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Ecosystem services case studies

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Steve Killeen

Head of Science

Executive summary

Ecosystem services – the multiple benefits provided to society by ecosystems – have been developing as a branch of science and policy since the late 1980s. The 'ecosystems approach', a planning paradigm founded on the basis of ecosystem services and the optimisation of benefits to their many beneficiaries (including future generations), has been promoted by various international bodies including the Commission on Biological Diversity. Significantly, the UN's Millennium Ecosystem Assessment (MA) integrated various strands of ecosystem service science into a standardised set of 'services', generically applicable across habitat types and geographical zones. This MA suite of ecosystem services were grouped into four categories: provisioning services, regulatory services, cultural services and supporting services. The MA strongly advocated the ecosystems approach as a basis for more sustainable policy formulation, highlighting the critical importance of ceasing destructive trends in global ecosystems if we are to secure human wellbeing into the future.

In 2007, Defra (the Department for Environment, Food and Rural Affairs) championed uptake of ecosystem services as a basis for more sustainable and inclusive policy formulation in England.

The two case studies in this report, one undertaken at catchment scale and the other at site scale, provide learning for the Environment Agency about the applicability of an ecosystems approach to its policies and other activities. The catchment selected was the River Tamar on the Devon/Cornwall border, and the site-scale study was undertaken on the Alkborough Flats managed realignment scheme on the Humber Estuary. These case studies cover historical projects, and seek to evaluate benefits across the suite of ecosystem services reclassified by the MA. It is recognised that the power of the ecosystems approach proactively to help engage a range of stakeholders and seek innovative management solutions that create optimal public benefit was not addressed by examining schemes that have already been completed. However, the case studies enable generic learning to be taken forwards and, as importantly, help the Environment Agency learn about the benefits of using ecosystem services in its work.

A wide range of learning was achieved from these case studies including:

- Although not perfect, the suite of ecosystem services classified by the Millennium Ecosystem Assessment proved helpful for comparing benefits.

- The method can help optimise the value stemming from environmental management decisions across a broad range of stakeholders, and also help to identify opportunities and avert unforeseen negative consequences.

- The ecosystems approach is compatible with economic valuation methods, helping bring ecosystems into decision-making processes. However, ecosystem valuation is an aid to decision-making, not a substitute.

- The ecosystems approach is also invaluable for engaging stakeholders around commonly understood benefits, helping to identify novel and equitable solutions through participative decision-making.

- There remain significant research needs to enable more robust implementation of the ecosystems approach. Three primary research needs identified were: (1) a procedural basis for assessing the net contribution to climate change regulation arising from a complex set of saltmarsh/floodplain processes; (2) the contribution of saltmarsh/floodplain to fish recruitment; and (3) a procedural basis for assessing the net contribution to air/water interactions in tidal/freshwater. A number of other research needs are also identified.

- There is major benefit to be gained from application of ecosystem services into ongoing programmes (such as the wider Humber Estuary Strategy or river restoration schemes), uptake into tools and processes (including Strategic Environmental Assessment), informing land use policies (for example, Environmental Stewardship subsidies or Catchment Sensitive Farming), and informing planning processes (such as flood risk management initiatives and River Basin Management Plans).

- Ecosystem services provide a common, outcome-based language which helps different organisations communicate, both together and with a broad spectrum of stakeholders, around common desirable outcomes of value and meaning to the constituencies that they serve.

- Optimising delivery of ecosystem services of benefit to wide constituencies can help maximise value from public (and other) investment, even where funding streams are currently tied to issue-specific initiatives.

- Ecosystem services help demonstrate the value of biodiversity as a source of multiple societal benefits, and hence the critical importance of the maintenance or enhancement of ecosystems for securing future wellbeing.

- It is necessary to integrate the ecosystems approach within operational tools for use by non-specialists if it is to be taken up.

- As a society, we are at the very earliest steps in uptake of the ecosystems approach; its logical culmination is full market internalisation.

- Ideally, the ecosystems approach should be embedded in inclusive and deliberative stakeholder engagement processes, with the framework of ecosystem services providing a transparent basis to support the stakeholder dialogue process.

- Many perceived weaknesses are, in reality, related to current shortfalls in knowledge and tools in the ecosystems approach.

This research report outlines the background, methods, results, conclusions and further recommendations arising from the ecosystem service case studies.

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1 Ecosystem services case studies

This report outlines the background, methods, findings and recommendations from a study into the application of ecosystem services in two case studies: the Tamar catchment and the Alkborough Flats managed realignment site.

The purpose of these studies was to test the applicability and value of the ecosystems approach – management based on ecosystem services (described in more detail in the following section) – for the Environment Agency. Both case studies were on historical schemes, acknowledging that further benefit could be derived from the ecosystems approach applied proactively to schemes in the planning or inception stage in order more effectively to engage appropriate stakeholders, frame problems, explore alternative solutions and agree priorities.

1.1 Introduction to the ecosystem services case studies

The purpose of this document is to provide a context for two ecosystem service case studies undertaken on the Tamar catchment and the Alkborough Flats, and to distil lessons from them. The document has benefited from a workshop of practitioners and interested parties held in London on 11 December 2008 (agenda, attendees and feedback at Annex 1) as well as presentations and discussion in other fora addressed subsequently in this document.

1.2 Background to ecosystem services

Ecosystem services describe the multiple beneficial ‘services’ derived by society from ecosystems. These services are many and substantial, underpinning basic human health and survival needs as well as supporting economic activities, the fulfilment of potential and enjoyment of life. The essence of the ‘ecosystems approach’ – that is, management of whole ecosystems and their benefits using the framework of ecosystem services – is to determine multiple, simultaneous benefits, such that realisation of one benefit is not achieved through the inadvertent degradation of other benefits with net harm to other beneficiaries (which can include future generations). By definition, studies that select only a limited subset of ecosystem services, overlooking potential conflicts with others, are NOT consistent with the ecosystems approach.

Our historical trajectory of industrial development has largely overlooked or disregarded many of these ecosystem services. Current trends in ecosystem degradation necessitate greater recognition and improved stewardship of essential ecosystems if human wellbeing is not to be systematically undermined.

Modern conceptions about ecosystem services represent the convergence of diverse strands of resource protection science and practice emerging since the

1980s. An important milestone was set in the history of environmental economics with the publication of a paper by Bob Costanza and colleagues in 1997, titled 'The value of the world's ecosystem services and natural capital'. Costanza et al. conservatively estimated the value of all of the Earth's ecosystem services at $33 trillion a year, at least, on the basis of replacement costs at current market rates. This was close to the world's total gross domestic product at the time (ignoring for this purpose that many key ecosystem services cannot in fact be substituted). This paper still remains the best-known, albeit speculative, attempt to ascribe monetary values to the ecosystem services from which society benefits on a global scale. The key point for our purposes is that recognition of the value of ecosystems to human wellbeing can focus our minds on better means for the sustainable use of ecosystems.

The power of the ecosystem services concept is that, by recognising and potentially quantifying resultant societal benefits, ecosystems are brought into planning and other decision-making processes. If they are not valued, they are effectively deemed as worthless in decision-making processes, which explains much of the unintended but systematic historical decline in ecosystems of all types and scales across the world. An approach founded on ecosystem services also provides a consistent means for assessment for different ecosystem types and bioregions.

The UN's Millennium Ecosystem Assessment (MA, 2005) harmonised these diverse strands of science into a consistent typology of 'ecosystem services' as a basis for assessing the status of global ecosystems and their capacity to support human wellbeing. The MA grouped ecosystem services into four main categories: provisioning services, regulatory services, cultural services and supporting services. Provisioning services are those things that can be extracted from ecosystems to support human needs, more or less synonymous with a prior definition of ecosystem 'goods' and including such tangible assets as fresh water, food (crops, fish, etc.), fibre and fuel, and so forth. Regulatory services include those processes that regulate the natural environment, including the regulation of air quality, climate, water flows, erosion, pests and so on. Cultural services include diverse aspects of aesthetic, spiritual, recreational and other cultural values. Supporting services do not necessarily have direct economic worth but include processes essential to the maintenance of the integrity, resilience and functioning of ecosystems, and so the delivery of other benefits, including matters such as soil formation, photosynthesis and water recycling. The complete MA classification of ecosystem services is listed in Table 1.1.

Table 1.1 Millennium Ecosystem Assessment classification of ecosystem services

Provisioning services
Fresh water
Food (e.g. crops, fruit, fish, etc.)
Fibre and fuel (e.g. timber, wool, etc.)
Genetic resources (used for crop/stock breeding and biotechnology)
Biochemicals, natural medicines, pharmaceuticals
Ornamental resources (e.g. shells, flowers, etc.)
Regulatory services
Air quality regulation
Climate regulation (local temperature/precipitation, GHG* sequestration, etc.)
Water regulation (timing and scale of run-off, flooding, etc.)
Natural hazard regulation (i.e. storm protection)
Pest regulation
Disease regulation
Erosion regulation
Water purification and waste treatment
Pollination
Cultural services
Cultural heritage
Recreation and tourism
Aesthetic value
Spiritual and religious value
Inspiration of art, folklore, architecture, etc.
Social relations (e.g. fishing, grazing or cropping communities)
Supporting services
Soil formation
Primary production
Nutrient cycling
Water recycling
Photosynthesis (production of atmospheric oxygen)
Provision of habitat

*GHG = greenhouse gas

Although neither perfect nor complete, the MA typology provides a broadly inter-comparable set of services across bioregions and ecosystem types. It also exposes the complexity and multiplicity of interactions between social and natural systems, the knowledge gaps about how all ecosystem services are 'produced', and the need for methods to monitor them.

Ecosystem service analysis further supports holistic economic valuation, helping overcome the oversights so common in appraisal and decision-making that can marginalise environmental values by effectively ascribing them a zero value. Environmental economics provide a common and transferable basis for assessing the different categories of benefits and dis-benefits associated with

changes in ecosystem services consequent from interventions in environmental systems.

1.3 Selection of case studies

Selection criteria for these case studies included:

- A stated requirement (Pam Gilder, Head of Wildlife, Recreation and Marine in the Environment Agency) of these case studies was to deliver, '…case studies that summarise the interconnections between natural processes and how our interventions reach into natural systems and their broader values'.

- Two case studies were required, one at site scale and another at broader, catchment scale.

- It is necessary to tie benefits and costs back to discrete interventions.

- It is important to select schemes delivering wider ecosystem service benefits beyond the initial intentions.

- It will be necessary to found benefit assessment upon some measure of value, although we cannot automatically assume that such an evaluation will be well supported by pre-existing data since post-project monitoring is far from ubiquitous, particularly across multiple benefit areas that were not part of the original scheme design.

- Ideally, benefits should be quantified, including economic appraisal where possible but using other forms of quantification (such as number of beneficiaries of a less tangible benefit) and qualitative benefits/costs assessed where quantification is not possible.

- There must be adequate evidence to support a more detailed study.

Various schemes were considered and evaluated against these criteria, with the Alkborough Flats managed realignment site and the River Tamar catchment finally being selected. Characteristics of each site suiting to them to this are addressed in the following sections detailing each of the case studies.

1.4 Notes on valuation of ecosystem services

Defra states that, 'An ecosystems approach to valuation provides a framework for looking at **whole ecosystems** in decision making, and for **valuing the ecosystem services they provide**, to ensure that we can maintain a healthy and resilient natural environment now and for future generations'.

There is a long-standing and broad consensus that financial values derived from such economic appraisals have no absolute values, sensitive as they are to a broad spectrum of factors including what is omitted or included, explicit and implicit assumptions, valuation methods and the scale of evaluation (e.g.

Costanza et al., 1997; Defra, 2007). However, determination of relative values (also known as marginal values), comparing a baseline condition to an altered state, provide insight into the tendency and scale of changes and are helpful in informing analysis and decisions.

In both case studies, identification of total 'baseline' values for the different categories of ecosystem service would not merely be a daunting task but would also one that is ultimately likely to result in subjective values given the large area, the many necessary assumptions and the inevitable data gaps. For this reason, the 'baseline' value was generally taken to be zero (except where stated), with pre-intervention status acting as a datum from which relative benefits and dis-benefits are calculated. Environmental economics provide a common and transferable basis for assessing the different categories of benefits and dis-benefits associated with changes in ecosystem services consequent from interventions in environmental systems, the ecosystem services themselves being largely amenable to economic valuation as they relate to different categories of human benefit. Various references and standard databases (for example EVRI^{TM}, Woodward and Wui (2001), etc.) are also used to extract standard values. However, the economic benefits of most ecosystem services are calculated on the basis of a range of stated assumptions linked to surrogate market prices.

Where data (actual or surrogate) are available to support the economic analyses in these two case studies, they often come from prior work conducted at different dates ranging from 2000 to the present. While it is acknowledged that this creates future uncertainties, these transferred values are NOT corrected for current value in the two case studies as this would give a spurious impression of the precision of the estimate and underpinning assumptions.

For the evaluation of Tamar 2000, a discrete economic valuation has been carried out already by Tusa (2000). The Tusa study, described in more detail in Annex 2, provides a rich evidence base for benefit assessment in the Tamar but is limited in that not all ecosystem services are addressed, some methods do not yield data directly applicable to the MA categorisation of ecosystem services, and the assessment was made on the basis of assumed rather than monitored uptake of farm advice recommendations (for reasons described subsequently). Tusa's study is therefore augmented by various other sources from which benefits are transferred either directly or on the basis of stated assumptions. Sometimes, surrogate values serve as market mechanisms reflecting aspects of the ecosystem service of interest. For some ecosystem services, the scientific literature was interrogated to seek to quantify production of the ecosystem service with subsequent monetisation of the assumed benefits. Similar methods, again stated in the analytical tables, were applied in the Alkborough Flats case study. In undertaking economic evaluation in both case studies, the following principles are adopted:

- Tusa's study is based on conservative estimates, which helps overcome exaggeration of the benefits assessed.
- All monetary values derived are NOT corrected for current prices as this implies a spurious confidence in initial values. This also contributes to overcoming exaggeration of benefits.
- Where monetary values cannot be ascribed, or too many uncertainties persist, no monetary value is presented.
- No contributory value derived is assumed to be absolute, but is merely assumed to indicate the significance of the impact on ecosystem services. Further targeted studies would generally be required if more reliable data were to be generated.
- In general, relevant 'revealed preferences' are preferable to 'stated preferences' deduced using such methods as 'willingness to pay', reflecting deeper values as compared to general appreciation of amenity potential.
- Given the constraints of this study, there was no option but to use transferable values from other projects or else to seek to monetise surrogate market metrics associated with each ecosystem service. (There was no investment available for bespoke *de novo* economic assessments.) For many purposes, this more qualitative approach is acceptable as it indicates ranges of likely impact. However, for the most significant impacts, or where the results are likely to be contested (e.g. in a public enquiry), further original valuation may be necessary.
- We sought to apply appropriate effort for the appraisal, bounded by the decision-making context.
- Sensitivity analysis was not undertaken within the confines of this study, but would have been advantageous to acknowledge and accept the likelihood of significant uncertainties.
- We have sought to be transparent about analysis, providing an 'audit trail' of key assumptions, transferred benefits, limitations, omissions and uncertainties.

Specific methods, assumptions and transferred values applied to each ecosystem service are described in subsequent sections of this report dealing with each of the two case studies.

The UK government's 'Green Book' (HM Treasury, undated) is used as a reference for methods to assess the total economic value of the benefits and costs entailed in these case studies. This includes a discount rate of 3.5% spread over 25 years. The exception to this is for the Alkborough Flats ecosystem service of 'Natural hazard regulation (i.e. storm protection)' for which a 100 year assessment period is applied with a graduated discount rate, reflecting the longevity of the planned benefit and as described in Table 3.2.

Pearce et al. (1989) discuss the 'tyranny of discounting' for environmental schemes, where higher discount rates and a relatively short assessment period can undervalue the often enduring benefits of environmental schemes, whilst Turner et al. (2008) argue that reliable total valuations for wetlands can only be derived from 'willingness to pay' studies. However, in an operational context there is rarely either time or budget to make such a bespoke assessment, which is anyhow contentious in that many assumptions, transferred values and other simplifications cast doubt on the absolute values deduced.

In the interests of proportionality, and reflecting that assessments made here and more generally are for decision support rather than decision making purposes, the standard 'Green Book' methods are employed in this study.

1.5 Summary results from the Tamar catchment case study

Detailed analysis and derivation of values is included in the subsequent section addressing the Tamar 2000 case study. Table 1.2 contains a summary of results abstracted from the detailed analysis of Tamar 2000 impacts on ecosystem services described in Section 2 of this report.

