The Adaptation-Resistance Spectrum: a classification of contemporary adaptation approaches to climate-related coastal change

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Abstract

The realisation of climate change and its potential impacts on coastal environments and coastal communities has prompted much activity in the realm of 'adaptation'. Adaptation is typically viewed as actions in response to climate change that seek to limit its impacts and/or bring some benefit to human society. In this paper we consider adaptation actions in response to the twin risks of coastal flooding and recession both of which are likely to increase in frequency/rate and magnitude as a result of global climate change. Adaptation actions are classified on a spectrum based on the degree of planned modification of (i) human activities or (ii) the physical coastal environment.

At one end of the spectrum is a set of activities that involve changing human activities to suit the changing environment (e.g. innovative building design, relocation of infrastructure and/or people, changing landuse or livelihoods). At the other extreme are activities (e.g. building or raising flood defences, building or strengthening seawalls, nourishing beaches) that involve resisting environmental change in order to preserve existing infrastructure and human activities. Between these two extremes are a few initiatives that involve components of both approaches. A qualitative review of current practice suggests that most adaptation activity is in the category of seeking to preserve human activities and infrastructure. This form of response is better termed 'resistance' than 'adaptation'. These conservative and short-term goals of protecting fixed assets and existing activities, are damaging to the environment, involve significant cost and increase future risk of catastrophic failure. Those measures that involve adaptation of human activities in response to the changing coastal environment are likely to be more sustainable in the longer term, but are politically more difficult to implement.

1. Introduction

Global climate change is manifest in different ways according to location. There is consequently great variability in the nature and degree to which its impacts will be reflected in the natural and built environment. In coastal zones global climate change is generally and primarily manifest in rising sea levels, changes in precipitation (amount, timing and nature), changing wind and wave patterns, increased land and sea temperatures and ocean acidification. Other impacts related to the frequency of extreme events, and delivery of sediment (e.g. from rivers) are highly site-specific. These factors interact with each other and produce a range of subsequent changes in the natural and human coastal environment (Cooper, 2008). It is anticipated that human interaction with the coast will change as a result of global climate change, creating a new relationship between humans and their coastal environment. The way in which humans react to these actual or projected changes is frequently termed 'adaptation' (Adger et al., 2009).

There is a significant body of literature on the need for adaptation to climate change and the constraints (legislative social, political and economic) upon it. There is rather less discussion on the nature of actual adaptation measures beyond individual or regional case studies (Kenchington et al., 2012). The European Commission (2007, p.3) provides as examples of adaptation, "using scarce water more efficiently, adapting existing building codes to stand future climate conditions and extreme weather events, construction of flood walls and raising levels of dykes against sea level rise, development of drought tolerant crops, selection of forestry species and practices less vulnerable to storms and fires, development of spatial plans and corridors to help species migrate". In this paper we assess the types of actions being undertaken as adaptation measures in coastal environments in response to the likelihood of increased rates of shoreline recession and flooding. On the basis of the extent to which these adaptation measures represent modifications of the environment or of human actions, we present a novel classification.

2. Definitions of Adaptation

Adaptation has been defined in many different ways. Early definitions of 'adaptation' reviewed by Klein and Tol (1997) include:

- The process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides (Burton, 1992);
- Adjustments to enhance the viability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events as well as longer-term climate change (Smit, 1993);
- Any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change (Stakhiv, 1993);
- All adjustments in behaviour or economic structure that reduce the vulnerability of society to changes in the climate system (Smith, 1996).

The UNFCCC (United Nations Framework Convention on Climate Change) website (http://unfccc.int/focus/adaptation/items/6999.php) glossary subsequently (2006) defined adaptation as:

- Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.
- 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
- A process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented. (UNDP, 2006)
- The process or outcome of a process that leads to a reduction in harm or risk of harm, or realisation of benefits associated with climate variability and climate change. (UK Climate Impact Programme - UKCIP, 2003)

In a report for OECD (The Organisation for Economic Co-operation and Development) the following definitions are provided and discussed (Levin and Tirpak, 2006):

- 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 (IPCC TAR, 2001)
- Practical steps to protect countries and communities from the likely disruption and damage that will result from effects of climate change. For example, flood walls should be built and in numerous cases it is probably advisable to move human settlements out of flood plains and other low-lying areas…" (UNFCCC)
- A process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented. (UNDP, 2006)
- The process or outcome of a process that leads to a reduction in harm or risk of harm, or realisation of benefits associated with climate variability and climate change (UK Climate Impact Programme (UKCIP, 2003)).

