An ecosystem services approach to assess managed realignment coastal policy in England

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Abstract

The east coast of England is under threat from climate change effects such as the sea level rise, and because of isostatic movements. In the face of these problems, the UK government is reorientating its coastal management strategy with a view to increasing its flexibility and adaptability. On the east coast this policy switch has included a series of managed realignment projects by which some sea defences are breached and the land flooded. These projects result in the restoration of salt marshes, which are a soft and more sustainable flood defence helping to dissipate wave energy. Salt marshes are considered as a benefit because they also create the opportunity for biodiversity enhancement, as well as expanded opportunities for amenity and recreation. Furthermore, carbon is stored underneath salt marshes helping to mitigate the effects of climate change.

An ecosystem services approach was used to provide a framework for the cost-benefit analysis of multifunctional coastal schemes in the Blackwater estuary (Essex – UK). This method allowed a wide range of welfare impacts to be considered on a common monetary scale. The valuation of ecological services such as carbon storage, fish nurseries, and recreation and amenity can be encompassed in this method.

A binary choice experiment was designed and a survey conducted in Essex, Norfolk and Suffolk (UK) to elicit the value of salt marshes created by a series of managed realignments considered as a single project in the Blackwater estuary.

The final aggregate value of salt marshes was then inserted in a CBA assessing the efficiency of management realignment schemes on a catchment level such as an estuary area together with the other benefits of the project: carbon storage and fish nursery. The combined work of science and economics produced interesting results showing the economic efficiency of managed realignment projects realised at an estuary scale level.

1. Introduction

A combination of driving pressures, including climate change, is ‘forcing’ an escalation in the rate of environmental change in coastal areas. Coastal zone policy in the UK and Europe is consequently being re-orientated towards a more flexible and adaptive approach, while linked water catchment management is also being reformulated under the Water Framework Directive. A key component of this new thinking will be managed realignment (ie setting back of sea defences and erosion controls). Any comprehensive deployment of this strategy, however, will be conditioned by a complex set of factors in a highly ‘contested’ political economy context. Argumentation will be focused on the trade offs between grater resource efficiency, social justice, equity and compensation objectives. The aim of this paper is formulate and deploy a cost-benefit model and ecosystem services approach which quantifies the economic gain and losses associated with a future more adaptive coastal protection.

The research highlights that managed realignment policy needs to be appraised across a more extensive spatial end temporal scale than has been the case in the traditional scheme-by scheme coastal management system. Whole estuaries or multiple coastal cells need to be treated as a single 'project' encompassing a number of realignment sites. A sequential approach to the appraisal process should first identify all sites in which the opportunity costs of realignment do not involve significant social justice/ethical concerns. In these cases an efficiency-based CBA could provide the decisive information in policy choice (Randall, 2002; Turner, 2007). In the cases where people, property, culture/historical assets end designated freshwater conservation sites are part of the opportunity cost calculation, CBA will not be as decisive and must be subsumed within a multi-criteria decision support system and process. Environmental change impacts such as climate change and biodiversity loss often carry with them long term consequences and so policy responses need to be flexible and adapted to long time horizons and future surprises. The standard CBA practice of positive, fixed and short term (<25 years) discounting does not sit easily with these contexts but is critical in determining whether as project/policy passes a CBA test. There is now growing consensus on the adoption of a time declining discount rate (DDR) procedure over at least a 100 year time horizon. Official guidance on UK public sector project/policy appraisal now advocates such an approach (HMT, 2003). As the process of environmental change across local to regional and up to the global scale has intensified and increased in pace, so the risk posed to the integrity and resilience of ecosystems, not least in coastal areas, has increased in parallel. This has required the adoption of what is called an ecosystem services approach to support the case for more protected areas or better management and sustainable use of ecosystems under threat of conversion or degradation from economic development (Costanza et al., 1997; Daily, 1997; Daily and Ellison, 2002; Bockstael et al., 200; Balmford et al., 2002).