Table 1.2 Summary of results from the Tamar 2000 catchment case study

Ecosystem service	Annual benefit assessed	Research gap/note
Provisioning services		
Fresh water	**£304,000**	
Food (e.g. crops, fruit, fish, etc.)	**£263,319**	**Value not used = Employment in farms**
ADDENDUM SERVICE: Fish stocks	**£8,269**	
Fibre and fuel (e.g. timber, wool, etc.)	**£2,511**	**Unquantified value = *Miscanthus* planting** **Value not used = Employment in woodlands**
Genetic resources (used for crop/stock breeding and biotechnology)	**No net value ascribed**	
Biochemicals, natural medicines, pharmaceuticals	**No net value ascribed**	
Ornamental resources (e.g. shells, flowers, etc.)	**No net value ascribed**	
Regulatory services		
Air quality regulation	**It was not possible to value this ecosystem service**	**Quantification and valuation of air quality regulation**
Climate regulation (local temperature/precipitation, GHG sequestration, etc.)	**£2,455,304**	**Unquantified benefits = upland peat** **Unquantified benefits = microclimate effects** **Unquantified benefits = implications for estuarine saltmarsh**

		Research need: This work has exposed the fact that, despite some simple tools, there are complexities inherent in the dynamics of carbon sequestration, methanogenesis, nitrous oxide production and other mechanisms important for greenhouse gas dynamics under different soil types and wetting and oxygen regimes. This needs to be teased out including a digest useful to practitioners
Water regulation (timing and scale of run-off, flooding, etc.)	**Benefit not assessed**	**Quantification of contribution to hydrology**
Natural hazard regulation (i.e. storm protection)	**£12,500**	
Pest regulation	**Benefit not calculated**	
Disease regulation	**No value ascribed due to methodological difficulties**	**Value not used (to avoid double-counting) = animal disease** **Research gaps include assessing human and shellfish contamination**
Erosion regulation	**Pessimistic value = £7,151**	**Contribution from sites to catchment erosion risk**
Water purification and waste treatment	**Value not ascribed in order to avoid double-counting**	
Pollination	**Ecosystem service not quantified**	
Cultural services		
Cultural heritage	**£2,511**	**Methods required for hedonic property values**
Recreation and tourism	**£317,966**	

Aesthetic value	**Assumed no net contribution from Tamar 2000**	
Spiritual and religious value	**Assumed no net contribution from Tamar 2000**	
Inspiration of art, folklore, architecture, etc.	**Assumed no net contribution from Tamar 2000**	
Social relations (e.g. fishing, grazing or cropping communities)	**Benefit not ascribed a monetary value**	**Methods required to value social networks**
Supporting services		
Soil formation	**£6,269**	**Research gap includes more direct measure of soil formation**
Primary production	**No net value ascribed**	
Nutrient cycling	**£66,032**	**Nitrous oxide generation is a major research gap**
Water recycling	**£360,360**	
Photosynthesis (production of atmospheric oxygen)	**Assumed to be value-neutral**	
Provision of habitat	**£69,114**	**Research gaps include benefits from broader habitat restoration**
ADDENDUM SERVICE: Resilience of salmonid stocks	**Benefit acknowledged as significant but not valued**	

The sum of all annualised ecosystem service benefits of the Tamar 2000 scheme are therefore £3,875,307:82.

Assessed over 25 years with a discount rate of 3.5%, this equates to a gross benefit of £65,284,893:63.

The gross costs of the Tamar 2000 scheme documented by Tusa (2000) at £600,700:00.

On the basis of the full suite of ecosystem services addressed in this case study, the Tamar 2000 scheme yields a very favourable benefit to cost ratio of 108.98.

1.6 Summary results from the Alkborough Flats case study

Detailed analysis and derivation of values is included in the subsequent section addressing the Alkborough Flats case study. Table 1.3 contains a summary of results abstracted from the detailed analysis of Alkborough Flats impacts on ecosystem services described in Section 3 of this report.

Table 1.3 Summary of results from the Alkborough Flats site case study

Ecosystem service	Annual benefit assessed	Research gap/note
Provisioning services		
Fresh water	**No net value ascribed as brackish site**	
Food (e.g. crops, fruit, fish, etc.)	**MINUS £28,075**	**Contribution of saltmarsh to fish recruitment**
Fibre and fuel (e.g. timber, wool, etc.)	**£26,820 (wool minus straw)**	
Genetic resources (used for crop/stock breeding and biotechnology)	**£3,000**	
Biochemicals, natural medicines, pharmaceuticals	**No net value ascribed**	
Ornamental resources (e.g. shells, flowers, etc.)	**No net value ascribed**	
Regulatory services		
Air quality regulation	**Not possible to quantify at present**	**Major research gap**
Climate regulation (local temperature/precipitation, GHG sequestration, etc.)	**£14,553 from carbon sequestration**	**Research gap: microclimate assessment** **Research gap: confounding GHG impacts**
Water regulation (timing and scale of run-off, flooding, etc.)	**No benefit assessed**	
Natural hazard regulation (i.e. storm protection)	**£12.26 million OVER 100 YEARS AT VARIABLE DISCOUNT**	
Pest regulation	**No value ascribed**	
Disease regulation	**Neutral impact of scheme**	
Erosion regulation	**No value ascribed**	**Contribution from site to catchment erosion risk**

Water purification and waste treatment	**No value ascribed**	
Pollination	**No value ascribed**	
Cultural services		
Cultural heritage	**No monetary value assigned**	**Methods required for hedonic property values**
Recreation and tourism	**£164,830 ignoring informal recreation**	
Aesthetic value	**No monetary value assigned**	
Spiritual and religious value	**No monetary value assigned**	
Inspiration of art, folklore, architecture, etc.	**No monetary value assigned**	
Social relations (e.g. fishing, grazing or cropping communities)	**No monetary value assigned**	
ADDENDUM SERVICES: Navigation	**Net annual COST of £5,000**	
Supporting services		
Soil formation	**Benefit not quantified**	**More direct measure of soil formation**
Primary production	**£8,160 (monoculture to complex habitat)**	**Quantification of secondary production**
Nutrient cycling	**Benefit not quantified**	**Quantification of nutrient cycling**
Water recycling	**Benefit not quantified**	**Quantification of water recycling**
Photosynthesis (production of atmospheric oxygen)	**No value assigned**	
Provision of habitat	**£749,438**	
ADDENDUM SERVICE: Increased estuarine resilience	**No value assigned**	

The gross benefits of the Alkborough Flats scheme are therefore £27,989,899:51, comprising:

- Gross benefits of 'Natural hazard regulation (i.e. storm protection)' = £12,260,000

- Total of annualised benefits for all other ecosystem service benefits = £933,726:00.

- Assessed over 25 years with a discount rate of 3.5%, this equates to a gross benefit for all other ecosystem services of £15,729,899:51.

- This then yields a gross benefit value of £12,260,000 ('Natural hazard regulation') + £15,729,899:51 (all other ecosystem services evaluated) = £27,989,899:51.

The gross costs of the Alkborough Flats scheme are documented in the PAR document (Environment Agency, 2005) as, "The present value of the cost of developing Alkborough Flats is £8.69 million".

The PAR document records, "an average benefit to cost ratio of 2.72" based on more generalised habitat values.

However, on the basis of the full suite of ecosystem services addressed in this case study, the Alkborough Flats scheme yields an enhanced benefit to cost ratio of 3.22. Note that this is based on very conservative valuation.

1.7 Learning from the case study process

A variety of issues were uncovered from carrying out each of the case studies, from the overall process of applying an ecosystems approach, and from related presentations outlined in Box 1.1.

Box 1.1: Presentations and workshops informing project learning:

- *Watercourse capacity-building* workshops in South Africa in 2008 supporting water allocation reforms, funded by the Foreign and Commonwealth Office/Defra and based in part upon ecosystem services.
- The workshop *Wetland and Aquatic Ecosystems: Their Functions and Values*. Oxford University, 24–25 November 2008.
- The workshop *Ecosystems Valuation and Strategic Environmental Assessment (SEA)*. School of Oriental and African Studies, London, 26 November 2008.
- Presentation to *Freshwater Habitat Advisory Group Meeting*. Lake Country House, Llangammarch Wells, 27–28 November 2008.
- Ecosystem services case study workshop arranged for this project, and held in London on 11 December 2008 (agenda, attendees and feedback at Annex 1).

These issues are raised and discussed in the following clusters:

- 1.7.1: Learning from application of ecosystem services
- 1.7.2: Learning about valuation of ecosystem services
- 1.7.3: Stakeholder engagement
- 1.7.4: Research needs

- 1.7.5: Specific lessons from case studies
- 1.7.6: Further application of ecosystem services
- 1.7.7: Implementation of ecosystem services

1.7.1 Learning from application of ecosystem services

The generic Millennium Ecosystem Assessment (MA) suite of ecosystem services proved helpful for intercomparability. However, consideration of its application in the different workshops noted above suggests that the basic MA suite of services may on occasion need modification for specific purposes (i.e. fire and salinity control in arid environments such as South Africa, or live fish sales and resilience of salmonid stocks in the Tamar, etc.) The MA's suite of ecosystem services may not be perfect for every application, but it is both helpful and broadly comparable across habitat types and bioregions.

It was clear from the case studies that all forms of intervention at all scales rebalance the production of ecosystem services. This observation applies:

- across ecosystem service categories, for example trading 'provisioning' (i.e. food production) for 'regulating', 'cultural' and 'supporting' services as for example in the change in emphasis of flood risk management, 2003 Common Agricultural Policy (CAP) reform, etc.; and

- within ecosystem service category, i.e. the surprising value neutrality of provisioning service benefits arising from changed land use at Alkborough Flats. (For provisioning services, a net loss of £28,075 for food production is largely compensated by a £26,820 gain for fibre production and there is a further estimated £3,000 gain from genetic resources.)

Appraising the full suite of ecosystem services helps identify multiple, potentially interdependent benefits. Cognisance of this broad spectrum of potential outcomes from interventions can help planning to reduce risks (environmental risks, missed opportunities, getting things wrong, reputation impacts, etc.) and so help in maximising the benefits for the broadest range of stakeholders. Taking a broad view of ecosystem services helps avert narrow benefit-specific interests blinding decision-makers to opportunities and synergies.

Boosting of provisioning services (i.e. the food production gain of £265,319 on the Tamar case study) can be compatible with wider public benefits (i.e. climate regulation of £2,455,304, recreation and tourism of £317,966, provision of habitat of £69,114, etc. in the Tamar).

Although 'provision of habitat' is a specific *supporting* service, a feeling was expressed at the project workshop that habitats and biodiversity needed to be treated as a separate service, particularly so for scarce, sensitive and ancient/irreplaceable habitats. This could be related to the cost of replacement or re-creation of habitat (overlooking for a moment the feasibility of re-creation of some habitats).

The ecosystems approach potentially allows site-specific interactions to be identified on broader ecosystems. For example, planting trees in some parts of the catchment could be good (ameliorate high flow), whereas in other areas it could be an impact (reduce low flows).

1.7.2 Learning about valuation of ecosystem services

A proportionate approach is required, transferring values where there is low controversy but undertaking bespoke valuations where issues are likely to be significant, contested or without precedent. Although we have sought to monetise ecosystem services in this case study, the Defra risk-based filter (++, +, o, –, – –, ?) may be adequate for many first-pass purposes.

Ecosystem valuation is best achieved on the basis of marginal, not total, valuation.

We need an increasing and available transferable benefit database to facilitate operational use of ecosystem service valuation.

Price changes – for example the recent doubling in land prices, rising wheat prices, etc. – inevitably influence deduced values. This should inform a cautionary approach to values deduced in a given time period, and also in their transfer to other studies.

Further uncertainties arise from how economic valuation is applied in dealing with a largely unknown/unpredictable future (i.e. climate, market values, etc.)

Although some values deduced are stated down to the level of pence, others are only at the level of thousands of pounds. No greater certainty is implied for smaller denomination figures. Indeed, no value could be given with confidence for some ecosystem services. There is therefore considerable disparity between our current ability to ascribe values for all of the ecosystem services, either through transferable benefits or by identifying real or surrogate markets (for example in seeking to ascribe monetary values to ‘pollination’ or ‘social relations’).

Economic costs were perceived as requiring: (1) confidence limits or lower/upper bands; and (2) clear statements relating to assumptions and underlying data. It was felt that explaining how costs are derived is critical to sell/explain the outcomes to people. This will allow those services which are easy to cost to be identified and conversely those services which are harder will have wider confidence limits. The cost range will also facilitate sensitivity testing which will allow the key services (the ones that contribute most to the overall cost profile) to be identified. Key services or services with low confidence limits may also feed into identification of needs for research or collection of more data.

1.7.3 Stakeholder engagement

The rebalancing of ecosystem service production across catchments as a result of all interventions brings with it a linked set of interdependent ‘winners and

losers', all of which raise equity issues from environmental management decisions/policies.

The ecosystems approach thereby helps in identification of the full spectrum of stakeholders affected, or potentially affected, by interventions in environmental (and other) systems.

Ecosystem services provide a framework from which to identify novel solutions and to appraise competing options, increasing awareness of ecosystems as the foundation of human benefits and potentially leading to innovations that optimise sustainability of outcomes.

Ecosystem services provide a common language to bring ecologists, social scientists and economists together.

Furthermore, while the complete ecosystem services concept is quite complicated for a lay audience, the individual services themselves (fresh water, spiritual and religious value, soil formation, climate regulation and so forth) are readily understood and communicated to the public.

Ecosystem services form the basis for human livelihood support, and so can constitute the starting point for negotiation for equitable and sustainable outcomes.

Ecosystem services are therefore a robust basis upon which to found inclusive dialogue through: identification of all affected stakeholders; communication about interrelated benefits arising from natural resources; negotiation about how these benefits are shared; and dialogue to maximise value to all stakeholders in interventions.

1.7.4 Research needs

There are significant knowledge gaps, which can shape research questions.

Our work to date highlights: (1) major research gaps; (2) areas where improved methods would add rigour and replicability; and (3) tools development needed to improve operational use. The major gaps are noted in Box 1.2 below.

Box 1.2: Research priorities

- We need a simple procedural basis for assessing the net contribution to climate change regulation arising from a complex set of saltmarsh/floodplain processes:
    - carbon sequestration, carbon oxidation, methanogenesis and nitrous oxide; occurring in
    - different soil moisture/redox/salinity regimes.
- The contribution of saltmarsh/floodplain to fish recruitment, supporting apparently substantial (though at present impossible to quantify) contribution to populations of commercial and recreational species.
- We need a simple procedural basis for assessing the net contribution to air/water interactions in tidal/freshwater addressing:
    - air quality regulation (PM10s, SOx, etc.); and
    - microclimate.

Additional lower-level research priorities identified in conducting this analysis are listed in Box 1.3.

Box 1.3: Lower-priority research requirements

- Contribution of site-scale riparian habitat to catchment hydrology.
- We need to review the nitrogen dynamics of tidal and freshwater floodplains to determine potential for nitrification, denitrification, genesis of nitrous oxide, etc. This should ideally be added onto the review of climate change regulation issues (already highlighted above as a major research gap).
- More direct measure/quantification of:
    - soil formation;
    - secondary production;
    - nutrient cycling;
    - water recycling;
    - photosynthesis/production/pest control/pollination.
- Impact on riparian habitat on estuarine oxygen regime, significantly including potential contribution to reducing the effects of a low-oxygen barrier that may inhibit migratory fish from using the wider catchment.

Tools development to improve operational use are listed in Box 1.4.

Box 1.4: Tools development to improve operational use

- We need a database of transferable benefits (which may best be achieved by collaborating/coordinating with a network of partner organisations).

- Further research is required into how various ecosystem services are produced (again, best addressed by collaborating with wider research programmes).

1.7.5 Specific lessons from case studies

A general conclusion from reflection on the draft case studies was that it would be advantageous to engage more diverse stakeholders in valuation to reflect different objectives for sites/catchments.

The case study analysis demonstrates significant net societal value stemming from the Tamar 2000 project, spread over a wide range of ecosystem service benefit categories. The intended benefits for provisioning services (food and other values contributing to farm incomes) and cultural services (wider contribution to the rural economy) are significant, but so too are incidental benefits including regulatory services (such as climate regulation) and supporting services (including habitat provision, nutrient cycling, etc.)

A similar observation applied to the Alkborough Flats case study, with multiple benefits at different scales and no significant net loss for the provisioning services which were initially expected to have been reduced for the farm business.

A weakness of the relatively simplistic approach taken in both case studies was that interactions between services were not adequately identified and costed. For example, tourism results in benefits in terms of increased visitor numbers/revenue, but there are associated costs including increased temporary population, more travel miles (carbon), use of resources (water), production of pollution, footfalls, etc. This should be addressed in more detailed and better resourced studies.

The Tamar 2000 case study would benefit from identifying scale (i.e. a defined population) for each service. For example, carbon sequestration has a global impact, whereas water is more at a regional scale. The benefits flowing from different ecosystem services were identified to some extent in the Alkborough Flats case study.

