeed, many coastal sites of the UK are expected to suffer increasingly from combined river and tidal floods, when storm conditions create high tides that prevent high levels of river runoff discharging into the sea. Altogether, the number of properties in England thought to be at risk from coastal flooding and coastal erosion over the next 100 years has been estimated as over one million (Defra, 2004).

Climate change therefore poses special dilemmas for coastal management. On the one hand the worst-case impacts of climate change may be highly significant in coastal zones, requiring a concerted adaptive response in specific locales. As articulated by Bijlsma et al (1996), the alternative strategies available for coastal adaptation to climate change impacts are often categorised in terms of 'protect', 'accommodate' or 'retreat' options. Protection from flooding/erosion could include at the extreme massive engineered sea defences, such as high sea walls and embankments, or large-scale beach nourishment and other high-maintenance 'soft' defences. Accommodation might mean measures to cope with regular inundation such as extensive flood-proofing or elevation of property, modification of urban drainage systems and raising of roads. Retreat means major changes in land use and the distribution of homes away from vulnerable sites, involving perhaps acquisition of land and property by public authorities, planning set-back zones or subsidies to coastal dwellers to relocate inland. (For further examples of response options see Bray et al, 1997 and Klein et al, 2001).

Yet, on the other hand, not only are most changes likely to take place over long (multi-generational) timescales, but the task of defining what may take place at specific sites is clouded by uncertainty. Together, these aspects of the problem make it difficult to formulate an adaptive strategy. Tackling the climate change threat

therefore places complex demands on coastal decision-making processes – demands that we argue have important scale dimensions in time and space.

4. Christchurch Bay: climate change and coastal defence

To illustrate scaling issues in adaptation the paper draws on a case study of coastal defence management at Christchurch Bay on the south coast of England. The future of coastal defence (encompassing both flood defence and coast protection against erosion) is a major management issue in this area - one that, as for many coastal sites of the UK, is likely to become more acute in the context of climate change (Evans et al, 2003; SCOPAC, 2001).

The coastline of Christchurch Bay stretches 18km from the elevated headland of Hengistbury Head in Dorset to the narrow, shingle promontory of Hurst Spit in Hampshire (see Figure 1). For most of its length the sweeping curve of the bay is fronted by cliffs of relatively unresistant geological composition that are subject to high natural rates of erosion: average rates of more then 1.5m per year have been recorded in some undefended sections (Wright *in* Bray and Hooke, 1998). To the west, the cliff line is broken where the lower valleys of the rivers Stour and Avon combine to form Christchurch Harbour, the sheltered waters of which are connected to the sea by a narrow channel. The Christchurch Bay coast and its immediate hinterland are largely urbanised, but lightly-industrialised. Primarily residential land use runs almost continuously along the west of the Bay from Christchurch to Barton-on-Sea. Further to the east lies the settlement of Milford-on-Sea, flanked by open land of agricultural, recreational and conservation use. Administratively, the eastern section lies within New Forest District in the county of Hampshire. The western section lies mostly within the Borough of Christchurch in the county of Dorset, with Hengistbury Head apportioned to the neighbouring Borough of Bournemouth.

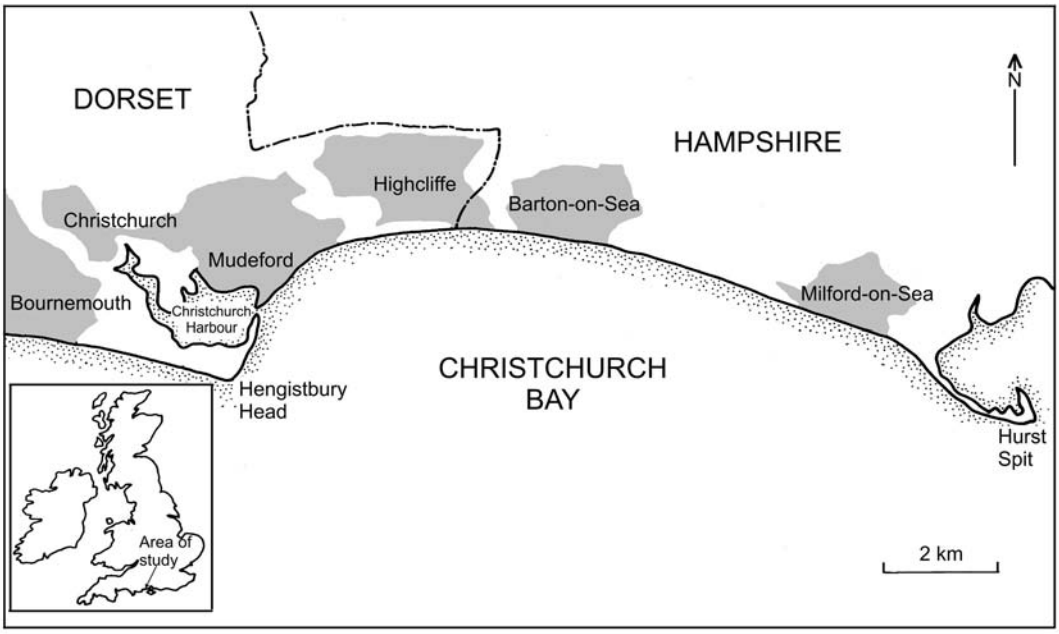

Figure 1 Case study site: Christchurch Bay, UK

Initial consultations for the study suggested that coastal defence was the predominant local concern relating to climate change in the Christchurch Bay area. Rising sea level and/or potential changes in precipitation, wave regimes and severe

weather systems would likely exacerbate present threats from cliff erosion and sea flooding around the Bay (Hosking et al, 2002; Wade et al, 1999). Much of the coastline already has hard and soft engineered sea defences and future strategies for defences are currently being developed. However, some of the existing works appear to have caused changes of longshore sediment supply that have themselves impacted on coastal defence elsewhere (Bray and Hooke, 1998). There is also some concern expressed about future riverine/tidal flooding, affecting particularly some of the urbanised portions of the coast (Halcrow Group, 1999; Hampshire County Council, 2003).

Two sites within the Bay area selected for more detailed research were Christchurch Harbour and Barton-on-Sea. Christchurch Harbour is urbanised along most of its north shore, except for the very low-lying Stanpit Marsh. Open recreational and protected areas cover Hengistbury Head to the south, with some 360 beach huts clustered along the narrow spit of Mudeford Sandbank, which separates the harbour from the sea. Barton-on-Sea stands along part of the naturally fast-eroding, cliffed coastline on the Hampshire stretch of Christchurch Bay. A 60-100m wide strip of mostly recreational land runs along the clifftop itself, with the town's residential development stretching behind. However, there are also approximately 15 residential and commercial properties lying within the strip, some less than 10m from the cliff edge itself. To the east of the town lies a golf course and to the west is a holiday village development.