The European Commission (2007, p.3) considers that "Adaptation actions are taken to cope with a changing climate, e.g. increased rainfall, higher temperatures, scarcer water resources or more frequent storms, [either] at present or anticipating such changes in future. Adaptation aims at reducing the risk and damage from current and future harmful impacts cost-effectively or exploiting potential benefits [...] Adaptation can encompass national or regional strategies as well as practical steps taken at community level or by individuals. Adaptation measures can be anticipatory or reactive. Adaptation applies to natural as well as to human systems. Ensuring the sustainability of investments over their entire lifetime taking explicit account of a changing climate is often referred to as 'climate proofing'."

This selection of definitions demonstrates some commonalities and some major differences in conceptions of adaptation. Some definitions restrict adaptation to human actions while others include natural changes. Levina and Tirpak (2006) contend that the term would benefit from further clarification. Until such times as that happens, they recommended use of the IPCC TAR (2001) definition above. This definition, however, includes natural responses of the environment to climate change. These are by definition, outside the realm of human influence and are therefore in themselves outside most conceptions of 'adaptation' which limit the concept to changes influenced by deliberate human actions.

Central to all of the definitions of adaptation is the reduction of harm and/or realisation of benefits to humans. In the coastal zone the notion of harm and benefits has, however, been shown to vary according to the individual's perspective (Cooper and McKenna, 2008a) and deciding on which human benefit to favour in taking decisions on adaptation is not straightforward. For example, protection of land on a retreating sandy shoreline by coastal defences may be beneficial to the landowner (at least in the short term and especially if someone else pays for the defences). It is, however, damaging to the coastal ecosystem and to beach users and economic costs accrue in the construction and future maintenance of the defences (Cooper and McKenna, 2008b). Conversely, permitting beachfront property to be lost as a shoreline adjusts is beneficial to the coastal ecosystem and coastal users but economically harmful to the property owner.

Some of the definitions above are focussed on immediate benefits to humans rather than on long-term sustainability of the coastal environment. These differences in definition of adaptation lead to different stakeholders interpreting them to suit their own needs (Srinavasan, 2006). Similar selective interpretation of poorly defined terms in coastal management has been alluded to in the EU's ICZM Recommendation (McKenna et al., 2008) and many examples exist in which opposing interests use the same principle to support different management actions. Consequently, adaptation is not a straightforward concept and can be the basis of considerable conflict. Tompkins et al. (2010) consider adaptation to involve two components: building adaptive capacity, and implementing adaptation decisions. Here we focus on the implementation aspects.

3. Physical manifestation of global climate change at the coast

Rising sea levels precipitate changes in coastal configuration as the coastal morphology adjusts to the changed conditions (Woodroffe, 2002). The changes are strongly 3-dimensional and may involve changes in plan as well as profile. Many factors (in particular, sediment supply and antecedent topography) influence the nature of coastal change in response to rising sea level (Cooper and Pilkey, 2004), but in most cases there is a tendency for the shoreline to migrate landwards. For natural shorelines this may involve a simple migration of existing features (e.g.

barrier islands), an increase in the rate of erosion on cliffs, or increased rates of flooding and sediment accretion on salt marshes (Morris et al., 2002; FitzGerald et al., 2008). The ability of a natural shoreline to adjust to changes in sea level is primarily dependent on whether it is constrained by human structures. Those that *are* so constrained (e.g. beaches or saltmarshes backed by seawalls) cannot adjust and are likely to become narrower (Fletcher et al., 1997) and ultimately disappear through coastal squeeze (Schlacher et al., 2006). On artificial shorelines (urban environments) this in turn leads to an increased frequency of overtopping and increased rates of damage to sea defences whether hard (e.g. seawalls) or soft (e.g. nourished beaches) (Jackson et al., 2012).