There would be value in analysing the net social value to be derived from the Westcountry Rivers Trust's hypothetical 'stretch target' of increasing the extent of wetland in the Tamar catchment to 20%. This may be compatible with priorities identified in the Wetland Vision programme (http://www.wetlandvision.org.uk/). We could make a linear extrapolation of benefits from Tamar 2000 wetland restoration, but this would be unsafe. Further study would be required to make the case for the contribution to society of restored wetlands and their associated ecosystem services throughout the catchment.

1.7.6 Further application of ecosystem services

The research and its associated presentations and workshop identified a wide range of further potential applications of the ecosystems approach. Further opportunities to apply the ecosystems approach included:

- Further application of learning and methods to management and communication of new managed realignment sites under the Humber Estuary Strategy. Subsequent to his engagement in the Alkborough case study, the Environment Agency's Humber Strategy Manager (Philip Winn) has invited a contribution to the ongoing work from experts in ecosystem services-based work.

- Further application to river restoration schemes. (The Tyne Rivers Trust has subsequently included positive contribution to ecosystem services as part of its project appraisal principles.)

- Valuation of existing environmental enhancement initiatives on the basis of broader public benefit, for example:

    - While the purpose of the 2003 EU CAP reform was fundamentally a shift in public payment for (from 'Pillar 1' private benefit) output subsidy towards land management for public benefit ('Pillar 2'), the practical reality of national implementation (i.e. the UK's Environmental Stewardship payment scheme) is more on the basis of basic feature checklists than a link to production of public benefits from land. Ecosystem services can provide us with that 'language' of public benefits arising from catchment management, providing a basis for markets between beneficiaries (i.e. the public purse or even discrete water/landscape users) and 'producers'.

    - The close similarities between the Westcountry Rivers Trust's Tamar 2000 project and the government's Catchment Sensitive Farming (CSF) programme were inescapable, with the Trust scheme observed to be a more bottom-up approach and CSF more top-down with consequently less acceptance of prescribed actions by landowners. The Tamar 2000 ecosystem, services case study was seen to have been useful in identifying a wide range of benefits, and hence could allow potential benefits to be identified, refined and communicated for the CSF programme.

    - The ecosystems approach could support ongoing conservation initiatives, such as the current north Devon proposal for a UNESCO Biosphere Reserve largely around the Taw–Torridge catchments.

- Determining the broader cross-disciplinary implications and interdependences of function-specific policies and practices. These include, for example, the identification of broader public benefit from:

    - flood risk management initiatives; and
    - River Basin Management Plans (RBMPs) undertaken to implement the Water Framework Directive (WFD).

- Uptake of ecosystem services clearly requires their implementation into a range of operational tools and procedures, which will in turn benefit from the systemic framework of ecosystem services. Being outcome-based and constituting an integrated set, the MA classification of ecosystem services is compatible with many existing tools. These include:

    - Strategic Environmental Assessment (SEA) – a presentation of these case studies has already been made to the Environment Agency's SEA team, which is keen to progress internalising the ecosystems a approach;
    - Environmental Impact Assessment (EIA);
    - better determination of 'public benefits' and optimisation of public benefits from agri-environment payments consistent with the intent of the 2003 EU CAP reforms (including the UK's Environmental Stewardship' payments but also through such related programmes as the CSF programme and SSSI management plan support);
    - flood risk management project appraisal, building upon the existing multi-criteria analysis approach;
    - 'natural capital'-based approaches;
    - cost–benefit assessment;
    - et cetera.

- Linking into broader-scale planning guidelines. Simultaneous consideration of the suite of ecosystem services can be helpful in identification of novel options that maximise public benefit from project design, for example to help identify opportunities for optimal achievement of public value within plans and synergies between them, including for example:

    - Regional Spatial Strategies; and
    - Shoreline Management Plans.

- Ecosystem services provide an outcome-based language which helps different organisations communicate around common desirable outcomes of value and meaning to the constituencies that they serve.

- Ecosystem services also offer a robust, widely accepted and publicly comprehensible basis of public/stakeholder engagement around optimally equitable and sustainable outcomes in term of who benefits from catchment/site management.

- A net outcomes of the above measures could be the more efficient use of investment, achieved through identifying and delivering wider benefits from funding streams tied to narrowly defined activities.

- NGO participants in these dialogues and ensuing discussion felt that the ecosystems approach gave them greater confidence to justify the schemes that they undertake on the basis of a broader set of public benefits likely to flow.

- There was also a feeling expressed at the project workshop that the ecosystems approach would underpin issues that may be better delivered by local communities/NGOs rather than government agencies.

- The identification of potentially greater public benefits flowing through ecosystem services from environmental interventions may possibly open up new funding streams. This approach has already been pioneered and championed by the River Trusts movement, where significant (mainly European) public investment in river restoration has been justified on the basis of stimulus of the regional economy.

1.7.7 Implementation of ecosystem services

The ecosystems approach provides a robust and comprehensive evidence base for policy formulation.

Although based on human benefits rather than inherent values deduced for habitats and organisms, ecosystem services help demonstrate the source of multiple societal benefits and hence the critical importance of the maintenance or enhancement of ecosystems for securing future wellbeing. The ecosystems approach helps promote biodiversity into decision-making processes, rather than the situation common today where it is regarded as secondary to securing social and economic benefit.

The ecosystems approach is consistent with the growing momentum of Defra, the EU and UN agenda.

When taking an ecosystems approach, it is essential to look at entire socio-ecological systems. To focus too narrowly on disaggregated services or localities of interest risks overlooking opportunities, synergies and maximisation of public value.

Ecosystem services have proven their utility. However, it is necessary to integrate the ecosystems approach within operational tools for use by non-specialists if it is to be taken up.

The language of ecosystem services is helpful in exploring the ‘bigger picture’. However, this broader scale of thinking is often less easy to communicate or rationalise to vested local interest, perhaps because the local ‘surrender’ of benefits (such as intensive farming or flood-defended land) confers broader-scale benefits to other constituencies (i.e. flood risk management). It is here that

effective markets between ‘providers’ and ‘users’ of ecosystem services would be beneficial.

Ecosystem services provide a language for the Environment Agency (and others) to collaborate with partner organisations (such as Natural England, the River Trusts, etc.) around common desired outcomes.

Ecosystem services also provide the Environment Agency (and other bodies) with a language to identify the wider benefits of pre-existing work (as demonstrated at the Alkborough Flats and Tamar case studies but also applicable to other river restoration initiatives, Catchment Sensitive Farming, Water Framework Directive, etc.)

Ecosystem valuation is an aid to decision-making, not a substitute.

If the full potential of ecosystem services is to be achieved, there is a need to further develop it towards a point where methodologies applied are accepted by all relevant stakeholders.

As a society, we are at the very earliest steps in uptake of the ecosystems approach, the logical culmination of which is full market internalisation.

A significant perceived advantage of the ecosystems approach is that it facilitates education/knowledge management across different stakeholder groups (policy, science, community, all sectors of society) and clearly allows people to see and discuss benefits. It is a framework for consultation at many levels, which can be supported with case studies, real-life examples, success stories, etc. However, it is essential to identify and have in place appropriate champions/ambassadors for leading on this approach.

Another very strong benefit identified was that the ecosystems approach provides a framework for explicit identification of multiple benefits (including in financial terms). This can inform strategies, schemes, projects, etc. and enable them to connect with investment and importantly start to facilitate the justification and establishment of multi-functional funding streams (i.e. meeting flood risk management, WFD, soil strategy, biodiversity objectives).

In common with the benefit evaluation methods and values, learning and key principles are also transferable across sites, catchments and scales with appropriate caution.

Uncertainties were raised at the project workshop about whether expressing costs and benefits in monetary values was helpful. Overall, the consensus was that it is a helpful approach, as it was essential to better integrate environment into the decision-making process, although costs/benefits had to be spatially specific/adjusted. However, the role and limitations of economics have to be explicitly stated. Are economics, for example, good for relating to short-term changes but not so good at the long-term scale? (Is discounting a sufficient approach?)

Monetary values may in fact be quite inappropriate to connect to people and issues at the very local scale, missing some stakeholder concerns and issues.

A gap was identified in the capture of costs and benefits of education. A CEH case study (not specified) was reported to the 11 December 2008 project workshop. It compared benefits derived from farmer financial incentives to improve land management versus farmer training/education with no payments; education was reported to have provided bigger benefits.

Related to the above point, it would be helpful to identify institutional/organisational links for each service, including who is responsible for managing each service. This could be facilitated by analysis of how these services fit together into local structure plans, RBMPs and other planning frameworks. This will also aid the educational role provided by the ecosystem services framework.

Given increasing recognition of future uncertainty, the ecosystems approach needs to be applied adaptively and flexibly, including accommodating changes in the ecosystem services typology, costing methods, and so forth.

Discussion following presentations of the developing case studies, including in detail during the case studies project workshop itself, highlighted the value of ecosystem services as a common language of ecosystem-derived benefits, and how they could support dialogue between the many stakeholders that they affect leading towards sustainability and equity. However, it was also recognised that this called for setting ecosystem service analysis within an inclusive and deliberative process of stakeholder engagement. The excellent research conducted by Lindsey Colbourne for the Environment Agency (Colbourne, in press), focusing on the relative benefits and transition from DAD (decide-announce-defend) to EDD (engage-deliberate-decide) stakeholder engagement processes, was seen as particularly useful in this context, with the framework of ecosystem services providing a transparent basis to support the stakeholder dialogue process.

Having outlined a great many strengths of the ecosystems approach, the following were identified as potential weaknesses:

- Due largely to an incomplete understanding of how ecosystems produce some ‘services’, the role of biodiversity is not always clear and particularly for rare species and habitats.
- Using ecosystem services does not automatically account for special conservation interests.
- At present, we are in need of a greater number and range of studies with transferable benefits if we are to operationalise the approach.
- There are conflicts between culturally created systems (e.g. peat uplands) versus climax ecosystem services.
- There is a risk that ecosystem services can be used loosely within a ‘trade-off’ mentality, rather than as intended as a stimulus for innovation to achieve optimal public value (i.e. protecting/enhancing services of value to all stakeholders).

Taken in the round, many of these weaknesses are in fact merely current shortfalls in knowledge and tools rather than inherent weaknesses in the ecosystems approach.

1.8 Summary of recommendations arising from discussion

A number of key recommendations for exploiting the benefits of the ecosystems approach have been proposed in the presentation to Environment Agency policy leads (see Annex 3) as a result of these case studies. Recommendations are outlined in Box 1.5.

Box 1.5: Recommendations about the benefits of uptake of the ecosystems approach

- Provides comprehensive evidence base for policy formulation.
- The Environment Agency is seen as engaging with a strategic agenda.
- Review potential to maximise public value from activities:
  - General: SEA, EIA, CAP, CSF, FRM, etc.
  - Currently narrower focus: WFD/RBMPs, etc.
- Use to communicate the wider benefits of Environment Agency work
  - Ideally backed up by more case studies.
- Address shortfalls in operationalising valuation methods:
  - Robust economic methods and transferable benefits.
- Address the major research gaps identified by case studies.
- Further case studies on new schemes to broaden options.

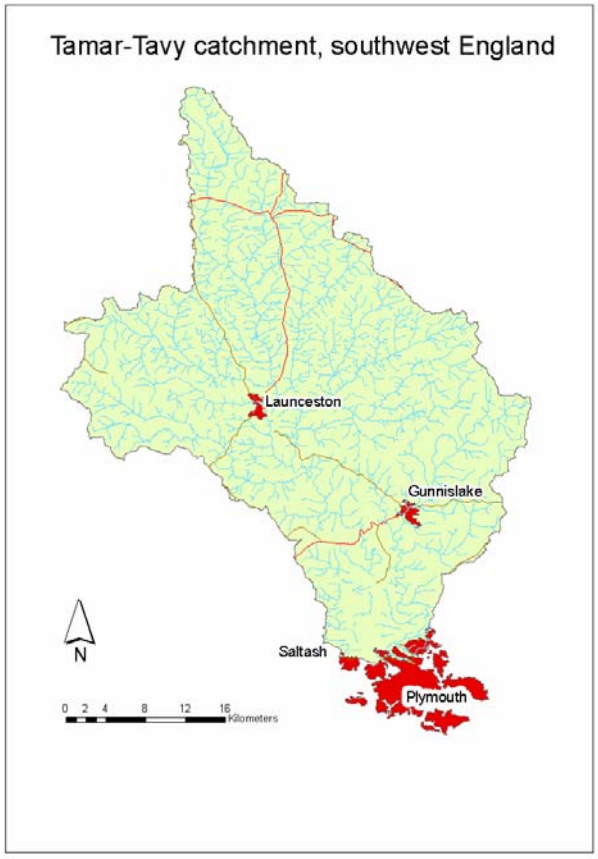
1.9 Policy issues arising from case studies

One of the required outcomes of these ecosystem services case studies was production of a PowerPoint presentation, with associated notes, for Pam Gilder (Head of Wildlife, Recreation and Marine in the Environment Agency), containing key messages and recommendations.

A copy of this presentation and its notes pages is attached at Annex 3.

2 The Tamar catchment: evaluation of ecosystem service impacts

The main stem of the River Tamar is approximately 80 kilometres in length, rising close to the north Cornwall coast around 6.5 kilometres to the south of the town of Bude. The Tamar then runs predominantly north to south, forming a natural boundary between Devon and Cornwall for much of its length. Various tributaries join the river's main stem from source to sea, including the rivers Ottery and Inny from Cornwall and the Tavy and Thrushel from Devon. The Tamar reaches the sea at Plymouth Sound in south-west Devon, a large ria (or drowned estuary) in which the Tamar merges with the rivers Tavy, Plym and Lynher. The city of Plymouth and the associated Devonport dockyard is the only substantial conurbation in the catchment, though the town of Launceston is situated in the middle catchment and Tavistock straddles the River Tavy in Devon.



2.1 Attributes of the Tamar suiting it to this study

Screening pre-studies covering relevant attributes of a range of catchments suggested that those of a predominantly rural character, with less confounding factors introduced by greater population density, settlements and urban areas with associated large-scale discharges, were optimal study sites to determine the impact of targeted interventions on ecosystem services. These pre-studies also exposed difficulties with confounding factors at broader geographical scales, the evidence suggesting that taking a whole-catchment approach in these instances is likely to lead to less discrimination of ecosystem service benefits stemming from specific interventions. For this reason, smaller rural river catchments offer the best options in terms of the confidence of determining contributions of specific interventions to a range of ecosystem services.

From the 'long list' of potential sub-catchment case studies identified for the purpose of testing the 'ecosystem approach', the River Tamar was selected for further study. The Tamar is a rural catchment in the West Country, with relatively few of the confounding factors (conurbations, etc.) that affect many other British catchments. The catchment has Class 3 and 4 flood risk areas along its length, and it is a focus for work on 'Making Space for Water' initiatives. Fish and biodiversity initiatives have been put in place (including addressing EU Fisheries Directive failures), as well as projects addressing water quality and tourism values (i.e. amenity).

Interventions in the River Tamar catchment carried out by the Westcountry Rivers Trust (WRT), a river restoration and regional development NGO, are particularly suitable for pre-/post-project appraisal of impacts on ecosystem services. Some benefit assessment has already been completed for some of these interventions, significantly including benefit assessment for work packages carried out under various packages of EU funding including Tamar 2000 SUPPORT (SUstainable Practices Project On the River Tamar) and the Cornwall Rivers Project. These independently audited studies provide valuable desk input to this work. The mixture of upland and lowland areas across the catchment also provides a focus for carbon storage. Notwithstanding potential issues of scale that had initially steered us towards selecting only a sub-catchment, the Tamar was accepted as a suitable case study catchment.

The Environment Agency has excellent and tested links with the WRT (Director: Dr Dylan Bright; dylan@wrt.org.uk; 01579-372140). The Tamar is also the focus of attention under the Environment Agency's Integrated Catchment Science (ICS) theme, under which aegis Neil Preedy (0117-914-2935) is modelling the Tamar using both scales of the PSYCHIC model. Furthermore, the Tamar catchment is the subject of initiatives under the Catchment Sensitive Farming (CSF) scheme.

The Tamar Estuaries Management Action Plan: 2007 to 2009 (Tamar Estuaries Consultative Forum, 2007) identifies priority actions for the delivery of the Tamar Estuaries Management Plan 2006–2012 over forthcoming financial years. Priority actions include 'Coordination of a Management Framework for the Tamar Estuaries', 'Marine Protected Areas Management', and 'Promoting Access and

Regeneration in the Upper Estuary'. However, despite their relevance, no references are made to Tamar 2000 or the Westcountry Rivers Trust in the plan.