Possible climate change impacts and responses

Assessment of future risks and potential responses to coastal hazards is already well advanced for the Christchurch Bay area, through the strategic work relating to Shoreline Management Plans, the work of SCOPAC (Standing Conference on Problems Associated with the Coastline), and a range of academic and applied studies. It is not the purpose of this study to reassess those predictions and plans. However, some description is necessary to set the context for our discussion of decision-making processes.

In brief, climate change is likely to exacerbate existing erosion and flooding trends, through a gradual rise in sea level and potentially through an increase in winter rainfall and storm conditions (SCOPAC, 2001). There may also be significant changes in wave direction and sediment transport regimes, though such shifts are much harder to predict (Halcrow Group, 2003; Wade et al 1999). The greatest certainty is attached to the prediction that sea level will rise. However, even the highest estimate of its rate of change suggests that sea level rise alone is unlikely to cause major impacts in most parts of the Bay during the present century. At both Barton and Christchurch Harbour, higher winter rainfall is potentially a more significant factor in exacerbating coastal changes that could be hazardous. At Barton groundwater seepage through the rocks of the cliff is a prime cause of cliff instability (Mackintosh and Rainbow, 1996), while the Harbour area may be especially prone to future flooding from a combination of high winter river flow and extreme tidal events (Christchurch Borough Council, 2001).

The largely urbanised coastline of Christchurch Bay heightens the risk of socio-economic impacts following coastal erosion and flooding. Existing and future hazards present a physical risk to properties and infrastructure close to the shore, as well as a threat to life and livelihood of the coastal population. Moreover, outside the urban areas, the coastal resources - including beaches, inland waters and cliffs - have high recreational and conservation value that might be placed at risk by coastal processes (Halcrow Group, 1999).

To date, various hard and soft engineering techniques have been applied in the Christchurch Bay area to reduce wave attack and minimize flooding, the majority undertaken by public agencies (currently the local authorities and Environment Agency). Most have been based on the premise that existing property and land use patterns should be protected – a perspective that Naylor et al (2003) suggest has become a deep-seated public and institutional expectation.

Around Christchurch Harbour there has been recent upgrading of coast protection and upstream flood defence works because of the potential for breaching and erosion of the sandbank, leading to flooding and wave attack on harbour-side properties, and because of the threat of riverine flooding to Christchurch town. These works are designed to withstand the tide, surge and wave attack of a 1 in 200 year storm event and provide protection against 1 in 100 year river floods. However, the northern shore of the harbour has mostly ageing, private sea defences that are not integrated to form a single line of defence – presently there are no planned public works here. In the Barton-on-Sea area, coast protection works intended to retard erosion have been applied along the Barton frontage only – and the current plans for coast protection do not seek to extend this line of defence (Halcrow Group, 1999). The future maintenance of the existing works was currently under review at the time of the research, as part of a general integrated review of coastal defence strategies for the entire coastline by the local authorities.

In the late 1990s the first Shoreline Management Plans were generated for the Christchurch Bay area (Halcrow Group, 1998; Halcrow Group, 1999). The first stage in a new strategic integrated approach to coastal defence management, they suggest policies for defence options for specified units of coastline over a 50 year timescale (Brampton, 2002). The four generic options in the first round of plans were 'hold the existing line', 'advance the existing line', 'retreat the existing line' and 'do nothing' (Halcrow Group, 1999). Currently the plans are under revision and the maritime authorities have also commissioned the next stage of the strategic approach – coastal strategy plans which will set closer technical guidelines for defence schemes. In the Christchurch Bay area, the planning process explicitly takes into account predictions of sea level rise of 5mm per year and certain other climatic change allowances including 15% increase in rainfall over the next 50 years (Halcrow Group, 2003).

As implied in the suite of Shoreline Management Plan options, however, the construction of coastal defence works is not the only potential response to flooding and erosion risk. Coastal engineers are now mandated to regard *not* defending as an alternative management option. As already noted, adaptation to climate change at the coast can be conceived in terms of three alternatives: protection, accommodation and retreat (Bijlsma et al, 1996). The latter two, and to some extent the first, suggest that responsibility for tackling future risks can lie in sectors beyond coast protection, including development control, storm drainage provision and spatial planning (Crichton, 2003; Klein et al, 2001). In the case study area some regulatory guidelines exist on new development within delimited erosion risk areas. However there appears to have been no strategic planning to date relating to adaptation of urban drainage systems to accommodate rising sea levels, or to the definition of long term spatial planning goals to allow for a settlement retreat process from sites of high risk.

Key stakeholders in coastal management

Response to coastal risk need not be the sole province of public agencies – arguably all stakeholders in the area have a potential role to play in adapting to climate

change hazards, both privately and collectively. Local stakeholders in the case study fall into two basic, but partially-overlapping categories: those directly vulnerable to climate change impacts; and those who play a role in decisions on coastal defence and management.

Since, as noted, predictions of climate change and associated impacts fall into an 'envelope of possibilities', we do not attempt to offer here a meaningful numerical estimate of population at risk from flooding and coast erosion within the Christchurch Bay area. However, it is feasible instead to identify stakeholder groups whose interests may be placed at risk. At Barton-on-Sea, more than 15 properties stand adjacent to the cliff edge and continuing clifftop recession means they 'will probably be lost in the next 20 years' (NFDC, 1997). Behind them stands a 1850m long frontage of continuous residential development, which may be at physical risk after several decades. The unprotected sections flanking the town will steadily be eroded, with loss of land and structures. At Christchurch Harbour, hundreds of properties are potentially vulnerable to tidal and/or riverine flooding include those running along the northern harbour shore and Mudeford Sandbank, and those in low-lying land at Christchurch and neighbouring centres.

At both sites, there are further groups whose livelihoods and lifestyles may be affected. They include people who use the harbour waters for commercial and recreational fishing, sailing and mooring, and those who value the landscape amenity and biodiversity of Hengistbury Head, Stanpit Marsh and the Barton cliffs. In broader terms, physical impacts may conceivably have wider socio-economic repercussions for local communities, such as the loss of key infrastructure, impacts on tourism revenue and disruption of business (Metcalf et al, 2003; SCOPAC, 2001).

Those stakeholders whose role is confined to decision-making are principally public sector bodies. Authority for coastal zone activities in the UK is shared by an array of organisations (Local Government Association, 2000). Responsibility for terrestrial coastal management in general falls to the standardised tiers of government: national, regional, county and district/borough. Coast protection is implemented in the Christchurch Bay area by the district/borough authorities, who are now mandated to take a long term view via the strategic coastal defence planning mechanisms. Increasingly the authorities are broadening the scope of their considerations to cover not just property protection issues but also environmental and amenity factors that might work counter to this. For example, at Barton-on-Sea, decisions are likely to be influenced by arguments against the cessation of cliff erosion: the continuation of exposure of fossil-bearing strata and the maintenance of longshore sediment supply (Halcrow Group, 1999). The local and county authorities are also responsible for other decision spheres, including development control and land use planning.

