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Valuing Ecosystem Services: Case Studies from Lowland England

Annex 2 - Reconnecting the Broads and Fens: Norfolk

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Valuing Ecosystem Services: Case Studies from Lowland England

Norfolk Broads

Preface

This report has been commissioned by Natural England under the contract reference number of 23092.

The work aims to present how a combined ecosystem services and economic valuation approach can be used to understand the implications of different environmental conservation plans. Guidance from Defra on ecosystem services and value transfer is followed (Defra, 2007, eftec, 2010). The approach is used to assess and, where possible, value the likely changes in ecosystem services resulting from an intervention.

The information thus generated can be incorporated into decision-making or support tools such as cost benefit analysis. This information could also inform the way in which the management and conservation projects are designed to maximise the ecosystem service generation.

This is one of the six case study reports prepared to illustrate the application of the ecosystem services – economic valuation approach.

The work has benefited greatly from the ideas, knowledge, data and critique provided by numerous individuals in Natural England and other organisations. These include:

Andrea Kelly, Stewart Clarke, Julian Harlow, John Hopkins and Ruth Waters.

We know that some others have provided advice or data to those who helped us and though we cannot list these people here, our sincere thanks go to them too. And our sincere apologies to anyone inadvertently omitted from the list above. Needless to say, any remaining errors are the fault of the authors alone.

Dr Robert Tinch, Adam Dutton, Laurence Mathieu (authors) and Ece Ozdemiroglu (internal reviewer).

24 November 2011

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1. The Decision Context

This study seeks to assess the costs and benefits of possible changes in ecosystem services following a project reconnecting wetland ecosystems within the Norfolk Broads, and to describe and where possible measure the impacts that reconnection would have on the different ecosystem services provided by the Broads.

The main direct effects of the reconnection of wetland ecosystems (waterways and fens) include the provision of corridors for aquatic wildlife, and more generally, enhanced natural functioning of extensive connected habitats. Reconnection could have a substantial impact on biodiversity through the improvement and creation of habitats suitable for specific fish and bird species. The reconnection and associated biodiversity improvements would also influence the landscape, aesthetic and recreational values of the area.

The Broads[1] are located in the counties of Norfolk and Suffolk in the east of England and cover an area of 303 km^2. The Broads are a complex of rivers, shallow lakes and fens, peatlands and marshland that are drained by a network of dykes of variable quality of water and emergent and submerged flora and attendant fauna forms the UK's largest lowland wetland. They include six rivers (Bure, Ant, Thurne, Yare, Chet and Waveney) and 63 broads[2].

Seventy seven percent of land in The Broads is privately owned. The Broads Authority (established in 1989) owns the How Hill National Nature Reserve (148 ha).[3] There are 28 Sites of Special Scientific Interest (SSSI) in The Broads (many of these sites are also national and local nature reserves). Most of the SSSI network is also designated as internationally important for nature conservation under the European Union Habitats and Birds Directives, and the Ramsar Convention on Wetlands of International Importance. The Broads are also identified as an Important Stonewort Area (Stewart, 2004) and is a stronghold for a number of stonewort (complex algae associated with clean water) species of conservation interest. The dykes within the Broads fens are a significant resource for wetland flora and fauna, including fish (ECON, 2010).

The Broads are visited by approximately 7 million people a year. The area also provides home for around 6,400 people, and provides a livelihood, directly and indirectly, for thousands.

The Lake Restoration Strategy for The Broads, developed in 2008 by the Broads Authority, focuses on "managing waterbodies within a more naturally functioning flood plain of extensive connected habitats, accommodating the longer-term impacts of climate change, social and economic influences over the next 50-80 years"

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[1] The term ‘The Broads’ refers to the whole area.
[2] The term ‘broads’ refers to shallow lakes.
[3] http://www.broads-authority.gov.uk/education/about-the-broads.html

(Broads Authority, 2008). The Broads Biodiversity Action Plan (Broads BAP) flows from this strategy.

The Broads BAP was created in order to provide a framework for the sustainable long-term management and large-scale restoration of high quality natural ecosystems within The Broads with the aim of achieving ecological quality targets within this internationally important wetland. Pressures such as nutrient enrichment, habitat fragmentation, non-native species as well as from increased population[4] combined with the changing climate and predicted sea-level rise set the context for this framework and its adaptive management approach.

The aim of the Broads BAP is to enhance biodiversity within The Broads (Broads Authority, 2009a). A non-exhaustive list of projects included in the framework comprises:

- Fen restoration and management;
- Fen survey;
- Lake restoration programme;
- Trinity and Lound Partnership Project, where the Broads Authority is working in partnership with Essex and Suffolk Water to deliver a catchment sensitive farming project at two lake sites of high biodiversity value;
- Connecting wetlands, a project to connect waterways to the surrounding wetlands[5];
- Peat project, a project which aims at assessing the ability of the peat resource to capture carbon in the Broads;
- Non-native species control; and
- Grazing marsh quality.

This case study focuses on part of the BAP, specifically the project of reconnection of wetlands of wetland ecosystems (i.e. connecting waterways and fens) to provide corridors for aquatic wildlife and more generally, to promote more natural functioning of extensive connected habitats.

In practical terms, this involves reconnecting fen habitats and dykes to waterways and the Broads river network, by clearing out of many kilometres of dykes (often formerly used for boat access associated with reed harvesting) that have over the past decades become overgrown and clogged, and maintaining openings or digging

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[4] Proposed major housing and economic growth scenarios in surrounding districts, including those planned for the Greater Norwich Area, Great Yarmouth and Lowestoft could put pressures on the Broads landscape character, water resources and water quality, and on the integrity of sensitive sites from resource demands, visitor pressures and general disturbance.

[5] http://www.edp24.co.uk/news/giant_reedcutter_mows_norfolk_broads_1_477525

new connections to the river network. In some cases, reconnection can be achieved through overland flow at high water levels rather than direct dyke connections. Specific management interventions include reed cutting, scrub clearance, dyke-edge management, weed-cutting, dredging, and in some cases water-level management, with details depending on the exact location (ECON, 2010) Many of the interventions are periodic rather than one-off, as the dykes will gradually silt up and grow over if left unmanaged.

Reconnections will enhance the resilience of the Broads and its wildlife in the face of climate change impacts and increasing social and economic pressures (Broads Authority, 2008). In addition to delivering benefits for landscape, wildlife and public enjoyment within the area, reconnection could have additional benefits of moderating damaging flooding to other parts of the Broads. There are also risks, however, for example associated with easier spread of invasive species and diseases or saline surges; additional interventions such as fish barriers can mitigate some risks. This case study seeks to explore the full range of ecosystem service changes likely to arise from the reconnection project. Figure 1 shows the area of the project.