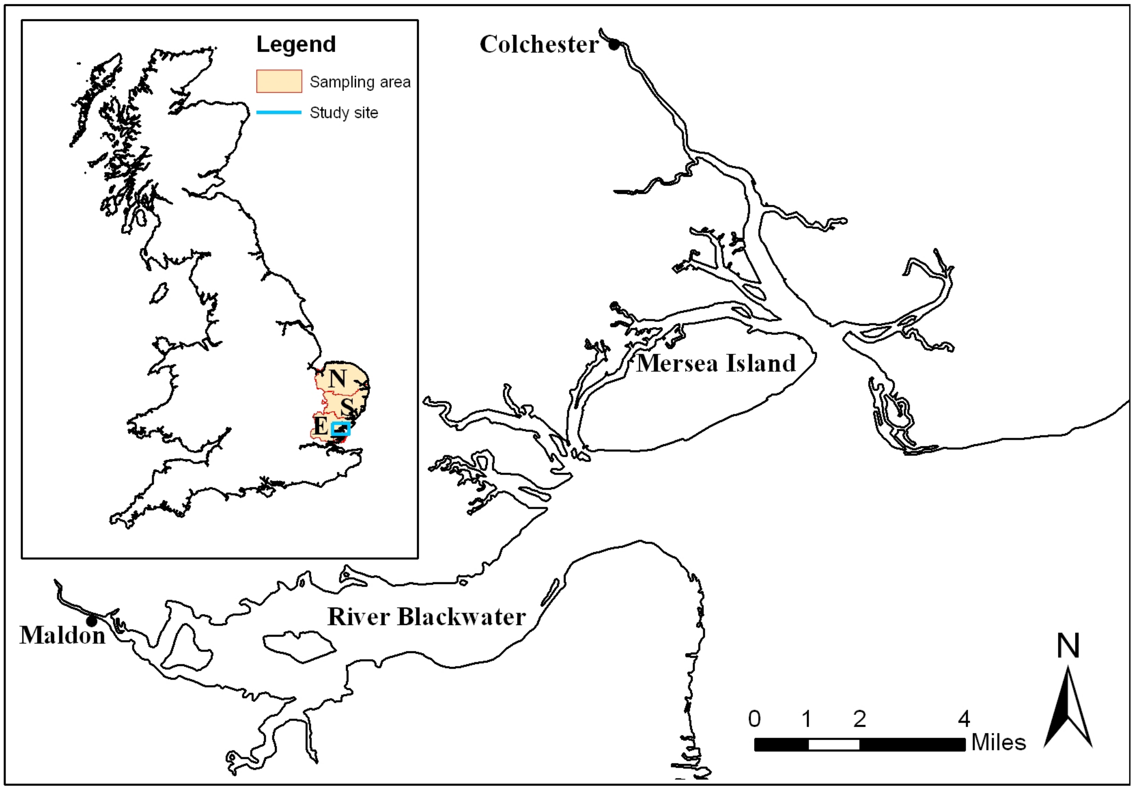
Recent research covering estuarine sites on the coast of England (Andrews et al, 2006; Shepherd et al, 2007; Turner et al, 2007) has indicated that managed realignment schemes can pass an economic efficiency test. Sensitivity analysis has revealed that the results are influenced by the valuation estimates used to account for the ecosystem services provided through the schemes (eg recreation, amenity and biodiversity gains). These previous studies utilised benefits transfer methods to account for some of the ecosystem service values. The study reported in this paper includes a site specific choice experiment survey to elicit ecosystem service values from the regional population proximate to the realignment scheme at issue. In this sense the analysis represents an advance on the existing published studies, as does the use of new biological and geochemical data from study site(s) fieldwork (C. Adams ad L. Fonseca PhDs research) relevant to carbon storage and fish productivity benefits.

On the east coast of England managed realignment (MR) projects involve the deliberate breaching of sea defences with the land behind them consequentially being flooded. These projects result in the creation/restoration of salt marshes, which are a soft and more sustainable flood defence which help to dissipate wave energy. Salt marshes are disappearing from coasts because of what is known as the ‘coastal squeeze’ phenomenon. This arises when, to protect coasts, sea walls are erected between the land and an intertidal habitat. Due to sea level rise, that intertidal habitat is gradually disappearing, constrained on one side by the sea and on the other by sea walls. Managed realignment allows the intertidal habitat to naturally move inland so that it can continue to protect the coast. Salt marsh ecosystems create also the opportunity for biodiversity enhancement, as well as expanded opportunities for amenity and recreation and in that sense can be considered a benefit for society.

The study site reproduced in Figure 1 is the Blackwater estuary catchment area in Essex in the East of England, Great Britain. The Blackwater is approximately twelve miles and a half long (from the city of Maldon to Mersea Island) and covering 5,500 hectares with open water, mudflats and saltmarshes[1].

[1] http://www.maldon.gov.uk/Leisure/ParksAndOpenSpaces/Parks/Blackwater+Estuary.htm

Figure 1 Study area map.



N = Norfolk; S = Suffolk; E = Essex

In addition to several nature designations, the estuary is a valuable asset in terms of heritage, landscape, and marine environment, as well as recreation, tourism, fishing agriculture and riverside industry. Management strategies have been proposed to provide sustainable flood defence and experiments are underway on the managed realignment of the coast (at Tollesbury, Orplands, Northy Island and Abbott's Hall) to mitigate flood risk.

Within the CBA, four scenarios were used: a *'Hold the line'* (HTL) scenario that represents the *status quo* in which the existing defences are maintained to a satisfactory level but intertidal habitat will be lost due to continued development and coastal squeeze; a so called *'Policy targets'* (PT) scenario in which economic growth is combined with environmental protection, with realignment undertaken to reduce flood defence expenditure and compensate for past and future intertidal habitat loss; a *'Deep green'* (DG) scenario in which environmental protection takes priority over economic growth, while development continues; an *'Extended deep green scenario'* (EDG) that emphasises the habitat creation using less restrictive criteria to identify suitable areas for realignment. Thus the extent of managed realignment increases from HTL through to EDG.

The future possible areas suitable for managed realignment in the Blackwater estuary were identified with GIS techniques applying the five criteria outlined in Turner et al. (2007) and avoiding, for all the scenarios, military areas and archaeological sites.

