Assessing the impact of climate change on visitor behaviour and habitat use at the coast: A UK case study

Article *in* Global Environmental Change · May 2010

DOI: 10.1016/j.gloenvcha.2009.12.004

2 authors:

Emma Coombes
University of East Anglia

Andy Peter Jones
University of East Anglia

Global Environmental Change 20 (2010) 303–313

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Assessing the impact of climate change on visitor behaviour and habitat use at the coast: A UK case study

Emma G. Coombes *, Andy P. Jones

School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, United Kingdom

ARTICLE INFO

Article history:
Received 4 March 2009
Received in revised form 9 December 2009
Accepted 15 December 2009

Keywords:
Biodiversity
Climate change
Coastal management
Coastal tourism
Visitor activities

ABSTRACT

Although tourism and recreation can bring economic benefits to an area, the presence of visitors may adversely impact biodiversity, particularly if they make use of sensitive environments. It is anticipated that the effects of global climate change alone may increase the vulnerability of many environments, but these effects may be magnified if warmer and drier weather encourages more visitors, or makes them more likely to participate in ecologically damaging activities. Using case study sites from the UK, this study examines how different types of beach visitors make use of coastal environments. Via a series of visitor surveys, information is elicited on the environmental preferences of a range of visitor types including walkers, bird watchers, and bathers. The use of different habitats by these visitors is also assessed via an analysis of walking routes undertaken in a Geographical Information System. From this, an assessment is made of the likely present day biodiversity impacts arising from different coastal users, and how these may change under a modified climate. This study finds that whilst higher temperatures are expected to increase visitor numbers, warmer weather may encourage greater participation in low impact activities such as bathing. The findings are discussed in the context of coastal management.

1. Introduction

Tourism is one of the worlds' largest industries and is strongly influenced by climate. Many forms of tourism and outdoor recreation are dependent upon favourable climatic conditions. For example, coastal recreation often relies upon a warm, sunny environment, and winter recreation is highly dependent on the presence of snow (Gössling and Hall, 2006). Climate change has the potential to alter weather conditions and landscapes at tourist destinations, and is therefore likely to modify tourist demand and travel patterns (Scott et al., 2004). Changes in climatic conditions would therefore have a considerable impact on the tourist and recreation industry and may affect the economies of tourist dependent regions.

1.1. Impacts of climate change on coastal recreation

Climate change is expected to affect outdoor recreation in three ways. Firstly, changes in weather conditions, including increased temperatures, longer summer seasons and shorter winter seasons, may affect the availability of certain recreation opportunities (Richardson and Loomis, 2005). Secondly, changes in climate may affect the overall comfort and enjoyment of outdoor activities (Amelung and Viner, 2006). Thirdly, they may alter the ecological systems of an area, which may in turn alter the quality of the recreation experience (Uyarra et al., 2005).

Of all types of outdoor leisure, coastal recreation is likely to be particularly affected by climate change because, in addition to changes in weather conditions, intertidal areas will undergo environmental modifications due to sea level rise (Braun et al., 1999). Given the importance of coastal recreation to the wider tourist industry, understanding changes in patterns of coastal visits will be economically valuable and also important in terms of conserving habitats, providing appropriate tourist facilities, and aiding coastline protection decisions (Turner et al., 1998). A small number of studies have examined the implications of climate change and associated sea level rise for coastal recreation. These have particularly focused on small islands which are economically dependent on coastal leisure, such as those in the Caribbean (e.g. Belle and Bramwell, 2005; Uyarra et al., 2005). Findings suggest that whilst increased temperatures could encourage greater levels of beach recreation, sea level rise may result in changes to the structure of beaches, such as reductions in beach width, which may reduce visits.

1.2. Impacts of coastal recreation on biodiversity

Whilst recreation has economic benefits, it may have adverse impacts on biodiversity. Coastlines encompass a range of habitats

* Corresponding author. Tel.: +44 01603 591376; fax: +44 01603 591327.
E-mail address: emma.coombes@uea.ac.uk (E.G. Coombes).

0959-3780/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.gloenvcha.2009.12.004

including mudflats, sandflats, shingle beaches, saltmarsh, sand dunes and cliffs, all of which support high levels of biodiversity. Recreational use of intertidal areas can result in losses of flora and fauna due to trampling and disturbance of wildlife (Alessa et al., 2003) and increased visitor numbers might magnify these impacts (Brown and McLachlan, 2002; Liley and Sutherland, 2007). Nevertheless, the impact of recreation on biodiversity is also determined by the activities in which visitors engage (Bellan and Bellan-Santini, 2001; Priskin, 2003; Nepal and Nepal, 2004; Andres-Abellan et al., 2005). For example, horse riders cause greater damage to vegetation and soils than walkers because they exert more pressure per unit of ground area (Weaver and Dale, 1978). Furthermore, visitors undertaking diverse activities may use different habitats, some of which may be more vulnerable to degradation than others. Notably, sand dunes and saltmarsh are particularly susceptible to damage from trampling which can reduce vegetation cover and species richness (Kutiel et al., 1999).

1.3. Interactions between climate change, visitor behaviour and biodiversity

Climate change could alter the proportions of visitors engaging in different activities (Braun et al., 1999; Richardson and Loomis, 2004). For example, a change to warmer and drier summers in countries with temperate climates could increase the number of sunbathers, yet may have little influence on frequent visitors such as dog walkers. Whilst there has been extensive research regarding the impacts that visitor numbers have on coastal vegetation (e.g. Andersen, 1995; Lemauviel and Roze, 2003), soils (e.g. Kutiel et al., 2000) and birds (e.g. Burger et al., 1995; Lafferty, 2001), few studies have examined how such biodiversity impacts might vary between different types of coastal user. Furthermore, although previous work has investigated visitors' preferences for beach characteristics (e.g. Morgan, 1999; Jędrzejczak, 2004; Tudor and Williams, 2006) and weather conditions (e.g. Dwyer, 1988; de Freitas, 1990), no studies have examined how these preferences may vary between different coastal users, nor have they examined how the proportions of visitors engaging in different activities might be affected by climate change.

1.4. Study aims

This study aims to improve understanding of the relative impacts that different user groups have on coastal habitats, and how these may be affected by climate change, by examining visitor use at two case study beaches in East Anglia, UK. The study has been designed around a theoretical framework, which is illustrated in Fig. 1. This framework specifies the links considered between climate change and visitor behaviour, and illustrates how changes in the composition of visitors engaging in different activities may modify impacts on coastal habitats. A globally applicable methodology is thus presented whereby visitor behaviour is studied for different activity groups in order to evaluate the magnitude of impacts that these groups exert on coastal habitats. Preferences for diverse environmental characteristics are assessed and these are integrated with information on predicted environmental changes to investigate the likely impact of climate change on the proportions of visitors engaging in different activities. The biodiversity implications of these changes are discussed.