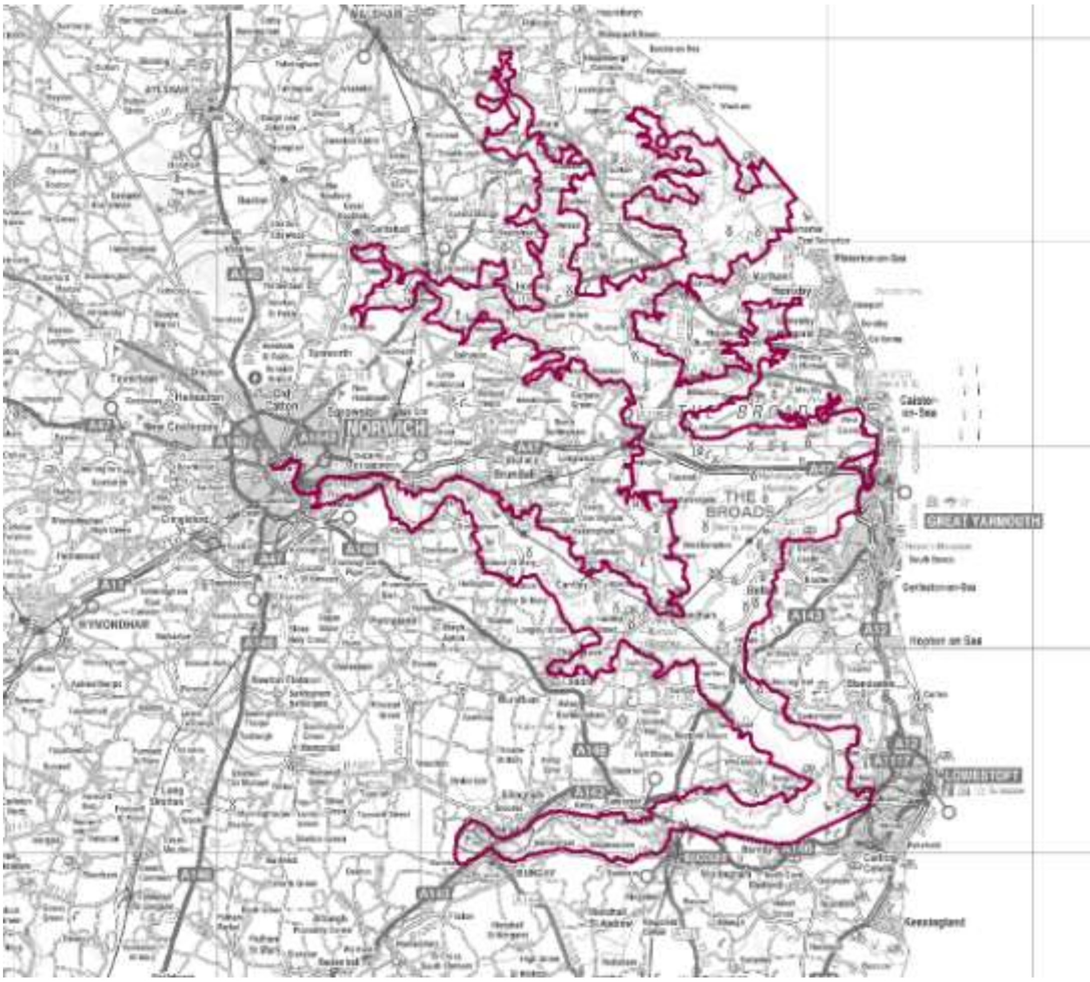

Figure 1: Map of the Broads National Park boundary

2. The Ecosystem Services and Affected Population

The main ecosystem service benefits arising from The Broads include recreation (land and water based), biodiversity conservation, drinking water and water for agricultural and industrial uses, climate regulation, flood control, and landscape and cultural values. The agricultural landscape contributes many other important services including habitat for wildlife, protection of historic sites and features, flood protection and management, and recreational opportunities.

The reconnection project will influence these services in various ways. In addition to delivering benefits for wildlife, the project will affect landscape and public enjoyment within the area, and could have additional benefits of moderating damaging flooding to other parts of the Broads. Services associated with water supply and agriculture could also be affected. Reconnection would also make possible the creation of habitats for specific bird and fish species.

2.1 Ecosystem services

Food and fibre: Agriculture in the Broads consists of a mix of livestock grazing and arable cropping and is a significant part of the Broads' economy. The farming industry in The Broads generates more than £150 million per year for the regional economy[6].

Reed and sedge cutting remains a traditional local and sustainable industry. This local product is under great demand and there is a desire for more commercial reed and sedge beds to be brought into sustainable management to support the local industry and reduce the need for imports from Eastern Europe and China (Broads Authority, 2011a).

Renewable energy: Some farmers in the Broads provide renewable energy for local consumers through the supply of wood sourced from sustainable woodlands in the region (NFU, 2010).

Fen products, including marsh hay and marsh litter, have been investigated for use as biofuel, with vegetation being burnt in power stations to generate electricity[7]. It is estimated that fen vegetation could provide up to 25% of the fuel needs for a biofuel energy plant which has been considered for construction by the Broads Authority[8]. Other materials such as woodchips would need to be brought in to make the plant feasible. However, although the construction of a biofuel energy plant in the Broads was demonstrated to be technologically feasible via the use of the 'Fen Harvester', its financial feasibility was considered to be far less certain (Luisetti, 2008a). Currently, fen products are used for agriculture, as a soil improver.

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[6] http://www.nfuonline.com/News/Why-Farming-Matters-to-the-Broads/
[7] http://www.broads-authority.gov.uk/broads/live/education/teachers-resources/fact-files/Farm_Land_man_section.pdf
[8] http://www.eeegr.com/news/info.php?refnum=263&startnum=2141

There are two wind farms in the Broads, generating energy to power more than 2,500 homes. These farms prevent about 6,500 tonnes of CO_2 from being released into the atmosphere every year (NFU, 2010).

It should be noted that the re-connection project will probably have no direct impact on those potential or existing renewable energy activities in the Broads. This service will therefore not be mentioned in the following sections.

Fresh water quality: Water quality in parts of the Broads has improved in recent decades, helped by improvements and new initiatives in sewage treatment, agri-environmental practices and the boating industry. However, currently, none of the 13 broads monitored for EU Water Framework Directive (WFD) purposes meet the minimum target of “good” overall ecological status/potential, with four broads classified as “poor” and one as “bad”. Similarly, of the 27 river reaches monitored within the Broads Executive Area, only one achieves the target overall ecological classification of “good” (Broads Authority, 2011a). Further deterioration of water quality may lead to increases in the frequency and magnitude of blue-green algal blooms which may be toxic. Coupled with this deterioration, climate change may lead to lower freshwater flows (and hence less dilution of pollutants) and warmer temperatures which will also encourage algal problems. In the past there have been fish kills associated with blooms of the alga Prymnesium which is toxic to fish. Future water quality issues will ultimately result in changes to the fish community and overall ecological quality.

Water flow regulation: Flood plains provide natural flood protection (flood control) via their water storage service, which can reduce the flood risk posed by fluvial or marine storm events for communities and wildlife. Climate change and changes in sea level are likely to lead to an increased threat of flooding; higher sea levels may hold back water trying to drain from the rivers, which can cause flooding and consequently put flood defences under threat. Risks of failure of embankments have been identified within the Broads (Environment Agency, 2009). The Lake Restoration Strategy focuses on managing waterbodies within a more naturally functioning flood plain of extensive connected habitats and will therefore contribute to reduced flood risk. However, the magnitude of this change is difficult to estimate. As an example of risks associated with flooding within the Norfolk Broads, the Environment Agency (2009) determined the risks to people and property within the fluvial/tidal rivers and within tidal Broads during a 1% annual probability river flood and 0.5% annual probability tidal flood, taking into account current flood defences. Currently 693 properties and 904 people are at risk from flooding within the Norfolk Broads. In the future (2100) 967 properties and 1377 people could be at risk from flooding.

Soil and erosion control: Erosion is gradually occurring. Bank erosion is a recurring issue, and a key sediment source. The action of wind and boat induced waves are major contributory factors, along with tidal action, water quality, land use, soil and vegetation type and feral geese, all of which may damage reed fringes.

Climate regulation: The peat formed by The Broads wetland, freshwater fens, as well as wet woodlands have an important value in terms of carbon storage: the amount of carbon stored in the Broads' soil is estimated to be 38.8 million tonnes, and the amount stored in the Broads' vegetation is estimated to be 1.1 million tonnes, or a total stored carbon of 39.9 million tonnes (data from 2009 Carbon Audit for The Broads, Broads Authority, 2010a). If the wetlands remain in optimal hydrological conditions then the carbon will remain locked in the peat and more will continue to be captured at a rate of between 0.7 and 1.8 tonnes CO_2 per hectare per year. However, drying out in the summer will potentially increase scrub and the release of carbon from soils, and will reduce further absorption of CO_2.

Air quality: Natural processes in the Broads ecosystems help to maintain local air quality, through the absorption of pollutants. The reconnection project is unlikely to have a significant impact on this service and hence this service is not included in the rest of the analysis.

Recreation: Over 7 million people visited The Broads in 2009, including 6,650,000 for land-based recreation and 350,000 for water-based recreation.[9] Important activities include walking, cycling, sailing, canoeing, motorised cruising, angling and bird watching.

Most of the broads are privately owned, but there is a public right of navigation on the areas known as navigable waterways, the length of which is over 200km. In 2009 there were over 12,000 licensed boats, 1,496 for hire and 10,835 private boats. There are 48 boating clubs in the Norfolk Broads and Broadland area. The Broads Authority's 2010 boat survey recorded a total of 11,728 boats navigating on the northern and southern Broads over three days in August 2010. Hire boats represented approximately two out every three boat movements (Broads Authority, 2011b). The existing rights of way network in The Broads provides 293km of public footpaths, 17km of public bridleway and 150ha designated as access land.

Angling accounts for at least 17% of visitors (approximately 1,200,000 visitors) and contributes in excess of £20 million to the local economy each year (Environment Agency, no date). It is popular in the Broads due to the presence of the best coarse fishing in England for pike, roach, rudd, bream, perch and tench.

Education and knowledge: Education takes place through The Broads Environmental Education Network[10] (BEEN), schools weeks, events programmes and the Forest Schools initiatives. In 2009, farms in the Broads that participated to the Open Farm Sunday were visited by an estimated 5,500 people. In addition, many farms within the Broads also host regular school visits with students of all ages.