Decision-making is also influenced by institutions at regional and national level, such as English Nature, English Heritage, Environment Agency and Department for Environment, Food and Rural Affairs (Defra). The first two are commonly consulted by coast defence planners in relation to conservation and archaeology. The Environment Agency has responsibility for flood defence on the rivers and around the harbour, and now takes certain predictions of future climatic changes into account in planning defences, via cost-benefit calculations and design criteria. Defra provides central government funding to the Environment Agency and local authorities for 35-80% of the value of capital projects for flood defences and coast protection.

Decisions on coastal management are also influenced by advisory groups, representing public and private organisations, including SCOPAC and the Dorset

Coast Forum. The former, which has a narrower focus on the coastline, has taken a particularly active role in strategic advisory work on shoreline management. A Christchurch Harbour Group also exists, but its membership is confined to public agencies and the local water company. As is common with local coastal fora (McGlashan, 2003), none of these bodies has statutory powers. Recent years have also seen the emergence of public/private partnership activities focussing on climate change, including the Hampshire and Isle of Wight Climate Change Summit and regional studies on the impacts of climate change for South-east and South-west England (Christchurch Bay falls between the two regions). Again these bodies have a wide public and private membership, but no statutory powers.

Table 1 provides a basic categorisation of the principal stakeholders and stakeholder groups and their principal interests in coastal defence decisions for Christchurch Bay. (In producing this simple table we stress that, given the complexity of decision processes, no assessment can reasonably include all those people or organizations at international, national, regional and local scales that ultimately impinge on decisions. Nor can the categorizations fully reflect the diverse identities and cross-groupings of local populations).

Key stakeholder group	**Prime interests in coastal defence decisions**
Local	
1 Vulnerable property/land owners	Protect asset, amenity
2 Commercial bay/harbour users	Protect moorings, access to sea
3 Local recreational user groups	Access, safety, moorings
4 Local conservation groups	Habitat conservation
5 Local residents	Local economy/amenity
6 Local businesses	Protect asset, client access
7 Local government	Local economy, amenity, conservation, public safety, coastal defence
8 Coastal advisory groups	Sustainable coastal development
National/regional	
9 Environment Agency	Flood protection, value for money
10 English Heritage	Archaeological preservation/record
11 English Nature	Habitat conservation, geological exposure
12 Defra	Coast/river defence, value for money
13 Regional climate change partnerships	Strategic planning to address climate change impacts

Table 1 Stakeholder assessment: Christchurch Bay

The following sections (5-7) of the paper develop a series of analytical themes that draw insights from the case study material for Christchurch Bay and from broader analysis of UK climate change and coastal management issues at regional and national levels. Data collection for the case study comprised consultation of local planning and coastal management documents, semi-structured interviews with a total of 38 local/regional stakeholders (from resident groups, community-based organisations, recreational groups, local businesses and public authorities), and a participatory workshop with a cross-section of coastal stakeholders on future management approaches in the context of climate change.

5. Central-local discontinuity: an issue of spatial scale

Presently, strategic coastal zone management activity in relation to climate change takes place predominantly at the regional or national scale. In national government, Defra has taken the lead in inserting climate change adaptation issues into government policy, both through its coastal defence and other funding operations and in commissioning a recent study on the implications of climate change for government activity (Defra, 2003). Planning Policy Guidance Note 25 from the Office of the Deputy Prime Minister (ODPM) is another central government policy advance, stating explicitly that development in flood risk zones should take account of climate change impacts. Input at the regional level from regional government, and from climate change and coastal management fora provides further policy level advice.

Ultimately, however, coastal management relies not just on policy but on actual intervention. In the case of response to climate change impacts on coastal hazards, generic policy must translate into specific physical actions designed to prevent, manage or retreat from flooding and erosion. It is just this continuity of long-term planning between scales from policy to action that the research has brought into question.

Within the narrow zone of the coastline itself, major and novel efforts are now underway to create an integrated system of strategic planning that translates broad options for shoreline protection into proposals for specific sites and interventions (Ballinger et al, 2002; Brampton, 2002). This process explicitly takes into account predictions of climate change impacts. The Poole and Christchurch Bays Shoreline Management Plan, for example, recommends a continuation of 'hold the line' defences for Mudeford Sandbank, a low-lying spit across the entrance of Christchurch Harbour (Halcrow Group, 1999). The presence of the spit reduces wave attack in the harbour and attenuates tidal range by narrowing the harbour entrance (Christchurch Borough Council, 1997). Christchurch Borough Council decided to upgrade the defences, opting for a set of new rock groynes and a rolling programme of beach nourishment. The scheme is intended to cope with changing conditions over its design life of 50 years. Similar considerations are now part of the design process for flood alleviation inland (Defra, 2003).

However, though the narrow approach to planning for shoreline intervention may be sufficient in cases where secure protection is feasible, in others consideration of climate change impacts will have major implications for the hinterland beyond the shoreline strip. Options of partial protection or less will require adaptation of land use, infrastructure, buildings and perhaps even the settlement pattern itself to prepare for predicted risks of erosion and inundation (Bray et al, 1997; Crichton, 2003).

Neither Barton-on-Sea nor parts of Christchurch Harbour can be regarded as having complete security of protection in the long term. Funding for the future provision of defences for the Barton coastline cannot be guaranteed, with the prospect of

potentially inexorable recession of the cliffline and loss of housing, roads and amenity space. Christchurch Harbour might seem well defended at its mouth, but agency and local level officials expressed concern about the potentially severe impacts of combined river/tidal flood events on Christchurch town, the prospect of sea level rise disrupting urban drainage systems, and the possibility of a catastrophic breach to the south across the low-lying portion of Hengistbury Head. Mudeford Sandbank itself has been vulnerable to past breaching during high seas, which caused extensive flooding around the harbour (Christchurch Borough Council, 1997). Engineers interviewed predicted that natural or artificial sedimentation processes will enable the sandbank to maintain its height vis-a-vis a rising sea level, but pointed out that this assumption depends heavily on the assumption that present beach recharge will continue along the beaches further to the west.

Preparedness against these risks requires specific plans and actions from local authorities in a range of sectors, including development control, highways and utilities and, in the most strategic sense, from spatial planning (Leafe et al, 1998; Titus et al, 1987). Yet, at present, the local authorities under study have no requirement to make specific plans for action within these sectors based on long term (multi-decade) assessments of need, let alone of climate change. For reasons discussed in section 5, in the absence of this requirement there is little or no effective planning for climate change impacts at this level, and hence a mismatch between the nascent generic policy statements at national/regional scale and actions at the local scale in terms of intervention decisions.

One particular aspect stressed repeatedly in generic policy is that coastal defence protection can no longer be assumed. Paragraph 9 of Planning Policy Guidance Note 25 states that: 'some existing development in more exposed locations may not be sustainable in the longer term and may need to be replaced in safer locations' (ODPM, 2001). Both the regional studies noted above emphasize that a balance of protection, accommodation and retreat will be necessary in areas of coastal risk, and that this will require some difficult decision-making. "Some areas may have to be sacrificed to rising sea levels and this will provide some difficult choices for the future" (Metcalf et al, 2003, page 6.17).