In addition to this, a new project is starting up to protect the Tamar Lakes, two reservoirs 6 kilometres from the head of the Tamar and vulnerable to eutrophication from intensive dairy and beef farming in the 17 km^2 upper catchment. The Lower Tamar Lake is approximately 100 years old, with the upper lake operational since construction in the 1980s. This work brings with it the support of the utility company South West Water, which will benefit from any pollution abatement as nutrient reduction may offset some of the costs of reservoir destratification. (The key contact at South West Water is Martin Ross.) This Tamar Lakes project is to be funded under the EU Interreg ALICE programme, with partners in France, the Netherlands and Ireland joining in with the Westcountry Rivers Trust (Dylan Bright), the Environment Agency (Neil Preedy) and a number of British universities. Wider benefits for the river system are anticipated in addition to protecting the viability of water source for abstraction for supply.

2.2 Background to the Tamar with respect to ecosystem services

Further attributes of the Tamar catchment are listed below, classified into the four major categories of ecosystem services as defined by the Millennium Ecosystem Assessment (MA, 2005).

Provisioning services

- River water is of a generally high quality. The catchment is the dominant source of water for the city of Plymouth and the south Devon/Cornwall coast area.
- Location and climate have historically made the Tamar Valley an important area for market gardening. Apple orchards were once extensive, and cherries, strawberries and daffodils have also been produced both for local consumption and serving wider markets. Market gardening in the Tamar valley currently occurs at a far smaller scale.
- There was a long history of mineral extraction, which was formerly the key industry in the Tamar Valley dating back many centuries. In 2006, the Cornwall and West Devon's Mining Landscape won World Heritage Site status. Tin, silver, lead, granite and copper were all mined in areas like Lopwell, Bere Alston and Morwellham.
- The Tamar remains a significant salmonid fishery, including Atlantic salmon, sea trout and brown trout as well as grayling. Some of this resource is taken for domestic consumption.
- The estuary also supports a sea fishing industry and holds good fish stocks.

Regulating services

- The upland, low nutrient zone of the Tamar catchment allows peat formation, while lowlands are affected by drainage but also restoration initiatives.
- There are flood risk concerns in the catchment, for which a Catchment Flood Management Plan is in place. Areas of the catchment are Class 3 and Class 4 flood risk areas.
- The Tamar is also a 'Making Space for Water' focus catchment.

Cultural services

- Together, the Tamar, Tavy and Lynher form a designated Area of Outstanding Natural Beauty.
- At the mouth of the Tamar, on the Devon side, there is the port city of Plymouth, and Devonport Dockyard.
- The Tamar valley has historically importance, with evidence of Stone and Bronze Age settlements especially on the Cornish side of the river.
- The Tamar is spanned by a number of medieval stone arch bridges along its course, some over 500 years old. Isambard Kingdom Brunel's iconic Royal Albert Bridge spans the lower Tamar. It was completed in 1859 and built to bear the weight of three express trains. It remains the main rail link between Cornwall and the rest of the country.
- The Tamar Bridge, opened to road traffic in 1961, was then the longest suspension bridge in the UK. This toll bridge has been more recently widened.
- Devonport Dockyard's origins date back to 1691, when William of Orange commissioned the building of a new dockyard to support the Royal Navy in the Western Approaches.
- The Tamar Valley is now a World Heritage Site for its mining landscape. Morwellham Quay, on the Devon side of the river, was a centre for shipping minerals for 1,000 years. The Quay is now a visitor attraction. The minerals were transported down the river to the sea until the advent of the railways.
- A succession of Torpoint ferries have operated during the past 200 years. Today, there are three: the *Plym*, the *Lynher* and the *Tamar*.
- The Tamar is a popular recreational venue supporting visitor attractions, walking, boat trips, angling, and taking in the scenery and wildlife. It remains one of the most distinctive county boundaries in England. It is one of the major tourism centres of the South West of England, with high visitor numbers.
- The Tamar is a popular salmonid fishery (Atlantic salmon, sea trout and brown trout as well as grayling) of significant recreational angling value.

Supporting services

- A range of rare and valued habitats occur throughout the Tamar, including ancient woodlands, intertidal mudflats, saltmarshes and reedbeds, and other wetland and terrestrial habitats including important heathland up the river. All are havens for diverse wildlife including breeding avocets and other bird life, otters and other mammals, butterflies and plants including rare lichen and orchids.
- The Tamar–Tavy Estuary and the Lynher Estuary are both protected Sites of Special Scientific Interest (SSSI) because of this habitat and wildlife.
- The estuary is an important spawning and nursery site for marine fish, as well as allowing the passage of migratory species including salmon, lampreys and eels.

2.3 Interventions explored in the Tamar

In common with all British rivers, the Tamar has been the focus of many interventions ranging from investment in sewage and industrial waste treatment, agri-environment subsidies, angling and conservation initiatives and others besides. However, two significant interventions of particular interest to this ecosystem services study are the Tamar 2000 project and the subsequent Cornwall Rivers Project. The secretariat of the Convention on Biological Diversity has cited Tamar 2000 specifically as the UK's example of the successful implementation of the ecosystems approach (see http://uk.chm-cbd.net/Default.aspx?page=7021), amplifying its appropriateness for this ecosystem services analysis. An overview of the Tamar 2000 and the Cornwall Rivers Project, together with supporting studies, is provided in Annex 1.

As a strategic and aspirational measure, the Westcountry Rivers Trust (WRT) has also identified a target of restoration of wetlands in the Tamar catchment. This reflects the conclusions of a study by Hogan et al. (2000), which concluded that the Tamar is currently impoverished in terms of wetland extent due to historic land drainage and change of use, with the current resource covering only 5% of the catchment. On the basis of soil maps, Hogan et al. estimate that 20% of the Tamar catchment could comprise wetlands were drainage to cease. This may not be an immediately achievable target, but it does emphasise the opportunity for restoration not only of habitat but also its associated ecosystem services. For example, were government policy to favour a shift from provisioning services (such as food production) to regulating services (such as natural flood regulation or carbon sequestration mitigating climate change), the latent resource of wetlands provides a strategic method for delivery that is also likely to result in a wide range of collateral benefits. The 5 to 20% wetland extent 'stretch target' represents a strategic opportunity, but also a timely reminder that we should not automatically accept today's *status quo* as a healthy baseline for environment management. The WRT vision, idealistic rather than detailed, is founded on taking opportunities to restore this 'missing' 15% and ideally targeting restoration of the most critical areas for catchment functioning. Our initial aspiration in this case study had been to identify the public benefit associated with ecosystem

service benefits stemming from restoring this 15% of hypothetical wetlands, although time constraints prevented this extrapolation of the study.

2.4 Determining the confounding effects of other catchment interventions

The selection of the Tamar as a study catchment is based largely on the low 'background noise' in a predominantly rural catchment. Nevertheless, a range of initiatives – improvements to effluent treatment, catchment-sensitive farming, changing land use and so forth – have been and are taking place within the catchment.

In the Tamar, we have the benefit of a direct economic study on Tamar 2000 advice, which helps avoid the confounding effects of these other initiatives.

2.5 Results of the Tamar 2000 ecosystem services evaluation

Valuation of benefits arising from Tamar 2000 is determined on the basis of the Millennium Ecosystem Assessment categorisation of ecosystem services, across its four broad areas of *provisioning services*, *regulatory services*, *cultural services* and *supporting services*.

Cost savings to farmers through following advice (i.e. reduced fertiliser inputs, composting manure, under-sowing maize, fencing, rotational ditch clearing, separation of roof and foul water, and hedge cutting regimes) were substantial, and qualify as marginal benefits in the production of the 'provisioning service' of food production. Since the benefits calculated by Tusa (2000) were in order to comply with the economic and social reporting requirements of the EU Objective 5B structural funding (EAGGF) and were not geared primarily towards wider environmental improvement, Tusa's findings are augmented by appraisals of the related Cornwall Rivers Project and Angling 2000 projects. Additional methods, assumptions and transferred values are outlined in Tables 2.1–2.4 below.

Table 2.1 Provisioning service evaluation arising from the Tamar 2000 scheme

Provisioning services and the methods and assumptions used for their evaluation	
Fresh water	• The water service company with responsibility for the Tamar region is South West Water, which treats and/or blends water abstracted from the catchment before reticulating it for public/industrial consumption to meet stringent drinking water standards. Tamar 2000 advisory measures, such as fencing of stock from the river or clean/dirty water separation, have significant impacts on abatement of faecal coliform, BOD, ammonia, particulates, nutrients and other pollutants entering the river. The PSYCHIC model takes account of 44 pollution control measures (directed by the MOPS 2 programme), based upon the 44 guidance notes/control measures produced under Tamar 2000, from which water quality improvements can be modelled on a 1 km^2 granularity. Various direct methods were attempted to obtain annualised values for this ecosystem services including: o Feeding farm advisory information (measures and numbers of farms) to into the PSYCHIC (or ALICE) models to produce pollution reduction estimates, from which costs could be determined; and o Attempting to get direct estimates of cost savaings from the averted pollution in water abstracted and treated from the Tamar. However, owning to technical factors and issues of commercial confidentiality of data, these methods did not provide productive. Therefore, the following assumptions were extrapolated from basic information applied in the South West Water (2008) document *Welcome to South West Water*: • £760 million investment in the South West Water service area over the 2005-1010 planning period equates to £152 million annual investment; • Assuming a split between maintenance of infrastructure and the treatment of both sewage and water abstracted for potable use, we will assume that 'clean water' treatment accounts for 20% of this total annual investment (= £30.4 million); • The Tamar services around 20% of the area and population of Devon and Cornwall, and therefore uses 20% of that annual expenditure (= £6.09 million); • If the Tamar 2000 project results in a (conservative) 5% reduction in the pollutant load of the river, this then equates to an annualised saving

	of £304,000 • Note 1: implications arising from improved water quality for fishing, recreational activities, agriculture, industry, general environmental value, industrial use and property values are NOT assessed here. They are not a provisioning service, and their exclusion avoids double-counting. **Total monetary value = £304,000**
Food (e.g. crops, fruit, fish, etc.)	• Tusa (2000) found cost savings to farmers through following advice (fertiliser reduction, composting manure, under-sowing maize, fencing, rotational ditch clearing, separation of roof and foul water, hedge cutting regimes, and 'other') to improve farm profitability and also improve ecosystem services through reduced pressure on the river system. These farm cost savings count as an opportunity cost, and hence are admissible as benefits under this ecosystem service as an increment to baseline. Average per sampled farm was £2,158.29 which, multiplied by the 117 farms in the catchment for which Tamar 2000 farm plans were produced, yields a gross benefit for farmed food production of £252,519.93. • In terms of employment creation, Tusa (2000) provides part-time job creation figures for farming totalling £10,800 per annum. **Total monetary value = £263,319.93** **Value not used = Employment in farms**
ADDENDUM SERVICE: Fish stocks	• For the sale of fish (sale of fish stocks as a farm diversification as distinct from angling/recreation), Tusa (2000) found that there was a total benefit of £8,269. **Total monetary value = £8,269**
Fibre and fuel (e.g. timber, wool, etc.)	• Tusa (2000) estimates that woodland thinning operations and coppicing yield net estimated annual benefits of £900 year and estimated £1,611 respectively relative to baseline, which combine to a total of £2,511. • There is commercial forestry in the upper and lower Tamar, with some scattered around the catchment. Tamar 2000 recommended forestry diversification for some farmers, including the drawing down of associated agri-environment subsidies. Although landowners will often perceive this boosting a provisioning service, it is counted under 'supporting services' in this analysis and therefore ignored here to avoid double-counting. • Tamar 2000 recommendations did include planting of *Miscanthus* and short-rotation coppicing, both of which will yield fibre/energy, but these were not captured in Tusa's farm survey sub-sample and therefore we have no data. • It is assumed that Tamar 2000 interventions will not have significant impact of sheep numbers or markets, merely excluding them from sensitive areas of riverbank. There

	is therefore no market impact for this provisioning service. • In terms of employment creation, Tusa (2000) provides full-time job creation figures for woodlands totalling £16,380 per annum. **Total monetary value = £2,511** **Unquantified value = *Miscanthus* planting** **Value not used = Employment in woodlands**
Genetic resources (used for crop/stock breeding and biotechnology)	• No impact perceived from Tamar 2000. **No net value ascribed**
Biochemicals, natural medicines, pharmaceuticals	• No impact perceived from Tamar 2000. **No net value ascribed**
Ornamental resources (e.g. shells, flowers, etc.)	• No impact perceived from Tamar 2000. **No net value ascribed**

Table 2.2 Regulatory service evaluation arising from the Tamar 2000 scheme

Regulatory services **and the methods and assumptions used for their evaluation**	
Air quality regulation	• A range of methods were explored, none with satisfactory outcome, to derive a value for the air quality regulation benefit of Tamar 2000. These included: o Extrapolating from surveys by the New York City Department of Parks and Recreation, in 1995–1996 and repeated in 2005–06, which mapped the city's street trees providing input to models operated by the US Forest Service to quantify annual benefits. In summary, Forest Service figures translate into the fact that, for every $1 invested in planting a tree, there is a return of benefits of more than $5. This is achieved through improved air quality (leaf absorption of carbon dioxide, nitrogen dioxide and sulphur dioxide), capture of airborne particles (dirt, dust and soot), climatic improvements (shading, suppressed wind speeds, cooling through transpiration) offsetting emissions from energy generation plants and suppressing formation of ground-level ozone, sequestration of carbon dioxide, reduced flooding, improved run-off water quality, and upward influence on property values. Negative effects include interference with overhead wires and damage to pavements. New York's street trees had a cumulative benefit to the city of millions of

	dollars per year. However, persuasive though the ecosystem service analysis is for New York City, none of these conclusions are immediately transferable to the rural Tamar catchment. o A study by Hewitt et al. (2008) into relative deposition rates of PM10, ozone, nitrogen dioxide and sulphur dioxide to various types of wetland habitat, including salt and fresh water marshland, woodland and wet woodland, looked at wet deposition and dry deposition processes. A literature review records ranges of dry deposition rates for different pollutants over various land cover types, with wet deposition more clearly tied to rainfall. Frustratingly, land cover is not adequately broken down to make inferences about likely removal rates resulting from habitat change at scales relevant to Tamar 2000 interventions. o Consideration of catchment absorption of pollutants (on advice from Bernard Fisher) arising from history of mining, particularly wind-blown dust, though the absence of any open cast mining may mean that there are few local metal air-blown issues. o Critical loads exceedence for assessment of ecological risk. **It was not possible to value this ecosystem service** **Research gap: quantification and valuation of air quality regulation**
Climate regulation (local temperature/precipitation, GHG sequestration, etc.)	• The SWIMMER (2007) report *An Examination of the Potential for Carbon Sequestration Using Changes in Land Use Management* explores carbon acquisition rates, particularly in relation to the dynamic interactions of the greenhouse gases carbon dioxide, methane and nitrous oxide, the interrelationships among these gases, and the potential for their emissions under land use changes. It demonstrates how ecosystem restoration is valid in terms of lasting carbon storage, with increase in carbon content as habitats move back towards a climax state (except for upland peat), with associated improvements to ecology and biodiversity. The SWIMMER report reviews the literature on soil organic content and also standing crop. Taking a conservative assumption, 2% of farm area (65.84 ha average x 117 farms advised = total 7,703.28 ha) will be rewetted (i.e. transition from floodplain permanent grass with soil carbon of 20,324 C t ha^{-1} (g m^{-2}) towards floodplain woodland with soil carbon of