The Broads Authority maintains an evidence-based approach to managing the Broads ecosystem. An indicative list of research projects undertaken in the past three to four years is available in The Broads Authority Natural Environment Research and Monitoring Register (Broads Authority, 2009b).

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[9] If we consider that 95 % of the visits are land based and 5% of the visits are water based recreation (according to the figures for 2005) then land based recreation for 2009 is 6,650,000 and water based recreation 350,000.

[10] Ranger programmes and partnership working with local schools, colleges, youth groups.

Cultural and spiritual: The Broads is a man-made landscape; the creation of the broads was the result of man's intervention to dig peat for fuel. Traditional activities include traditional skills of the boat builder, marshman, reed and sedge cutter, thatcher, millwright and eel catcher. The importance of the Broads is recognised by a range of national and international designations for its landscape, nature conservation and cultural features. The Broads is a member of the UK National Park family, and several parts have been designated for particular conservation interest (see "Biodiversity/habitat" for details). The reconnection project will protect and enhance some of these values, which are otherwise at risk of deterioration.

Landscape and aesthetics: The characteristics of the Broads rest on their distinctive and unique low-lying, wetland landscape. This landscape also includes buildings with a specific Broads character such as boat sheds, wind pumps or river side houses. If not appropriately managed, the landscape will change due to changes in the economy, population growth and mobility, agriculture and land use, technology, governance, and from the impacts of sea level rise and climate change. However, there is a controversial issue over the preservation of the area in an artificial state, which if not managed would gradually fill up with water and would turn into a large area of muddy woodlands.

The Norfolk Coast was designated as an Area of Outstanding Natural Beauty in 1968, and some of this area overlaps with the Broads.

Biodiversity/habitat: The Broads Biodiversity Audit (http://www.broads-authority.gov.uk/authority/publications/conservation-publications.html) revealed that this small area, which makes up only 0.4% of the UK, is a haven for an incredible quarter of Britain's rarest species. The Audit pooled 1.5 million records collected since 1670 and identified 11,000 species, of which over 1,500 are rare, 66 are special to the Broads and 31 are rarely seen elsewhere in Britain.

Many of these species occur in the species-rich peat fen. The Broads contain 75% of the remaining fen in lowland Britain and the largest area of floating forest and wet woodland in Britain (Wansbury, 1996). Forty percent of the Broads executive area is made of grazing marsh and support internationally important populations of wintering birds. Grazing marshes support freshwater dyke plants and invertebrates, breeding waders and general bird interest. Wet woodlands have an important value in terms of biodiversity, especially invertebrates.

Within the Broads' executive area, 28 sites have been scheduled as being of Site of Special Scientific Interest (SSSIs) under the Wildlife and Countryside Act 1981. Many have also been designated as being of international nature conservation importance under the EU Habitats and Birds Directives or the Ramsar Convention on Wetlands of International Importance. The SSSIs covers 7,571ha of land and some open water. Currently 5,160ha (or 68%) of the Broads SSSIs meet the national Public Service Agreement condition target i.e. are in favourable or recovering condition

The biodiversity of the area is important to tourism and also highly valued by people for conservation / non-use reasons. Since the reconnection project will have an important impact on biodiversity, changes in the value of these services are to be expected. Particularly important species in the context of the biodiversity conservation value of the Broads, include eels, stoneworts[11] and bitterns, as well as other aquatic and wetland plants in general.

The bittern is a particularly rare and iconic bird species breeding in the Norfolk Broads. Lack of food and inappropriate water management within breeding sites are some of the limiting factors for successful breeding of bittern within the area[12]. Saline inundation also negatively affects bitterns and periodic inundation would lead to a temporary reduction in the suitability of the affected areas of their freshwater habitat (Gilbert, 2010). For freshwater fish species, saline intrusion can be particularly dangerous and access to freshwater refugia can be an important feature of resilience to extreme events. Stoneworts typically grow in fresh or brackish water and high salinity levels could be harmful to the species (Stewart, 2004).

Although reconnecting the Broads and fens could increase exposure to inundation and saline intrusion events, reconnection can also allow for better access to freshwater refugia, thereby reducing the severity of impacts for mobile freshwater species. Connections have the potential to increase habitat diversity and availability for fish populations, though various aspects such as water quality, potential shifts in fish community structure and management of wet woodland areas need to be assessed before re-connection takes place, in order to prevent negative impacts. In certain cases re-connection might not be desirable, in which case some of the benefits of re-connection could still be achieved by alternative methods, such as for example eel ladders.

Practical experience at How Hill National Nature Reserve in the Ant Valley confirms some biodiversity benefits arising from reconnection. To reconnect wetland habitats and create areas of shallow water for bittern, aquatic invertebrates and fish, the re-excavation of old field drains and the restoration of a reedbed were undertaken. As a result, species including cranes, Bewick swans, bittern, redshank, lapwing, black-headed gulls and breeding pairs of marsh harrier have been attracted to the area. Furthermore, a surface scrape on dried-out fen has opened up a wet peat surface, which should become colonised by the rarest invertebrates and plants (Broads Authority, 2010b). However direct connection to rivers can result in lower invertebrate populations due to higher fish predation and increased nutrient enrichment.

2.2 The affected population

The stakeholders and beneficiaries in The Broads are local residents, farmers and land owners, water companies, conservationists, agencies and holiday makers (local and non local), hire boat and boat building industry, services industry, and private boat owners.

The Broads National Park provides a home for around 6,400 people and a livelihood, directly and indirectly, for thousands of people. The wider area surrounding the

[11] http://www.norfolkbiodiversity.org/actionplans/species/stonewort.asp
[12] http://www.norfolkbiodiversity.org/actionplans/species/bittern.asp

Broads, extending across eight district local authorities and two counties, has an estimated population of more than 650,000 people (NFU, 2010). 135,800 people (2008 estimates) live in the city of Norwich, and Great Yarmouth has a population of 47,288 (2010 census). North Norfolk has a population of 101,500 (2008 estimates).

The whole of Norfolk has a population of 850,000 (2008 estimates) and Suffolk has a population of 715,700. The total population in the East of England is 5,800,000 (2009 estimates).

The Broads are visited by over 7 million people a year (figure for 2009). As already mentioned in the 'recreation' section above, there are 48 boating clubs in the Norfolk Broads and Broadland area. The Broads Authority's 2010 boat survey recorded a total of 11,728 boats navigating on the northern and southern Broads over three days in August 2010 (Hire boats represented approximately two out every three boat movements) (Broads Authority, 2011b). It is important to note that hire boats are likely to be used by different people most (if not all) of the time, while private boats are used by the owners. Therefore, even though the total number of private boats is much higher, the total number of people using the hire boats will be much higher.

Around 250 people regularly volunteer for the Broads Authority. They provide support in caring for the Broads such as patrolling the waterways, carrying out habitat management for nature conservation, improving areas for public enjoyment or helping in the office (Broads Authority 2010b).

Table 1 summarises the above information on the affected population.

Table 1: Local Population estimates

Area	**Population**	**Household***
East of England *(1)*	5,800,000	2,416,667
Norfolk *(1)*	850,000	354,167
Suffolk *(1)*	715,700	298,208
North Norfolk *(1)*	101,500	42,292
Norwich *(1)*	135,000	56,250
Great Yarmouth *(1)*	47,288	19,703
Area surrounding the Broads *(2)*	650,000	270,000
The Broads national park *(3)*	6,400	
Visitors to the Broads in 2009*(3)* land based recreation (2005) (of which angling) water based recreation (2005)	7,000,000 6,650,000 (1,190,000) 350,000	

*Estimated number of households based upon an average household size of 2.4 (ONS, 2009); 1- ONS; 2- NFU, 2010; 3- Broads Authority.

3. Ecosystem Service Changes

Here we summarise the likely effects the Broads reconnection project may have on the ecosystem services provided in the area (as reported in Section 2.1). The changes are the difference between what is provided now and will be provided in the future without the project, i.e. the baseline (Section 3.1) and what is likely to be provided when the project is implemented (Section 3.2). All quantitative information available is reported in Section 3.2 and the spider diagram at the end of that sub-section summarises the likely changes based on our analysis of the existing information.

3.1 Assessing the baseline

The baseline for assessing the impact of reconnection is the situation where reconnection does not occur. This would have implications for a range of ecosystem services in the Broads, but in particular for biodiversity (for example, fragmented habitats lead to the decline in certain fish species, which need to travel between different habitats).

The main current human activities in the area include water based and land based recreation, and agriculture.