Increased water temperatures and ocean acidification resulting from global climate change have direct and indirect impacts for coastal ecosystems and their exploitation by humans. These include changes in the distribution of coastal species (Burrows et al., 2011). In high latitudes, increased temperatures are leading to reduction in the extent and timing of freezing of coastal waters and consequently greater exposure of the coast to the effects of wave erosion, resulting in increased rates of shoreline recession (Mars and Houseknecht, 2007).

Similarly, climate change is anticipated to produce changes in the volume, timing and nature (snow, sleet or rain) of precipitation (Hanssen-Bauer et al., 2003). Such changes are likely to be manifest at the coast mainly in the form of changes in sediment yield from fluvial systems and in the nature of coastal vegetation, particularly in dunes and saltmarshes.

The future scenarios for wind velocities and in particular, storms, are regarded as more uncertain than other factors. They are also likely to be strongly site-specific. Changes in wind strength, direction and seasonality all have the potential to exert major changes in coastal conditions. Jackson and Cooper (2011) and Miot da Silva and Hesp (2013), for example, attributed regional scale resealing of coastal dune blowouts by vegetation to progressive climate changes (warming, reduced wind speeds and increased growing season).

A major difficulty in deciding upon adaptation measures is in differentiating the effects of long-term climate-related processes from changes driven by short-term climate variability (Srinavasan, 2006) or infrequent, high magnitude events. Often the latter events precipitate most action whereas the former tend to be less noticeable, progressive changes. Jacob et al. (2001) have suggested that adaptation might also be best implemented by slow, progressive changes in human activities. Experience, however, suggests that the dramatic effects of extreme events precipitate most action in the realm of adaptation (Young et al., this volume). It is of course speculated in many instances that the frequency of extreme events will increase as a result of climate change; rising sea level alone precipitates a reduction in return period for various flood levels.

The focus in this paper is adaptation to the associated physical risks of increased marine flooding and shoreline recession as a result of global climate change. These risks are near-global in their extent, only being reduced or absent in areas of high sediment supply and/or significant land uplift.

4. Implications of physical coastal environmental change for human activities

Although the rate and magnitude of climate change into the future remains uncertain, awareness of the potential impacts enables coastal communities to be proactive in planning the use of coastal areas, both natural and developed. From the perspective of adaptation, action is either precipitated by (i) awareness of the likely impact of future climate change on various spheres of activity or (ii) direct experience of environmental changes. These include, for example, impacts on: exploitation of coastal resources (farming, aquaculture, fisheries, mining); commerce (ports, coastal roads and other infrastructure); habitation (coastal population centres from individual dwellings to cities); recreation, tourism and nature conservation. In this section a variety of adaptation strategies and actions in response to such changes are described. The description is arranged according to the likely impacts followed by selected case studies that demonstrate the adaptation strategies being implemented.

The two main impacts considered here are increased flood risk and increased rates of shoreline change. Increased frequency of flooding when water exceeds critical elevations and floods low-lying land is one major consequence of rising sea levels (Cooper, 2009). Even a small increase in mean sea level can greatly decrease the recurrence interval for a given flood level (Emery and Aubrey, 1991). Most coastal urban environments already suffer some degree of flood risk which is commonly reduced by construction of flood defences. In such settings, adaptation to climate change is typically viewed simply as a need for better defences to protect human settlements, infrastructure and activities from future flooding (Woodroffe et al., 2006). Rural areas with scattered settlement and less infrastructure are less likely to have flood defences in place.