	26,064 C t ha^{-1}). Annualised by averaging over 100 years of succession to climax state, this yields soil carbon sequestration of 88,433.65 C t ha^{-1} a^{-1}. To this is added the standing crop of trees (alder forest has a 100-year annualised average carbon storage of 65 t C ha^{-1} a^{-1}) growing on fenced riparian land on 0.5% of land yielding carbon sequestration of 2,503.57 t C ha^{-1} a^{-1}. The total 100-year annualised sum for carbon sequestered in soil (88,433.65 C t ha^{-1} a^{-1}) and wood (2,503.57 t C ha^{-1} a^{-1}) equals 90,937.22 t C ha^{-1} a^{-1} which, multiplied by the current marginal cost of carbon @ £27 per tonne, yields an annual ecosystem service benefit value of £2,455,304. • Further benefits accrue from the microclimate effects of restored wetlands, but there appears to be no current means for quantifying this. • It is assumed that few if any Tamar 2000 interventions related directly to upland peat. Were it necessary to further explore GHG issues in upland peat, this may be approached using 'Carboeurope emission factors' to determine avoided loss as an annual value. (For study on C in bog in pristine and drained condition, speak to david.thompson@naturalengland.org.uk). • There were no direct Tamar 2000 interventions in the estuary, nor is there any evidence upon which to found an assessment of how Tamar advice may have influenced the carbon dynamics of saltmarsh. **Quantified benefit = £2,455,304** **Unquantified benefits = upland peat** **Unquantified benefits = microclimate effects** **Unquantified benefits = implications for estuarine saltmarsh** **Research need: This work has exposed the fact that, despite some simple tools, there are complexities inherent in the dynamics of carbon sequestration, methanogenesis, nitrous oxide production and other mechanisms important for greenhouse gas dynamics under different soil types and wetting and oxygen regimes. This needs to be teased out including a digest useful to practitioners**
Water regulation (timing and scale of run-off, flooding, etc.)	• The Environment Agency's 2006 *River Tamar Catchment Flood Management Plan – Summary of Draft Plan* document includes a wide variety of actions targeted at sub-catchments relevant to habitat improvement work. These include the creation of wetlands where feasible, investigation of flood storage possibilities, and promotion of afforestation. However, the means to quantify and

	monetise the Tamar 2000 contribution to this benefit – increasing field soil capacity, drain blocking, wetland recreation, etc. – remain difficult to determine reliably. **Benefit not assessed** **Research need: quantification of contribution to hydrology**
Natural hazard regulation (i.e. storm protection)	• Management of woody debris in the river that was likely to move and cause a problem was undertaken under Tamar 2000, using a five-point protocol for decisions as woody debris in rivers has other ecological values. About 100 such large woody remains were physically moved by the Environment Agency on advice from the Westcountry Rivers Trust. Overlooking for now the big costs associated with disaster flooding (such as was seen in Boscastle in North Cornwall and to which large woody debris made an acknowledged contribution), we assume that 5% of these potentially mobile large obstructions could result in reactive work by the Environment Agency at £2,500 per team call-out, with a total value of £12,500 **Total value = £12,500**
Pest regulation	• The 're-wilding' of habitat, particularly riparian habitat, under Tamar 2000 will have resulted in creation of refuges for natural predators equating to the targeted advice to install beetle banks. This has associated cost savings from pesticide reduction within the PSYCHIC model. However, it was not possible to make a confident assessment of this benefit. **Benefit not calculated**
Disease regulation	• Animal disease benefits can be assessed by a range of methods. For 50% of the 117 farms advised in the Tamar 2000 study, there were recommendations to exclude cattle from water/wetlands. Similar management was recommended for sheep and pigs. (Agricultural Census 2000 data show there are a total of 122,922 cattle (dairy, beef, special breeds and followers) in the Tamar catchment, 27,917 pigs and 284,000 sheep.) Tusa (2000) notes that fencing along riverbanks and different type of wetland areas creates an estimated annual saving of £720 per farm, as a result of reduced stock losses and reduced vet bills for injury treatment of the livestock. However, these benefits have already effectively been captured under the provisioning service of food production, and so are not evaluated here as this would result in double-counting. • EU Bathing Water Directive and Shellfish Water

	Directive implications arise from faecal contamination of rivers by stock. Assuming that 20% of (122,922) cattle in the catchment had access to the river pre-Tamar 2000 and that Tamar 2000 fencing cut this to 5% on 117 farms advised, we can calculate a theoretical reduction in loading, though in practice it may be impossible to extrapolate this into estuarine/marine loadings. Another method is to look at bacterial loadings in shellfish flesh in the estuary in 1999 (five-year averages up to) as compared to 2001 (five-year average after), though this will be confounded by AMP (Asset Management Planning agreements on investment by the water industry) implications and ascribing causality may be elusive. In practice, theoretical difficulties may confound attempts to value this benefit. • There are human disease implications from improved habitat management, both in terms of the self-purification processes and the exclusion of stock/faeces from watercourses. The public supply implications (faecal coliforms, viruses, cryptosporidium, etc.) of this are already covered under the provisioning service of 'fresh water' and are not double-counted here. **No value ascribed due to methodological difficulties** **Value not used (to avoid double-counting) = animal disease** **Research gaps include assessing human and shellfish contamination**
Erosion regulation	• Tusa (2000) addressed Tamar 2000 recommendations to control erosion (fencing of vulnerable riverbank, river corridor restoration, re-planting and provision of livestock drinking access, and river corridor woodland regeneration or re-planting), projecting reductions in soil loss to the river. Ignoring wider benefits such as improved natural habitats particularly for fish, Tusa integrates literature sources suggesting a net reduction in soil erosion across the catchment of between 1168.5 and 3,259.5 t a^{-1}, with values of £2.19 per tonne (value of productivity loss) ranging up to £40 per tonne (transport cost of returning the soil from the estuary to source). Taking a median value of £20 per hectare, this equates to a catchment total of between £23,370 and £47,190, of which 30.6% (corresponding to 188 ha of 615 ha of river corridor restored) can be attributed to Phase II of the Tamar 2000 project. We will therefore use benefit figures of £7,151 to £14,440. • The Shoreline Management Plan covering the Tamar

	estuary carries no information useful for identification of benefits likely to accrue from improved river management. **Pessimistic annual benefit assessed at £7,151** **Research gap: contribution from sites to catchment erosion risk**
Water purification and waste treatment	• Finding a proxy value for in-stream purification (including marginal wetland functions) is complex but probably best captured via reduced treatment costs for abstracted water or wastewater through lower inputs and improved dilution. These estimates are already effectively captured under the 'provisioning service' of fresh water, so are not addressed here in order to avoid double-counting. • Values to farmers (i.e. disease control, etc.) and to water quality arising from wetland protection and regenerations under Tamar 2000 are effectively already captured under the respective 'provisioning services' and so are not addressed here in order to avoid double-counting. This benefit may be significant, in terms of fenced areas but also improved rotational ditch management that effectively converts ditches into more biodiverse linear wetlands with rewetting impacts on adjacent land. **Value not ascribed in order to avoid double-counting**
Pollination	• Parallel methods to the identification of pest control services can be applied here. Information gained from the Bee Farmers' Association indicates a cost of about £45 to rent a hive of bees, although the secretary of the Devon Beekeepers (Glyn Berrington, 01822-840418, bee.glyn@virgin.net) helpfully advises that there is relatively little orchard or oilseed rape monoculture in the Tamar Valley so there is reasonable natural pollination. Figures of numbers of hives rented are elusive, and the marginal contribution to pollination services by habitat improvement under Tamar 2000 is almost impossible to disaggregate. This ecosystem service is therefore not quantified. **Ecosystem service not quantified**

Table 2.3 Cultural service evaluation arising from the Tamar 2000 scheme

Cultural services and the methods and assumptions used for their evaluation	
Cultural heritage	Surrogate values are provided for various aspects of this assessment: • Some studies (i.e. Lockwood et al., 1992) indicate that social benefits for non-market goods from forests are sizeable and may exceed those provided by traditional forest market products. Clearing and coppicing (i.e. market values) of Tamar 2000 woodlands combined were estimated as being worth £2,511. Conservatively, £2,511 is also used as an indicative non-market value for these woodlands. • The Tamar 2000 work explored the contribution to regional tourism on the basis of angling and associated ecotourism. This is NOT evaluated here in order to avoid double-counting. • Hedonic pricing methods theoretically enable attribution of environmental (and other) factors to the value of property. However, due to the Tamar already being a high quality river environment and uncertainty about the marginal contribution of Tamar 2000, allied to practical difficulties associated with assessment across catchment scale, this aspect of the contribution of the scheme to cultural heritage has not been quantified. **Net annual benefit evaluated = £2,511** **Benefit not quantified = contribution to property values**
Recreation and tourism	Various strands of evidence help quantify this service including: • Tusa (2000) found that there was a net annual farm income from coarse fishing of £2,240 consequent from diversification advice. Assuming this benefit is enjoyed by 10% of the 117 farms, this yields a catchment value for coarse fishing of £26,208. • Tusa (2000) found that there was a net annual farm income from game fishing of £1,055 consequent from habitat improvement and inclusion in the Angling 2000 scheme. Assuming this benefit is enjoyed by 75% of the 117 farms, this yields a catchment value for game fishing of £92,576.25. • Based on various literature sources, Tusa (2000) estimates improvements in salmon and sea trout numbers of between 500–1,000 and 1,000–1,500 respectively over the five years following Tamar 2000 habitat improvements. (This approach is broadly consistent with Radford et al., 1991) It is possible to value this assuming a 16% of river rod exploitation for salmon (Environment Agency, 1996) and 7% for sea trout (Piggins, 1984) multiplied by transferable values per angler per fish, but this has not been done due to the

	uncertainty of an increase in angling pressure relative to the figures above. • Tusa (2000) found that two farms from the Tamar 2000 sample that decided to provide shooting drives will have a total estimate annual net income from this activity of £420 per year. Extrapolating this from the sample to all farm businesses (117/30), this yields an annual economic value of £1,638. • The consequences of Tamar 2000 for the estuary and the coastal zone, and implications for their associated tourism value, is tenuous and has not been evaluated. • Figures calculated by Tusa (2000) show annual incomes for sampled farms of £8,250 for letting cottages with fishing, £12,250 for letting barns residentially (with conversion costs deducted), £2,400 for payments for stabling blocks in conjunction with tourism, and a further £3,360 for B&B earnings. Aggregating this up to the full 117 farm businesses receiving advice, this yields a gross annual return of £102,414. • In terms of employment creation, Tusa (2000) provides full-time and part time job creation figures for tourism, barn converting and fishing totalling £95,130 per annum. **Total annual benefit = £317,966.25**
Aesthetic value	• It is assumed for the purposes of this study that these values are captured by 'recreation and tourism'. **Assumed no net contribution from Tamar 2000**
Spiritual and religious value	• Nothing quantifiable on this service. **Assumed no net contribution from Tamar 2000**
Inspiration of art, folklore, architecture, etc.	• There is a great deal of heritage associated with the Tamar (landmark bridges, mining heritage, etc.) but it is unlikely that Tamar 2000 will have significantly changed anything quantifiable. **Assumed no net contribution from Tamar 2000**
Social relations (e.g. fishing, grazing or cropping communities)	Various stands of this assessment are considered below, though it is probably meaningless to ascribe an economic value to each. • Among the primary objectives of the Tamar 2000 and the Cornwall Rivers Project was to boost the viability of farming. This has a contribution to farm incomes (captured under various dimensions above) but also to promoting the environmental awareness of farmers and the viability of the rural economy. This benefit is beyond simple quantification methods, though may be significant. • The principles applied in the demonstration of Tamar 2000 that the way to effectively deal with farmers is through dialogue and consultation and not blunt regulations, has led to such progressive schemes as Catchment Sensitive Farming. The secretariat of the

	Convention on Biological Diversity has cited Tamar 2000 specifically as the UK's example of the successful implementation of the ecosystems approach (see http://www.cbd.int/). • The Bishop Fleming Chartered Accountants (2004) evaluation of the Cornwall Rivers Project records significant community and education work strands, public engagement with conservation and heritage being an important project objective. The activities are recorded and costed but, by their nature, benefits are difficult or impossible to quantify though again may be significant. • Bill Watts notes that it may be possible to quantify these through a targeted 'wellbeing study'. • WRT was the first of the now big river trust movement. This movement is strong, big and expanding and this has significant benefits in terms of working with farmers, Environment Agency and related agencies and businesses. • Various WRT reports have been plagiarised by other organisations (i.e. the Environment Agency's *Best Farming Practices: Profiting from a Good Environment* which uses WRT photos, diagrams and text). **Benefit not ascribed a monetary value** **Research gap: methods required to value social networks**

Table 2.4 Supporting service evaluation arising from the Tamar 2000 scheme

Supporting services and the methods and assumptions used for their evaluation Note: The Millennium Ecosystem Assessment classifies this category of ecosystem services as those entailed in the internal functioning and resilience of the ecosystems. As such, they are disastrous if lost yet often hard to quantify in operation. Many of our cultural practices have in fact depended on 'consumption' of these services, for example the way that industrial-scale farming 'mines' soil structure and fertility.	
Soil formation	• There is no obvious means for direct assessment of the contribution to soil formation of Tamar 2000 interventions. Theoretically, this is achievable based on detailed soil mapping, and assumptions could be made from the role of buffer zones, but the quantitative science to achieve this is lacking. • Tusa (2000) notes that advice to farm businesses on under-sowing maize crops as a means of soil protection leads to an increase in savings of 40p per acre in retaining soil productivity (based on Boardman, 1990; Evans 1993, 1994; Nix 1998), representing an average annual saving of £1,607.60 in the 30-farm sample. Although this soil stabilisation value actually relates to erosion control, it can serve here as a surrogate for soil

	formation without double-counting (as soil erosion is valued using other metrics). Extrapolating this figure up to all 177 farms, the gross benefit of protecting soil formation is £6,269.64. **Total annual benefit valued at £6,269.64** **Research gap includes more direct measure of soil formation**
Primary production	• Although some changes in land use may change land cover, there is in all probability no net change to vegetation cover. Hence there is a zero assessment for changes to this ecosystem service as a result of the Tamar 2000 project. **No net value ascribed**
Nutrient cycling	• Pessimistic data applied by McInnes et al. (2008) as a result of literature review suggest that total N removed by storage and export is 170 kg N ha^{-1} a^{-1} (on flat land) and total P removed by storage and export is 25 kg P ha^{-1} a^{-1}. Using the conservative assumption 2% of farm area (65.84 ha average x 117 farms advised = total 7,703.28 ha) rewetted, as used for the climate regulation service, and that this can account for 25% of these nutrient cycling values, and market values of £8.32 kg^{-1} ha^{-1} a^{-1} for N and £12.00 kg^{-1} ha^{-1} a^{-1} for P (based on a literature review by McInnes et al., 2008), yields a total annual benefit value of £66,032. • Other parameters that it has not been possible to quantify are: o Calculation of nutrient load reductions/rises if nutrient monitoring is in place in the catchment. o Determination of nitrous oxide generation – this is a major research gap. o Increased nutrient spiralling in river through (a) decreased fertiliser (replaced by organic manure or showing farmer it is not needed – see fertiliser advice that may be in cost savings under provisioning service) and (b) internal recycling in ecosystem. **Total value assessed = £66,032** **Nitrous oxide generation is a major research gap**
Water recycling	• One of the primary purposes of Tamar 2000 was to enhance the connectivity of land and water and hence improve recycling, but it is not obvious how to count this. • Moreo et al. (2007) measured annual evapotranspiration (over a one-year period in Nevada) of 10.02–12.77 inches for shrubland sites and 26.94 inches at a grassland site (25.45–32.44 and 68.43 cm respectively), with much of the water drawn from groundwater rather than precipitation in both cases. Assuming that this relationship of doubling of evapotranspiration between shrubland and grassland applies in the Tamar Valley, the

	complexity of wetland habitat and the transition of fenced riverbanks from grassland to climax forest may significantly halve water loss through more efficient water recycling. A catchment mean evapotranspiration (ETP) rate of 555 mm is used (recommended by Neil Preedy on the basis of NEAPEN modelling on long-term climate data for the Tamar/Tavy), with grassland assumed to account for 600 mm and scrub for 300 mm. Assuming 300 mm ETP savings through reversion to scrub, water on 2% of farm area (i.e. 2% of total 7,703.28 ha) rewetted, and a (Tusa, 2000) value of 78p per m^3 water, annual water savings through catchment recycling are £360,360. • Capture of roof water rather than mains water has been assessed by Tusa (2000) based on farm visits and benefits in the WRT farm guidance manual; however these values are not included here as they would double-count benefits assessed under 'provisioning services' (i.e. farming efficiency). **Total value assessed = £360,360**
Photosynthesis (production of atmospheric oxygen)	• Although some changes in land use may change land cover, there is in all probability no net change to vegetation cover, and hence a zero assessment for changes to this ecosystem service as a result of the Tamar 2000 project. **Assumed to be value-neutral**
Provision of habitat	• Tusa (2000) also concludes that there was an improvement at 79 sites which would allow migratory fish to penetrate further upstream to relatively sediment-free upper reaches where egg survival will be enhanced, removal of 23 obstructions to fish migration, and improvements in riparian and instream habitat leading to a likely increase in the salmon and trout population. However, ascribing values to this is hard or impossible. Aspects of this have been valued already under the exploitable angling yield (cultural services), which may act as a surrogate. This spawning benefit is not quantified. • Restoring the river corridor also links up different habitats throughout the catchment, not creating a large new area but enhancing ecological integrity and resilience through connectivity. Methods for quantifying this are not obvious, so this benefit is not evaluated. • Evidence from the COMCOAST project suggests that restored tidal habitat, and by inference probably river-margin habitat, may be actively selected by juvenile fish and therefore play a crucial role in their nutrition and growth. However, this science is not yet quantified and so cannot be ascribed a monetary value. • The Tusa (2000) study reported that 5 farms from the

	sample of 30 (out of 117) had already joined or were about to finalise agri-environment agreements as a result of the advice provided by project advisors (an indirect benefit of the project). The total parallel public funding was £17,721.64 per year, and most of this is targeted at woodland. Although this is a poor indicator of provision of habitat, and also further water quality, erosion control and other benefits can be expected to flow from this woodland restoration, planting and management, there are no other obvious methods for quantification and monetisation. Hence, it is assumed here that these payments are the best available metric of the benefits of provision of (woodland) habitat. Total annual benefit is assessed by dividing the total number of farm businesses in the Tamar (117) by the number sampled (30), multiplied by parallel public funding (£17,721.64 per year), yielding a gross catchment habitat value for woodland of £69,114. Given uncertainties in this figure, and the absence of obvious means to evaluate other habitat benefits, this woodland figure will be used as a surrogate for all habitat provision. **Evaluated annual benefit £69,114** **Research gaps include benefits from broader habitat restoration**
ADDENDUM SERVICE: Resilience of salmonid stocks	• WRT activities under Tamar 2000 and related schemes address the opening up of sections of river, for example the installation of a fish pass on the Cary (a Tamar tributary). This contributes to the overall resilience of salmonid fish stocks in the Tamar (access to alternative tributaries and greater spawning and nursery areas), without necessarily contributing to overall recreational and food values of fish. Although potentially significant, it is not obvious how to value this benefit. **Benefit acknowledged as significant but not valued**

2.6 Discussion and conclusions

Some of the key points arising from evaluation of Tamar 2000 and ensuing debate, in particular points captured during the 11 December 2008 case study workshop, are highlighted below. Key issues emerging, synthesised with those from the Alkborough Flats case study, are addressed and discussed in detail in the generic discussion section earlier in this report.