It has been established that climate change and predicted sea-level rise over time will increase the amount of surface water in the Broads. However, the additional area that will be under water due to the effects of climate change will be relatively small compared to the total area of the Broads and open landscape will therefore remain a significant feature. Waterways will also flood more in the future but for much of the year, they will retain their existing qualities. This climate change induced situation of wetter winters with higher water levels will make the management of the fens more difficult and; these conditions together with drier, warmer summers and winters will also lead to a shift in species from the present mosaic found in the fen (terrestrial plants, invertebrates, birds, fen water interface). Finally, drying out in the summer will potentially increase scrub. Increased instability is not appropriate for the fenland plants and fluctuating conditions (between very dry and very wet) put tree species under greater stress as they cannot adapt quickly.

Another issue related to the predicted sea-level rise is the increase in salinity of the water within the Broads. For example, areas like Upper Thurne marshes and fens may become increasingly saline and populations of Bittern and Swallowtail may decline. A continuing increase in salinity would eventually have an impact on grazing marshes the freshwater required for cattle as well as the freshwater dyke plant and invertebrates, breeding waders and general bird interest. In the rivers it could also lead to the development of the golden alga *Prymnesium parvum* (toxic organism capable of causing extensive kills of fish in particular). The current flood defence should protect the Yare valley marshes against salinity for the next 20-25 years unless a major breach occurs.

Finally, an increase in the presence of pathogens in the water, could impact on native species through the deterioration of fresh water quality, which will lead to an increase in fish kills, with a knock on impact on tourism. We can therefore conclude that a total lack of management is likely to result in the loss of habitat for fish and other species, and perhaps even in the local loss of species themselves.

Based on the above discussion, two baselines are presented in the next section: the current situation and the future ‘do nothing’ situation (without the reconnection project). The impacts are quantified against the latter.

3.2 Qualitative and quantitative assessment of the change

The reconnection of the Broads will result in various impacts, in particular on biodiversity and habitat. There is considerable potential for management regimes in dykes to impact on fish populations both directly and indirectly. The likely impacts are summarised below using the ecosystem service categories presented in Section 2.1.

Food and fibre: The main positive impact of reconnection on agriculture will be associated with the cost and the availability of freshwater. A possible negative impact would be the risk of saline intrusion further upstream. However, due to a lack of data and uncertainty related to climate change, it is not possible to state precisely what the impact will be.

Fresh water quality: The Broads Water Quality Partnership is working towards addressing the impacts of diffuse pollution, sewage and saline water within the Broads. The Broads Lake Restoration Strategy, Sediment Management Strategy and Biodiversity Action Plan present a list of specific actions to tackle those issues.

Despite the fact that significant improvements in water quality in parts of the Broads have occurred in recent decades, none of 13 broads monitored for WFD purposes have met the target of ‘good’ ecological status (Broads Authority, 2011a). Various measures are being taken to improve the quality of water in the Broads. The longer-term strategy includes possible interventions to reduce impacts of saline intrusion and of sediment and nutrient input from headwaters. Actions to combat saline intrusion include provision of fish refuges and creating new waterbodies within the upper river corridor, as well as reconnecting fens to waterways to provide corridors for aquatic life (Broads Authority, 2008). Hence reconnection is a tool for reducing the impacts of saline intrusion, in particular allowing sensitive fish populations to move to connected fresh water areas. However the process of reconnection is likely to interact with other measures, including possibly greater risks of pollution and the presence of invasive species spreading from one broad to the other. It is not possible to quantify these impacts with the available data.

Water flow regulation: It seems likely that reconnection, by making a more naturally functioning flood plain possible, will help to reduce flood risk (Broads Authority, 2008). However it is not possible to quantify this impact without additional hydrological modelling.

Climate regulation: The Connecting Wetlands partnership is working towards the issue of wetland reconnection, which will prevent areas from drying out and make possible the creation of new reedbed habitats[13] (Hickling North and Oulton Marshes). The creation of these new habitats could have a positive impact on carbon storage, but the production of methane and nitrous oxide associated with decomposition in wet soil could also be enhanced. Furthermore, emissions associated with the works themselves should be taken into account. The GHG Reduction Strategy for the Broads (Broads Authority, 2010a) identifies emissions directly and indirectly connected with the Broads and also describes carbon storage and sequestration in soil and vegetation within the Broads.

Recreation: As explained under the biodiversity/habitat heading, the project will lead to increases in fish and bird populations and reduced risk of damage during extreme events. This will be beneficial to recreation and in particular fishing and bird watching because of the improvement brought to the quality of each of their visit to the area. For other forms of land-based recreation, impacts directly associated with the reconnection project are likely to be minor: the creation of further reedbed habitat will be beneficial in particular to bird-watching (noted above).

Water-based recreation will continue to benefit from the management of sediments and from the cutting of aquatic plants in some areas used for navigation, independently of the reconnection project. There may be improvements in navigation associated with the reconnection.

Education and knowledge: A variety of research projects on wetland habitats are being undertaken under the reconnection project (Broads Authority, 2009a). The re-connection approach also creates opportunities to learn about the restoration of ecosystems and the response of freshwater systems and species to re-connection.

Cultural and spiritual: The cultural values are subtle and associated with enhanced conservation of the Broads in a more natural state. We assume that the values are reflected in non-use values estimated under other categories.

Landscape and aesthetics: The project will have an impact on the landscape, with for example the creation of new reedbed habitats and more natural functioning floodplain, via the connection of floodplain fen and the broads or rivers. An increase in the amount of surface water could have an impact on isolated water bodies, which could silt up quicker and be lost if not managed.

There is also a potential for these changes to interact with other landscape change, not directly associated with the project. In particular, there will be changes in farming such as reversion of arable land to grazing marsh, since farmers are rewarded for environmental management through agri-environment schemes and management options under these schemes include such reversion. Although this is not considered to be part of the reconnection project, the changes will interact in affecting the overall

[13] Reedbed habitat is defined here as reed vegetation growing on non-peat soils.

landscape of the Broads, and both reconnection and reversion of arable land to marsh will together create a more natural aesthetic.

Biodiversity/habitat: The reconnections will support biodiversity in particular by enhancing resilience to extreme events, and by enhancing access to diverse habitats needed at different stages in the life cycle. Fish species will benefit from permanent refuge habitat which cannot be provided within the fen wetland system itself. Many species have to disperse across different aquatic habitats during their life-cycle, and wetlands with connections of fen dykes to lakes or rivers allow enhanced fish species richness, density and biomass. Reconnection could also have a negative impact on habitats and biodiversity, if water bodies are polluted or in a poor condition. However, with ongoing improvement of water quality in the Broads, reconnection of fens would be of particular benefits to fish (ECON, 2010).

Reconnection does carry risks associated with invasive species. There are already a lot of invasive species in the Broads (including for example mink, zebra mussels, and crayfish: a complete list of invasive non-native species is presented in the Lake Restoration Strategy document (Broads Authority, 2008)). Reconnection involves the risk of making it easier for these species to spread around, and could make measures to combat them harder (more expensive and/or less effective). Desirable fish communities within isolated wetlands could be negatively affected by re-connection, introducing or increasing the contact with competitors such as roach and common bream. There is also potential for introduction of alien fish species such as common carp into the wetland fish community, and alien plant or animal species into previously isolated wetlands (ECON, 2010).

Reconnection is beneficial for eels. It could improve eel density within wetlands which could be important for the eel populations, which have been declining in the broads (and in Europe) for the past 25 years. The European eel is listed as Critically Endangered on the IUCN Red List, is a UKBAP Priority Species, and a “species of principal importance for the purpose of conserving of biodiversity” under the Natural Environment and Rural Communities Act 2006 – the ‘NERC list’.[14] It has been established that distance from the river, rather than distance upstream, is a key factor behind the colonisation by eels. Reconnection will help by making more areas available closer. At suitable fens directly adjacent to rivers locations, the colonisation of small eels may be enhanced by careful placement of re-used cobweb brushes from broad restoration projects (Broads Authority 2010c). Those “ladders” will be used as part of the reconnection project in order for the eels to reach suitable habitats.

The Broads Authority has already created substantial areas of reedbed (for example, at Mown Fen and Buttle Marsh) appropriate for important Broadland species including bittern. The reconnection project will make possible the creation of new

[14] http://www.naturalengland.org.uk/ourwork/marine/protectandmanage/mpa/mcz/features/species/europeaneel.aspx

reedbed habitats[15] (for example, creation of 20ha of new reedbed and 30 ha of naturally functioning reedbed at Hickling North; creation of new reedbed at Oulton marshes), which will increase the population of wetland BAP species, such as the bittern and reed bunting.

On balance, the impact of re-connection are most likely to be positive but with some negative risks notably associated with invasive species.