It is unclear at present how such intervention options articulated at the coarse scale are going to be followed through at a scale where fine resolution is required: local implementation 'on the ground'. At the local level, at present, few areas of the UK have explicitly been marked for managed realignment of the coast (Naylor et al, 2003), let alone for a phased 'retreat' of settlement. The political controversy of doing is likely to be considerable. Yet, given the potential for increasing climate change impacts, their implications for fiscal budgets, and the broader environmental considerations all reflected in generic policy statements, it is a conceivable response (Leafe et al, 1998). At some stage it may have to happen. Is retreat, either planned or de facto, not a potential future scenario for 'frontline' settlements at places such as Barton and Christchurch Harbour?

6. Short-termism: an issue of temporal scale

As already has been made evident, active adaptation to climate change implies a consideration of long-term strategy. Although much climate change impact is predicted to take the form of a continuous or incremental intensification of current hazards, the rate of change is unlikely to bring significantly greater impact for several decades. In the Christchurch Bay area it may be well into the second half of the 21st century before sea level rise and altered weather patterns compromise the design capacity of sea defences or bring major changes to cliff erosion rates. Predictions of

climate change therefore increase the challenge to coastal management to take strategic long term planning decisions (TCPA, 2003; UKCIP et al, 2003). (It should be noted that the above assumes the absence of any emissions-induced catastrophic change to global hydrometerological systems in the short term: a prospect that remains a low-probability, but high-consequence 'wild-card' in the climate change debate (Hulme, 2003)).

Yet, organisations concerned with flood and coastal management in the UK have been charged with short-termism in relation to existing hazards, let alone any potential changes in these hazards (Cobbold and Santeema, 2001; Metcalf et al, 2003). Even if there were no climate change impact, cliff erosion along the Barton coastline would be an ongoing process. Unless retarded by major protection works it will almost certainly have implications for property and land ownership and for the distribution of settlement within the coming decades. However, apart from a 'redlining' measure to prevent new development within a predicted 60-year erosion risk belt along the clifftop (NFDC, 1999), local authority planners presently argue they can make no long term provision for other adaptive measures such as the relocation of infrastructure and housing (which by its nature requires advance planning). If erosion rates increase because of higher levels of winter rainfall and sea level rise, the physical threats to existing development may accelerate. Similarly, as noted above, there is limited long term planning within the boroughs responsible for Christchurch Harbour. Only the coastal protection sector is able to take any sort of multi-generational perspective in its work.

In this respect coastal management institutions receive little formal empowerment from central government to develop long term strategy. Although Defra is putting in place provision for shoreline management planning to take into account risks 100 years from now, the discounting of future costs and benefits in project appraisal, coupled with cyclical funding for schemes means that planning tends to remain on a much shorter time horizon. Short-termism is yet more pronounced within spatial planning, where central government has provided no mandate for local planning authorities to plan for the long term. The timescale for the current Local Plans for both New Forest District and Christchurch Borough runs only to 2011, a forward planning period advised by Regional Planning Guidance. In future, local development frameworks will have to comply with new regional spatial strategies from the regional authorities, but even for these the time horizon is likely to be limited to 20-30 years, according to one regional-level interviewee.

Yet timing is another crucial aspect of climate change response, because advance adaptation - especially that which requires radical action – requires a long lead-in to allow sufficient time for public inclusion, negotiation, integrated planning and implementation. Moreover, if authorities are to implement settlement retreat processes they will need central government to provide new guidelines and enabling legislation in key areas (Bray et al, 1997). They may require concomitant statutory measures to be enacted for compensation and acquisition of property in erosion or flood risk zones (Crichton, 2003; Halcrow Group, 1999). According to one local planner, they will also need incorporation of longer time horizons into planning guidelines if they are to make a financial case for settlement retreat.

It should be noted that actions to tackle climate change risks need not relate only to future impacts. For some coastal management issues it may be feasible to follow a cautious approach of concentrating in the short term on adaptive measures that simultaneously serve immediate needs (Kay and Alder, 1999). However, the scope of such adaptive responses is limited. Kay and Alder (1999) go on to suggest that

this approach can only go so far before a more concerted response is required that may raise difficult trade-offs between short term and long term benefits.

7. Local difficulties?

A recurrent theme in the case study work in the Christchurch Bay area is the difficulty of undertaking localised decision-making for coastal management in the context of potential climate change. Study participants from both public and private sectors identified a series of impediments to strategic adaptive planning at the local scale.

On the one hand, local authorities, and their planning departments in particular, are severely constrained not just by the time limits of their planning mandate, but also by resource constraints (Ballinger et al, 2002). Respondents within the planning system pointed to the lack of concrete evidence on climate change impacts on which to base decisions as well as the technical ability within their offices to interpret that information. These factors acted together with other demands on limited human and financial resources within local government that tend to enforce a short-term outlook among planners and the prioritization of immediate urgent matters. According to one local planner strategic work on issues such as climate change is difficult for a local authority, which is basically an "all-singing, all-dancing body that only scratches the surface of most issues" (Interview: Christchurch, February 2003). All of these issues work against proactive long term planning in the absence of a clear mandate on authorities to undertake such efforts.

On the other hand, it is not only state agencies that may have a role to play in adaptive decision-making. Coastal management can also be the responsibility of private stakeholders, both as individuals and collectively, through the decisions they make about defence, usage and retention of their property, and through the prospects for public involvement in decision-making fora. At present, the latter are poorly developed, although governmental decisions may take advice from cross-sector partnerships such as coastal groups or from stakeholder representatives on liaison committees. The principal channel for public input on decisions is currently via elected local representatives on council committees. In these contexts, more subtle but perhaps more fundamental constraints on local action were identified, again by a spectrum of local respondents.

First, a number of respondents from different backgrounds questioned the motivation and capacity of local citizens to consider long-term issues and particularly those that span an inter-generational time scale. This echoes comments reported by Treby and Clark (2004) on public willingness to engage in strategic future management issues for the Hampshire coast. The concept of 'sustainable development', with its long term planning implications, may now have common currency in resource management discourse, but no assumption can be made that it has wide public acceptance (Warburton, 1998). Competing immediate priorities should not automatically be regarded in a negative sense, of course, but public input into decision-making arguably is devalued if information on long-term implications of climate change is insufficiently accessible and if wide public debate on such novel issues is not facilitated. A case can at least be made that lack of consideration by the public of the long term is a cause for concern.