Coastal erosion is often cited as a major potential impact of sea level rise (Dickson et al, 2007; Heberger et al, 2009; Richards et al, 2008). The term ‘erosion’ is unfortunate in that it implies permanent loss of material, whereas many instances of shoreline migration involve the conservation of material in the coastal zone. In all cases, sea level rise precipitates some reorganisation in the configuration of the coast. This commonly involves migration of landforms or changes in their shape. Deciphering the long-term climatic or sea-level component of physical coastal change from other, short-term, high magnitude change is difficult (Woodroffe, 2002). The various definitions of climate change have been discussed above. Here we focus on the adaptation options employed in response to actual or potential physical coastal change (usually manifest as changes in locus and rate of shoreline recession or flooding). These involve efforts to modify the environment or alter human activities, which are considered in turn below.

5. Adaptation measures

5.1. Adaptation measures that modify the environment

Many approaches to adaptation involve efforts to protect human interests from a changing environment. Some of the common approaches are discussed below with reference to case studies. The common goal of such actions is to minimise the impact of coastal changes on existing human activities.

The response to increased flood risk from storm surges in coastal urban environments is usually to construct defences. This is particularly common when large cities are threatened and often such actions were undertaken in response to extreme events. The 1953 storm in the North Sea, for example, prompted the construction of major flood defences in the Netherlands and the United Kingdom. One such structure was the Thames barrage, a moveable flood barrier constructed to provide protection for the City of London. The barrage was opened in 1984 but rising sea level means that this is now regarded to be of limited utility under future flooding scenarios. Consequently a new barrage is being planned (Lonsdale et al., 2008; Reeder et al., 2009) that takes account of future climate-related impacts on flood frequency.

Recognition of the influence of climate change is that whereas flood defences were traditionally raised after damaging floods to a level just above that flood, they are now being designed and modified taking account of the likely influence of future sea level rise on future flood risk. This has added a more proactive component to flood risk management particularly in urban coastal areas. Reeder et al. (2009) assessed the limits to engineering adaptation and concluded that there are scenarios when the rate and magnitude of change would be so great that the technical and economic aspects of flood defences could not be implemented.

At Scheveningen, the Netherlands, a major engineering project was recently completed to raise the level of a dyke and artificially widen the beach by beach nourishment (Figure 1). The intention was to create a buffer against future climate-change-related flood risk that was consistent with the level of defence afforded by adjacent defences.

Concerns over shoreline recession (often, but not always when it is likely to impact infrastructure) often lead to the construction of new hard defences. In the western Isles of Scotland (Young et al., this volume) a damaging storm in 2005 (Dawson et al., 2007; Angus, this volume) prompted action by the Scottish government and the local authority. This resulted in the emplacement of several stretches of rock armouring along what had previously been a largely natural coast (Figure 2) . The intention was to reduce the likelihood of such damage (and loss of life) by preventing shoreline recession. Shoreline recession via overwash and windblown sand is, however, a natural survival mechanism for these sandy deposits (Cooper et al., 2012). Periodic storms wash over the barriers and transport sand landwards, causing the sandy deposits to migrate landwards. Unfortunately, the defences in attempting to stabilize the coast and protect low-lying areas from flooding, are likely to contribute to the demise of the adjacent beaches and dunes. This in turn will have negative implications in the long term for preservation of the agricultural land, immediate negative impacts on the landscape and place the burden of ongoing maintenance on the local authority.

At Vik in southern Iceland, concerns over rapid shoreline recession led to a planned seawall to protect community infrastructure as an adaptation measure. Shoreline change at Vik is influenced by the timing of eruptions of nearby Katla volcano. These eruptions deliver large quantities of sand to the coastal zone and cause rapid coastal progradation. Subsequently, high wave energy disperses this sediment alongshore and offshore at rates in excess of 8 m/year since 1971. The last eruption was in 1918 and the coastline has receded to a point where there is societal concern over ongoing erosion (although no buildings are at immediate risk). An intervention at a public meeting during the CoastAdapt project pointed out the damaging effect of seawalls on beaches fronting them. The black sand beach is one of Vik's main attractions and concern over the potential future loss of the beach through coastal squeeze caused the community to abandon the seawall idea. Unfortunately, the alternative approach that has been implemented was a shore-perpendicular groyne. Designed to halt longshore losses of sand, this structure may increase erosion rates downdrift. Its impacts are not yet apparent, but its construction points to a perceived societal need for some kind of engineering intervention (or vigorous marketing by engineering interests).