- The case study analysis demonstrates significant net societal value stemming from the WRT Tamar 2000 project, spread over a wide range of ecosystem service benefit categories. The intended benefits for provisioning services (food and other values contributing to farm incomes) and cultural services (wider contribution to the rural economy) are significant, but so too are incidental benefits including regulatory services (such as climate

regulation) and supporting services (including habitat provision, nutrient cycling, etc.).

- Taking a broad view of ecosystem services helps avoid narrow benefit-specific interests blinding decision-makers to opportunities and synergies.

- A significant perceived advantage of the ecosystems approach is that it facilitates education/knowledge management across different stakeholder groups (policy, science, community, all sectors of society) and clearly allows people to see and discuss benefits. It is a framework for consultation at many levels, which can be supported with case studies, real-life examples, success stories, etc. However, it is essential to identify and have in place appropriate champions/ambassadors for leading on this approach.

- Another very strong benefit identified in the 11 December 2008 workshop was that the ecosystems approach provides a framework for explicit identification of multiple benefits (including in financial terms), which can inform strategies, schemes, projects, etc. to connect with investment and importantly start to facilitate the justification and establishment of multi-functional funding streams (i.e. meeting flood risk management, WFD, soil strategy, biodiversity objectives).

- The approach also allows site-specific interactions to be identified; for example planting trees in some parts of the catchment could be good (ameliorate high flow) whereas in other areas it could be an impact (reduce low flows). An ecosystems centred approach is broadly consistent with the findings of the *Pitt Review* of significant summer flooding in the UK during 2007 (Pitt, 2007).

- Price changes – for example the recent doubling in land prices, rising wheat prices, etc. – inevitably influence deduced values. This should inform a cautionary approach to values deduced in a given time period, and also in their transfer to other studies.

- Further uncertainties arise from how economic valuation is applied in dealing with a largely unknown/unpredictable future (i.e. climate, market values, etc.).

- Queries were raised in the project workshop as to whether expressing costs and benefits in monetary values was helpful. Overall, the consensus was that it is a helpful approach, as it was essential to better integrate environment into the decision-making process, although costs/benefits had to be spatially specific/adjusted. However, the role and limitations of economics have to be explicitly stated. Are economics, for example, good for relating to short-term changes but not so good at the long-term scale? (Is discounting a sufficient approach?)

- Monetary values may in fact be quite inappropriate to connect to people and issues at the very local scale, missing some stakeholder concerns and issues.

- A gap was identified in the capture of costs and benefits of education. A CEH case study (not specified) reported to the 11 December 2008 project workshop compared benefits derived from farmer financial incentives to improve land management versus farmer training/education with no payments; education was reported to have provided bigger benefits.

- Economic costs were perceived as requiring: (1) confidence limits or lower/upper bands, and (2) clear statements relating to assumptions and underlying data. It was felt that explaining how costs are derived is critical to sell/explain the outcomes to people. This will allow those services which are easy to cost to be identified and conversely those services which are harder will have wider confidence limits. The cost range will also facilitate sensitivity testing, which will allow the key services (the ones that contribute most to the overall cost profile) to be identified. Key services or services with low confidence limits may also feed into identification of research or collection of more data.

- Habitats and biodiversity needed to be treated as a separate service, particularly so for scarce, sensitive and ancient/irreplaceable habitats. This could be related to the cost of replacement or re-creation of habitat (overlooking for a moment the feasibility of re-creation of some habitats).

- A weakness of the approach taken in this study was considered to be that key interactions between services were not adequately identified and therefore costed. For example, tourism results in benefits in terms of increased visitor numbers/revenue but there are associated costs including increased temporary population, more travel miles (carbon), use of resources (water), production of pollution, footfalls, etc.

- Given increasing recognition of future uncertainty, the ecosystems approach needs to be applied adaptively and flexibly, including accommodating changes in the ecosystem services typology, costing methods, and so forth.

- The Tamar 2000 case study would benefit from identifying scale (i.e. a defined population) for each service. For example, carbon sequestration has a global impact, whereas water is more at a regional scale.

- Related to the above point, it would be helpful to identify institutional/organisational links for each service including who is responsible for managing the service. This could be facilitated by analysis of how these services fit together into local structure plans, RBMPs and other planning frameworks. This will also facilitate the educational role provided by the ecosystem services framework.

- There were similarities identified between this Tamar 2000 ecosystem services case study (perhaps a more bottom-up approach) and ongoing Catchment Sensitive Farming (CSF) initiatives (perhaps a more top-down approach and therefore less readily accepted by landowners) in terms of actions prescribed. Therefore, this Tamar 2000 analysis could allow potential benefits to be identified and refined for the CSF programme.

- There would be value in analysing the net social value to be derived from the WRT hypothetical 'stretch target' of increasing the extent of wetland in the Tamar catchment to 20%. This may be compatible with priorities identified in the Wetland Vision programme (http://www.wetlandvision.org.uk/). We could make a linear extrapolation of benefits from Tamar 2000 wetland restoration, but this would be unsafe. Further study would be required to make the case for the contribution to society of restored wetlands and their associated ecosystem services throughout the catchment.

3 Alkborough Flats: evaluation of ecosystem service impacts

The Alkborough Flats site is the location of a coastal setback scheme in the Humber Estuary. Alkborough Flats is one of the largest managed retreat sites and one of the largest flood storage schemes in Europe, located on the south bank of the inner Humber Estuary at the confluence of the River Ouse and the River Trent. The flats lie below the village of Alkborough, adjacent to the Trent and Humber and in the parish of Alkborough. To the rear of the flats is a natural escarpment, which makes the flats an ideal location for managed realignment as the rising ground contains the floodwaters.

The £10.2 million multi-objective managed realignment scheme – a partnership between the Environment Agency, Natural England, Associated British Ports and North Lincolnshire Council – was designed to deliver flood risk management and biodiversity benefits as well as social and economic benefits to the local community while maintaining the viability of local farms affected by the change of land use and the navigability of the Humber Estuary. This £10.2 million figure covers land purchases, property management, capital works and operational costs.

The Alkborough Flats site was among the first and most important managed realignment sites on the Humber Estuary. It constitutes part of a wider Humber Estuary Strategy (a Defra-approved £320 million programme over 25 years) that aims to protect the homes and businesses of over 400,000 people. Allowing the Alkborough Flats to flood helps to safeguard land throughout the Humber Trade Zone (HTZ) by reducing high water levels elsewhere within the Humber Estuary and its tidal tributaries. At the same time, the Alkborough Flats scheme has direct longer-term wildlife conservation benefits through 440 hectares of re-created habitat, but also indirectly as it allows the wider estuary to change and adapt to sea level rise. (The conservation lead is Natural England.) It will constitute one of the largest wetland habitat creation projects in England, providing major benefits in terms of new jobs in conservation, visitor management and green tourism, as well as being a springboard for community involvement and local business and agricultural diversification. The Alkborough Flats Project will therefore help to safeguard existing businesses and jobs, and enable businesses across the Humber to expand with reduced threats from flooding. The scheme has also been designed to provide a focus for education and access opportunities for local communities, contributing to sustainable development, including the sustainable management of flood defences of the Humber Estuary, supporting the local economy through the establishment of new recreational, green tourism facilities and agricultural diversification. North Lincolnshire Council is also leading a £4 million project funded by Yorkshire Forward to develop a range of new visitor and tourism opportunities along the Humber from Barton to Alkborough. It will also enable a wise growth strategy for ‘green’ tourism that integrates economic, social and environmental considerations and spreads benefits throughout society consistent with the principles of *Tomorrow's Tourism* (Department of Culture, Media and Sport, 1999).

Inundation of the Alkborough Flats site provides a massive flood storage area that is sufficient, according to Environment Agency predictions, to reduce high tide levels over a large part of the upper estuary by 150 mm (with a pessimistic estimate of 100 mm). At a projected annual sea level rise of 4 mm per year until 2025, and then 8.5 mm per year until 2055, the Alkborough Flats scheme therefore modifies the regime to account for perhaps 25 years of this climate change impact. The Humber has a tidal range of the order of 3.5 metres (variable across the estuary), so large volumes of water and significant energy is associated with the tidal cycle.

Providing flood storage at Alkborough will make it possible to defer improvements to other flood defences in the tidal rivers upstream of the site that would otherwise be needed to counter the effects of sea level rise. The Environment Agency will save many millions of pounds of public investment as a result of being able to defer these schemes, money which can be diverted to other, more pressing, flood alleviation projects.

The Humber is a major estuary, accepting the drainage from a fifth of the land area of England. Studies carried out on the Humber Estuary show that important intertidal and wetland habitats will be lost over the next 100 years as a result of sea level rise. Extensive tidal mudflats make the Humber Estuary internationally important for wildlife including over 160,000 waterfowl annually. Other estuary habitats of importance to wildlife include sand bars, shingle banks, saltmarsh, saline lagoons (an internationally threatened habitat), reedbeds and freshwater marshes. Rare birds such as bittern (*Botaurus stallaris*), marsh harrier (*Circus aeruginosus*) and bearded tit (*Panurus biarmicus*) inhabit reedbeds in the estuary, while breeding populations of little tern (*Sterna albifrons*) use the coastal shingle. The Humber Estuary includes seven Sites of Special Scientific Interest (SSSIs), which are further subdivided into a number of habitat units, and is designated a Special Protection Area (SPA) under the EC Birds Directive, and a Ramsar Site under the Ramsar Convention on Wetlands of International Importance. Large parts of the estuary have also now been recommended as a possible Special Area of Conservation (pSAC) under the EU Habitats Regulations. Protection of longer-term wildlife conservation interests depends on allowing the estuary to change and adapt to sea level rise.

The new wetland habitats created at the Alkborough Flats site met all of the Environment Agency's national Biodiversity Action Plan targets for saltmarsh and mudflat habitat creation for 2006–2007. Part of the Alkborough Flats site is also being developed as freshwater reedbeds to support a different range of species from the main intertidal area. The huge, re-created intertidal habitat will attract more species of wildfowl and wading birds to the area including shelduck (*Tadorna tadorna*), wigeon (*Anas penelope*), teal (*Anas crecca*), avocet (*Recurvirostra avosetta*) and redshank (*Tringa totanus*). The Alkborough Flats management team is looking at the feasibility of creating a wet grassland area to provide important habitats for breeding waders, which are declining in the lowlands due to issues such as land development and drainage, and efforts are being made to develop up to 20 hectares of freshwater reedbeds to attract bittern and other specialist freshwater species.

The Alkborough Flats site is delivering another key objective for the Humber region: to provide long-term recreational opportunities and economic, environmental and social benefits for local communities. The opening up of 5.5 kilometres of footpaths in May 2008 following completion of capital works brought the total footpath network at Alkborough Flats up to 8 kilometres, many of them designed for access by people with disabilities. The first of five planned bird hides has also been constructed, with interpretation panels being installed and a calendar of events under development. A monthly volunteer group helps with practical work on the site throughout the year. Contributing to the broader visitor and tourism development, one of the tenant farming families has diversified to open a caravan park and tea room on their land.

As well as providing these flood risk, habitat and amenity benefits, the higher parts of the site will be used for grazing, which will add to the range of plants and animals which the site can support.

Other interesting aspects of the site include an extensive archaeological record for the area dating back to prehistoric times. Artefacts from the Bronze Age onwards are particularly evident, with finds including Bronze Age boats discovered on the foreshore and evidence of settlements on higher land above the estuary. The Humber was also a northern frontier during Roman occupation, and a number of Romano-British settlements were established in the area. The Saxons and Danes also settled in the area, creating many place names which are still in use today.

3.1 Background and design of the managed realignment scheme

Given the importance of the Humber to so many people and interests, there has been extensive planning on the estuary over many years. Spanning all of these is a Humber Management Scheme (HMS) which is a joint initiative led by a partnership including the Environment Agency, the Countryside Agency, Natural England and North Lincolnshire Council. The overall vision for the Humber shared by its partners is, ‘A sustainably managed estuary, in balance with natural processes and providing a home for prosperous ports, industry and agriculture, thriving wildlife and a vibrant community that understands, cares for and enjoys the Humber’. Part of the HMS embraces the risks posed by climate change, which will see an escalation in the cost of maintaining existing flood defences due to predicted sea level rise.

Beneath this upper tier, the Humber Flood Risk Management Strategy (FRMS) is led solely by the Environment Agency and is responsible for delivering relevant schemes. (The Humber FRMS supersedes the former Humber Estuary Shoreline Management Plan which was delivered in 2000.) Under the Humber FRMS, much of the defence line will continue on present alignment. However, the strategy also identifies managed realignment as a vital tool in achieving a sustainable flood defence system for the estuary. This technique sets back the line of existing defences at selected sites, allowing additional areas of land to flood. It enables

the creation of new wildlife habitats and helps to reduce the effects of sea level rise on more strategic defences elsewhere on the estuary.

The Alkborough Flats Project has been undertaken as part of the broader Humber FRMS. The Alkborough Flats Project report states that sea level will have risen by up to half a metre by the year 2050 on the Humber due to both climate change and geological tilting. Within the Humber Estuary, the rising sea level will result in a relative increase in wave height and threaten to overtop existing flood defences. The Humber Estuary has long been recognised as an important site for monitoring and managing the effects of the predicted rise in sea level, being one of the busiest commercial estuaries in the UK and an internationally important wildlife site.

The full 400 hectares of the Alkborough Flats site were jointly purchased by Natural England, the Environment Agency and Associated British Ports (ABP), with the land controlled through a management group. Purchase was eased by 60% of this land area being formerly in the ownership of one family, and all was bought at market rates with no threat of compulsory purchase.

One of the major restrictions to the managed retreat at Alkborough Flats was the need to maintain navigability in the Humber Estuary, for which the engineering solution was to lower the outer defence with the Humber but to breach only an armoured 20-metre gap through which the tidal cycle moves water on and off the inundated part of the Alkborough Flats site. This 20-metre breach was made in 2006, serving as a throttle on water flows. The remaining 1,500 metres of embankment with the Humber was lowered to permit overtopping in extreme events. On the shoreline with the River Trent, which joins the Ouse on the outer corner of the Alkborough Flats site, the old floodbank was retained to prevent re-meandering of the river, and also thereby to protect navigation in the Humber. A new setback bank has been constructed on the landwards side of the Alkborough Flats site to protect a pre-existing sewage treatment works (owned and operated by Severn Trent Water).

Now 170 hectares of the site is permanently exposed to flooding, reverting to mudflat, saltmarsh and, at least in part, reedbed. Aside from the major benefit of flood risk management, this habitat already supports a wide range of wildlife including waders and other birds, as described previously.

The remaining 230 hectares of land beyond the regularly inundated areas will serve as storage capacity during extreme surge events, though this changes the nature of viable agriculture. Whereas the land was formerly farmed intensively for wheat and oilseed rape, this was phased out between 2006 and late 2007. With the risk of inundation during surge conditions, mainly by fresh water though with some salt content, this area is being returned to grass and grazing land. It therefore serves three simultaneous primary objectives: flood risk management, habitat for biodiversity and farm management on an economic basis. The activities of the two tenant farmers is crucial to the success of the project. One tenant farming family is building up a herd of Limousin cattle, while the other is building a flock of sheep for the food market and to produce ewe lambs for breeding.