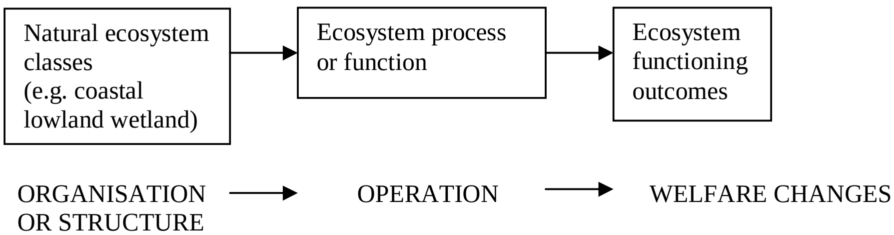
2. Wetland Ecosystem services

There are several definitions provided for ecosystem services in the literature (Daily, 1997; Costanza et al., 1997; Boyd and Banzhaf, 2007). The Millennium Assessment (MA) developed the following general definition in 2005: “ecosystem services are the benefits people obtain from ecosystems”. That definition divides ecosystem services into *supporting*, *regulating*, *provisioning* and *cultural* services. As pointed out by Fisher *et al.* (2008) and Wallace (2007), when the focus is on the valuation of ecosystem services, that definition can lead to confusion because it lists both ‘ends’ and ‘means’ as services. In other words, that definition implies that the ecosystem services are the benefits for society, but at the same time that the services are the means by which the benefits are created. Since the main purpose of this study is to assess the value of the benefits that the salt marshes in the Blackwater estuary can bring to society, it is important to clarify what is an ecosystem service and what is a benefit for society.

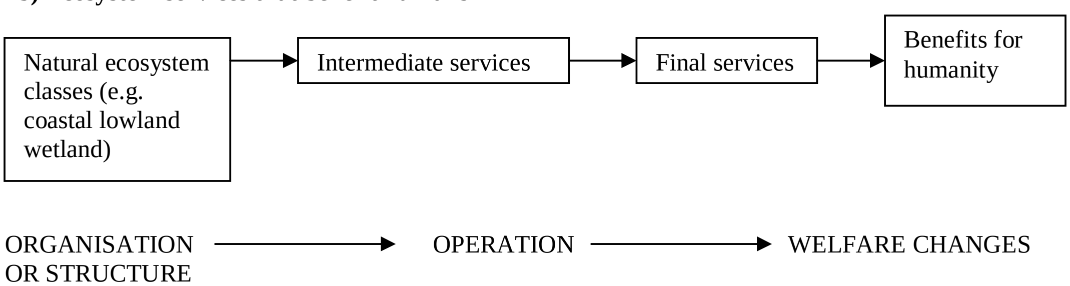
The definition proposed by Fisher *et al.* (2008) clarifies the distinction between ecosystem services and benefits and for that reason will be used in this study: *ecosystem services are the aspects of ecosystems utilised (actively or passively) to produce human well-being*. Fisher *et al.* see ecosystem services as being the link between ecosystems and things that humans benefit from, not the benefits themselves. The focus is on the benefits that humans receive from the ecosystem. Ecosystem services include ecosystem organisation or structure (the ecosystem classes) as well as ecosystem processes and functions (the way in which the ecosystem operates). The processes and functions become services only if there are humans that (directly or indirectly) benefit from them. In their definition of ecosystem services the key feature is then the separation of ecosystem processes and functions into intermediate and final services. Figure 2 summarises in a simple diagram when an ecosystem produces services and hence benefits to humans. If humans are not the beneficiaries of the examined ecosystem, then we talk of ecosystem processes or ecosystem functions (Figure 2a) that lead to ecosystem functioning outcomes. When the ecosystem processes or functions lead to human benefits, then they become services (intermediate and final services) (Figure 2b).

Figure 2 Ecosystem services approach

2a) Ecosystem services that benefit nature



2b) Ecosystem services that benefit humans



The general framework described in the previous section can be applied to any ecosystem. Figure 3 is a more detailed version of Figure 1.b, and shows the ecosystem services provided by the salt marshes in the Blackwater.

Figure 3 Classification of the wetland ecosystem services in the Blackwater and valuation methods of the benefits

WETLAND CLASSES	INTERMEDIATE SERVICES	FINAL SERVICES	BENEFITS FOR HUMANITY	VALUATION/ EVALUATION
Specific characteristics of the salt marsh as determined by locational factors and structures of the area	• Water storage	• Flood alleviation	• Natural flood protection (soft flood defence)	• Market analysis (flood defence maintenance cost)
	• Carbon sequestration	• Carbon emission reduction	• Climate change effects mitigation	• Damage cost avoided
	• Water provision	• Habitat for (migratory) species	• Biodiversity maintenance	• Non-use values, intrinsic value
		• Nursery for plants and animals	• Fish production	• Market analysis, non-use values, intrinsic value
			• Amenity and recreation	• Use values, non-use values, intrinsic value

2.1 Ecosystem services in the Blackwater estuary

Four key benefits were identified for the salt marshes in the Blackwater: maintenance cost savings on coastal defences; carbon sequestration, fish nurseries and productivity effects; amenity and recreation together with biodiversity conservation that were treated in this study as a composite environmental benefit (CEB).

Intertidal habitats are considered a soft coastal defence from flooding, so that a secondary line of defence might not be necessary if the land elevation in the realigned site is adequate to act as a sea defence. In those areas where a second defence line is still required, the intertidal habitat will protect the new defence from the sea requiring less maintenance. Defence breaches are relatively low priority and for that reason a contingency cost is routinely included in the overall maintenance cost estimates for sea defences.