5.2. Adaptation measures aimed at changing human activities

There are many ways in which humans can adapt to a changing environment (rather than trying to constrain environmental change) that involve modifications of the way activities are undertaken. A selection is discussed below.

Deconstructing or realigning engineered structures

Recognition of the ineffectiveness of hard defences has in some cases prompted their partial or total removal as a deliberate adaptation measure. The most widespread form of this is known as managed retreat (Townend and Pethick, 2002) or managed realignment (French, 2006) and it involves the surrender of previously reclaimed (usually agricultural) land with the objective of permitting reoccupation of former intertidal areas and retreat of the protected shoreline to a more landward position. The approach is deemed to give an added protection benefit by enabling the restoration of salt marsh in front of the new defence line. To date this has been applied to several estuarine sites in the UK and the European mainland. The sites tend to be small scale and affect only agricultural land. Some studies (Turner et al., 2007) have shown, however, that they are economically more feasible than continued defence. Defra (2002) concluded from a survey of stakeholders that the main driver of managed realignment was as a means of providing sustainable and effective coastal defence. This would tend to place it in the same category as building sea defences. The alternative view is that the primary motivation behind managed realignment is in preserving, creating or improving natural habitat, i.e. salt marsh (Milligan et al., 2009). Economic and natural defence coastal defence benefits are of secondary importance, but are ancillary benefits of the approach (Doody, 2012).

On open coasts, the deconstruction or abandonment of coastal defences is not a common adaptation practice. In Norfolk, UK, however, a policy decision to not maintain sea defences around the town of Happisburgh was made primarily on economic grounds (Cooper and McKenna, 2008b). A series of sea defences of various materials is now decaying on the beach and foreshore. The National Trust in England and Wales has decided to abandon sea defences at a number of its open coast sites. This is consistent with the organisation’s overarching policy of non-intervention in natural coastal processes. At Mullion Cove in Cornwall, a harbour built in 1890 and owned by the National Trust requires considerable expenditure to maintain it. The decision was made in consultation with local community to no longer maintain it, in the expectation that eventually the harbour walls will be destroyed and the cove revert to its natural state (DeSilvey, 2012).

Changing construction styles

Historically, many rural communities have been able to occupy coastal sites subject to periodic flooding by implementing specific building styles. In the Halligen, low-lying saltmarsh islands in the German Waddensea (Figure 3), tidal flooding occurred several times per year. This enabled the marsh surface to accrete as each inundation brought fresh supplies of sediment. Farmers were able to exploit this salt marsh by constructing their houses and farm buildings on artificial mounds on the marsh surface such that they were elevated above the flood levels. Even so, periodic floods did still reach these elevated levels and additional measure such as sand floors with loose wooden boards were used to enable water to drain. Recent adaptation measures have seen a change of perspective as these involved construction of dykes around the edges of the islands to reduce flooding frequency.

In southern Iceland, small rural settlements at Eyrarbakki and Stokkseyri experienced periodic flooding. Consequently, buildings typically had a sacrificial lower level with the living quarters reached by a staircase (Figure 4). It was accepted that the lower level would flood periodically and this was a means of living with the flood risk. Recent construction of dykes to reduce the flood frequency has seen these former basements converted to permanent living areas.

Ironically, while these rural communities have seen a change from a situation where building styles enabled the community to live with periodic flood risk, to one where efforts have been made to remove the risk, the reverse is happening at a number of other localities. Accepting that flood risk may increase, one adaptation option that has been implemented in several locations is to require changes in infrastructure either through changes in building standards for new structures and/or retrofitting of existing structures. Such approaches might establish elevation requirements for buildings or other structures to maximize protection from flooding or specify the use of particular flood-resistant materials (Grannis, 2011).

Meyer (2006) outlines an innovative approach to transport infrastructure in light of future climate change, which is to design infrastructure for shorter useful lives. Designing coastal bridges with a 50 year rather than a 100 year design life recognises the uncertainty of future climate impacts on flood risk and accepts the need for more frequent replacement of infrastructure.