2. Materials and methods

2.1. The study area

The East Anglian coastline comprises a diversity of coastal habitats including mudflats, sandflats, shingle beaches, saltmarsh,

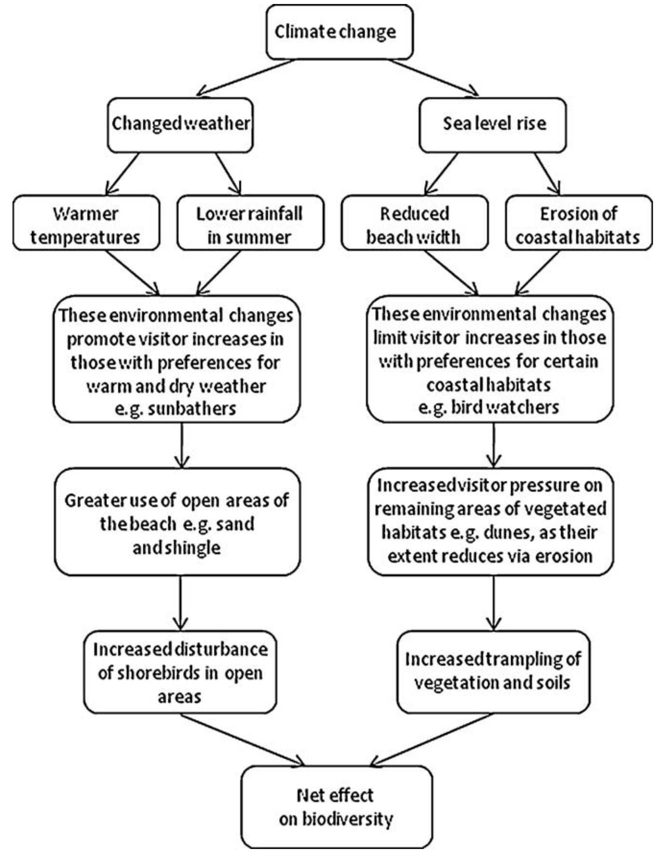

Fig. 1. A theoretical framework illustrating the links between anticipated future impacts of climate change on visitors' behaviour and the implications for coastal habitats.

sand dunes and cliffs. It is internationally protected under the Ramsar Convention on Wetlands for the biodiversity it supports, and the wide variety of habitat types present means it attracts a diverse range of coastal users (Environment Agency et al., 2006). It is predicted that the characteristics of this section of coast may be significantly altered by climate change, because it is generally low-lying and easily erodible. Hence a small increase in sea level would have a considerable impact on beach width and morphology (Pethick, 2001).

This study focuses on the impacts of visitor use at two beaches in East Anglia; Holkham and Cley (Fig. 2). These beaches differ considerably in their physical appearance and the number of visitors they receive. Holkham is a wide sandy beach with a shallow gradient, and includes areas of saltmarsh and sand dunes. It receives approximately 500 000 visitors annually (English Nature, 2003). In contrast, Cley is a narrow shingle beach with a steep gradient, and encompasses mudflats and saltmarsh. It receives approximately 100 000 visitors each year (Klein and Bateman, 1998). Visitors can be considered to be either recreationists or day visitors who live locally, or tourists who have travelled from outside the region (McKercher, 1996). Within the study area, both recreation and tourism are important to the local economy, but recreationists account for the majority of visitors (North Norfolk District Council, 2003). Studying visitor use at these two sites provided an insight into how these visitors behave at physically contrasting beaches.

Climate change is expected to alter beach structure at Holkham and Cley, both of which are anticipated to experience reductions in the extent of coastal habitats due to sea level rise. At Holkham, the dune system (including young developing foredunes and more established yellow and grey dunes) plus areas of saltmarsh may

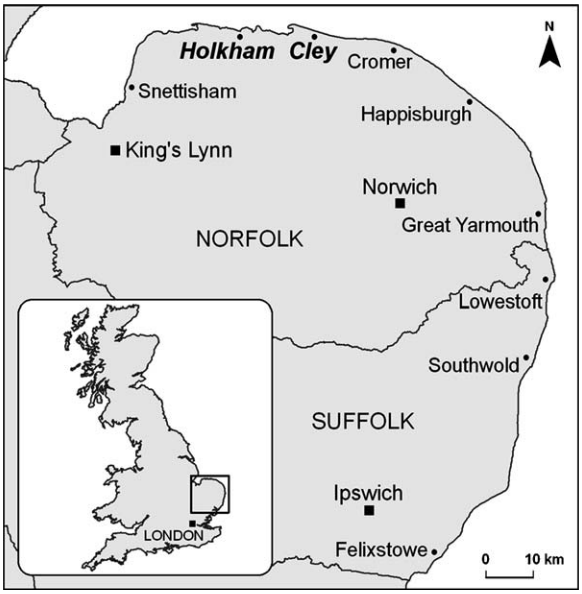

Fig. 2. Map of the East Anglian coastline, which shows Holkham and Cley and the location of the study area within the UK (inset).

experience some losses, whereas at Cley the mudflats and saltmarshes are expected to decrease in area under the changed conditions (English Nature and Environment Agency, 2003).

2.2. Visitor surveys

To examine the behaviour of visitors participating in different activities, approximately bi-weekly surveys were undertaken at Holkham and Cley beaches between January 2004 and July 2005. Surveying over a year allowed visitor behaviour to be studied for a range of seasonal conditions. Surveys were conducted at the main beach entrance between 08:00 and 17:00 hours or until 21:00 during the summer.

The questionnaire surveys were undertaken with visitors as they left the beach. Surveying was continuous whereby as soon as one survey was completed, a new interview was undertaken with the next consenting visitor leaving the beach. When there was more than one visitor present in a group, the respondent was selected as the adult whose birthday was soonest. The questionnaire employed examined three levels of use. Firstly, visitors were asked about their use of the coast in general, including how often they visit and their preferences regarding different types of beach characteristics. Secondly, they were asked about their use of the survey beach (Holkham or Cley), including the number of visits they made in the last 12 months, and what they liked and disliked about the beach. Finally, they were asked about their visit on that particular day. This included why they chose to visit, the activities they undertook, how long they stayed, and whether they had travelled from home. Participants were shown a map of the survey beach and were asked to draw a line showing the route they had walked.

The results from the questionnaires were used in a four stage assessment methodology. Firstly, behaviour was examined for different activity groups in order to assess their relative impact on biodiversity. Secondly, the beach characteristic and weather condition preferences of each activity group were identified. Thirdly, this information was applied to assess the impacts of climate change on the proportions of visitors engaging in different activities for two future scenarios. Finally, the implications of changes in visitor behaviour on biodiversity were identified, and are discussed.

2.2.1. Stage 1: assessing the current impact of visitors on coastal habitats

Visitor behaviour was examined according to the primary activity (for example, walking a dog, recreational walking, bird watching, relaxing or sunbathing, and playing or paddling) that respondents undertook on the day they were interviewed. The relative impacts that these activity groups had on biodiversity was inferred from their characteristics and behaviour. Previous studies have shown that an increase in visitor numbers within coastal habitats generally results in greater reductions in vegetation cover, species richness and species diversity (Andersen, 1995; Kutiel et al., 2000). Furthermore, they have shown that birds prefer to make use of areas with few visitors and that disturbance increases with increased visitor use (Burger et al., 1995). Based on these observations, visitor impacts on biodiversity in this study were considered to increase with the size of visitor groups, the number of visits made to the beach, the length of time spent at the beach, and the distance visitors walk.

The routes drawn on the visitor maps were digitised into the ArcGIS 9.1 (ESRI, Redlands, California) Geographical Information System (GIS), to a precision of approximately 10 m. Whilst the method used to enter the data was precise to 10 m, the accuracy of the route positions varied according to the amount of care that visitors took when drawing their routes. The distance that visitors walked during their visit was then calculated within the GIS.

The current distribution of habitats at both sites was identified from Ordnance Survey MasterMap data (Ordnance Survey, 2007), and habitat type and extent were verified using aerial photographs and field surveys. These included non-vegetated areas of beach (sand, shingle and mudflats), foredunes, yellow dunes, forested grey dunes and saltmarsh. The intensity of use each habitat received annually was estimated by creating a grid across the study sites, coding the grid cells according to habitat type, and calculating the number of visitor routes that intersected each cell. A 40-m grid cell size was used because it provided sufficient resolution to measure variation in visitor impact across habitats whilst recognising likely inaccuracy in visitors' route drawing. The route for each respondent was coded by the number of people in their group and the number of visits they made during the last 12 months, to proxy their annual use. The proportion of total annual visits accounted for by the sample interviewed was calculated for both sites (2.4% at Holkham and 7.2% at Cley), and the derived estimates of trampling were adjusted according to these proportions to produce total annual disturbance estimates.