Second, responding to the prospect of climate change under conditions of uncertainty and long-term impact is not only 'complex' (Willows and Connell, 2003) but inherently controversial. It requires active decision-making on financing and implementing action targeted to changes that may or may not arise, whose

magnitude is unknown and that are likely to become manifest over timescales of more than one generation (Kay and Alder, 1999). If the adaptive measure under consideration entails some kind of radical change – such as large-scale defence works, major alteration of infrastructure or phased abandonment of dwellings – the implications are yet more controversial. For example, loss of property and amenity, changes to local economies and landscapes, biodiversity changes, and even threats to place-based identity are all potential impacts of different adaptive responses to climate change around Christchurch Harbour. Interview material suggests that decisions on any long term option pursued in the present will almost certainly have to contend with strong dissenting voices.

As King (2003) points out, disagreement, in itself, is not necessarily an impediment to considered decision-making, but several study participants argued that the political conditions of local democracy in the UK can make it so. Proposals that generate controversy and that do not have a strong advocative lobby among the public are difficult for council members to consider rationally, they claimed, because of the short term local political cycles. Councillors elected every four years are unwilling to take decisions on local issues that may be unpopular with their constituencies, that are opposed by a vociferous minority, or that entail long term financial commitment with no obvious short term benefits. Local governance, they argued, is ill-equipped for strategic decisions of such nature.

One regional level interviewee also pointed out that contemporary economic and developmental political priorities (such as housing shortage) can run counter to any strategic attempt to consider the long term viability of established settlement in coasts and floodplains. It is difficult to talk of the vulnerability of areas in cases where the current political momentum is toward promoting development.

8. Conclusions

The scale issues in time and space discussed in this paper have important implications for coastal management practice, posing major challenges for adaptive response to potential climate change impacts. In both senses, they highlight ‘problems of fit’ between the climate change threat and the structure or capacity of institutions to take concrete action to address that threat.

Time might seem to be on our side in preparing for long term impacts of climate change, but the magnitude of those possible impacts suggests that effective adaptation may itself require lengthy processes of technical, legislative and social change. If the climate change threat is to be taken seriously, there may need to be concerted effort now to initiate such strategic processes. Yet, the timing of response to climate change impacts by coastal management agencies will almost inevitably be affected by pragmatic as well as strategic considerations: by issues such as available resources, funding, competing policy priorities and public support for adaptive measures. Presently, planning and funding guidelines at all levels in the UK do not enable long term considerations to have a major influence on present-day coastal management activity. Mechanisms are therefore needed to extend the time horizons for coastal planning and decision-making. Without such extended horizons it will be difficult to justify and source expenditure on anticipatory action to tackle the predicted effects of climate change.

Spatial scale of response is also a crucial issue. In the case study there is to some degree a mismatch between the strategic analysis of climate change adaptation needs undertaken at national or regional scale and the capacity and mandate of a range of agencies at the local scale to decide on and coordinate specific adaptive

action in specific places. In the UK there is, as yet, no statutory integrated coastal zone management (ICZM) planning – although, at the time of writing, the UK government is currently reviewing coastal management arrangements and developing a strategic response to a European Union Recommendation on ICZM. Yet, the problems of long timescale and scientific uncertainty that complicate response to climate change risks may in many cases strengthen the case for vertically as well as horizontally integrated structures for coastal zone management (emphasized in the recent Foresight Future Flooding report for the UK - Evans et al, 2004). Even in circumstances where decision-making structures on coastal management may be seen to form a nested hierarchy of authority, that does not mean that there is necessarily operational equivalence between the different levels (Gibson et al, 2000). The fact that each tier operates at a distinctive geographical scale means that successful integration cannot be presumed. Vertical integration of planning requires a continuity of policy and action between those scales. In order to create a continuity between strategic policy relating to climate change and action 'on the ground' we suggest there is a need to invest resources in local adaptive capacity, strengthen local long-term planning mechanisms and establish genuinely cross-scale institutions on coastal management to take and support what may be difficult decisions.

The research in Christchurch Bay suggests a need for a cross-scalar approach to coastal decision-making and perhaps new forms of collective involvement if society is to address long term climate risks. However, there are also more fundamental issues arising from this exploration of temporal and spatial issues that ultimately may prove more critical in shaping response capacity at the local level to climate change impacts. The case study highlighted issues of motivation, and hence politics, that may limit societal capacity to tackle the inter-generational problem of long-term climate change adaptation, especially when the precise rates of impact are uncertain. As Dovers (1995, page 96) suggests in a discussion of temporal scale in sustainability policy issues: "there will be some point at which potential, but very far-off impacts will be judged outside the pragmatic or moral realm of responsibility". Society may respond in pragmatic terms by delaying action until changes become more manifest, even though this may lead to high future costs. Alternatively, if society is to take action to address such long-term risks and take decisions that may be controversial in the short term then this may reinforce a centralization of decision-making, limiting the scope for locally-based, participatory action. Such a trend would run counter to calls for greater local responsibilities and rights that underscore much of the advocacy for inclusive and integrated coastal management (Kay et al, 2003; McGlashan, 2003; O'Riordan and Ward, 1997). This is an issue that we plan to explore in greater depth in subsequent work.

The analysis of place-specific responses to climate change risks is a crucial undertaking for the climate change research community. It requires us to explicitly consider how adaptation to climate change sits with other priorities and issues: the extent to which it is embedded and entwined and sometimes confused with other issues. But the importance of such studies is not confined to one global environmental problem. Understanding the context and socio-economic and political dynamics of adaptive responses adds a new dimension to our knowledge of environmental change governance in general. It reveals in part the politics of sustainable development and the decision spaces that can be opened, closed and exploited, with implications for the development of institutions for environmental governance at multiple scales.

Acknowledgements

The research on which this paper is based was carried out under project T2.42 funded by the Tyndall Centre for Climate Change Research, UK.

References

Adger W N, Brown K, Fairbrass J, Jordan A, Paavola J, Rosendo S, Seyfang G (2003) Governance for sustainability: towards a 'thick' analysis of environmental decision-making *Environment and Planning A* 35, 1095-1110

Ballinger R, Taussik J, Potts J (2002) *Managing coastal risk: making the shared coastal responsibility work.* Summary Report to the Local Government Association's Special Interest Group on Coastal Issues, Local Government Association, London

Berkes F (2002) Cross-scale institutional linkages: perspectives from the bottom-up, in *Drama of the Commons* National Research Council, (National Academy Press, Washington DC) pp 263-292

Bijlsma L, Ehler C N, Klein R J T, Kulshrestha S M, McLean R F, Mimura N, Nicholls R J, Nurse L A, Pérez Nieto H, Stakhiv E Z, Turner R K, Warrick R A (1996) Coastal zones and small islands, in *Climate Change 1995 - Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses.* Eds R T Watson, M C Zinyowera, R H Moss (Cambridge University Press, Cambridge) pp 289-324

Brampton A (Ed) (2002) *Coastal Defence* (Thomas Telford, London)

Bray M, Hooke J, Carter D (1997) Planning for sea-level rise on the south coast of England: advising the decision-makers *Transactions of the Institute of British Geographers* NS 22, 13-30