Saltmarsh ecosystems are assumed to be areas in which sediment burial can take place. As reported by Jickells et al. (2000) and Andrews et al. (2006), burial of sediments containing organic matter within an estuary acts as a sink for carbon, nitrogen and phosphorous. The storage of carbon in intertidal areas such as mudflats and saltmarshes has an economic value given consequent reductions in emissions of greenhouse gases. The value of the carbon stored is then assessed through the damage cost avoided. When the carbon is buried under fresh water marshes, the storing process can create greenhouse gases such as methane that could offset the effect of the carbon storage. However, methane is not a concern when the carbon is stored under coastal marshes, where methane releases are low thanks to the salt water involved. Assuming that salt marsh forms immediately following realignment[2] (Andrews et al., 2006; French, 2006), two sedimentation rates for both mudflats and salt marshes were estimated and the quantity of nutrients buried annually for the two sedimentation rates were calculated. Old and recent managed realignment sites in the Blackwater were sampled. The first rate calculated is 1.5 mm a^{-1}, which corresponds to the long term sustainable rate observed elsewhere (Shepherd et al., 2007). The second, 6 mm a^{-1} corresponds to the upper limit which *may* be achieved during the immediate post-realignment phase.

The economic value of the refugia service provided by the new saltmarshes created through managed realignment can be calculated via the production function approach (Barbier, 1994; Barbier, 2000). With this technique, the ecosystem is valued as an input into the fishery production equation. The production function was estimated by fisheries experts sampling the fish nurseries in two natural marshes adjacent to the sites of Tollesbury and Abbott's Hall and a managed realignment site within Orplands. The results of the studied sites were combined to get the final value estimate of saltmarsh nurseries. Bass was the only fish species with an economic value investigated because sampling showed that there were not enough fish juveniles from the other species to be able to say that those areas are nursery grounds.

To avoid double counting the CBA for this study takes account only of independent goods and services produced by the intertidal habitat treated as a single aggregate value. The composite environmental benefit measures the economic value of water quality, which in turn enhances biodiversity that are fundamental factors for an enjoyable landscape, amenity and recreation. Thus, for example, nutrient storage is an intermediate service of the ecosystem,

[2] After realignment it takes usually at least six months before saltmarshes develop.

which indirectly leads to enhanced amenity and recreation via improved water quality. As noted in Barbier (1994) if the nutrient retention function is integral to the maintenance of biodiversity, then giving both nutrient retention and biodiversity separate monetary values would double count the nutrient retention which is already 'captured' by the biodiversity value. By valuing amenity and recreation, we are indirectly valuing the basic factors for a healthy saltmarsh ecosystem.

2.2 The monetary valuation of the ecosystem services in the Blackwater

Although different methodologies need to be applied to value the benefits shown in Figure 3, for the first three the value is easily calculated referring to their market value. The cost of maintaining hard defences has a market price[3], and the cost of maintaining a second line of defence is assumed to be half of the cost of the old defence maintenance because of the buffering provided by the intertidal habitat. The value of fish nurseries can be inferred from the market price of those fish species that grow in the salt marsh creeks and are then sold in the wholesale market. Carbon sequestration and the relative carbon burial are more difficult to estimate. Three different prices were considered in this study: the highest price that could be used is the figure suggested formerly by Pearce et al. (1996) and confirmed by Tol (2005) of $50/tC (equivalent to about £30 in 2007); another much lower figure that could be applied is £7, which is in the range of the estimates recommended by the Second Assessment Report ($5-125/tC) as well as in the range suggested by Pearce (2003) (£4.30-27/tC) and confirmed by Li et al. (2004); another possible figure is given by the mean price of traded carbon that in October 2007 was equal to €21.50[4] which is about £15. A stated preference study, which is described in the following section, was conducted to elicit from the public the composite (amenity, recreation and biodiversity) value of the Blackwater salt marshes.

3. Choice experiment: design

Giving the aim of finding a value of wetlands expressed via people's willingness to pay (WTP), a choice experiment (CE) study was designed and a survey conducted in Essex as well as the neighbouring counties of Norfolk and Suffolk (UK) as shown in Figure 1.

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[3] The maintenance cost taken from Halcrow (2007) and used for this analysis is not expected to vary significantly with climate change.

[4] That value is reported by http://www.pointcarbon.com. It should be noticed that this price is higher than usual due to the dollar price that in the same period was anomalously going down.

Following a series of preliminary and focus group investigations with policy makers, stakeholders and members of the public, a set of attributes was identified to define the salient features of the good and policy under investigation. These attributes and their units of measurement were as follows:

- The area of new salt-marshes to be created (variable label '*AREA*'); measured both as acres (the most well understood standard unit in the UK) and as the corresponding number of football pitches (as a further approach to enhance comprehension);
- Bird species observable ('*BIRDS*'): measured as the number of protected species; a key policy focus;
- Distance from respondent's home to the nearest site ('*DISTANCE*'); measured in miles;
- Whether the created salt-marsh would be open-access or not ('*ACCESS*'): a simple binary variable;
- Increase in the respondent's annual local (council) tax to pay for the option ('*TAX*'); measured in £ per household per annum.