Figure 2 provides an overview of the relative changes in ecosystem services which we might expect from this project. This is eftec's assessment based on the information available about the project. It compares three situations: the current situation, the 'do nothing' situation (reconnection does not take place) and the situation with the reconnection. A scale of 0 to 5 is used where 0 means the service is not provided and 5 means the service is provided and is at best quality possible for the site.

The key findings from the above assessment are that:

- Reconnection will have a positive impact on recreation, through an increase in the quality and quantity of trips undertaken by visitors, and on biodiversity with an increase in specific bird and fish species; and
- The impact on the ecosystem service 'Food and Fibre' is uncertain, it could be positive (increase in the availability of freshwater) or negative (risk of saline intrusion).

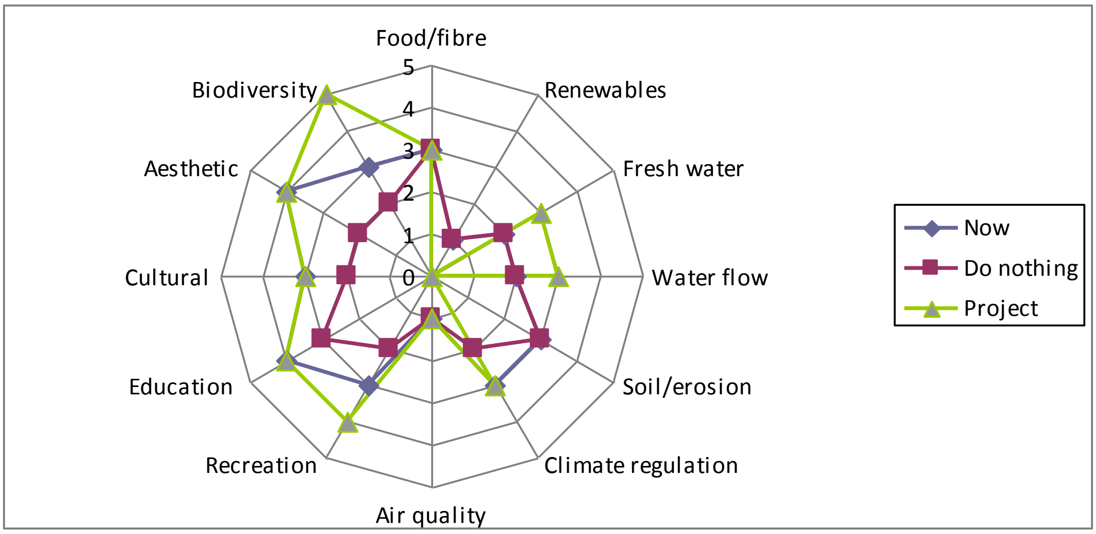

Figure 2: Ecosystem service changes in the two baselines and the Broads reconnection project (eftec's assessment)

15 Reedbed habitat is defined as reed vegetation growing on non-peat soils, such as the clay and silts deposited by past estuarine conditions (Broads Authority, 2009a).

As the summary in Table 2 shows quantitative impacts associated with reconnection are not known except for the creation of 50ha of reedbeds. Consequently, only some impacts will be monetised in section 5. However, all the impacts will be covered in the sensitivity and reporting sections.

Table 2: Qualitative and quantitative impacts of reconnection

	Qualitative Impact of reconnection	**Quantitative Impact of reconnection**
Food and fibre	Nature of the impact unknown Potential positive impact: Impact associated with the cost and the availability of fresh water Potential negative impact: risk of saline intrusion further upstream	Unknown
Fresh water quality	Positive impact: Reduction of the impacts of saline intrusion	Unknown
Water flow regulation	Positive impact: Reduction of flood risk	Unknown
Climate regulation	Potential positive impact: increase in the capacity of carbon storage	Possible increase in the capacity of carbon storage in the Broads through the creation of 50 ha of reedbeds
Air quality	Unlikely to be significant	
Recreation	Positive impact: Beneficial to recreation, and in particular fishing and bird watching through increases in fish and bird populations	Increase in the quality of trips to the area and in the number of trips.
Education and knowledge	Positive impact: Beneficial through the creation of opportunities for research and learning	Unknown
Cultural and spiritual	Positive impact: Associated with enhanced conservation of the Broads in a more natural state	Reflected in other categories (recreation, biodiversity)
Landscape and aesthetics	Positive impact: Associated with the creation of new reedbed habitats	Reflected in recreation and habitats
Biodiversity/habitat	Positive impact: Increase habitat diversity and availability for fish and bird populations	Creation of 20 ha of new reedbed and 30 ha of naturally functioning reedbed

4. Appropriate Monetary Valuation Evidence

Here we report the process of review and selection of the unit economic value estimate that is appropriate to the case study. The value evidence includes market prices, estimated premia where relevant and estimates of willingness to pay (WTP) or willingness to accept compensation (WTA) for non-market goods and services.

The appropriateness is determined by similarities between the context on which the estimate is based and the context of the case study. The key factors that define this context are decision making context, place, ecosystem services and population affected. The estimates also need to be robust or at least variations explainable.

Luisetti (2008a) has carried out a valuation of the total ecosystem service values arising from the Broads. The results from this valuation are summarised in Table 3. These results form an indicative baseline for the total services arising from the Broads. The aim of this report is to assess the marginal changes in values that may be expected to arise due to the reconnection project specifically, not the total value of the area.

Below, we summarise the monetary valuation evidence available for each of the services that are likely to be significantly impacted by the reconnection project specifically. The actual transfer of values to the reconnection project, and subsequent aggregation, are presented later in Sections 5 and 6. Table 4 is a quick reference for the value estimates selected. The same estimates are presented in bold throughout the text.

Table 3: Estimated ecosystem service values from Luisetti (2008a)

Benefits (year of reference)	Method	Total estimate (in £, per year)	Marginal estimates (in £)
Biodiversity	WTP - CV meta-analysis (Woodward and Wui, 2001)	18,692,100	
	MWTP - CE PHD (2007)		3.57/household/y
	WTP - CV meta-analysis (Brower et al.,1999)		57.17/household/y
Land based recreation (2005)	STEAM model for expenditure	228,200,000	
Water base recreation (2005)	STEAM model for expenditure	91,740,000	
Drinking water (2006)	Market prices	17,482,389	
Water for agriculture (2006)	Market prices	189,452	
Water for industrial use (2006)	Market prices	83,435	
Carbon emission reduction (2007)	Damage cost avoided (max)	240,210	30/tC
	Damage cost avoided (min)	56,049	7/tC
	Carbon trading price	141,964	17.73/tC
Biofuel	n/a		
Composite environmental value (1992)	Non-users WTP – CV study (Bateman et al., 1992)		23.29 (Mean) /household/y
Composite environmental value (2007)	Non-users WTP – CV study (Bateman et al., 1992) - 2007		34.24 (Mean) /household/y
Composite environmental value	Users WTP – CV study (Bateman et al., 1992)		67.19 (Mean); 30 (Median) /household/y
Composite environmental value (2007)	Users WTP – CV study (Bateman et al., 1992) - 2007		98.77 (Mean); 44.10 (Median) /household/y
Flood protection	WTP - CV meta-analysis (Brower et al.,1999)		69.56/household/y

Source: Adapted from Luisetti (2008a).

Table 4: Unit economic value estimates used in the analysis

<table>
<tr><th>Ecosystem service</th><th>Value</th><th>Reference</th><th>Key reason for selection</th></tr>
<tr><td>Food and fibre</td><td colspan="3">Changes in food production are not considered directly, but rather indirectly via the impacts of the project on fresh water availability.</td></tr>
<tr><td>Freshwater quality</td><td colspan="3" rowspan="2">We do not have the necessary information to estimate the impact of reconnection on the value of this service.</td></tr>
<tr><td>Water flow regulation</td></tr>
<tr><td colspan="4">Climate regulation</td></tr>
<tr><td>Non-traded carbon price</td><td>£51.70 per tonne in 2010 to £268 in 2100</td><td>DECC, 2010</td><td>Standard UK carbon prices</td></tr>
<tr><td colspan="4">Recreation</td></tr>
<tr><td>Improved angling experience</td><td>£1 per trip</td><td>eftec’s assumption extrapolated from angling studies</td><td>Based on the review of relevant literature</td></tr>
<tr><td>Birdwatching</td><td>£2,900 per hectare</td><td>Woodward and Wui (2001)</td><td>Meta-analysis study</td></tr>
<tr><td>Education and research</td><td colspan="3">While there is an estimate of school trips, we do not have the number of school trips to carry out the valuation.</td></tr>
<tr><td>Cultural and spiritual</td><td colspan="3">We do not have the necessary information to estimate the impact of reconnection on the value of this service, but if such information became available the unit values estimated in Bateman et al., (1992) cited in Luisetti (2008a), could be applied.</td></tr>
<tr><td>Landscape and aesthetic</td><td colspan="3">Assumed to be reflected in the recreation category in particular, and that non-use aspects are covered under biodiversity.</td></tr>
<tr><td colspan="4">Biodiversity / habitat</td></tr>
<tr><td>Improvement in fish population</td><td>£ per household per year</td><td>Spurgeon et al (2001)</td><td>Marginal change value to complement the recreational values</td></tr>
</table>

Food and fibre: In the Broads, there will be an increase in land conversion from arable to grazing marsh, but this is not directly related to the project. The main changes related to the project are associated with better availability of fresh water for irrigation purposes and for livestock. These impacts are considered under "Fresh water quality" below. It should be noted however that the values of agriculture in the area are relatively minor in comparison to the values of recreation and tourism, and of biodiversity conservation.