Bray M, Hooke J (1998) Geomorphology and management of sites in Poole and Christchurch Bays, in *Coastal Defence and Earth Science Observation* Ed J Hooke (The Geological Society, Bath) pp 233-266

Bridge G, Jonas A E G (2002) Governing nature: the reregulation of resource access, production, and consumption (Guest editorial) *Environment and Planning A* 34, 759-766

Brown K (2003) Integrating conservation and development: A case of institutional misfit *Frontiers in Ecology and the Environment* 1 479-487

Brown K, Rosendo S (2000) The institutional architecture of extractive reserves in Brazil *Geographical Journal* 166 (1), 35-48

Christchurch Borough Council (1997) *Mudeford Sandbank C.P.W.: environmental impact assessment*, Christchurch Borough Council, Christchurch, Dorset

Christchurch Borough Council (2001) *Borough of Christchurch local plan*, Christchurch Borough Council, Christchurch, Dorset

Cobbold C, Santema R (2001) *Going Dutch on the Manhood Peninsula*, Report from Going Dutch on the Manhood Peninsula workshop, Chichester, UK, March 2001

Cowell R (2003) Substitution and scalar politics: negotiating environmental compensation in Cardiff Bay *Geoforum* 34, 343-358

Crichton D (2003) *Flood risk and insurance in England and Wales: are there lessons to be learned from Scotland?,* Technical Paper 1, Benfield Greig Hazard Research Centre, http://www.benfieldhrc.org/

Defra (2003) *The Impacts of Climate Change: Implications for Defra. Report by the In House Policy Consultancy* (Department for Environment, Food and Rural Affairs, London)

Defra (2004) *Making Space for Water: Developing a New Government Strategy for Flood and Coastal Erosion Risk Management in England* (Department for Environment, Food and Rural Affairs, London)

Dovers S (1995) A framework for scaling and framing policy problems in sustainability *Ecological Economics* 12, 93-106

Evans E, Penning-Rowsell E, Hall J (2003) *Foresight Flood and Coastal Defence Project. Phase 1 Technical Report: drivers, scenarios and work plan*, Working Paper, Office of Science and Technology, London.

Evans E, Ashley R, Hall J, Penning-Rowsell E, Saul A, Sayers P, Thorne C, Watkinson A, 2004 *Foresight. Future Flooding. Scientific Summary: Volume I Future risks and their drivers* (Office of Science and Technology, London)

Gibson C, Ostrom E, Ahn T (2000) The concept of scale and the human dimensions of global change: a survey *Ecological Economics* 32, 217-239

Halcrow Group (1998) *Western Solent and Southampton Water shoreline management plan*, Halcrow Group Ltd, Burderop Park, Swindon, Wiltshire, UK

Halcrow Group (1999) *Poole and Christchurch Bays shoreline management plan*, Halcrow Group Ltd, Burderop Park, Swindon, Wiltshire, UK

Halcrow Group (2003) *Poole and Christchurch Bay Strategy Studies: discussion paper on Hengistbury Head*, Halcrow Group Ltd, Burderop Park, Swindon, Wiltshire, UK

Hampshire County Council (2003) *Hampshire Water Strategy* Hampshire County Council, http://www.hampshireswater.org.uk/#

Hosking A, Moore R, Parsons A, Bray M, Lee M, McInnes R (2002) *Assessing the impacts of climate change on the SCOPAC coast*, paper presented at Defra 36th Flood and Coastal Management Conference, 2002.

Hulme M, Jenkins G, Lu X, Turnpenny J, Mitchell T, Jones R, Lowe J, Murphy J, Hassell D, Boorman P, McDonald R, Hill S (2002) *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report* Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK

Hulme M (2003) Abrupt climate change: can society cope? Tyndall Centre Working Paper 30 http://www.tyndall.ac.uk/publications/

IPCC (2001) *Climate Change 2001: The Scientific Basis.* [Eds Houghton J, Ding Y, Griggs D, Noguer M, van der Linden P, Dai X, Maskell K, Johnson C,] (Cambridge University Press, Cambridge)

Kay R, Alder J (1999) *Coastal Planning and Management* (E & FN Spon, London)

Kay R, Alder J, Brown D, Houghton P (2003) Management cybernetics: a new institutional framework for coastal management *Coastal Management* 31, 213-227

King G (2003) The role of participation in the European Demonstration Projects in ICZM *Coastal Management* 31, 137-143

Klein R, Nicholls R, Ragoonaden S, Capobianco M, Aston J, Buckley E (2001) Technological options for adaptation to climate change in coastal zones *Journal of coastal Research* 17 (3), 531-543

Leafe R, Pethick J, Townend I (1998) Realizing the benefits of shoreline management *The Geographical Journal* 164 (3), 282-290

Local Government Association (2000) *On the Edge – the Coastal Strategy* (Local Government Association, London)

Mackintosh I, Rainbow J (1996) *Naish Beach, Barton-on-Sea Coast Protection Scheme*, Engineers Report, New Forest District Council, Town Hall, Avenue Road, Lymington, Hampshire, UK

McGlashan D (2003) Funding in integrated coastal zone management partnerships *Marine Pollution Bulletin* 46, 393-396

Meadowcroft J (2002) Politics and scale: some implications for environmental governance *Landscape and Urban Planning* 61, 169-179

Metcalf G, Chambers F, Charlesworth A, Forrest V, Hunt J, McEwen L, Russell K, Schofield S (Eds) (2003) Warming to the idea, Technical Report, South West Region Climate Change Impacts Scoping Study, http://www.oursouthwest.com/climate/scopingstudy.htm

Millennium Ecosystem Assessment (2003) *Ecosystems and Human Well-being: A Framework for Assessment* (Island Press, Washington DC)

Naylor L, O'Riordan T, Gill J, Watkinson A (2003) Climate change and the coastal challenge: innovative means of stakeholder involvement, in *ICE ICZM 2003 Proceedings* (Thomas Telford, London)

NFDC (1997) *Coastal management plan*, New Forest District Council, Town Hall, Avenue Road, Lymington, Hampshire, UK

NFDC (1999) *Adopted New Forest District local plan*, New Forest District Council, Appletree Court, Lyndhurst, Hampshire, UK

ODPM, (2001) *Planning policy guidance note 25: development and flood risk* Office of the Deputy Prime Minister http://www.odpm.gov.uk/stellent/groups/odpm_planning/documents/page/odpm_plan_606931.hcsp

O'Riordan T, Ward R (1997) Building trust in shoreline management: creating participatory consultation in shoreline management plans *Land Use Policy* 14 (4) 257-276

Ostrom E, Burger J, Field C N, Norgaard R B, Policansky D (1999) Revisiting the commons: local lessons, global challenges *Science* 284, 278-282

Pritchard L, Colding J, Berkes F, Svedin U, Folke C (1998) *The problem of fit between ecosystems and institutions*, IHDP Working Paper 2, IHDP, Bonn, Germany