The extent of salt marsh for the *AREA* attribute was determined using GIS techniques considering areas that could be reasonably created in the estuary with managed realignment and taking account of several constraints[5] such as urbanised, military and archaeological areas and infrastructure as well as natural and protected sites (SSSI and SAC).

Since birds are one of the final links in the food chain of salt marshes, and they also represent saltmarsh biodiversity in general (non-use values), they were a good candidate to reflect the quality of the environment in the area. The lower limit for the *BIRDS* attribute, which is also the *status quo* level, was determined as the number of the protected species of birds currently living in the estuary (Wetlands Trust). The upper level was determined mostly on the base of statistical properties required for the experimental design.

The attribute *ACCESS* was dummy coded, and was used to uncover respondents' preference for the recreation provided by salt marshes.

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[5] Some restrictions for areas suitable for managed realignment schemes are the same imposed by Turner at al., 2007: the area below the High Spring Tide Level; the present land use of the area; the infrastructure of the area; the historical context of the area; the spatial context of the area. Others, such as the existence of archaeological and/or military sites, have been added in this study.

Since saltmarshes concern use and non-use values, the use of national taxes (as a payment vehicle) was judged to be the appropriate for two reasons: MR projects are implemented with public expenditure and the benefits of the saltmarshes are available for both users and non-users. However, it is well known in the literature that it is easy to get high positive rates of response because the subjects do not believe that they will have to pay the proposed tax increase. A good compromise was the use of council tax. Council tax is more difficult to evade and can be perceived by respondents as a meaningful payment vehicle. We refer to the cost attribute as *TAX*.

Although considerable variation in the level of the *DISTANCE* attribute was derived by respecifying the location of putative wetlands around what is a large estuary, further substantial variation is of course induced by the different locations of respondent's home addresses. This allowed us to define two non-overlapping vectors of levels for this attribute, respondents being allocated to one or the other according to their home location.

Attributes and their levels are presented in Table 1 which also details the division of the '*DISTANCE*' attribute into those seen by the *'Far'* sample (living in Norfolk and Suffolk) and those seen by the *'Near'* sample (living in Essex).

Table 1 Attribute levels used in the choice experiment design.

Attribute	Label	Levels
Area of new salt-marshes	*AREA*	25acres = 10fp*; 74acres = 30fp; 123acres = 50fp; 173acres = 70fp
Number of protected bird species observable	*BIRDS*	2, 3, 4, 5 species
Distance from your home (in miles)	*DISTANCE*	'Near sample': 2, 12, 22, 32 miles 'Far sample': 42, 52, 62, 72 miles
Access to the salt-marshes	*ACCESS*	Yes; No
Increase in your council tax per year	*TAX*	£2, £6, £10, £14

*fp stands for football pitches

3.1 Choice experiment: implementation

Choice sets were determined based on a fractional factorial design. Each respondent answered eight choice questions, each consisting of two options: a status quo option, representing the current situation (or policy) of no new salt marsh in the area; and an alternative, in which new salt marshes were created. The questionnaire was composed of six sections: the first two introduced the respondent to the resource and the policy change context. Subsequent sections presented the CE exercise followed by a contingent behaviour and contingent valuation exercise described elsewhere. The final sections of the questionnaire gathered socio-economic and demographic data and conducted an interviewer evaluation of the interview.

The choice experiment was presented to respondents via a standard tabular format, an example of which is given in Figure 4. Here n/a denotes aspects of the present situation where attributes were not available because in that option there are no new salt marshes created.

Figure 4 Example of choice card shown to respondents.

INFORMATION about the Blackwater estuary	**Present Situation**	**Option A**
Area of new salt-marshes	No new salt-marshes	25 Acres = 10 football pitches
Number of protected bird species observable	2	2
Distance from your home (IN MILES)	n/a	42
Access to the salt-marshes	n/a	NO
Increase in your council tax per year	No tax	£2.00
	Choose ‘Present Situation’	**Choose ‘Option A’**
Which would you choose? (tick one box only)		

Interviews were conducted by a team of trained interviewers at various locations within both the *‘Near’* and *‘Far’* distance zones[6]. After cleaning for yea-saying and protest responses a total sample of some 508 completed questionnaires was obtained of which 162 originated within the *‘Far’* zone (within Norfolk and Suffolk) and 346 from the *‘Near’* area (within Essex). Socio-demographic characteristics of these samples are presented in Table 2. As can be seen the sub-samples appear highly similar in their characteristics. A *t*-test and a Kruskal-Wallis test on the age, sex and income variables showed that the *‘Far’* and the *‘Near’* sample are not significantly different from each other.

[6] Non-probability sampling techniques were adopted, a convenient and frequently used approach for hypothesis testing purposes. The survey was conducted over six weeks during summer 2006.

Table 2 Descriptive statistics for the overall and sub-samples.