Construction had been completed at the time of the site visit when conducting this ecosystem services case study (September 2008), with the site in permanent management mode. Management is coordinated by a small North Lincolnshire District Council office on site. A total of 150 different species of birds have been recorded on the site and to date, 30 red- and amber-listed bird species have bred on site including avocet and, in the winter of 2007/08, 10,000 lapwing (*Vanellus vanellus*), 6,500 golden plover (*Charadrius apricarius*) and 600 shelduck were recorded feeding and roosting on the site (Maslen and Pygott, 2008). In addition, 14 species of mammals, 20 types of butterflies and 14 species of dragonfly and damselfly have also been recorded.

The site has been used as a demonstration project to help promote new approaches to the impacts of sea level rise across Europe. The effects of climate change are expected to increase high tide levels in the Humber Estuary which, if defences were left as they are, would increase the risk of flooding for the 400,000 people who depend on Humber defences.

The scheme was officially opened by Ian Pearson, Environment and Climate Change Minister, on 20 September 2006. Since then, the Alkborough Flats scheme is reported to have delivered against its ambitious design specification, but has also delivered on broader benefits that may include carbon sequestration, biodiversity and stimulus of local businesses.

Alkborough Flats is now part of the South Humber Collection, a partnership initiative to promote the cultural and environmental assets along the south bank of the estuary.

3.2 Suitability of Alkborough Flats as an ecosystem services case study

The Environment Agency's Humber Strategy Group is keen for this evaluation of additional benefits to proceed. (Philip Winn [07769-648886], Humber Strategies Manager for the Environment Agency, is very keen for this evaluation of broader benefits to proceed, hoping that it may extend out to the broader Humber Estuary in due course.) The Alkborough Flats site is favoured by local support, coastal location and the potential to factor in such features as carbon sequestration, amenity and business diversification.

With numerous settlements, port facilities of national economic importance (Goole, Hull, Immingham and Grimsby collectively account for 12–15% of the total UK seaborne trade including the movement of one-third of the nation's oil), much industry and many thousands of hectares of high-grade agricultural land within the floodplain and hinterland of the Humber, flood defence is a major concern. The wellbeing of all these interests is subject to the same forces that shape the estuary for wildlife, and solutions to the problem of rising sea level must be acceptable to all estuary users. Coastal squeeze, of both designated and wider habitat, reduces the buffering protection afforded to flood defences by the presence of the intertidal mudflats and marshes and can result in erosion and the

undermining of defences, as well as compromising the importance of the Humber Estuary for wildlife. Maintenance of the estuary's marshes and mudflats is therefore essential for both human life and wildlife.

In September 2000, the Environment Agency published its initial Humber Estuary Shoreline Management Plan (HESMP). The HESMP set out the Environment Agency's strategy for the sustainable management of the Humber's flood defences now and in the future. The plan takes into account the economic, environmental and social impacts of proposed defence works and acknowledges the Environment Agency's role in implementing the UK's commitments to maintaining coastal habitats. One of the HESMP's key recommendations is to establish a number of 'setback' sites where flood defences can be realigned, creating new intertidal areas. This realignment was conceived as helping to reduce the impact of rises in sea level elsewhere within the estuary and its main tributaries, the Rivers Ouse and Trent.

A number of possible setback sites were identified in a preliminary selection, with the Alkborough Flats site among those finally selected. The Alkborough Flats Project constitutes one of the largest tidal defence and intertidal wetland habitat creation projects in the UK, accounting for an investment of £10.2 million of public money, and is a fundamental part of the Environment Agency’s long-term strategy for managing flood risk on the Humber Estuary.

The 440 hectares of the Alkborough Flats site comprised low-lying agricultural land formerly surrounded by a flood embankment built in 1956 following extensive flooding in 1954. Due to a combination of bank settlement, erosion and sea level rise, the pre-existing embankment would have been compromised within the next ten years.

It was vital that the Alkborough Flats Project gained the support of the local communities surrounding the site. Project partners recognised that this could only be achieved if members of the communities were consulted and actively engaged in development of the project from its inception to implementation. This aspiration was delivered via detailed community-based feasibility and planning studies, enabling the project to act as a rural and local regeneration project, maximising opportunities to improve the regional tourist product and promoting rural business enterprises in the Alkborough area. A series of community consultation events also took place with the support of a community liaison officer. Connections were also made with related initiatives such as the Countryside Agency's Vital Villages Project. Project partners have also been active in acquiring funding for the project, with substantial contributions secured from the Heritage Lottery Fund (HLF), Department for Environment, Food and Rural Affairs (Defra) and the European LIFE-Nature and Interreg IIIb programmes.

3.3 Determining the confounded effects of other management interventions

The extent of intervention on the Alkborough Flats site is of a huge scale, dwarfing other recent initiatives around the Humber Estuary: sewage treatment improvements, management of other sites, navigation dredging, flood defence works in inflowing river systems, etc. It is therefore assumed that ecosystem service changes on site and its environs are substantially attributable to the Alkborough Flats Project.

3.4 Results

Valuation of benefits arising from the Alkborough Flats Project is determined on the basis of the Millennium Ecosystem Assessment (2005) categorisation of ecosystem services, across the four broad areas of provisioning services, regulatory services, cultural services and supporting services. These evaluations, together with their associated assumptions and methods, are detailed in Tables 3.1–3.4.

Table 3.1 Provisioning service evaluation arising from the Alkborough Flats scheme

Provisioning services and the methods and assumptions used for their evaluation	
Fresh water	• There is little or no direct contribution to domestic, industrial or agricultural water supply from the Alkborough Flats scheme. **This benefit is not relevant to the brackish site**
Food (e.g. crops, fruit, fish, etc.)	• In terms of agricultural land, there is a net reduction from 400 to 167 ha areas actually farmed, and management regimes will change from arable to grazing on the remaining farmed land due to the risk of major floods (mainly with fresh water but with some risk of saline intrusion). Using a diminution (assuming 50%) on the 167 ha and the 'loss' of the wetted 233 hectares, based on a grade 2 land value of £6,500 per hectare, we have a one-off value of £2,057,250. Annualisation of this figure approximates to division by 30, yielding an annual loss of £68,575. • There is no fishing on site, so there is not direct exploitation of fish stocks. However, the site reportedly acts as an important nursery area for estuarine and potentially commercially valued fish (and bird) species, for which there is a strong likelihood of significant benefit. However, it proved impossible to quantify these benefits despite this compelling anecdotal evidence and a range of relevant studies including:

	• Advice from Steve Colclough informed by (1) studies in Essex and also (2) COMCOAST work (Leila Fonseca's PhD) on the Blackwater is that, although large numbers of juvenile fish (both freshwater and marine) use these optimal nursery grounds and feed extensively on them, it is not yet possible to quantify the benefit. • The Wallasea Wetland Creation Project, carried out by Defra with support from the landowner (Wallasea Farms Ltd) and advice from Natural England and the RSPB, involves the creation of new coastal habitat through the 'realignment' of sea defences on a low-lying area of land beside the Crouch Estuary. This habitat creation is designed to compensate for losses of saltmarsh and mudflat (and the seabird species that used them) that occurred following past port developments on the east coast. The project also serves to enhance the levels of flood protection afforded to the agricultural land behind the new sea wall. On behalf of Defra, ABPmer have contributed to the scheme design and impact assessment work, including a five-year monitoring programme commencing in February 2006 (five months before the breach of old defences) to describe how it develops over time with recommendations for further management. Although a Lesson Learned report highlights the importance of the site as a nursery and feeding area for fishery recruitment beneficial to commercial and recreational angling (Scott, 2007), no quantified conclusions have thus far arisen from site monitoring though anecdotal evidence suggests a significant contribution. • John Pygott further advises that results from the first year's monitoring indicate that there are substantial numbers of juvenile fish within the site, supporting findings elsewhere. Within a few months we will know more about whether these are from commercially important species. There will thus be a benefit here – perhaps a significant one – but thus far it has not been possible to quantify it. • There is wildfowling around the site (Alkborough Gun Club), but John Pygott advises that there has been no significant change in wildfowling activity overall nor the numbers shot by individual guns since club membership is limited and effort is controlled by Natural England as part of the SSSI protection. No impact is therefore assumed from the managed realignment. • Prior to inundation, there was a small orchard on site, but

	this was of minor scale and of no commercial interest so the loss of this provisioning service is not quantified or monetised.
	• Following scheme initiation, plans for stocking on site by the tenant farmers include:
	  • Sheep: target flock of 1,200 including 100 Black Hebrideans, 300 mixed stock, 700 lambs and 200 ewe lambs. Of these, 90% will go to the food market, while 10% will be kept for breeding. Hebrideans make around £30 each and mixed stock make £55 each. No stock are sold for breeding. This yields a (sheep) food value of 100 x £30 + 300 x £55 = £19,500.
	  • Cattle: target flock of 4 bulls, 70 cows, 30 heifers, 70 1–2 years and 70 calves, all Limousins used for meat production and breeding stock. Price varies with animal, with good stock valued at £4,000+. Assuming a more conservative £3,000 per animal with 70 slaughtered annually, this yields a (beef) food value of £21,000.
	• 'Sea salt' is an established industry in some estuaries (i.e. the River Blackwater estuary in Essex) but no parallel benefit is observed in the Humber. Additional potential opportunities (*Salicornia* and/or shellfish production, etc.) are also not ascribed a value in this analysis.
	• Note that agricultural subsidies are a potentially confounding factor here but are assessed overall as cost-neutral. The reason for this is that attraction of subsidies is effectively internalised in the sale price of land.
	Total annual benefits assessed = MINUS £28,075
	Research gap: contribution of saltmarsh to fish recruitment

Fibre and fuel (e.g. timber, wool, etc.)	• The value calculated here is a sum for the loss of barley straw production and a positive value for other fibre/fuel production (mainly wool as there were no sheep on site prior to managed retreat). • An article in the *Shropshire Star* newspaper (2007) provides an average value of spring barley straw production of £32 per acre (1 acre = 0.4047 hectares) which, calculated for 400 hectares, yields a total annual LOSS of profit of £5,180. • Wool production on site will be the product of fleeces sold from target herd size and value per fleece. At the time of this study, the farmer is seeking to build up the flock to approximately 1,000 head. Beyond this stock level, stable fleece production is assumed to be 800 per annum at a per-fleece value of £40 (assumptions corroborated by John Pygott), yielding a total benefit of

	£32,000. • Although wood is currently being taken off site for sale as a result of trees dying after site inundation, this is a one-off activity of low economic value and is not quantified here. In effect, it is also captured in land sale values (addressed in the 'food production' service above). • The site does not have a biomass production purpose. However, periodic reed thinning will be required for conservation purposes once the reedbeds mature; however, John Pygott advises that this yields no potential commercial benefit as the reed is not of sufficient quality and is too difficult to harvest. • There is a range of additional confounding factors here. For example, the need for additional site management to protect sheep from drowning during flood events may be an unforeseen cost. This may be offset by the reduced cost of agrochemicals used on site which will have broader associated benefits to other ecosystem services (via water quality, invertebrate survival, etc.) Overall, these confounding factors are assumed to cancel each other out. **£26,820 (wool minus straw)**
Genetic resources (used for crop/stock breeding and biotechnology)	• Some of the sheep used on the site are rare breeds and are considered important as a resource in the wider area. Assuming that 50 animals are sold per annum (once full stock level is attained) at a mean value of £60 per animal (based on internet review of rare breed market values) this yields a benefit of £3,000. **Annual benefit = £3,000**
Biochemicals, natural medicines, pharmaceuticals	• Not applicable on this site. **No net value ascribed**
Ornamental resources (e.g. shells, flowers, etc.)	• Not applicable on this site. **No net value ascribed**

Table 3.2 Regulatory service evaluation arising from the Alkborough Flats scheme

Regulatory services **and the methods and assumptions used for their evaluation**	
Air quality regulation	• The ideal here would be, as Bill Watts puts it, to determine the contribution of changed complexity in habitat at Alkborough Flats to 'cleaning Goole's air '. Various methods have been attempted to quantify this. Some indicate likely pathways but none has as yet provided a basis for quantification: • A study by Hewitt et al. (2008) into relative deposition rates of PM10, ozone, nitrogen dioxide and sulphur dioxide to various types of wetland habitat, including salt and fresh water

	marshland, woodland and wet woodland, looked at wet deposition and dry deposition processes. A literature reviews record ranges of dry deposition rates for different pollutants over various land cover types, with wet deposition more clearly tied to rainfall. Frustratingly, land cover is not adequately broken down to make inferences about likely removal rates consequent from habitat change at Alkborough Flats pre- to post scheme: arable, mudflat, saltmarsh and reedbed. • Critical loads transfer (recommended by Jim Longhurst) relates to threshold of tolerance by vegetation types. • Dry deposition over different vegetation types has very high uncertainties (other than at the micro and the regional scales) with poor chance of quantification on the basis of habitat change. Two areas worth pursuing here are dry deposition studies in upland Wales and also discussion with the ITE Penicuik team. • Mark Everard has had discussions with Bernard Fisher, suggesting 'critical loads exceedence' for assessment of ecological risk. • The reality at present is that we are not yet close to being able to quantify and monetise this ecosystem service. **Not possible to quantify at present** **Major research gap**
Climate regulation (local temperature/precipitation, GHG sequestration, etc.)	• Alkborough Flats featured as a case study in the Environment Agency's *Flood and Coastal Erosion Risk Management: Economic Valuation of Environmental Effects* handbook (EFTEC, 2007). In this case study, it was estimated that the scheme with a 20 metre breach would sequester approximately 539 t C a^{-1}. At a current marginal cost per tonne of carbon of £27, this equates to an annual value of £14,553. • Relative to arable fields, restored mudflat, saltmarsh and reedbed habitat will transpire different quantities of moisture and, particularly with increasing complexity in vegetation structure, will form a more differentiated microclimate. However, there are no apparent methods at present to value this contribution to microclimate. • NOTE: climate change impacts may be confounded by uncertainties about relative rates of carbon

	sequestration, methanogenesis and the generation of nitrous oxide. Potential sources of information include: • Tim Jickell at UEA who has looked at this supervising the COMCOAST PhD. • Yorkshire Forward are likely to support work on carbon sequestration on the Humber Head (between Trent and Ouse) with involvement of the Stockholm Institute (Fred Worrall (University of Durham) from the Stockholm Institute is the carbon assessment expert) and may use Alkborough as test site. • Stopping oxidation of existing carbon on site through wetting. • Any information in the BERR Wallasea island study beyond what is already published. • The reality is that it is impossible to quantify these potentially confounding factors at present. **£14,553 from carbon sequestration** **Research gap: microclimate assessment** **Research gap: confounding GHG impacts**
Water regulation (timing and scale of run-off, flooding, etc.)	• This is one of the primary purposes of the Alkborough Flats flood risk management scheme, together with Habitats Directive restoration and viable farming. However, this benefit to property is already effectively included in the 'natural hazard regulation' benefit below. • In terms of benefit to ecosystems, an EU LIFE Environment project called MR MOTOWFO (managed realignment moving towards water framework objectives) establishes a linkage between managed realignment for Habitats Directive purposes and the extent to which there is a payback in terms of WFD compliance. The project is under way with only one partner (Environment Agency) and the manager is John Pygott (NCPMS, Phoenix House, Leeds). John Pygott advises that the main benefit of the scheme is for Protected Areas objectives which transfer over directly from the Birds and Habitats Directives. There are other minor ecosystem quality benefits, for example in relation to fish, but these are not yet quantified. However, he does not believe that there are any other WFD benefits for either morphological or water quality parameters. **No benefit assessed**
Natural hazard regulation (i.e. storm protection)	• This is a key and long-lasting benefit of the scheme, for which the Environment Agency's Project Appraisal Report (PAR) document for the