2.2.2. Stage 2: assessing visitors' preferences for environmental conditions

Visitors' propensity to visit the coast, the length of time they stay, and the types of activities they undertake may be influenced by a variety of factors including the physical appearance of the beach and the weather conditions on any given day. To examine how climate change may modify visitor behaviour, preferences for beach characteristics and weather conditions were assessed for each activity group.

Visitors were asked to rate their preferences for beach characteristics, coastal habitats, presence of sea defences, and facilities on a 5-point Likert scale, whereby −2 indicated a strong preference against a characteristic or habitat, −1 = weak preference against, 0 = no preference, 1 = weak preference for, and 2 = strong preference for. Visitors were also asked to rate the importance of factors that influenced their decision to visit the beach on the day they were interviewed. These included the amount of free time they had, the distance they travelled to the beach, the weather, level of the tide, and their perception of how many people would be at the beach. For each factor, importance was assessed using the 3-point Likert scale; 0 = not important, 1 = moderately important, and 2 = very important. The scores recorded from respondents were used to calculate the mean preference score for each environmental characteristic for the different activity groups, so that variations between their preferences could be identified.

2.2.3. Stage 3: examining the impact of climate change on different coastal users

The UK Climate Impacts Programme (UKCIP) scenarios (Hulme et al., 2002) provide a framework for assessing the potential impacts of climate change on the coastal zone for four greenhouse gas emissions scenarios (low, medium–low, medium–high, and high). The UKCIP scenarios were developed from the Special Report on Emissions Scenarios (IPCC, 2000) and represent alternative pathways for future economic, social and technical developments. These scenarios provide estimates of greenhouse gas emissions, temperatures and sea level rise for each pathway, and were used to examine the impact that climate change may have on total annual visitor numbers to the East Anglian coastline by the year 2080, irrespective of visitor types. This work is described in detail in Coombes et al. (2009) and is outlined briefly here. In this work, a model was developed to predict visitor numbers within 200 m long sections of the East Anglian coastline in relation to a diverse range of beach characteristics and weather conditions. Using a Geographical Information System, the output from this model was combined with data on likely changes in beach width, temperature, and precipitation to predict future annual beach visitors to East Anglia for the year 2080. The results showed that reductions in mean beach width of between 13 and 16 m may reduce visitor numbers by 0.4–0.5%, depending on whether a low or high emissions scenario was considered. In contrast, increases in mean annual temperatures of between 1.9 and 3.8 °C were predicted to result in an overall increase in visitor numbers of between 24 and 46%. Changes in precipitation patterns may alter the distribution of visitor numbers across the year but are unlikely to have a significant effect on total annual visitor numbers.

The results from this analysis were used to assess the impacts of climate change on the numbers of visitors participating in different activities using the UKCIP low and high emissions scenarios up to the year 2080. In order to estimate changes in visitor numbers for each activity group, the predicted changes in total annual visitor numbers were partitioned between the different activity groups based on their stated preferences for beach width and warm weather conditions from Stage 2. These two variables were used because they are likely to have the greatest magnitude impact in East Anglia. The methodology used was as follows.

The mean preference scores for a wide beach, as calculated for each activity group from the survey data, were summed to calculate the total preference score across the groups. The predicted percentage change in annual visitor numbers due to reduced beach width from Coombes et al. (2009) (−0.4% for low emissions) was divided by the total preference score. This value was then multiplied by the individual preference score for each activity group respectively, to estimate change in visitor numbers due to reductions in beach width for each group. This process was repeated for the high emissions scenario. The effect of warm weather conditions on visitor numbers for each activity group, as represented by an increase in mean annual temperature, was assessed using the same methodology. Predicted changes in visitor numbers due to modifications to beach width and weather conditions were summed for each activity group to assess the overall impact of climate change on the proportions of visitors engaging in different activities.

Climate change is also likely to result in other environmental modifications that may affect visitor numbers, in particular changes in the presence of coastal habitats as a consequence of sea level rise. Sea level rise is expected to encompass a variety of processes, including erosion and inundation, which are likely to be important in determining the distribution of coastal habitats under a changed climate. However, there is considerable uncertainty regarding which processes may predominate and what their implications may be on different sections of the coast (Pethick, 2001). Furthermore, adaptation initiatives may lead to an increase in the construction of sea defences in the future to offset the processes described above. Yet it is particularly difficult to predict where the defences may be constructed, as this will depend on the configuration of the coastline and sediment type, amongst other factors. Given these uncertainties, a quantitative modelling exercise to predict the morphological response of the study beaches was not considered. Instead we adopted the pragmatic approach advocated by Stive (2004), which assumes that sea level rise will generally lead to coastal inundation, with only limited roll-back, and that the extent of intertidal habitats is thus anticipated to reduce as a consequence. The likely impact of these changes on visitor behaviour was estimated using a semi-quantitative methodology.

In order to model likely impacts, respondents' preference scores for different habitats were compared to anticipated reductions in habitat availability to evaluate how they may affect visits by each activity group. For example, predicted erosion of dunes and saltmarsh may be expected to result in a reduction in future visits by groups who stated a preference for these habitats. The magnitude of change in visits for each activity group was thus rated as 'no change', 'small', 'moderate' or 'large' according to their mean preference score taken across all the habitats. Activity groups who stated no preferences for any affected habitats were assumed to have 'no change' in future visits. Those with weak preferences for between 1 and 3 habitats were assumed to have a 'small' change, those with weak preferences for 4 or 5 habitats or a strong preference for between 1 and 3 habitats were assumed to have a 'moderate' change. Finally those with a strong preference for 4 or 5 habitats were assumed likely to have a 'large' change in future visit frequency. The effect of increased presence of sea defences on visits was assessed using the same method.

To provide an indication of the overall effect of climate change on the different activity groups, predicted alterations to visitor numbers identified from the quantitative and semi-quantitative assessments were summarised in a matrix. In this matrix, the quantified effects of warmer weather conditions and reduced beach width on visitor numbers were expressed as 'very small' ($\pm$<2%), 'small' ($\pm$2.1–4%), 'moderate' ($\pm$4.1–6%) or 'large' ($\pm$>6%) increases or decreases, classified according to the minimum predicted change. These changes were then considered alongside the semi-quantitative estimations of the effect of habitat loss and increased presence of sea defences in order to provide an overall estimation of changes in visitor numbers for each activity group, which was rated as 'small', 'moderate' or 'large'. In addition, the relative magnitudes of visitor impacts on coastal habitats were summarised as 'low', 'medium' or 'high' for each activity group. These impacts were assumed to be based on trampling frequency and were hence calculated from the mean distance walked per visit and the proportion of that distance which traversed each habitat.

2.2.4. Stage 4: evaluating the biodiversity implications of changes in visitor activities

Once predicted changes in visitor numbers, and associated indicators of trampling frequency, had been summarised in the matrix for each activity group, they were considered alongside information on the effects of trampling on vegetation and soils, as well as the effects of visitor presence on bird species identified from a literature review. This review is described in detail in

Table 1
Percentage of people engaging in different activities at Holkham and Cley beaches, based on the number of visitors within groups interviewed and the number of visits they make annually.

	Dog walking	Walking	Bird watching	Relaxing or sunbathing	Playing or paddling
Holkham	65%	27%	4%	3%	1%
Cley	42%	16%	31%	10%	1%
Overall	57%	22%	14%	6%	1%
Total sample size (*n*)	319	735	197	185	73

Table 2
Visitor behaviour of different activity groups, based on the combined data for Holkham and Cley.