Fresh water quality: The value of drinking water sustained by The Broads system, is at least £17 million, which is the price paid by the consumer population (Luisetti, 2008a). This approach may lead to an underestimation of drinking water value because it does not take account of consumer surplus values, though it does not account for costs of supply either.

Luisetti (2008a) presents values of water for agriculture as £189,452, and for industrial use as £83,435 (2006) based on market prices (water licence price). Since they are based on costs, these figures for water for agriculture and industrial use are an underestimate of real value of the benefits that The Broads provide in terms of water uses. Here, the value of water is not the value of the *change* in the service, but the total value and it would need to be adjusted to get to the change only.

Valuing water use for agriculture presents a risk of double counting with food values. It should also be noted that the cost-based measure for water abstraction is not really a value estimate but rather a proxy, and it is not much related to the social cost of using the water. It may also be assumed that there is too much water used because of agricultural subsidies that push up the marginal benefit of water use for the farmer, above the social marginal benefit.

Water flow regulation: The wetland creation would be likely to result in reduced flood risks, or (more likely) reduced flood risk management costs. Estimating these benefits would be an important step in appraisal of a re-connection project.

The mean value for wetland flood protection presented in Luisetti (2008a), £69.56 per household per year, was determined by Brower et al. (1999) (in Luisetti, 2008a) from meta-analysis (WTP, CV). Luisetti (2008a) applied value transfer; however, it should be noted that this value is not specific for The Broads area and that the wetlands considered in the meta-analysis might not have similar characteristics to The Broads.

Climate regulation: The value of the benefits of carbon storage in the Broads is estimated by Luisetti (2008a) to be between £50,000 per year (marginal estimate: £7/tC) and £240,000 per year (marginal estimate: £30/tC) in 2007 prices (based on evidence from Pearce et al., 1996; Tol, 2005; Pearce, 2003; Li et al, 2004 cited in Luisetti, 2008a)). The price of traded carbon in March 2008 was £17.73 (total estimate: £141,964 per year (value reported by http://www.pointcarbon.com in March 2008, in Luisetti, 2008a). More recent guidance (DECC 2010) gives substantially higher estimates for the value per tonne of carbon.

The impact on climate regulation for this case study is valued using DECC guidance figures for carbon values (DECC, 2010). The relevant figures are those for non-traded carbon. **The mid-range values rise from £51.70 per tonne in 2010 to reach £268 in 2100.**

Recreation: The value of recreation changes can be considered in terms of individual willingness to pay for recreation, based on value transfer from stated preference and/or travel cost studies. This could be applied to the number of trips generated, although this risks omitting the change in quality for existing visits. Alternatively values can be estimated for specific access improvements, or on a £ per household or per hectare basis.

Alternatives to WTP estimation include direct use of wage rates (opportunity cost of time) or assessment of trip expenditures, but neither of these methods results in economic value estimates.

For the ChREAM travel cost study (ChREAM, 2011) focusing on river-side recreation visits in the North of England, assuming an improvement across sites from medium to good quality an adult is willing to pay £5.90 per visit. Increasing quality from poor to good the adult WTP is £6.80 per visit. This value is the single site payment for a visit to an improved site.

Spurgeon et al. (2001) report average consumer surplus estimates in the region of £2-3 per trip for both coarse and game fishing (see also Annex 1). These estimates are based on contingent valuation scenarios that elicited anglers' willingness to pay to maintain the existing quality of fishing at the respondent's regular site, hence they are broad indicative value estimates that do not account for differences in site quality and characteristics. The estimates can also be considered marginal in the sense that they relate to avoiding a decline in quality, not the full value of the trip. Similar values are also reported from specific case studies of Spurgeon et al (2001) considering game fishing in the River Teifi (approximately £7 per trip) and coarse fishing in and around Leeds (approximately £2 per trip).

More recent evidence is provided by Johnstone (2006) who estimates consumer surplus for recreational angling trips in relation to river quality indicators, including number and abundance of fish species. The principal findings indicate that river flow, biological quality and nutrient pollution levels affect the likelihood and choice site for a fishing trip. Estimated average consumer surplus is approximately £25 per trip, with estimates ranging over river types: upland rivers (approximately £47 per trip), lowland rivers (approximately £19 per trip) and chalk rivers (approximately £6 per trip).

In the context of sea angling, Drew Associates (2004) apply both revealed preference (travel cost) and stated preference (contingent valuation and choice experiments) methods to produce a breakdown of estimated angling days, expenditure and value by sea angler type (shore, charter boat and private boat) in the UK. Reported value estimates from the travel cost analysis range from approximately £26 - £110 per day per angler (depending on the type of activity), with an average value across all angling types of approximately £70 per day. Basic travel cost results are based on travel from home to angling site or embarkation point, estimated average value of £26 per day per shore angler, £90 per day per charter boat angler and £108 per day per private boat angler. The average across all angler types was £69 per day.

Extended travel cost results are based on travel from home to angling site or embarkation point plus car parking charges, charter boat or private boat costs, estimated an average value of £35 per day per shore angler, £42 per day per charter boat angler and £104 per day per private boat angler. The average across all angler types was £105 per day.

Based on the above review above of the potentially appropriate estimates, we **use £1 per angling trip.** We also assume that reconnection adds 5% the value of each angling trip for the improved conditions (an assumption in the absence of quantitative assessment).

Bird watching values for wetlands have been estimated in meta-analysis by Woodward and Wui (2001). Their model allows valuation of the impacts of various amenities including bird watching, with estimates (in 2010 £) of approximately £1,250 (low), £2,900 (mid) and £6,650 (high) per hectare. **The medium estimate of £2,900 per hectare is used for this case study.**

Values could also be considered per household rather than per trip. Brouwer and Bateman (2005) present contingent valuation estimates of the recreational benefits of the Norfolk Broads, estimating £363.36 per household per year. However flood protection and water quality benefits are thought to be included in this value.

Luisetti (2008a) establishes that the visitors to The Broads generated some £320 million per annum in 2005, including £228 millions for land based tourism and £92 millions for water based tourism. In order to determine these values, the Scarborough Tourism Economic Activity Monitor (STEAM) method (approximate of GVA) was used. As these are total value estimates, they are not appropriate for this case study.

Education and knowledge in principle education services could be valued using willingness to pay methods, but for practical reasons this is difficult. An alternative proxy is to use the costs of engaging in education activities. Mourato et al. (2011) value educational trips made by schools to the London Wetland Centre and the Hanningfield Reservoir in 2009 and bird watching activities for the RSPB-organised Big School Birdwatch.

The value of educational trips is the sum of transport costs, value of teachers' time, value of student time based on the cost to government of keeping students in education and (if applicable) the cost of HLS payments to the farmers who receive education trips.

Mourato et al (2011) estimate the above (with the exception of the cost to farmers) as follows:

- Transport costs: The average cost to parents of a primary and secondary school day trip in the UK was used to value transport costs = between £7.75 and £16.18 per child per trip.

- Teachers' in-vehicle travel time: was valued using 'wage rate' – 125% of their wage (estimated at £35,000 per annum, to reflect the cost of their time and labour overheads).

- Student time: was valued at the cost to government of students in education (about £5,140 per student per year).

- Time spent travelling in the vehicle was calculated using GIS from the postcode locations of each school. The ‘excess time’ - time spent waiting or walking to and from school buses - was valued at 200% of in-vehicle travel time costs, following standard procedures in transport analysis.

The final values were £628 per educational trip or £19 per child for the London Wetland Centre, and £839 per educational trip or £30 per child for the Hanningfield Reservoir. While this value could be used, we don’t have the number of additional school trips that would be generated (or current visits that would be maintained) because of the reconnection project to carry out valuation

Cultural and spiritual: eftec (2006) examined household willingness to pay for conservation of cultural heritage at the scale of English regions. For a ‘large’ change (‘rapid decline’ to ‘much better conservation’), South East households were WTP £15.79 (confidence interval of 11.47-20.64) per household per year. While this is evidence of value, it is difficult to transfer to the specific case of *reconnection* of the Broads, which will have some relatively minor marginal impact on cultural heritage in the region.