Variable	*'Far' sample*	*'Near' sample*
Mean age group	36 – 45 years	36 – 45 years
Sex (% male)	55%	47%
Mean annual personal income (£)	£19,500	£18,920
Number of respondents	162	346

3.2 Choice experiment: general results

To calculate the aggregate value of WTP for the CBA, we present here[7] the model of the *'Near'* sample data:

$$V_A = \beta_1 Const + \beta_2 LnAREA + \beta_3 BIRD3 + \beta_4 BIRD4 + \beta_5 BIRD5 + \beta_6 DIST + \beta_7 ACC + \beta_8 TAX + \varepsilon_A$$

where *Const* is the constant variable, *LnAREA* is the natural logarithm of the attribute *AREA* , *BIRD3*, *BIRD4*, *BIRD5* are the dummies created for the attribute *BIRDS* using the level of the status quo option as the base level, DIST represents the attribute *DISTANCE*, *ACC* is the *ACCESS* variable and *TAX* is the cost variable.

To take account of the fact that each individual made eight choices, a random effects binomial logit model was estimated to investigate the significance and the adequacy of the model fit as well as the presence of heterogeneity in the model.

[7] The results of the random effects binomial logit model for the *'Far'* and *Pooled* sample are presented elsewhere.

Table 3: Choice experiment model: '*Near*' sample data.

Variables	*Coefficient*	*Standard error*	*t-ratio*	*P-value*
Constant	0.2754	0.2581	1.0670	0.2860
LnArea	0.2519	0.0609	4.1373	0.0000
Bird3	0.4172	0.1137	3.6683	0.0002
Bird4	0.6936	0.1224	5.6639	0.0000
Bird5	0.8078	0.1070	7.5440	0.0000
Distance	-0.0118	0.0036	-3.3042	0.0010
Access	0.9745	0.0615	15.8391	0.0000
Tax	-0.2260	0.0080	-28.2128	0.0000
Rho	0.2368	0.02121	11.161	0.0000
LL		-1399.659		
P-value		0.00010		
Correct predictions		73.483%		
Observations		2768		
Respondents		346		

The *CONSTANT* is positive meaning that, everything else held constant, the respondents receive more utility from the new salt marsh projects going ahead than not. However, the variable is not significant, meaning that other elements that the respondents might have considered in making their choice had a little weight in comparison to the attributes presented in the choice experiment.

The attribute *AREA* is highly significant and of the expected sign. It is reasonable to think that locals prefer a bigger area to a smaller one. However, we assume a log-linear relationship for the attribute AREA rather than a linear relationship.

The BIRDS attribute, representing the quality of the environment, was initially modelled using a single linear variable. However, such a form yields a significantly lower degree of explanation than the more flexible, non-linear specification permitted by the use of the dummy variables BIRD3, BIRD4 and BIRD5. All three dummy variables were significant at the 99% level and of the expected positive sign indicating that providing habitat for a higher number of endangered bird species results in higher utility levels. Examining parameter values suggests that the satiation point is attained at the *BIRD4* level suggesting a positive but declining marginal WTP for bird habitat.

The attribute *ACCESS* turns out to be positive, as expected, and significant at 99%. That means that respondents are interested in seeing and enjoying the natural environment of salt marshes.

The *DISTANCE* variable has the expected negative parameter value and is significant at the 99% level. This result shows that, as expected, the utility of new wetland sites diminishes the further away they are from the individual.

The cost variable, *TAX*, is highly significant at the 99% level and of the expected negative sign. It represents the cost the respondents were asked to bear for the creation of new salt marsh areas in the Blackwater estuary. The results show that the probability of choosing Option A diminishes as its cost increases.

4. Aggregating the willingness to pay for the CBA

In a choice experiment it is possible to calculate the MWTP for each attribute included in the design. However, for purposes of decision making, an aggregated WTP for a policy that creates new salt marshes in the Blackwater estuary area was considered. The following equations show the variables involved in two hypothetical decision policies. In Equation 1, which considers use and non –use values of the salt marshes, the aggregated WTP is defined for a policy involving a defined extent of new salt marsh area created and for a high (BIRD5) level of environmental quality involving four distances from respondents' home to Abbott's Hall (Essex) and with possibility of access:

$$WTP = \frac{\beta_2}{\beta_8} LnAREA + \frac{\beta_5}{\beta_8} BIRD5 - \frac{\beta_6}{\beta_8} DIST + \frac{\beta_7}{\beta_8} ACC \qquad (1)$$

Equation 2 follows a conservative approach taking account only of the use values of salt marshes:

$$WTP = \frac{\beta_2}{\beta_8} LnAREA - \frac{\beta_6}{\beta_8} DIST + \frac{\beta_7}{\beta_8} ACC \qquad (2)$$

The variable *DISTANCE* is the key variable in determining the aggregated WTP. Adding that variable, the WTP is calculated proportionally to the distance from the respondents' home to the salt marshes following the distance decay revealed in the econometric analysis. An approach similar to the one used by Bateman et al. (2006) is applied in this study. The distance between each Essex district and Abbott's Hall, a well known managed realignment site in the Blackwater, was calculated with GIS techniques. Those districts and relative distances were grouped in four main distances of 8, 15, 23 and 32 miles. Equations 1 and 2 were then calculated so to obtain a WTP for the number of households at each distance considered. The total WTP for salt marshes is simply the sum of those WTPs. Inserting the extent of new salt marsh area created for each scenarios in the equations, we calculated the WTP for the PT, DG and EDG scenarios. Table 4 shows the WTP calculated for each scenario:

Table 4 Aggregated WTP under each scenario

		PT: 81.6 Hectares		*DG: 816.5 Hectares*		*EDG: 2404.1 Hectares*	
Distance to Abbott's Hall (miles)	Households population	WTP use and non-use values Benefits (£/yr)	WTP use values Benefits (£/yr)	WTP use and non-use values Benefits (£/yr)	WTP use values Benefits (£/yr)	WTP use and non-use values Benefits (£/yr)	WTP use values Benefits (£/yr)
8	63706	771,120	546,764	930,385	706,029	1,005,170	780,814
15	349836	4,106,770	2,874,739	4,981,360	3,749,329	5,392,037	4,160,006
23	97974	1,109,236	764,197	1,354,171	1,009,132	1,469,184	1,124,145
32	33185	360,129	243,260	443,092	326,223	482,048	365,179
		6,347,255	4,428,961	7,709,008	5,790,713	8,348,440	6,430,145

The mean WTP for one hectare is equal to £6.72 in the use and non-use values situation, and to £3.20 considering use values only. These WTP values are much lower than the mean WTPs per person per year elaborated in the meta-analysis of Brower *et al.* (1999). The value obtained by Woodward and Wui (2001) is not comparable with the one obtained in this study because they calculated a value per hectare per year.

6. Realignment cost-benefit model

The elements of the analysis are summarised in Table 5 and in the two equations below, which illustrates the values used to estimate the costs and the benefits of realignment.

Table 5 Values used to estimate the costs and the benefits of realignment

Item	*at time of reference*	*relates to*	*adjustment to the financial year 2006-2007*	*other adjustments*
Capital cost of realignment (realigning defences)	£811,893/km	2001-2002	£929,252/km	£929,252/km
Opportunity costs (Grade 3 land)[a]	£7,904/Ha	2001	£8,907/Ha	£5,138/Ha•
Maintenance cost of non-realigned defences	£866/km/yr	2007		£866/km/yr°
Maintenance cost of realigned defences[b]	£433/km/yr	2007		£433/km/yr
General habitat creation benefits*:				
PT (use and non-use values) Area: 81.6 Ha	£6,347,255/ha/household/yr	2007		£6,347,255/ha/household/yr
PT (use values) Area: 81.6 Ha	£4,428,961/ha/household/yr	2007		£4,428,961/ha/household/yr
DG (use and non-use values)Area: 816.5 Ha	£7,709,008/ha/household/yr	2007		£7,709,008/ha/household/yr
DG (use values)Area: 816.5 Ha	£5,790,713 /ha/household/yr	2007		£5,790,713 /ha/household/yr
EDG (use and non-use values) Area: 2404.1 Ha	£8,348,440 /ha/household/yr	2007		£8,348,440 /ha/household/yr
EDG (use values) Area: 2404.1 Ha	£6,430,145 /ha/household/yr	2007		£6,430,145 /ha/household/yr
Carbon sequestration benefits	£30; £15; £7 /tonne CO_2e	2007		£30; £15; £7 /tonne CO_2e
Fish nursery benefits	£11.55; £7.43 /kg/ha	2007		£11.55; £7.43 /kg/ha

[a] Based on sale prices (DEFRA, 2005)

[b]Assuming maintence cost being 50% than for non-religned defences

• Adjusted downwards for the effects of the single payment following Penning-Rowsell et al (2005) - that is the 65% of the value at 2007

° Based on Halcrow (2007)

Table 6 presents the details of the areas that were identified as suitable for realignment for each scenario, showing the implications of realignment on defence length, the amount of habitat that could be created and the relative amount of agricultural land that could be lost.

Table 6 Details of areas suitable for realignment

	Scenarios			
	HTL	*PT*	*DG*	*EDG*
Length of defences before realignment (km)	124.1	124.1	124.1	124.1
Length of defences after realignment (km)	124.1	121.2	106.5	85.66
Length of realigned defences (km)	0	2.9	18.4	40.17
Amount of intertidal habitat created by realignment (Ha)	0	81.6	816.5	2404.1
Estimated amount of agricultral land converted in intertidal habitat (Ha)	0	9.9	365.9	886.81

The present value of total HTL 'status quo' defences at time t (£million) is given by Equation 3:

(3) $$PV_t^{sq} = -\sum_{t=0}^{T} \frac{1}{(1+r)^t} \left[\left(l^{sq} C_{m,t}^{sq} \right) \right],$$

where PV_t^{sq} is the present value of total cost of status quo defences at time *t* (£ million), *r* the discount rate, l^{sq} the length of the status quo defences (km), $C_{m,t}^{sq}$ the maintenance cost[8] of the status quo defences at time t (£/km/yr).