	Dog walking	Walking	Bird watching	Relaxing or sunbathing	Playing or paddling	Kruskal–Wallis *P*-value
Mean number of visits per year	45.5	8.8	15.8	7.1	5.3	<0.001
Mean number of visitors in group	2.1	2.6	2.0	2.9	3.5	<0.001
Mean number of dogs in group	1.5	0.0	0.0	0.1	0.2	<0.001
Mean length of visit (hours)	1.5	1.8	2.2	3.1	2.2	<0.001
Mean distance walked (km)	1.9	1.6	1.9	1.3	0.9	<0.001

Coombes et al. (2008). The findings from this review were summarised in such a way as to indicate the types of biodiversity impacts that might arise from the predicted changes in habitat use for each activity group. For example, an increase in visitor numbers for activity groups who make use of vegetated habitats would lead to greater levels of trampling damage to vegetation and soils, although the relationship is not linear.

3. Results

Table 1 provides an overview of the types of recreational activities undertaken at Holkham and Cley beaches and shows the composition of visitors classified according to their primary activity at each location. Whilst the mix varies between the sites, dog walking accounts for the majority of visits at both locations. Relaxing or sunbathing and playing or paddling are generally undertaken during the summer and only account for a small percentage of the overall visits. The number of bird watchers at Cley is high because the site is internationally recognised for its passage migrants (English Nature, 2003). Eighty-four percent of visitors to Holkham and Cley were found to be people who lived locally and had travelled from home on the day they were interviewed, confirming the importance of day visits to the overall use of these sites.

3.1. Impact of visitors on coastal habitats

The visit characteristics of each activity group are summarised in Table 2. Although the findings for Holkham and Cley were initially examined separately, little difference was found in activity group characteristics and behaviour between the two locations, and consequently the combined results for both sites are presented

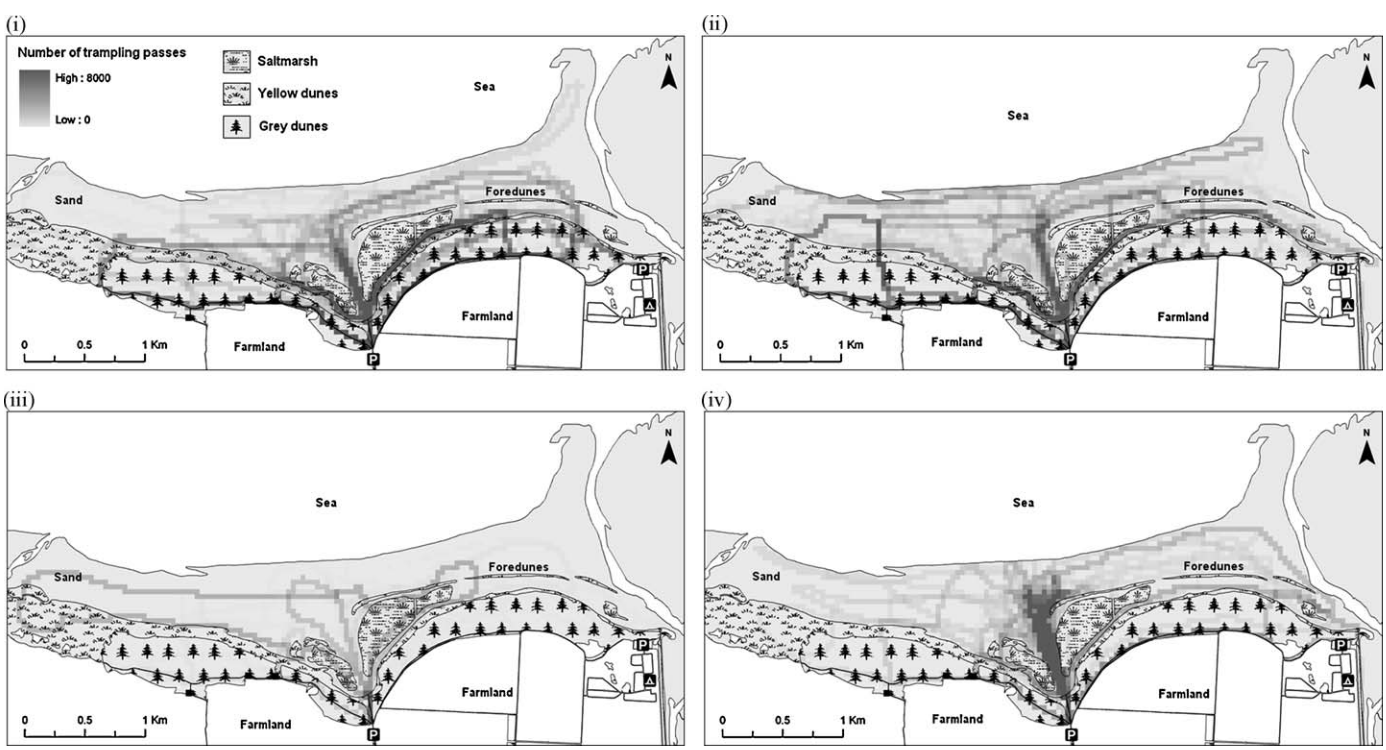

Fig. 3. Intensity of visitor use across Holkham beach based on visitor routes recorded during surveys: (i) dog walkers, (ii) walkers, (iii) bird watchers, and (iv) visitors relaxing, sunbathing, playing or paddling. The area over which visitor impact was evaluated is shown in grey.

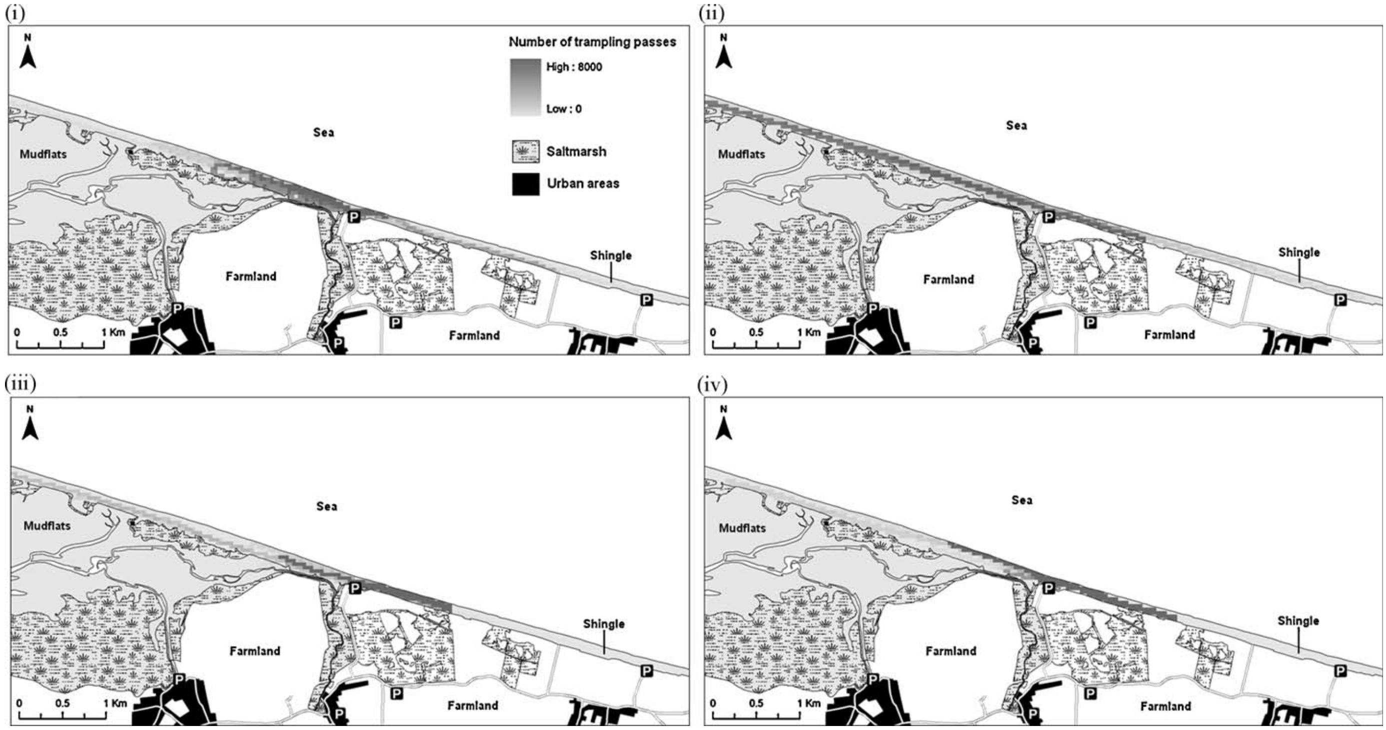

Fig. 4. Intensity of visitor use across Cley beach based on visitor routes recorded during surveys: (i) dog walkers, (ii) walkers, (iii) bird watchers, and (iv) visitors relaxing, sunbathing, playing or paddling. The area over which visitor impact was evaluated is shown in grey.