Alternative approaches involve changes in building practice. These are often implemented through building codes in which buildings and other infrastructure are designed to avoid or cope with increased flooding risk. These adaptations are best suited to new developments but retrofitting existing infrastructure is also a possibility.

Early warning/evacuation planning

Accepting that in some cases it is not possible or desirable to completely eliminate risks from flooding or shoreline recession, adaptation can be accomplished in the form of adequate provision for emergency procedures (Tompkins, 2005). These adaptation measures usually apply to extreme climatic events (floods, storms), rather than those changes manifest progressively or incrementally. Hurricane and tsunami warnings and the development of evacuation routes and emergency procedures provide a template for development of climate change adaptation strategies of this type (O'Brien et al., 2006). Flood risk can be reduced by evacuation or shelter-in-place structures that provide refuges (Wilby and Keenan, 2012). Meyer (2006) also points to the adaptation measure of taking evacuation into consideration when designing new road or bridge projects in coastal areas- in a storm-prone area for example, bridges might be made wider to facilitate increased traffic flows during evacuations.

Migration

Mitigation may be the best or only means in some instances of avoiding risks related to climate change (McGranahan et al., 2007). There are many examples in human history of populations leaving particular locations when changing environmental conditions made it impossible to sustain livelihoods in coastal communities (McLeman and Smit, 2006). Such migrations were probably more common in the pre-industrial era but the removal of populations has also been cited as an adaptation measure in the context of contemporary climate change (Black et al., 2011). Vietnam's 'Living With The Flood' programme has resettled one million people residing within the Mekong Delta (Danh and Mushtaq, 2011) and the possibility of the Maldivian population being resettled has received much attention in the press in recent years. McGranahan et al. (2007) discuss the barriers that need to be overcome if migration from coastal urban environments is to be pursued as an adaptation action. Gradual migration from small settlements or rural environments is more easily envisaged as support systems for human life become increasingly stretched as a result of climate change. In contrast, migration in response to extreme events is influenced by perceptions that such events are rare. After the 2004 Indian Ocean tsunami, limited migration from low-lying vulnerable areas resulted - instead the damaged areas were re-occupied after the tsunami (McGranahan et al., 2007). Post hurricane human response in the eastern United States follows the same pattern.

Avoid development in at risk areas.

This can best be done by preventing development in the first place through enlightened planning and many regions implement development controls for this reason. In Denmark, for example, development is prohibited on undeveloped land within 300m of the coast and restrictions apply up to 3 km inland (Juhola et al., 2011). Abandoning land and infrastructure in high risk areas measures not only reduce climate change risks, but provide a buffer zone for infrastructure to landward.

6. Discussion: A Spectrum of coastal adaptation activities

There are many different ways of viewing climate change adaptation in general and at the coast specifically. Smit et al. (2000) proposed classifications of adaptation based on three questions: (i) adapt to what? (ii) who or what adapts? and (iii) how does adaptation occur? In their approach adaptation occurs within a 'system' (incorporating both human and environmental components) and modifying either component is deemed equally valid.

In England and Wales the government identified three types of adaptation responses to flooding and coastal erosion:
(http://archive.defra.gov.uk/environment/flooding/manage/risk.htm)

- Working with natural processes to reduce risks (implying maintaining the resilience of natural coastal systems)
- Planning communities to reduce risks (using planning policy to keep new developments outside risk zones and introduce appropriate design for buildings that have to be there)
- Helping communities live with flood and erosion risk (early warning and evacuation systems)

This too places modification of the environment and human activities on an equal footing and does not promote one approach over any other. Jacob et al. (2006) identify 3 broad categories of response to (mainly coastal) climate change impacts for the New York Metropolitan area. These were as follows:

- Short-term protective measures (building dykes, raising existing structures)
- Regional mega-engineering (major regional protective structures (such as in the Netherlands)
- Changed landuse. In a metropolitan area this would involves moving infrastructure (laterally and vertically)

This categorization of approaches again offers environmental modification and landuse changes on an equal footing, although the authors do point out that changing landuse offers the best long-term response.