SCOPAC (2001) *Preparing for the impacts of climate change: a strategy for long term planning and management of the shoreline in the context of climate change predictions*, Standing Conference on Problems Associated with the Coastline, c/o Isle of Wight Council, County Hall, Newport, Isle of Wight, UK

Sneddon C (2003) Reconfiguring scale and power: the Khong-Chi-Mun project in northeast Thailand *Environment and Planning A* 35, 2229-2250

TCPA (2003) *Climate change*, TCPA policy statement, Town and Country Planning Association, London, UK

Titus J, Kuo C, Gibbs M, LaRoche T, Webb M, Waddell J (1987) Greenhouse effect, sea level rise, and coastal drainage systems *Journal of Water Resources Planning and Management* 113 (2), 216-225

Treby E, Clark M (2004) Refining a practical approach to participatory decision making: an example from coastal zone management *Coastal Management* 32 353-372

UKCIP, LGA, IDeA, COSLA, Welsh Local Government Association (2003) *Climate Change and Local Communities – How Prepared Are You? An adaptation guide for local authorities in the UK* (UKCIP, Oxford)

Wade S, Hossell J, Hough M, Fenn C (Eds) (1999) *The Impacts of Climate Change in the South East: Technical Report* (WS Atkins, Epsom)

Warburton D (1998) A passionate dialogue: community and sustainable development in *Community and Sustainable Development: Participation in the Future* Ed D Warburton (Earthscan, London) pp 1-39

Wilbanks T J (2002) Geographic scaling issues in integrated assessments of climate change" *Integrated Assessment* 3, 100-114

Willows R, Connell R (Eds) (2003) *Climate adaptation: risk, uncertainty and decision-making* UKCIP Technical Report, UK Climate Impacts Programme, Oxford, UK

Tyndall Centre for Climate Change Research

The trans-disciplinary Tyndall Centre for Climate Change Research undertakes integrated research into the long-term consequences of climate change for society and into the development of sustainable responses that governments, business-leaders and decision-makers can evaluate and implement. Achieving these objectives brings together UK climate scientists, social scientists, engineers and economists in a unique collaborative research effort.

Research at the Tyndall Centre is organised into four research themes that collectively contribute to all aspects of the climate change issue: Integrating Frameworks; Decarbonising Modern Societies; Adapting to Climate Change; and Sustaining the Coastal Zone. All thematic fields address a clear problem posed to society by climate change, and will generate results to guide the strategic development of climate change mitigation and adaptation policies at local, national and global scales.

The Tyndall Centre is named after the 19th century UK scientist John Tyndall, who was the first to prove the Earth's natural greenhouse effect and suggested that slight changes in atmospheric composition could bring about climate variations. In addition, he was committed to improving the quality of science education and knowledge.

The Tyndall Centre is a partnership of the following institutions:
University of East Anglia
UMIST
Southampton Oceanography Centre
University of Southampton
University of Cambridge
Centre for Ecology and Hydrology
SPRU – Science and Technology Policy Research (University of Sussex)
Institute for Transport Studies (University of Leeds)
Complex Systems Management Centre (Cranfield University)
Energy Research Unit (CLRC Rutherford Appleton Laboratory)

The Centre is core funded by the following organisations:

- Natural Environmental Research Council (NERC)
- Economic and Social Research Council (ESRC)
- Engineering and Physical Sciences Research Council (EPSRC)
- UK Government Department of Trade and Industry (DTI)

For more information, visit the Tyndall Centre Web site (www.tyndall.ac.uk) or contact:
External Communications Manager
Tyndall Centre for Climate Change Research
University of East Anglia, Norwich NR4 7TJ, UK
Phone: +44 (0) 1603 59 3906; Fax: +44 (0) 1603 59 3901
Email: tyndall@uea.ac.uk

Tyndall Centre for Climate Change Research

Recent Working Papers

Tyndall Working Papers are available online at
http://www.tyndall.ac.uk/publications/working_papers/working_papers.shtml

Mitchell, T. and Hulme, M. (2000). **A Country-by-Country Analysis of Past and Future Warming Rates**, Tyndall Centre Working Paper 1.

Hulme, M. (2001). **Integrated Assessment Models**, Tyndall Centre Working Paper 2.

Berkhout, F, Hertin, J. and Jordan, A. J. (2001). **Socio-economic futures in climate change impact assessment: using scenarios as 'learning machines'**, Tyndall Centre Working Paper 3.

Barker, T. and Ekins, P. (2001). **How High are the Costs of Kyoto for the US Economy?**, Tyndall Centre Working Paper 4.

Barnett, J. (2001). **The issue of 'Adverse Effects and the Impacts of Response Measures' in the UNFCCC**, Tyndall Centre Working Paper 5.

Goodess, C.M., Hulme, M. and Osborn, T. (2001). **The identification and evaluation of suitable scenario development methods for the estimation of future probabilities of extreme weather events**, Tyndall Centre Working Paper 6.

Barnett, J. (2001). **Security and Climate Change**, Tyndall Centre Working Paper 7.

Adger, W. N. (2001). **Social Capital and Climate Change**, Tyndall Centre Working Paper 8.

Barnett, J. and Adger, W. N. (2001). **Climate Dangers and Atoll Countries**, Tyndall Centre Working Paper 9.

Gough, C., Taylor, I. and Shackley, S. (2001). **Burying Carbon under the Sea: An Initial Exploration of Public Opinions**, Tyndall Centre Working Paper 10.

Barker, T. (2001). **Representing the Integrated Assessment of Climate Change, Adaptation and Mitigation**, Tyndall Centre Working Paper 11.

Dessai, S., (2001). **The climate regime from The Hague to Marrakech: Saving or sinking the Kyoto Protocol?,** Tyndall Centre Working Paper 12.

Dewick, P., Green K., Miozzo, M., (2002). **Technological Change, Industry Structure and the Environment**, Tyndall Centre Working Paper 13.

Shackley, S. and Gough, C., (2002). **The Use of Integrated Assessment: An Institutional Analysis Perspective**, Tyndall Centre Working Paper 14.

Köhler, J.H., (2002). **Long run technical change in an energy-environment-economy (E3) model for an IA system: A model of Kondratiev waves**, Tyndall Centre Working Paper 15.

Adger, W.N., Huq, S., Brown, K., Conway, D. and Hulme, M. (2002). **Adaptation to climate change: Setting the Agenda for Development Policy and Research**, Tyndall Centre Working Paper 16.

Dutton, G., (2002). **Hydrogen Energy Technology**, Tyndall Centre Working Paper 17.

Watson, J. (2002). **The development of large technical systems: implications for hydrogen**, Tyndall Centre Working Paper 18.

Pridmore, A. and Bristow, A., (2002). **The role of hydrogen in powering road transport**, Tyndall Centre Working Paper 19.

Turnpenny, J. (2002). **Reviewing organisational use of scenarios: Case study - evaluating UK energy policy options**, Tyndall Centre Working Paper 20.