here. The results demonstrate that dog walkers are by far the most frequently visiting group and, along with bird watchers, generally walk the furthest. Visitors relaxing or sunbathing and playing or paddling visit the least frequently, and also walk the least, yet have the largest group size.

Figs. 3 and 4 illustrate the spatial distribution of visitor impacts and show the annual trampling passes derived from visitor routes mapped for different activity groups. They illustrate that dog walkers and recreational walkers walk over a large area and tend to use a wider range of habitats than other groups. The map for Holkham shows that, as may be expected, visitors tend to avoid areas of saltmarsh, walking around or between patches of marsh, with the exception of bird watchers who use saltmarsh margins where they can view wildlife. Similarly, at Cley bird watchers spend time close to freshwater marshes immediately behind the beach, which can be seen in the centre of the map. Visitors relaxing or sunbathing and playing or paddling showed very similar patterns of use, and hence the results for these groups are shown together. The area used by these visitors is concentrated between the main beach car park and the sea.

Table 3 summarises habitat use by the different activity groups as determined from the visitor routes illustrated in Figs. 3 and 4. It shows the clear diversity in habitat use between the types of visitor ($\chi^2 = 71.219$, df = 20, $p < 0.001$). Dog walkers and recreational walkers use vegetated habitats, including all types of dunes, to a greater degree than other users and may therefore be expected to cause more damage to vegetation and soils due to trampling. In contrast, Table 3 shows visitors relaxing or sunbathing and playing or paddling tend to use non-vegetated areas of sand and shingle. Since they make less use of vegetated habitats compared to the other activity groups, they may therefore cause relatively less trampling damage.

3.2. Visitors' preferences for environmental conditions

The visitor preferences for different beach characteristics are summarised in Table 4. In this table, the numeric values presented are the mean preference scores from the 5-point Likert scale. To aid interpretation, the table also shows symbols that represent these numeric scores. The table shows some differences between visitors' preferences. Whilst most visitors stated rather weak preferences for the presence of certain coastal habitats, bird watchers tended to have stronger preferences and they particularly favoured sand dunes, saltmarshes, and remote beaches. Consequently, this group may be more likely to respond to habitat loss due to sea level rise. Visitors' preferences for characteristics that will not directly be affected by climate change, such as the presence of facilities, are also shown in Table 4. These preferences

Table 3
The percentage of total distance walked passing through different habitat types, by activity group. Figures are based on the combined data for Holkham and Cley.

	Dog walking	Walking	Bird watching	Relaxing or sunbathing	Playing or paddling
Sand and shingle	13	20	26	30	28
Foredunes	5	7	24	16	22
Yellow dunes	33	30	31	26	29
Grey dunes	48	40	11	26	20
Mudflats	0	0	0	0	0
Saltmarsh	1	3	8	2	1
Total	100	100	100	100	100

Table 4
The beach characteristic preferences of different activity groups at Holkham and Cley. The table shows the mean Likert values recorded during surveys and also a symbol to represent each Likert value to aid interpretation, where: −− strong preference against, − weak preference against, no symbol represents no preference, + weak preference for, and ++ strong preference for.

Variable categories	Variable names	Activity groups										Kruskal–Wallis *P*-value
		Dog walking		Walking		Bird watching		Relaxing or sunbathing		Playing or paddling		
Beach characteristics	Remote beach	(+)	1.4	(+)	1.1	(+)	1.2	(+)	0.9	(+)	0.6	0.045
	Wide beach	(+)	1.1	(+)	0.8		0.4	(+)	0.7	(+)	0.8	<0.001
	Flat beach	(+)	0.9	(+)	1.0	(+)	0.8	(+)	0.7	(+)	0.9	0.378
Habitat features/types	Sand	(+)	1.3	(+)	1.2	(+)	0.8	(+)	1.1	(+)	1.3	<0.001
	Rocks and rock pools		0.0		0.4	(+)	0.6	(+)	0.6		0.0	<0.001
	Sand dunes	(+)	1.3	(+)	1.2	(+)	1.1	(+)	1.0	(+)	1.0	0.217
	Saltmarsh	(+)	0.6		0.4	(+)	1.4		0.3		0.1	<0.001
	Cliffs		0.1	(+)	0.6	(+)	0.7		0.2		0.4	0.003
Presence of protection	Sea defences present		−0.2		−0.1		−0.2		−0.4		−0.3	0.491
Facilities	Large car park		−0.2		−0.2	(−)	−0.5		0.0		−0.1	0.183
	Toilets		0.4	(+)	0.8	(+)	0.8	(+)	1.1		0.3	0.004
	Tea room or café		−0.3		−0.1		0.0		−0.1		−0.1	0.389

tended to be weaker than those recorded for physical environmental characteristics, with 'no preference' more commonly being stated. Hence changes in facility availability may have a comparatively small effect on visitor numbers.

Table 5 illustrates the importance of different factors, as reported by visitors, as determinants of decisions to visit the beach. The table shows the mean preference scores from the 3-point Likert scale and again symbols are used to aid interpretation. It illustrates that visitors rated most of the factors influencing their decision to visit the beach as moderately important, with the exception of those who were relaxing or sunbathing, who rated weather conditions as very important. Therefore, as expected, sunbathers may be more sensitive to changes in weather patterns due to climate change than other activity groups.

3.3. Impact of climate change on different coastal users

Table 6 shows the effect of reduced beach width and warmer weather conditions on visitor numbers for each activity group, calculated by partitioning predicted increases in total annual visitor numbers from Coombes et al. (2009) between the activity groups according to their preference scores from Tables 4 and 5. Reductions in beach width are predicted to have a relatively small effect on visitor use, resulting in a minor reduction in visits, with little difference between the activity groups. In contrast, warmer weather conditions are predicted to have a significant impact on visitor numbers. Taken together, these results suggest there will be a net increase in visitor numbers for all groups. As visitors relaxing and sunbathing have the strongest preference for warm weather conditions, this activity group is predicted to experience the greatest increase in numbers. In contrast, the number of visitors dog walking may increase a relatively small amount, as dog walkers are expected to be the least affected by increased temperatures due to the fact that they have the weakest preference for warm weather conditions.

Table 6 also demonstrates the influence of global socio-economic development pathways, and their associated magnitude of anticipated climate change, on visitor numbers for each of the activity groups. Whilst there is little difference between the predicted changes in visitor numbers due to reductions in beach width for the UKCIP low and high carbon emissions scenarios, the difference is marked for the effect of warm weather conditions. Notably, the predicted increase in visitors due to warmer temperatures under the high emissions scenario for 2080, is double that predicted for the low emissions scenario.