Bateman et al (1992) report a postal survey of households across the UK to determine the non-use values provided by The Broads; the value found was £34.24 (mean) per household per year in 2007 prices (non-users WTP, CV study, Bateman et al., 1992 cited in Luisetti, 2008a). The value of ecosystem services provided by the Broads is potentially larger if we consider their importance at an international level. The use value of ecosystems services was estimated via an on-site survey as £98.77 (mean) per household per year in 2007 prices (users WTP, CV study, Bateman et al., 1992 cited in Luisetti, 2008a).

The impact on cultural values specifically associated with the reconnection project is likely to be relatively minor and reflected in other categories (recreation, biodiversity), though the Broads do have high national and international significance. We should note that therefore even a small improvement in the cultural heritage status of the Broads could multiply up to a large value, if people are willing to pay a small amount per household but over a large area (for example the whole of England).

Landscape and aesthetics: Methods of valuation for this category involve a basic choice between valuing whole landscapes/areas and valuing specific features. The Environmental Landscape Features (ELF) model (IREM/SAC 1999, 2001, Oglethorpe 2005) is a form of meta-analysis / value transfer for valuing landscape features in England. Values, based on contingent valuation studies, were included for rough grassland, heather moorland, salt marsh, woodland, wetland and hay meadow (1999) and hedgerows and field margins (2001). However it is difficult to separate out these values from values associated with habitat conservation and recreation. Reconnection will have a marginal improvement in landscape, but we assume this is reflected in the recreation category in particular, and that non-use aspects are covered under biodiversity.

Biodiversity/habitat: Brander et al (2009) present a meta-analysis of wetland valuation studies, estimating an average value for UK wetlands of approximately £2,200 per ha per year, approximately double the European average. Inland marshes were estimated at £3,716 per ha per year for Europe, almost four times the average. It is not possible to say precisely what the value for UK inland marshes would be just on the basis of these figures, but it would be greater.

Other studies include the Brander et al (2006) meta-analysis of wetland valuations which includes a value function that can be used to estimate diminishing values based on areas. For example the value of grazing marsh is estimated at approximately £390 per ha at 50 ha, but falls to £260 per ha at 250ha. Unfortunately reedbed habitats are not explicitly included in this study.

Woodward and Wui (2001) used a meta-analysis of wetland valuation studies to estimate total annual wetland values from all different services per acre. Values for general habitat provision are around £700 per ha, with a range of £200-£2200; values for wetlands with particular use for birdwatching are much higher, around £2800 per ha with a range of £1200 to £6400.

The above estimates are all per-hectare. Alternatively, values have been estimated per household. Luisetti (2008b) found £3.57 per household per year as the marginal willingness to pay for the higher level of environmental quality/biodiversity proposed for saltmarshes of the Blackwater estuary biodiversity in Essex, estimated from a binary choice experiment conducted in Essex in 2006. This is close to the Broads area, but relates to coastal not freshwater wetlands. The ELF study (Oglethorpe 2005) gives an average value of £155 (133-176) per household per year, based on the avoidance of a 10% reduction in abundance of wetlands.

Christie and others (2006) present choice experiments for improvements from “continued decline” to various options for biodiversity. Results shown here are for Cambridgeshire:

- For general outcomes:
    - Stop decline in rare, familiar species: £39.47
    - Stop decline rare and common fam species: £103.51
    - Slow decline in rare species: -£51.68
    - Reverse decline in rare species: £127.47
    - Restore habitat: £38.09
    - Create new habitat: £67.93
    - Recover ecosystem services used by humans: £59.37
    - Recover all ecosystem services: £46.73
- For specific policies
    - Agri-environment schemes: £82.23
    - Habitat creation scheme: £60.86
    - Avoid development loss: £50.15
    - Three schemes above pooled: £65.18

This shows quite a diversity of values, and also illogical valuations in some cases – for example, “all services” valued less than just services used by humans. There is evidence too of embedding problems with the value for all schemes pooled being less than that for the agri-environment scheme alone. It is difficult to draw on these rather general results for application to the specific case of reconnection in the Broads, although they do provide evidence that people would be willing to pay to protect biodiversity interests.

Spurgeon et al (2001) report results from a contingent valuation study concerned with maintaining and improving fish populations in England and Wales. Willingness to pay to maintain the size and abundance of fish in the respondents' nearest waterbody was estimated to be approximately £2-6 per household per year. However, as with the angler survey reported above (also Spurgeon et al., 2001), the valuation does not account for differences in site quality and characteristics and hence should be interpreted in broad indicative value terms.

When considering the application to Broads reconnection, we need to bear in mind that the per hectare estimates for wetlands represent total values; here, there is relatively little creation/destruction of wetlands (50 ha of new reedbeds) and the main impact is a more general change in ecological and hydrological quality arising through reconnection. Since we will value the 50ha of new reedbed under the recreation heading (see above) using the Woodward and Wui (2001) estimate for wetlands with specific use for bird-watching, there would be significant double-counting in valuing them again under this heading.

The more general biodiversity improvement can be valued approximately via the willingness to pay for improvements in fish populations, from the Spurgeon et al (2001). Their lower estimate (**£2 per household per year**) is used as a rough estimate of the value of the general improvement in fish conservation as a consequence of reconnection. Since fish populations require good general environmental quality, we assume that this value in fact reflects not only fish, but rather the wider biodiversity and habitat benefits that are jointly provided with improvements in fish populations.

Costs of management: Dredging and the disposal of sediment is the largest cost faced by the Broads Authority in the maintenance of the navigation, with an estimated backlog of 1.17 million m^3 of material in the navigation system. The total cost of sediment removal required to achieve nature conservation goals is estimated at £5,865,000 and the overall cost of biomanipulation is £611,508 (Broads Authority, 2008). The Broads Authority is investigating the opportunity for land-raising prior to wetland/habitat creation through sediment disposal (Broads Authority, 2009a).

The planned budget for the connecting wetlands project, involving the creation of new reedbed habitats for wetland BAP species is £61,800 (between 2009 and 2014) (Broads Authority, 2009a).

The planned budget related to projects focusing on non-native species amounts to £86,000. Those projects are linked to the re-connection project because the spread of invasive species could occur and go against the positive outcome of re-connection.

5. Monetary Value of Ecosystem Service Changes

Having selected (or assumed) the appropriate unit value estimate, here we aggregate this to the affected ecosystem service and/or population. In many cases, this is a simple multiplication of the unit of change (from Section 3) and the unit economic value (from Section 4).

Table 5 summarises the results and the rest of this section explains the process behind these. The unit estimates from different years are converted to 2010 £ using the Retail Price Index and Consumer Price Index (Note the Consumer Price Index only began in 1996).

Table 5: Summary of Values for Likely Ecosystem Service Changes

Ecosystem service	Environmental Change	Economic Value	Value £
Climate regulation			
Carbon sequestration with the project	300-1370 tonnes/year	Yearly carbon price as in DECC (2010) guidance	£0.99 m present value over 100 years
Recreation			
Angling	1,190,000 trips	£1 per visit	£1.2 million per year
Birdwatching	50 ha	£2,900 per ha	£145,000 per year
Biodiversity / habitats / freshwater			
Improved fishing	270,000 households	£2 per household	£540,000

Food and fibre: It is not clear how the agricultural values of the area would be influenced by the reconnection project. Access to fresh water for irrigation is important to agricultural values, and the project could improve this access and/or reduce the cost of irrigation (see fresh water below) however data are not available to permit estimation of the values.

Fresh water supply and quality: The value of reconnection to agriculture is uncertain. The figure given by Luisetti (£189,452) is an underestimate and it represents a cost and not value. However, this estimate is likely to fall (because land is being reconverted to marsh) and may also be an overestimate since it does not allow for agricultural subsidies. Future rainfall patterns are hard to predict. Generally, it is not possible to draw firm conclusions, except that the reconnection is likely to improve the resilience of the food production system, by ensuring better access to water supply in times of need.

The reconnection project could also result in changes in risks associated with saline intrusion and the spread of invasive species and pollution. This could influence water quality and the costs of irrigation for agriculture, and have implications for biodiversity. However we do not have data to estimate these impacts or their monetary values.