Watson, W. J. (2002). **Renewables and CHP Deployment in the UK to 2020**, Tyndall Centre Working Paper 21.

Watson, W.J., Hertin, J., Randall, T., Gough, C. (2002). **Renewable Energy and Combined Heat and Power Resources in the UK**, Tyndall Centre Working Paper 22.

Paavola, J. and Adger, W.N. (2002). **Justice and adaptation to climate change**, Tyndall Centre Working Paper 23.

Xueguang Wu, Jenkins, N. and Strbac, G. (2002). **Impact of Integrating Renewables and CHP into the UK Transmission Network**, Tyndall Centre Working Paper 24

Xueguang Wu, Mutale, J., Jenkins, N. and Strbac, G. (2003). **An investigation of Network Splitting for Fault Level Reduction**, Tyndall Centre Working Paper 25

Tyndall Centre
for Climate Change Research

Brooks, N. and Adger W.N. (2003). **Country level risk measures of climate-related natural disasters and implications for adaptation to climate change**, Tyndall Centre Working Paper 26

Tompkins, E.L. and Adger, W.N. (2003). **Building resilience to climate change through adaptive management of natural resources**, Tyndall Centre Working Paper 27

Dessai, S., Adger, W.N., Hulme, M., Köhler, J.H., Turnpenny, J. and Warren, R. (2003). **Defining and experiencing dangerous climate change**, Tyndall Centre Working Paper 28

Brown, K. and Corbera, E. (2003). **A Multi-Criteria Assessment Framework for Carbon-Mitigation Projects: Putting "development" in the centre of decision-making**, Tyndall Centre Working Paper 29

Hulme, M. (2003). **Abrupt climate change: can society cope?**, Tyndall Centre Working Paper 30

Turnpenny, J., Haxeltine A. and O'Riordan, T. (2003). **A scoping study of UK user needs for managing climate futures. Part 1 of the pilot-phase interactive integrated assessment process (Aurion Project)**, Tyndall Centre Working Paper 31

Xueguang Wu, Jenkins, N. and Strbac, G. (2003). **Integrating Renewables and CHP into the UK Electricity System: Investigation of the impact of network faults on the stability of large offshore wind farms**, Tyndall Centre Working Paper 32

Pridmore, A., Bristow, A.L., May, A. D. and Tight, M.R. (2003). **Climate Change, Impacts, Future Scenarios and the Role of Transport**, Tyndall Centre Working Paper 33

Dessai, S., Hulme, M (2003). **Does climate policy need probabilities?,** Tyndall Centre Working Paper 34

Tompkins, E. L. and Hurlston, L. (2003). **Report to the Cayman Islands' Government. Adaptation lessons learned from responding to tropical cyclones by the Cayman Islands' Government, 1988 – 2002,** Tyndall Centre Working Paper 35

Kröger, K. Fergusson, M. and Skinner, I. (2003). **Critical Issues in Decarbonising Transport: The Role of Technologies,** Tyndall Centre Working Paper 36

Ingham, A. and Ulph, A. (2003) **Uncertainty, Irreversibility, Precaution and the Social Cost of Carbon,** Tyndall Centre Working Paper 37

Brooks, N. (2003). **Vulnerability, risk and adaptation: a conceptual framework**, Tyndall Centre Working Paper 38

Tompkins, E.L. and Adger, W.N. (2003). **Defining response capacity to enhance climate change policy**, Tyndall Centre Working Paper 39

Klein, R.J.T., Lisa Schipper, E. and Dessai, S. (2003), **Integrating mitigation and adaptation into climate and development policy: three research questions**, Tyndall Centre Working Paper 40

Watson, J. (2003), **UK Electricity Scenarios for 2050**, Tyndall Centre Working Paper 41

Kim, J. A. (2003), **Sustainable Development and the CDM: A South African Case Study**, Tyndall Centre Working Paper 42

Anderson, D. and Winne, S. (2003), **Innovation and Threshold Effects in Technology Responses to Climate Change**, Tyndall Centre Working Paper 43

Shackley, S., McLachlan, C. and Gough, C. (2004) **The Public Perceptions of Carbon Capture and Storage**, Tyndall Centre Working Paper 44

Purdy, R. and Macrory, R. (2004) **Geological carbon sequestration: critical legal issues**, Tyndall Centre Working Paper 45

Watson, J., Tetteh, A., Dutton, G., Bristow, A., Kelly, C., Page, M. and Pridmore, A., (2004) **UK Hydrogen Futures to 2050**, Tyndall Centre Working Paper 46

Berkhout, F., Hertin, J. and Gann, D. M., (2004) **Learning to adapt: Organisational adaptation to climate change impacts**, Tyndall Centre Working Paper 47

Pan, H. (2004) **The evolution of economic structure under technological development**, Tyndall Centre Working Paper 48

Awerbuch, S. (2004) **Restructuring our electricity networks to promote decarbonisation**, Tyndall Centre Working Paper 49

Powell, J.C., Peters, M.D., Ruddell, A. & Halliday, J. (2004) **Fuel Cells for a Sustainable Future?** Tyndall Centre Working Paper 50

Tyndall Centre for Climate Change Research

Agnolucci, P., Barker, T. & Ekins, P. (2004) **Hysteresis and energy demand: the Announcement Effects and the effects of the UK climate change levy** Tyndall Centre Working Paper 51

Agnolucci, P. (2004) **Ex post evaluations of CO2 –Based Taxes: A Survey** Tyndall Centre Working Paper 52

Agnolucci, P. & Ekins, P. (2004) **The Announcement Effect and environmental taxation** Tyndall Centre Working Paper 53

Turnpenny, J., Carney, S., Haxeltine, A., & O'Riordan, T. (2004) **Developing regional and local scenarios for climate change mitigation and adaptation, Part 1: A framing of the East of England** Tyndall Centre Working Paper 54

Mitchell, T.D. Carter, T.R., Jones, .P.D, Hulme, M. and New, M. (2004) **A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100)**, Tyndall Centre Working Paper 55

Vincent, K. (2004) **Creating an index of social vulnerability to climate change for Africa**, Tyndall Centre Working Paper 56

Shackley, S., Reiche, A. and Mander, S (2004) **The Public Perceptions of Underground Coal Gasification (UCG): A Pilot Study**, Tyndall Centre Working Paper 57

Bray, D and Shackley, S. (2004) **The Social Simulation of The Public Perceptions of Weather Events and their Effect upon the Development of Belief in Anthropogenic Climate Change**, Tyndall Centre Working Paper 58

Anderson, D and Winne, S. (2004) **Modelling Innovation and Threshold Effects In Climate Change Mitigation**, Tyndall Centre Working Paper 59

Few, R., Brown, K. and Tompkins, E.L. (2004) **Scaling adaptation: climate change response and coastal management in the UK**, Tyndall Centre Working Paper 60