Table 7 summarises the overall predicted impacts of climate change on the activity groups. It brings together the results from the quantitative assessment of the implications of reduced beach width and warmer weather conditions on visitor numbers presented in Table 6 with a semi-quantitative assessment of changes in habitat availability and increased presence of sea defences on visitor numbers, to give an overall evaluation of likely changes in numbers for each activity group. Overall, changes in weather conditions are predicted to have a greater influence on

Table 5
Importance of factors in influencing respondents' decisions to visit Holkham and Cley beaches on the day they were interviewed, for different activity groups. The table shows the mean Likert values recorded during surveys and also a symbol to represent each Likert value to aid interpretation, where: no symbol represents not important, + moderately important, and ++ very important.

Variable names	Activity groups										Kruskal–Wallis *P*-value
	Dog walking		Walking		Bird watching		Relaxing or sunbathing		Playing or paddling		
Having free time	(+)	1.3	(+)	1.4	(+)	1.3	(++)	1.5	(+)	1.3	0.842
Travelling a short distance to reach the beach	(+)	1.2	(+)	1.3	(+)	0.9	(+)	1.2	(+)	1.3	0.005
Warm weather conditions	(+)	0.9	(+)	1.1	(+)	1.0	(++)	1.5	(+)	1.1	<0.001
Level of the tide	(+)	0.5		0.4	(+)	0.5	(+)	0.5	(+)	0.5	0.177
Perception of how many people would be at the beach	(+)	1.0	(+)	0.8	(+)	0.8	(+)	0.9	(+)	0.7	0.029

Table 6
Range of predicted impacts of reductions in beach width and a change to warmer weather conditions on different activity groups. The ranges of numbers represent predicted changes in visitor numbers for the UKCIP low and high emissions scenarios respectively for 2080.

	Activity groups					Total
	Dog walking	Walking	Bird watching	Relaxing or sunbathing	Playing or paddling	
Beach width	−0.1 to −0.1%	−0.1 to −0.1%	0.0 to −0.1%	−0.1 to −0.1%	−0.1 to −0.1%	−0.4 to −0.5%
Weather conditions	3.9 to 7.4%	4.7 to 9.0%	4.3 to 8.2%	6.4 to 12.3%	4.7 to 9.0%	24.0 to 46.0%
Overall effect	3.8 to 7.3%	4.6 to 8.9%	4.3 to 8.1%	6.3 to 12.2%	4.6 to 8.9%	23.6 to 45.5%

visitor numbers than modifications to habitat availability resulting from sea level rise. However, there are distinct differences in the expected responses of the groups. As anticipated, visitors relaxing and sunbathing are predicted to be the most responsive to warmer weather conditions and this group is expected to experience the greatest increase in the number of visits made. In contrast, changes in habitat availability may have the greatest impact on bird watchers who stated a strong positive preference for all coastal habitats. Hence reductions in the extent of key habitats due to sea level rise could lead to fewer visits by this group. None of the activity groups are predicted to be affected by an increased presence of sea defences.

Table 7 also highlights the predicted biodiversity implications of these changes in recreation. Whilst the results of this analysis suggest that climate change will lead to an overall increase in visitor numbers, the impact of additional visitors on coastal habitats may not be directly proportional to the overall rise. This is because the greatest increase in numbers is predicted as being amongst visitors relaxing and sunbathing, yet this activity group has a relatively low impact on biodiversity as they use non-vegetated areas of the beach and walk short distances. In addition, it is noteworthy that dog walkers who have the highest impact on biodiversity, because they make use of the vulnerable dune environments and walk relatively long distances compared to the other activity groups, are likely to have the smallest increase in the number of visits made.

4. Discussion

Using a case study of the UK, this study has examined the impacts of climate change on visitor behaviour at the coast and the implications for biodiversity, under two scenarios. Using the case study sites of Holkham and Cley beaches, it has demonstrated that climate change may influence future levels of recreational impact that coastal habitats receive via modifications in numbers and types of visitors. Overall, there is predicted to be an increase in visitor numbers to these localities with greater participation in activities which are promoted by warm and dry weather conditions, such as sunbathing and paddling.

It is predicted that changes in weather conditions will have the greatest influence on visitor behaviour, with increased temperatures expected to result in an increase in visitor numbers for all activity groups. However, it is anticipated that different groups will be affected to varying degrees and these differences will be more evident under a high emissions scenario. As expected, visitors relaxing and sunbathing are likely to experience the greatest increase in visits as they are the most sensitive to increased temperatures. In contrast, loss of beach area due to sea level rise is predicted to have a comparatively small influence on visitor behaviour, and habitat loss is expected to detract visitors by a smaller amount than the attraction of improved weather conditions. Bird watchers are expected to be the most affected by changes to beach structure as they have a preference for the

Table 7
Summary of predicted impacts of climate change and associated environmental modifications on number of visits made by different activity groups, and implications for coastal habitats.

		Dog walkers	Walkers	Bird watchers	Relaxing or sunbathing	Playing or paddling
Habitats most used (primary and secondary)		Yellow dunes Grey dunes	Yellow dunes Grey dunes	Sand/shingle Yellow dunes	Sand/shingle Yellow dunes	Sand/shingle Yellow dunes
Relative magnitude of visitor impacts on habitats		High	Medium	Medium	Low	Low
Predicted change in propensity to visit due to environmental changes	Warmer weather conditions	Small increase	Moderate increase	Moderate increase	Large increase	Moderate increase
	Reduced beach width	Very small reduction	Very small reduction	Very small reduction	Very small reduction	Very small reduction
	Loss of habitats	Small reduction	Small reduction	Moderate reduction	Small reduction	Small reduction
	Increased presence of sea defences	No change	No change	No change	No change	No change
Predicted overall change in visits		Small increase	Moderate increase	Small increase	Large increase	Moderate increase
Likely main habitat impacts		Greater disturbance to habitats, as dogs can cause damage by digging vegetation and chasing birds (Lafferty, 2001; Miller et al., 2001).	Walkers and bird watchers tend to use a range of habitats, including vegetated areas. Consequently, greater visitor numbers may increase trampling of sand dunes and saltmarsh, leading to reduced vegetation cover and species richness (Andersen, 1995; Kutiel et al., 1999; Lemauviel and Roze, 2003).		Visitors sunbathing and paddling are less active than other users and tend to avoid vegetated areas. Whilst greater use by these groups may not significantly increase trampling of vegetation and soils, it could increase disturbance of shorebirds (Lafferty, 2001).	

presence of all habitats, and therefore losses of intertidal areas are predicted to lead to a decline in visits by this group. The effects of beach width and changes in habitat availability on visitor activities will vary between locations depending on coastal morphology and the types of management policies that are implemented in response to sea level rise.

An overall rise in visitor numbers is likely to result in coastal habitats experiencing a higher magnitude of impacts, particularly under a high emissions scenario, which is predicted to see a net increase in visitor numbers of 46% in the case study sites. However, the results show that the predicted increase in pressure on biodiversity is not anticipated to be proportional to the overall change in visitor numbers. This is because higher temperatures are expected to encourage more visitors to engage in low impact activities such as sunbathing. Since sunbathers are less active than other users and tend to avoid vegetated areas of the beach, greater use by this group may not significantly increase trampling of vegetation and soils. Despite this, a relatively small increase in visits by high impact groups, such as dog walkers, could encourage degradation of coastal habitats. Furthermore, higher levels of use may be compounded by loss of beach width, which is likely to result in visitors impacting on a reduced area, thus further increasing impact intensities. Finally, increased visitor numbers could lead to greater disturbance of shorebirds regardless of visitors' activity levels (Lafferty, 2001).