Climate regulation: It was estimated that marsh and fen in the Broads store 17,384 t CO_2e (Broads Authority, 2010a). The creation of 50 ha of reedbeds could increase the capacity of carbon storage in the Broads, although this does depend on what the alternative land use is. Based on Alonso, Weston & Gregg (in prep) and assuming conversion from "Lowland fen: cultivated & temporary grass" to "Lowland fen: restored" would give a net benefit of 27.4 tCO_2e per hectare per year; conversion from "Lowland fen (wasted) cultivated and temporary grass" to "Lowland fen: restored" would give a net benefit of 6 tCO_2e per hectare per year.

We use the lower figure for the base case (approximately 300 tonnes per year) and the higher figure for sensitivity (1370 tonnes per year). The actual values in each year vary, because the DECC guidance has year-dependent values for carbon. The total value per year peaks at around £92,000 in the late 2070s; the present (discounted) value per year peaks in the 2050s. The present value over 100 years totals £985,000 for the base case.

Recreation: The main impact is the improved quality of trips to the area, especially for anglers and to a lesser extent, bird watchers. We expect this to be reflected in some increase in the number of visits, compared to the baseline, but the bulk of the change is likely to be related to improved quality for the (already high) number of existing visits.

For angling, we assume that the improved quality of angling represents an additional 5% value per trip – in our opinion, probably a conservative assumption – this would suggest a marginal value of approximately £1 for the improved conditions. Based on 1,190,000 angling trips per year, this could represent a value in the region of £1.2 million per year. These estimates do not consider any additional new visits or displaced visits from other areas, though both may be expected to arise to some unknown extent.

The recreation values for the bird watching associated with the creation of new wetlands would be based largely on new visitors, although some of these might be displaced trips from elsewhere. The mean value given by Woodward and Wui (2001) is used for the initial estimate at £2,900 per hectare providing £145,000 per year in recreational value.

For other forms of land-based and water-based recreation, we have no strong evidence to show that the reconnection project would result in improvements. Though these activities may benefit from the project, to be conservative we assume no net impact.

Biodiversity/habitat: Based on values in Woodward and Wui (2001) and Brouwer at al. (1999), Luisetti (2008a) reported total values of £18,692,100/year for the Broads. For the purposes of this report specifically focusing on reconnection of the Broads, the total values are of limited relevance, and we need to focus on the marginal improvements associated specifically with the reconnection project. These impacts are (a) creation of 50ha of reedbed and (b) a general improvement in the conservation status of the Broads, due to reconnection, though with some increase in risks associated with invasive species and pollution incidents. We have estimated the value of wetland creation under the recreation category, through the use of a value for wetlands used for bird watching. There would therefore be substantial double-counting if we value the habitat creation separately here. In this category we estimate the value of a general improvement in fish conservation as a consequence of reconnection.

Using the evidence of household willingness to pay to conserve fish populations in nearby water bodies, from Spurgeon et al (2001), and considering "The Broads" to be the relevant "nearby water body" for approximately 270,000 households, taking a lower-end estimate for the willingness to pay of £2, gives an estimate of approximately £540,000 per year for the benefits of improved fish conservation.

Individuals expressing values for fish conservation are likely to consider a broader range of conservation outcomes, because fish conservation presupposes a healthy ecosystem generally. Therefore it would be conservative to assume that this value encompasses the biodiversity benefits generally. There may be some risk of double-counting with recreation values or with water quality (though this is only conceptual, since we have not applied a monetary value to that). On the other hand the value can be seen as conservative since we have used the lower end estimate, the biodiversity in the Broads is particularly rich, including iconic and threatened species such as eels and bittern, and the area involved is very large in comparison to most 'water bodies'.

6. Aggregation

Available values are aggregated in **Error! Reference source not found.Error! Reference source not found.**Table 5. The results are reported over 10, 50 and 100 year time frames, and with a changing discount rate according to Government guidance (HM Treasury, 2003): 3.5% for years 1-30; 3.0% for years 31-75; and 2.5% for years 76-125.

Table 5: Present values of service changes in the Broads (£ millions)

Ecosystem Service	**Present value**		
	10 years	**50 years**	**100 years**
Climate regulation	£0.005m	£0.52m	£0.99m
Recreation	£1.3m	£19.9m	£27.0m
Biodiversity	£0.52m	£8.0m	£10.8m
Total	£1.8m	£28.4m	£38.9m

The costs associated with the project of reconnection are small in comparison to the long term ecological benefits. As mentioned in Section 4, the direct costs of the connecting wetlands project amounts to £61,800. Other costs indirectly related to reconnection include £86,000 for non-native species management projects.

7. Sensitivity Analysis

In this study, we looked at improvements based on major changes to the connectivity that will have important impacts on biodiversity and in consequence on recreation.

The most significant values arising are for recreation and biodiversity. There is of course significant uncertainty regarding the physical and monetary measures of these services. Our valuation results for **recreation** can be considered as conservative because we have only considered values to angling and bird watching, and we might expect more angling visits under the improved conditions and not just higher value per visit.

The value for **biodiversity** conservation is similarly conservative, being based only on fish conservation, though there is likely to be some embedding reflecting wider conservation values. Higher values could be justified, however there is a problem linking conservation specifically to the reconnection project – this is one part of a broader package of environment management.

Other than for households in the area surrounding the Broads, we have not allowed for any non-use values associated with the reconnection project. These might arise for biodiversity and cultural heritage reasons, and could be significant: counting a small cultural heritage value of £1 per household per year in the East of England, or a few pence per household across the UK, could give over £2 million per year.

We have not fully considered the risks associated with the project, in particular in the context of reconnection potentially increasing the costs of invasive species and their management. This is more of a concern because there may be scenarios here in which the costs to biodiversity and cultural values, to angling and perhaps to other forms of recreation, are very high. But it is not possible to express these costs in monetary terms without more detailed assessment of the risks involved.

8. Conclusions

The reconnection project is part of the wider Broads Lake Restoration Strategy, which provides a framework for the sustainable long-term management and large-scale restoration of high quality natural ecosystems within the Broads, aiming to achieve ecological quality targets across the whole area. Conservation work is required in response to pressures including nutrient enrichment, habitat fragmentation, invasive species and increased human use of the area, coupled with climate change and sea level rise, bringing in particular risks associated with saline intrusion.

The reconnection project aims to reconnect broads and fens, enhancing biodiversity conservation by combatting habitat fragmentation and providing access to fresh water refuges for fish in the event of saline intrusions. The work will impact on most of the important ecosystem services arising from the Broads, although the quantitative prediction of these impacts is challenging.

In this case study, we have focused on the estimation of three important impacts: recreation, biodiversity and climate regulation. Recreation is the largest estimated impact, with potentially significant values due to the importance of the Broads as a resource for angling activities, and the potentially major impact of the reconnection project on the ongoing availability of healthy fish populations supporting angling. In addition, creation of 50ha of reedbed habitat is likely to improve nature watching / bird watching values and we have valued this area on that basis.

Our focus has been on willingness to pay (consumer surplus). There are also expenditure implications for the local economy that may be considered transfer payments from a national economic welfare perspective.

The biodiversity values have been conservatively estimated based on willingness to pay for conservation of fish populations. Considering this value to represent a composite environmental good, meeting the requirements for fish conservation but also providing additional benefits, including improved water quality and benefit to other species including birds, is conservative.

The carbon values estimated are relatively minor in comparison, a little under £1m over 100 years, although there is some doubt about the appropriate assumptions regarding the baseline and higher values of £4.5m could be appropriate. This relates only to the 50ha of new habitat; we are not able to estimate the impacts of the reconnection activities themselves.

Taking all the values into account demonstrates quite high present value estimates, approaching £40m over 100 years. This is likely to be substantially greater than the cost of the interventions, although we have no detailed breakdown of these. The value may be considered small in comparison to the total value estimates reported in Luisetti (2008a), of over £18m per year for biodiversity alone, and over £300m for tourism expenditure. But our aim in this case study is to assess not the total value of the area, but rather the marginal increment that may be expected to arise due to the reconnection project specifically.

It should be noted that there is some uncertainty surrounding the results because it has not been possible to make a full assessment of possible ecological risks that may be associated with the project. However, it is very likely that the risks are less than the risks associated with leaving the Broads to face climate change and saline intrusion without any attempt at reconnection.

It is also important to consider that the values presented here, although estimated specifically for the reconnection project, cannot be considered fully independent of other activities in the area. The conservation of the Broads requires a complex package of measures, and the values achieved through the reconnection project may depend on other actions being taken at appropriate places and times within the Broads environment.

The details of individual impacts are assessed on the basis of rather broad assumptions and the specific monetary estimates should be interpreted as indicative, but they are adequate to indicate the strong likelihood that actions to reconnect the Broads would pass a cost-benefit test.

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