The present value of total cost of managed realignment at time t (£ million) is given in Equation 4:

(4) $$NPV_t^{mr} = \sum_{t=0}^{T} \frac{1}{(1+r)^t} \left[l^{mr} \left(C_{k,t}^{mr} + C_{m,t}^{mr} \right) - \left(a_l^{mr} L_{agr,t}^{agr} \right) - \left(a_h^{mr} B_{e,t} \right) \right],$$

where NPV_t^{mr} is the net present value of the managed realignment scheme applied at time *t* (£ million), *r* the discount rate, l^{mr} the length of the managed realigned defences (km), $C_{k,t}^{mr}$ the capital cost of realignment, $C_{m,t}^{mr}$ the maintenance cost of realignment at time t (£/km/yr), a_l^{mr} the area of agricultural land lost if realignment takes place (ha), $L_{agr,t}^{agr}$ the forgone agricultural land value[9] if realignment takes place (£/ha), a_h^{mr} the area of intertidal habitat created by realignment (ha), $B_{e,t}$ the environmental value gain associated with realignment eg habitat services, functions and products (£/ha).

7. CBA results and sensitivity analysis

The NPV of the proposed managed realignment project has been calculated for a time horizon of 25, 50 and 100 years and with different discount rates: a constant rate (3.75%); a declining rate (3.5% for years1-30, 3% for years 31-75, 2.5% for years 76-125) following current HM treasury guidance for project appraisal (HMT, 2003); and the hyperbolic gamma discounting method following Weitzman (2001).

The results of the CBA show that managed realignment in the Blackwater estuary under any of the scenarios presented yields an efficiency gain. As expected the gamma discount approach gives more weight to future costs and benefits resulting in a higher NPV of benefits when applied as reported in Table 7.

[8] $C_{m,t}^{sq}$ includes an estimate of the cost of repairing breaches in the status quo defences at time *t*.

[9] We assume that the agricultural land converted is all of grade 3.

Table 7 NPVs for each scenario using constant and declining discount rates (£ million)

		Use values			*Use and non-use values*		
Discount rate	*Scenario*	*25 years*	*50 years*	*100 years*	*25 years*	*50 years*	*100 years*
3.75%	NPV HTL	-1.83	-2.51	-2.90	-1.83	-2.52	-2.90
	NPV PT	66.51	94.14	109.54	97.29	137.18	159.40
	NPV DG	72.33	108.76	129.05	103.11	151.79	178.91
	NPV EDG	60.05	100.71	123.37	90.83	143.75	173.23
Declining (HMT)	NPV HTL	-1.88	-3.96	-7.81	-1.88	-3.96	-7.81
	NPV PT	68.41	152.25	307.19	100.02	221.07	444.76
	NPV DG	74.83	185.35	389.58	106.45	254.16	527.14
	NPV EDG	62.83	186.22	414.24	94.46	255.04	551.80
Declining (Gamma)	NPV HTL	-2.18	-4.28	-8.75	-2.18	-4.28	-8.75
	NPV PT	80.71	165.13	344.75	124.14	246.00	505.33
	NPV DG	91.06	202.32	439.09	135.85	284.56	601.03
	NPV EDG	80.96	205.17	469.51	118.11	279.00	623.74

Closer inspection of Table 7 reveals a possible anomaly. We would expect to see the benefits growing from the PT to the EDG scenario, but it is actually the DG scenario that presents the highest positive value when the constant rate is applied for any time horizon considered. The use of declining discount rates attenuates that anomaly, which persist only for the short time horizon. A possible explanation concerns the length of defences to be realigned. In fact the EDG scenario has the longest length of defences to be realigned. However, the areas of realignment were chosen with appropriate elevation of the land in mind which would not then require a secondary line of defence. Assuming that none of the areas to be realigned in any scenarios required a secondary line of defences, we report in Table 8 how the results change in the case of a constant discount rate (but the same results are reached also with declining discount rates):

Table 8 NPVs once the costs of a second line defence are removed (constant discount rate)

		Use values		
Discount rate	*Scenario*	*25 years*	*50 years*	*100 years*
3.75%	NPV HTL	-1.83	-2.52	-2.90
	NPV PT	69.22	96.87	112.26
	NPV DG	89.56	126.03	146.35
	NPV EDG	97.66	138.43	161.15

The results highlight that the values are sensitive to the scale of the realignment scheme and local topography. If the scheme is very extensive and the topography of the area is such that a large number of secondary defences are required, the NPVs are reduced. It means that we cannot deliver a general rule saying that the DG is better than the EDG scenario, because the different values depend on the extent of the MR scheme and the specific topography of the region we are looking at. In our example we believe that an EDG scenario without a second defence line is a realistic situation. Nevertheless, other areas may not have such a convenient topography.

No sensitivity was found in terms of the carbon storage and the fish nurseries benefit estimates.

8. Concluding comments

The use of site specific (as opposed to benefit transfer data) value estimates derived via a choice experiment study have served to reinforce the positive NPV findings from previous managed realignment CBAs. These results are achieved even when a set of quite conservative assumptions are adopted.

The positive economic efficiency gains involved in this more adaptive approach to coastal policy should however be set in an appropriate context. The study sites benefited from a convenient coastal topography which avoided the need for secondary defences and consequent costs. The sites were also deliberately chosen to avoid opportunity costs related to humans and substantial property and infrastructure assets.

Managed realignment therefore can only be regarded as one component of any new future coastal strategy and one that is highly conditioned by local factors and circumstances. Extensive use of managed realignment clearly would involve a complex mixture of political, social, economic and ethical concerns. The use of CBA in such a ‘contested’ policy arena is unlikely to result in any decisive role for economic data alone.

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