In the UK and other similar temperate climates, our results suggest changes in coastal recreation will require management to minimise additional trampling and bird disturbance. Local measures to limit the spatial extent of visitor impacts at beaches could include restricting access to a single entrance point (Burger et al., 1995) and preventing access to sensitive areas (Kutiel et al., 2000). Since the results illustrate that coastal users exhibit diverse spatial patterns of habitat use, different types of management strategies should be targeted towards each user group. Sunbathers impact across a relatively small area of the beach, mostly confined within the section immediately between the car park and the sea, and therefore it may be relatively straightforward to limit their impacts compared to other users. Greater provision of strategies that control the spatial extent of their use, such as creating defined paths through dunes in high use areas to limit wandering, may help to minimise trampling (Andersen, 1995). Other users, such as dog walkers and recreational walkers, impact across a wide area and therefore it may be more difficult to restrict the spatial extent of disturbance they may cause. However, raising environmental awareness, for example via information centres, may help promote responsible use of coastal habitats to minimise the intensity of impacts (Priskin, 2003).

In terms of regional management measures, the results suggest that greater use of practices that aim to minimise reductions in beach width and maintain coastal habitats, such as beach nourishment and managed realignment of sea defences, are likely to benefit both coastal recreation and biodiversity. Firstly, coastal defence strategies which create new intertidal areas could promote increased visitor use if the types of habitats established at realignment sites match visitors' preferences. Secondly, locations which experience a reduction in beach width could see effectively greater visitor numbers impacting on a smaller area (Jennings, 2004). This would increase pressure on already vulnerable habitats, but retreating coastal defences to mitigate coastal squeeze could help to minimise these impacts. Furthermore, the likely outcomes of these types of coastal defence strategies, which focus on the maintenance of natural resources, correspond with the objectives of current European Union policies, such as the Habitats and Birds Directive, under which it is obligatory to compensate for the loss of designated intertidal habitats and maintain wildlife populations by the creation of a like-for-like habitat (Turner et al., 1998).

This study has number of strengths and weaknesses. In terms of strengths, it has presented a novel method for assessing how different users interact with coastal environments. Visitor maps were found to provide an effective means of examining routes through habitats and provide an alternative to traditional methods of observing visitors by eye or filming behaviour using cameras, which can be intrusive and are limited to open landscapes where visitors can be viewed for reasonable distances (Soini, 2001). In terms of limitations, the work undertaken is based on observations made at just two beaches and it is unknown how and if visitor responses may differ elsewhere. Although the case study beaches were chosen to be physically contrasting, some beach characteristics that visitors were asked to rate did not exist at either location. For example, Holkham and Cley are both situated in a rural area and neither possesses the full range of facilities, such as a pier, on which respondents were asked to state a preference. Therefore, surveying across a wider range of beach types may allow activity groups' preferences to be more fully represented.

A further limitation was that it was not possible to model changes in beach morphology associated with coastal squeeze, although these changes could have a considerable effect on spatial patterns of visitor use. In particular, loss of beach may force visitors into dunes and saltmarsh, which would further increase pressure on these sensitive areas. Although management plans are being implemented to moderate the effects of sea level rise, they may not completely mitigate these changes. The Coastal Habitat Management Plan (CHaMP) for North Norfolk, for example, aims to allow habitats to roll landwards in response to sea level rise in the medium term (the next 50 years) at Holkham and to retreat existing lines of defence at Cley (English Nature and Environment Agency, 2003). However, it is anticipated that some habitat erosion may also take place as a result of stormier conditions, particularly since intertidal habitats will be vulnerable given an accelerating rate of sea level change (Brown and McLachlan, 2002), yet the possible impacts of this erosion are unknown. To refine predictions of future visitor impacts, further work might focus on developing quantitative model based methodologies to predict how the spatial distribution of visitor routes may be affected by sea level rise and habitat changes.

A further limitation to this work is that we have predicted how visitor groups will respond to environmental changes based on their current stated preferences, yet there is uncertainty regarding whether visitors will actually respond accordingly (Scott et al., 2007). We did not ask visitors about their likely future behaviour change because there is good evidence that many find it difficult to evaluate the likely impact upon themselves of environmental changes some time in the future (Richardson and Loomis, 2004). Our approach thus does not take into account adaptation strategies that visitors may exhibit, for example, using alternative beaches, or visiting at different times of the year (Braun et al., 1999). It also does not take into account alterations to visitors' sensitivity to conditions in a changed future. Notably, levels of visitation may not increase by the amounts predicted here if visitors became less responsive to warm weather conditions in a future with more warmer days overall. Furthermore, other non-climate related factors also influence decisions to visit the beach, in particular the availability of free time, which each of the activity groups rated as either moderately or very important. Further work to understand the likely nature of societal adaptations will help refine understanding of the relative importance of both social and environmental changes in influencing predicted visitor responses, and would also allow measures of uncertainty, an important component of climate change predictions (Gössling and Hall, 2006), to be incorporated into the analytical framework we have developed.

Although visitor numbers were predicted to increase with rises in temperature in this study, a highly non-linear relationship may be present in some countries whereby declines become apparent when conditions become too hot (see Maddison, 2001; Hamilton et al., 2005). Our methodology would allow this to occur, but critical temperature thresholds would not occur over the time-frame of this study. Furthermore, tourists may hold different temperatures preferences depending on their country of origin. Travel patterns of British tourists reveal that the maximum daytime temperature they perceived as comfortable is 30.7 °C (Maddison, 2001). Yet tourists from countries of the Organisation for Economic Cooperation and Development (OECD), which includes parts of Europe, Australia and New Zealand, were found to prefer an average daily temperature of 21 °C (Lise and Tol, 2002). It is certainly the case that deviations from preferred conditions could result in tourists seeking alternative destinations or travelling at different times of the year.

According to these findings, increased temperatures could lead to a reversal in the trend of travel from northern Europe to the Mediterranean. Warmer and drier summers in northern Europe may result in these areas achieving optimal temperatures, whilst substantially hotter summers in the Mediterranean could lead to these areas being uncomfortably hot and consequently deter visitors (Amelung and Viner, 2006; Nicholls, 2006). Whilst northern Europe may see economic advantages, marine environments could experience enhanced pressure due to greater visitor numbers, a longer tourism season, increased tourism infrastructure (e.g. hotels, attractions and roads), increased waste such as sewage, and greater levels of environmental destruction (Amelung and Viner, 2006). These impacts are untested by our work, but the application of the methodological framework we have presented here to other locales will provide one means of identifying such impacts in very different contexts.

5. Conclusions

The trends predicted at the case study sites may be indicative of the types of changes that are likely to take place along the coastlines of northern Europe. Given the importance of warm weather conditions in promoting activities such as sunbathing and paddling, countries that experience a rise in temperatures are likely to see a corresponding increase in visitors who are less active. Whilst greater participation in low impact activities may help to limit additional stresses on biodiversity, greater visitor numbers overall will nevertheless require appropriate management strategies that are directed towards minimising the environmental impacts from diverse groups of coastal users. A possible means to achieve this may be through the use of coastal defence strategies which focus on the maintenance of natural resources as these are likely to benefit both coastal recreation and biodiversity by limiting reductions in beach width and maintaining coastal habitats.

Acknowledgements

This research was funded by an Economic and Social Research Council and Natural Environment Research Council Interdisciplinary Ph.D. Studentship. The authors thank Prof William Sutherland for providing advice throughout this study.

References

Alessa, L., Bennett, S.M., Kliskey, A.D., 2003. Effects of knowledge, personal attribution and perception of ecosystem health on depreciative behaviours in the intertidal zone of Pacific Rim National Park and Reserve. Journal of Environmental Management 68, 207–218.

Amelung, B., Viner, D., 2006. Mediterranean tourism: exploring the future with the tourism climatic index. Journal of Sustainable Tourism 14, 349–366.

Andersen, U.V., 1995. Resistance of Danish coastal vegetation types to human trampling. Biological Conservation 71, 223–230.