Each of these classifications of adaptation practice incorporate the components we have addressed above i.e. all have the same broad division between adaptation that modifies the environment and adaptation that involves modifying human activities (landuse). However, examining adaptation based on the relationship between human activities (landuse) on the one hand and the environment/ecosystem on the other provides a framework for decision making that brings this distinction into sharp focus. Consequently, a classification based entirely on this elementary distinction is proposed (Figure 5) that identifies actions that do involve adaptation and those that simply involve resistance. The selection of examples given above in response to flooding and coastal recession involves a range of modifications of either the environment and/or human activities.

The literature, both academic and professional is dominated by adaptation that involves reinforcing existing defences or building new ones. Hinkel (2010), for example, bases an economic appraisal of adaptation costs on the following narrow assertion: “If we protect following the DIVA approach [dyke construction and beach nourishment], the actual damages of sea-level rise will be much lower than the potential damages of sea-level rise if protection is ignored” (Hinkel, 2010, p. ix). This outlook is mirrored in the “Ourcoast” project’s collection of European case studies on coastal adaptation measures (http://ec.europa.eu/ourcoast/). Of the 26 case studies that document actual practice in coastal adaptation (rather than policy development or information gathering), 20 involved hard (11 examples) or soft (9 examples) engineering. Five of the remaining 6 examples were concerned with managed realignment and only one with changes in urban design.

In highly managed environments a legacy of technological fixes, engineering solutions and perceived control over resources can create a barrier to adaptation (Nicholson-Cole and O’Riordan, 2009; Gunderson and Light, 2006). However, in currently unmanaged environments a belief in technological fixes is also inhibiting other forms of adaptation. In the Western Isles of Scotland and at Vik in Iceland, considerable pressure was evident for engineered approaches to shoreline recession and flooding. At Vik there was such a determination to implement an engineered structure, that even when the damaging effects of a seawall were appreciated by the community, another engineered approach (a large groyne) was selected. Former innovations in building style on the Halligen and in flood-prone buildings in southern Iceland that enabled communities to live with the risk are now being abandoned in favour of engineered approaches that seek to eliminate the risk altogether.

The selection of adaptation options is often guided by public perception. The vast majority of examples reported in the literature involve resistance to change rather than adaptation. Despite a catalogue of the pitfalls of shoreline stabilization (Cooper and Pilkey, 2012), there is an unfounded belief for most areas of coastal activity that engineering 'solutions' exist that will enable coastal resources to be exploited in the same place and the same way as before. All adaptation measures are implemented within a local political and administrative framework that is frequently short-term in its outlook. Decision-making thus seeks to achieve the most cost-effective outcome that satisfies the immediate political realities. In this context it is much easier to adopt measures that maintain current human uses rather than those that require a change. Building defences is therefore a favoured adaptation option.

Managed realignment and abandonment of high risk coastal localities is difficult to implement in most instances (Myatt-Bell et al., 2002). This is partly because the risks associated with climate change are manifest progressively in increased rates or frequency of damaging events (Losses associated with extreme events, in contrast, attract much more attention because of their immediacy). It is also hindered by a belief in the efficacy of engineered 'solutions', whose long-term effects are either ignored or not appreciated.

Changes in landuse, whether through zoning, changes in building codes or in infrastructure design and location are all technically feasible adaptation options but they are probably taken up less often because of the public perception that simply defending assets involves less disruption. In this regard, we contend that considering adaptation approaches on the resistance-adaptation spectrum as advocated here is a useful concept in coastal management. Considering all such actions as equally valid forms of 'adaptation' selected according to the circumstances acts to inhibit selection of anything other than the 'defend' option.

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Figures

Figure 1. Construction of a new dyke on top of an existing one and nourishment to widen the beach are underway at Scheveningen, the Netherlands, to protect assets from climate-change related risks.