Andres-Abellan, M., Del Alamo, J.B., Landete-Castillejos, T., Lopez-Serrano, F.R., Garcia-Morote, F.A., Del Cerro-Barja, A., 2005. The impact of visitors on soil and vegetation of the recreational area "Nacimiento del Rio Mundo" (Castilla-La Mancha, Spain). Environmental Monitoring and Assessment 101, 55–67.

Bellan, G.L., Bellan-Santini, D.R., 2001. A review of littoral tourism, sport and leisure activities: consequences on marine flora and fauna. Aquatic Conservation-Marine and Freshwater Ecosystems 11, 325–333.

Belle, N., Bramwell, B., 2005. Climate change and small island tourism: policy maker and industry perspectives in Barbados. Journal of Travel Research 44, 32–41.

Braun, O.L., Lohmann, M., Maksimovic, O., Meyer, M., Merkovic, A., Messerschmidt, E., Riedel, A., Turner, M., 1999. Potential impact of climate change effects on preferences for tourism destinations. A psychological pilot study. Climatic Research 11, 247–254.

Brown, A.C., McLachlan, A., 2002. Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. Environmental Conservation 29, 62–77.

Burger, J., Gochfeld, M., Niles, L.J., 1995. Ecotourism and birds in coastal New-Jersey—contrasting responses of birds, tourists, and managers. Environmental Conservation 22, 56–65.

Coombes, E.G., Jones, A.P., Sutherland, W.J., 2009. The implications of climate change on coastal visitor numbers: a regional analysis. Journal of Coastal Research 25, 981–990.

Coombes, E.G., Jones, A.P., Sutherland, W.J., 2008. The biodiversity implications of changes in coastal tourism due to climate change. Environmental Conservation 35, 319–330.

de Freitas, C.R., 1990. Recreation climate assessment. International Journal of Climatology 10, 89–103.

Dwyer, J.F., 1988. Predicting daily use of urban forest recreation sites. Landscape and Urban Planning 15, 127–138.

English Nature, 2003. National Nature Reserves in Norfolk. Report produced by English Nature. Norwich, UK. 28 p.

English Nature, Environment Agency, 2003. North Norfolk Coastal Habitat Management Plan. Report published by English Nature. Norwich, UK. 103 p.

Environment Agency, English Nature, North Norfolk District Council, Great Yarmouth Borough Council, Waveney District Council, 2006. Shoreline Management Plan: Kelling to Lowestoft. Anglian Coastal Authorities Group, Peterborough, UK.

Gössling, S., Hall, C.M., 2006. Uncertainties in predicting tourist flows under scenarios of climate change. Climatic Change 79, 163–173.

Hamilton, J.M., Maddison, D.J., Tol, R.S.J., 2005. Climate change and international tourism: a simulation study. Global Environmental Change — Human Policy Dimensions 15, 253–266.

Hulme, M., Jenkins, G.J., Lu, X., Turnpenny, J.R., Mitchell, T.D., Jones, R.G., Lowe, J., Murphy, J.M., 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, School of Environmental Sciences, University of East Anglia, Norwich, UK, 120 p.

Intergovernmental Panel on Climate Change (IPCC), 2000. Special Report on Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Jędrzejczak, M.F., 2004. The modern tourist's perception of the beach: is the sandy beach a place of conflict between tourism and biodiversity? Coastline Reports 2, 109–119.

Jennings, S., 2004. Coastal tourism and shoreline management. Annals of Tourism Research 31, 899–922.

Klein, R.J.T., Bateman, I.J., 1998. The recreational value of Cley Marshes nature reserve: an argument against managed retreat? Journal of the Chartered Institution of Water and Environmental Management 12, 280–285.

Kutiel, P., Eden, E., Zhevelev, Y., 2000. Effect of experimental trampling and off-road motorcycle traffic on soil and vegetation of stabilized coastal dunes, Israel. Environmental Conservation 27, 14–23.

Kutiel, P., Zhevelev, H., Harrison, R., 1999. The effect of recreational impacts on soil and vegetation of stabilised Coastal Dunes in the Sharon Park, Israel. Ocean and Coastal Management 42, 1041–1060.

Lafferty, K.D., 2001. Birds at a Southern California beach: seasonality, habitat use and disturbance by human activity. Biodiversity and Conservation 10, 1949–1962.

Lemauviel, S., Roze, F., 2003. Response of three plant communities to trampling in a sand dune system in Brittany (France). Environmental Management 31, 227–235.

Liley, D., Sutherland, W.J., 2007. Predicting the population consequences of human disturbance for ringed plover *Charadrius hiaticula* population size: a game theory approach. Ibis 149, 82–94.

Lise, W., Tol, R.S.J., 2002. Impact of climate on tourist demand. Climatic Change 55, 429–449.

Maddison, D., 2001. In search of warmer climates? The impact of climate change on flows of British Tourists. Climatic Change 49, 193–208.

McKercher, B., 1996. Differences between tourism and recreation in parks. Annals of Tourism Research 23, 563–575.

Miller, S.G., Knight, R.L., Miller, C.K., 2001. Wildlife responses to pedestrians and dogs. Wildlife Society Bulletin 29, 124–132.

Morgan, R., 1999. Preferences and priorities of recreational beach users in Wales. Journal of Coastal Research 15, 653–667.

Nepal, S.K., Nepal, S.A., 2004. Visitor impacts on trails in the Sagarmatha (Mt. Everest) National Park, Nepal. Ambio 33, 334–340.
Nicholls, S., 2006. Climate change, tourism and outdoor recreation in Europe. Managing Leisure 11, 151–163.
North Norfolk District Council, 2003. Economic Impact of Tourism in North Norfolk. Report prepared by the East of England Tourist Board, UK.
Ordnance Survey, 2007. Ordnance Survey MasterMap land use data. www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/ (accessed June 2007).
Pethick, J., 2001. Coastal management and sea-level rise. Catena 42, 307–322.
Priskin, J., 2003. Tourist perceptions of degradation caused by coastal nature-based recreation. Environmental Management 32, 189–204.
Richardson, R.B., Loomis, J.B., 2005. Climate change and recreation benefits in an Alpine National Park. Journal of Leisure Research 37, 307–320.
Richardson, R.B., Loomis, J.B., 2004. Adaptive recreation planning and climate change: a contingent visitation approach. Ecological Economics 50, 83–99.
Scott, D., Jones, B., Konopek, J., 2007. Implications of climate and environmental change for nature-based tourism in the Canadian Rocky Mountains: a case study of Waterton Lakes National Park. Tourism Management 28, 570–579.
Scott, D., McBoyle, G., Schwartzentruber, M., 2004. Climate change and the distribution of climatic resources for tourism in North America. Climate Research 27, 105–117.
Soini, K., 2001. Exploring human dimensions of multifunctional landscapes through mapping and map-making. Landscape and Urban Planning 57, 225–239.
Stive, M.J.F., 2004. How important is global warming for coastal erosion? Climate Change 64, 27–39.
Tudor, D.T., Williams, A.T., 2006. A rationale for beach selection by the public on the coast of Wales, UK. Area 38, 153–164.
Turner, R.K., Lorenzoni, I., Beaumont, N., Bateman, I.J., Langford, I.H., McDonald, A.L., 1998. Coastal management for sustainable development: analysing environmental and socio-economic changes on the UK coast. The Geographical Journal 164, 269–281.
Uyarra, M.C., Côté, I.M., Gill, J.A., Tinch, R., Viner, D., Watkinson, A.R., 2005. Island-specific preferences of tourists for environmental features: implications of climate change for tourism-dependent states. Environmental Conservation 32, 11–19.
Weaver, T., Dale, D., 1978. Trampling effects of hikers, motorcycles and horses in meadows and forests. Journal of Applied Ecology 15, 451–457.