Figure 2. Natural barrier beach in Western Isles, Scotland (A), replaced by rock-armour (B) in an attempt to halt shoreline recession. Examination of A shows gravel on the landward side of the barrier, indicating the barrier is migrating by rolling landward, conserving its sediment volume. The barrier in B is no longer able to do so and the beach that fronts it will eventually suffer coastal squeeze.

Figure 3. The Halligen of the German Waddensea are remnants of salt marsh on which communities have historically lived with periodic flooding. Historic adaptation to living in this environment with periodic flooding ranged from simple measures such as constructing the floor of the church (A) from wooden boards on top of sand (B) so that flood water could drain easily. More elaborate measures were involved in construction of farms (werfen) on mounds on the marsh surface (C). This enabled the marsh to persist through periodic inundation and sedimentation. This natural resilience is being undermined by construction of dykes (D) to reduce flood frequency. The lower dyke eliminates most summer floods while the upper dyke reduces the frequency of winter flooding. Both have the effect of reducing the sediment input to the marsh surface.

Figure 4. Former strategies to cope with periodic flooding in Eyrarbakki and Stokkseyri, in southern Iceland, involved a sacrificial basement with living quarters reached via steps (A, B). Subsequent construction of dykes (C) to control flood risk has led to permanent occupation of these basements. The community has thus moved from a situation where they lived with floods to one where they actively resist them. Permanent occupation of the lower levels of buildings means that when flooding happens it will be much more damaging than before.

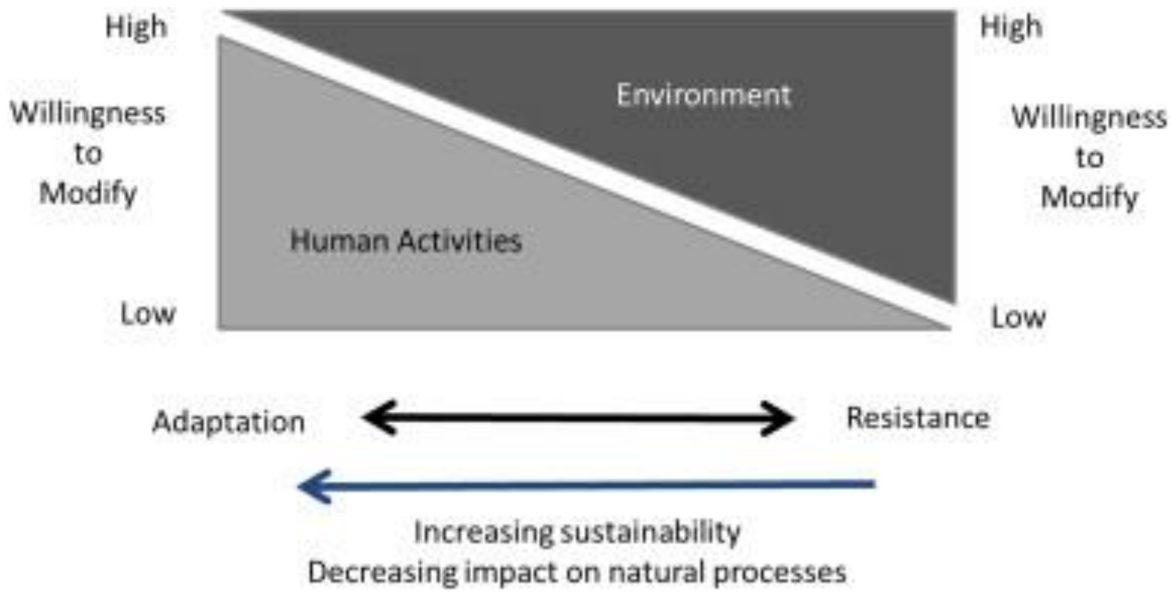

Figure 5. A conceptual classification of ‘adaptation’ actions based on the extent to which modification of the environment or of human activities is envisaged. A high willingness to modify human activities coincides with adaptation. At the resistance end of the spectrum are those actions that seek to maintain the *status quo* by building or extending defences. At the adaptation end of the spectrum are actions that aim to modify human activities in response to envisaged changes.