	Alkborough Flats scheme (Environment Agency, 2005) uses an assessment period of 100 years at a discount rate is 3.5% for years 0-30, 3.0% for years 31-75, and 2.5% thereafter. On this basis, the PAR notes that, "The flood defence benefit of the Alkborough Flats development is therefore £12.26 million". Unlike for other services, this benefit is not annualised as it relates to a longer expected benefit period. This is also a very conservative valuation. • As a more general observation, the Alkborough Flats scheme is designed to add resilience to the overall estuary. **Total benefit (100 years) = £12.26 million**
Pest regulation	• The replacement of monoculture on site with diverse habitats will contribute significantly to populations of predators implicated in pest control. This will confer a benefit to the wider arable hinterland of the Humber Estuary. However, quantifying and monetising this benefit remains elusive. **No value ascribed**
Disease regulation	• On the negative side, there is a perception among concerned neighbours that this may become a malarial zone or may see outbreaks of bluetongue or other animal diseases. Slightly saline conditions and climatic factors militate against this, so the impact is assessed as neutral. • Wetlands are effective places for treating water including potential pathogens. However, assessing the contribution to the overall estuary remains elusive. A small sewage treatment discharges over the managed retreat site. However, John Pygott has discussed the contribution to effluent purification with Severn Trent Water, the sewage treatment works owner, concluding that they perceive no additional benefits. **Neutral impact of scheme**
Erosion regulation	• Dissipation of energy on the managed realignment site can help reduce erosion in the wider estuary as well as resulting in substantial sediment deposition on site. There appears to be no science yet adequate to determine consequence and to quantify the impacts. **No value ascribed** **Research gap: contribution from site to catchment erosion risk**
Water purification and waste treatment	• Reedbeds and mudflats are efficient water purification habitats. However, means to quantify the purifying effect of the habitat on (1) estuary water and (2) effluent running across the site from the sewage treatment works are elusive although the

	observation from Severn Trent Water above suggests that effluent treatment benefits are neutral. However, reliable methods to assess the contribution of this ecosystem service to the wider estuary are elusive despite following various leads: • Bill Watts has mentioned Lippenbroek (Belgium) as a place where this is being studied. Bill to advise. • Is there any quantitative science for assessment of heavy metals sedimented and buried on site? • Is there any quantitative science for assessment of nitrogen stripping on site? **No value ascribed**
Pollination	• The replacement of monoculture on site with diverse habitats will contribute significantly to populations of pollinators, conferring a benefit to the wider arable hinterland of the Humber Estuary. It may be possible to approximate this through the number of beehives hired (values per hive in Tamar report) that used to be hired to pollenate monocultures but are no longer needed. However, John Pygott does not believe that there is a quantifiable benefit here. **No value ascribed**

Table 3.3 Cultural service evaluation arising from the Alkborough Flats scheme

Cultural services **and the methods and assumptions used for their evaluation**	
Cultural heritage	• The Environment Agency's PAR (Environment Agency, 2005, *Alkborough Tidal Defence Scheme: Project Appraisal Report*) highlights evidence of Neolithic, Roman and civil war finds on the high ground around Alkborough village, with Alkborough Flats identified as of high archaeological potential. However, surveys on the site suggested that the scheme could proceed with no detriment. Subsequent work on site did contribute to greater knowledge of the site, including the discovery and management of some unexploded bombs on site from World War II. However, no overall loss or benefit is ascribed to this ecosystem service. • Hedonic pricing methods theoretically enable attribution of environmental (and other) factors to the value of property. There are political and methodological difficulties entailed in assessing scheme impacts on the value of local property, added to which some of the contributions may be picked up in other cultural services (recreation and amenity, etc.). Therefore, this aspect of the contribution of the scheme to cultural heritage has

	not currently been quantified. **No monetary value assigned** **Research gap = methods for hedonic property values**
Recreation and tourism	• It is the intent of the Alkborough Flats scheme to create an amenity, and the aspiration of Natural England that the site would eventually become a National Nature Reserve. Birds sites are being built on site. At the time of this case study, no car parks have yet been built but numbers are probably around 3,000 per annum (September 2008). Referring to the Alkborough Flats case study in the Environment Agency's *Flood and Coastal Erosion Risk Management: Economic Valuation of Environmental Effects* handbook (EFTEC, 2007), there is a projected visitation to the site of 25,000 per annum, without detriment to local nature reserves such as Blacktoft Sands on the opposite bank of the River Trent. Advice from Paul Morling (Paul.Morling@rspb.org.uk at the RSPB reserve at Blacktoft Sand) based on surveys over the past five years (to October 2008) is that average per day visitor spend attributed to RSPB reserves as being the reason for the visit is £4.17 for day visitors (80% of visits) and £24.70 per longer-term holidaymaker (10%), with local visitors (10%) making no spend. On this basis, the perhaps ambitious visitor projection will yield £145,150 per annum. • Maslen and Pygott (2008) note that farm diversification by one tenant family includes the opening of a caravan park and a tea room, which is thought to be based largely on the attraction of the site. John Pygott advises that takings at the caravan park and tea room are often £1,000–2,000 per week. So, assuming that 50% of the value is associated with the restored Alkborough Flats site, and based on a £1,500 weekly figure assumed to apply (conservatively) to a 24-week holiday season of May–September, this yields an annual benefit of £18,000. • A bed and breakfast business has opened in the village of Alkborough, also anecdotally related to the attraction of the new habitat. Assuming 50% of the annual value of this B&B, with a benefit transferred from the Tamar 2000 project (Tusa, 2000) of £3,360, this yields an annual benefit of £1,680. • Wider enjoyment and informal recreation in the estuary is likely to be enhanced but impractical to quantify, and it is therefore not explored further for the purposes of this study. Likewise, benefits such as greater use of the village pub and other local facilities is assumed to be beneficial but is not quantified. **Annual benefit = £164,830 ignoring informal recreation**

Aesthetic value	• This is clearly a more subjective value. It may also have positive and negative aspects. For example, a study by Bateman et al. (2006) shows that, apart from the decay of value with distance to site and other complexities, people also generally value traditional landscapes as well as good habitat. The Alkborough site removes features of the old landscape, replacing it with improved habitat, so this benefit overall is assumed to be neutral. Furthermore, it is in any case probably also captured by the surrogate value derived from recreational numbers. **No monetary value assigned**
Spiritual and religious value	• There are no known spiritual/religious sites on Alkborough Flats, though wider spiritual values will accrue from open space and contact with nature. However, this is probably already captured under the recreational services. **No monetary value assigned**
Inspiration of art, folklore, architecture, etc.	• The Alkborough Flats scheme is perceived as 'putting Alkborough on the map'. However, it will take time to ascertain what benefits accrue and how much they are worth. For this purpose, it is assumed that there is no detriment to this ecosystem service arising from the scheme. Consequently, no change in value is ascribed to this service. **No monetary value assigned**
Social relations (e.g. fishing, grazing or cropping communities)	• The Alkborough Flats scheme has certainly got local people in the 500 households in Alkborough village and beyond talking. There are concerns about increased local traffic, fears associated with opening up accessibility to the site (concerns over syringes and paedophiles have been voiced in public meetings), but also local businesses have been founded on the attraction of the site. However, there is no obviously surrogate market value for this benefit which is therefore not quantified. • The design, planning and implementation and ongoing operation of this major, complex scheme entailed considerable learning between key partners and the local community, building both organisation and social capital on site and transferrably to other schemes. There is no obvious means to quantify this benefit, which is therefore not monetised. • Alkborough Flats is now part of the South Humber Collection, a partnership initiative to promote the cultural and environmental assets along the south bank of the estuary. However, in the absence of methods to quantify this benefit no monetary value is assigned. **No monetary value assigned**
ADDENDUM SERVICES:	• This ecosystem service is added to the standard MA set due to local context. In fact, the need to have a neutral

Navigation	impact on the pre-existing navigation service in the estuary imposed significant restrictions on scheme design with implications for rising cost. Lessons learned from the managed retreat at Paull Holme to the north of the estuary, where material deposition necessitated ABP to move the channel into port, focused the thinking of the Alkborough Flats design team. Consequently, a major part of the Alkborough design was to protect navigation, a constraint pushing up cost. John Pygott estimates that this resulted in an extra £150,000 being spent to provide reassurance of a lack of impact on navigation channels in the Humber. Annualisation of this figure approximates to division by 30, yielding an annual loss of £5,000. **Net annual COST of £5,000**

Table 3.4 Supporting service evaluation arising from the Alkborough Flats scheme

Supporting services and the methods and assumptions used for their evaluation The Millennium Ecosystem Assessment classifies this category of ecosystem services as those entailed in the internal functioning and resilience of the ecosystems. As such, they are disastrous if lost yet often hard to quantify in operation. Many of our cultural practices have in fact depended on 'consumption' of these services, for example the way that industrial-scale farming 'mines' soil structure and fertility.	
Soil formation	• There is strong evidence of sedimentation on site, though as yet no reliable method for quantification. **Benefit not quantified** **Research gap includes more direct measure of soil formation**
Primary production	• The replacement of monoculture with complex habitats can reasonably be expected to increase primary productivity. The replacement of arable land with grass on 230 hectares of the site is assumed to be neutral. However, for the 170 hectares that are inundated, we can assume an increase in productivity as the site matures. There are few surrogate values available in the literature, but a study by Haggar and Ewel (1997) on a tropical forest polyculture system suggests an increase of 50% relative to monoculture production of fibre (straw) for 170 hectares (1.5 x £32 x 170) = £8,160. • Not currently reflected in this grid, there is the considerable issue of SECONDARY PRODUCTION which may be a big issue in highly productive estuarine environment (fish, fish-eating birds, etc.) Aspects of this may already have been captured by fishery recruitment (unquantified under the 'provisioning' category) and by bird feeding and breeding ('provision of habitat'). **£8,160 (monoculture to complex habitat)** **Research gap: quantification of secondary production**

Nutrient cycling	• Major, but how to identify and quantify? **Benefit not quantified** **Research gap: quantification of nutrient cycling**
Water recycling	• Unknown. There were no apparent useful or transferable conclusions to be drawn from the Wallasea case study here about 'nutrient capture and cycling', as part of the 54 hectare compensatory creation of mudflat and saltmarsh when the inner sea wall was created and the outer wall breached in six places. What about implications for 'dead zones' in the North Sea? **Benefit not quantified** **Research gap: quantification of water recycling**
Photosynthesis (production of atmospheric oxygen)	• This category is tied closely to productivity, and it is assumed that the value for that service will cover this one too. This will avoid double-counting. **No value assigned**
Provision of habitat	• Biodiversity gain constitutes one of the three primary benefits intended from the Alkborough Flats scheme, replacing arable monoculture with a range of habitats (mudflats, saltmarsh, reedbeds, grassland, and some brackish lagoon) that has already attracted significant wildlife as described in the body of the document. Indeed, it is the hope of Natural England that the site will eventually become a National Nature Reserve. In part, the Alkborough Flats site mitigates some intertidal Habitats Directive sites lost at Paull Holme Strays, to the north of the Humber downstream of Hull. Transferable benefits reviewed in the EFTEC (2007), and derived from Woodward and Wui (2001), suggest low, medium and high estimates of £200, £700 and £2,200 ha a^{-1} for wetland habitat provision (transferred from $US into £2005 prices). Note that this figure is for willingness to pay and, as such, is related to people's appreciation rather than use value; however, this value can serve as a useful surrogate in the absence of more direct data. Since the site is recognised already for its biodiversity importance, the assumptions applied here are to use the medium estimate for the 230 hectares of surge protection habitat (700 x 230 £ a^{-1}) in addition to the high estimate value for the inundated 170 hectares (2,200 x 170 £ a^{-1}) yielding a total benefit from habitat provision of £535,000 a^{-1}. • Note that Ghermandi et al. (2008) generated benefit transfer values for European saltmarshes and intertidal mudflats of €5,734 and €4,112 respectively (excluding carbon). This may not be helpful as it aggregates a range of ecosystem services. • There is a significant contribution from the Alkborough Flats (in addition to the Paull Holme Strays managed realignment site) to overcoming coastal squeeze

	formerly impacting the condition of AT LEAST thirty additional designated sites around the Humber Estuary, as well as presumably on broader non-designated sites. According to UK BAP, approximately 80% of the area of saltmarsh in Great Britain has been notified as SSSI, reflecting high conservation value. The cost of the 21-hectare Tollesbury managed realignment project in Essex, undertaken by large measure for saltmarsh re-creation (with flood risk management and other associated ecosystem service benefits) was £107,219. Crudely extrapolating this to a conservative 30 sites (ignoring current costs, wider benefits and differences in area) now no longer flagged as unfavourable across the Humber Estuary yields a gross replacement cost figure of £3,206,570 which yields a (crude) annualised value of approximately £107,219. • However, further conservation benefits arise from the substantial numbers of waders and waterfowl using the Alkborough Flats site (significantly including avocets and other species of particular conservation focus) for which costs are averted for conservation measures across the wider bioregion. Full quantification of this impact is elusive, so an annualised figure for overcoming habitat squeeze across the wider Humber Estuary is used as an avoided cost value (£107,219), ignoring the likely wider geographical scale of savings. • A further value not quantified here due to methodological difficulties is the potential for oxidation of organic matter on site to help overcome the effects of a low-oxygen barrier inhibiting migratory fish from using the wider catchment. While a number of fisheries experts consider this a likely contribution of the functioning of the site, methods for its quantification remain elusive. **£749,438**
ADDENDUM SERVICE: Increased estuarine resilience	• The Alkborough Flats managed realignment makes a net contribution to the resilience of the Humber, adding to its sustainability in the face of climate change and development. This is a significant contribution to increased sustainability, consistent with the Dutch 'room for the river' and UK 'making space for water'. The overall impact is hard or impossible to quantify but is noted here separately so that the contribution is not overlooked. **Not quantified**

3.5 Discussion and conclusions

The summary results are informative about a number of aspects of the Alkborough Flats scheme, several aspects of which are discussed below.

3.5.1 A trade-off between ecosystem services

An unstated starting assumption was that the transfer of management regime would skew benefits from a presumption towards provisioning services (i.e. farmed food and fibre) towards regulatory services (i.e. flood risk), supporting services (i.e. biodiversity) and cultural services (i.e. amenity). The results do not, however, bear this out. Accepting substantial uncertainties in derived values, it is informative to compare the two provisioning services of 'Food (e.g. crops, fruit, fish, etc.)' and 'Fibre and fuel (e.g. timber, wool, etc.)'. The derived value for 'Food' is –£28,075, derived from loss of arable production replaced by returns from grazing. The derived value for 'Fibre' is a net +£26,820 derived by returns from wools sales minus loss of straw production. An annual benefit of £3,000 was also calculated for the provisioning service of 'Genetic resources'. The key point here is that the net impact of changing regime on provisioning services is close to cost-neutral or positive, and may be most strongly positive were we able to quantify the contribution of habitat to fish recruitment (which has both food and recreational values which appear to be significant). The management of habitat for wider public good and services need not be a 'trade-off' with other private benefits. This is a key message for the direction of agricultural subsidies to deliver wider public benefit.

3.5.2 Substantial public benefit

Beyond the traditional costs and benefits of near-market goods and services (largely the provisioning services), the analysis throws up a broad arrange of benefits expressed across the full range of ecosystem services. Many of these are highly significant, and not all were intended outcomes of this intervention. Furthermore, ecosystem services provide the analysis with a basis for expressing the broader benefits of ecosystem-based interventions, offsetting the common albeit often implicit political perception that conservation of biodiversity and environmental protection measures are necessarily a net cost and constraint upon general (i.e. economic) development.

Many of these elucidated benefits lie outside the formal economy, are assessed on the basis of some sweeping assumptions, and are subject to further uncertainties where surrogates have to be applied to derive values. However, when those values are assessed, notwithstanding considerable uncertainties, the scale of public benefits arising from improved ecosystem functioning appears to be significant.

This conclusion provides a powerful argument in favour of ecosystem-based interventions, and for an assessment based on ecosystem service, and justification for much of the work of the Environment Agency on the basis of contributions to optimal public value through the breadth of ecosystem services. This substantially endorses the value of the ecosystems approach to the Environment Agency and its partners.

Turning specifically to Alkborough Flats and the wider Humber Estuary, this ecosystem services analysis provides defensible evidence of how managed realignment can yield broader and more sustainable benefits to the population.

There are, however, some practical difficulties in explaining this to affected stakeholders. The confounding issues are that: (1) all changes to current land use and other regimes are generally perceived as representing a loss; and (2) there may be an exchange between private and localised impacts and the wider public benefits for which careful 'marketing' will be essential. (Philip Winn's experience to date is that the Humber Estuary Strategy is persuasive from an urban perspective, but farmers often see it as a 'war', with some of the best agricultural land in the country being 'lost'. See consideration of how this may be applied to the Donna Nook site in Box 3.1 below.) This has to be offset against the greater public benefits flowing from other ecosystem services as a result of ceasing defence for predominantly a narrow suite of provisioning services (crops, grazing, etc.), often for private gain, and also the fact that investment to maintain all flood defences is not available and anyhow may be unsustainable. There are, for example, 15,000 hectares of land around the Humber where there is not a case for defending the land that is sufficiently strong to be confident that the investments needed to improve the defences will be forthcoming. Other germane issues include the equity of flood risk management funding (essentially via tax revenues) paid largely by those not at risk of flooding. Furthermore, sea level rise may make some floodplain settlements uninhabitable. Creation of a 'market' for the wider suite of ecosystem services at Alkborough Flats may provide evidence of the value of this approach at far broader scales.

Box 3.1: Issues of concern at Donna Nook

Donna Nook is a site on the North Lincolnshire Coast downstream of Cleethorpes, to the south of the mouth of the Humber, where the Environment Agency is proposing a managed realignment scheme. As part of the wider Humber Strategy, the Environment Agency has bought 130 hectares at Donna Nook with a view to installing a setback scheme. Coastal defences will be breached and a new, lower setback defence will be installed.

An Environmental Statement is due to be ready in early 2009, after which it would be necessary to apply for planning permission. The intention is that environmental mitigation can be carried out in 2009 with a construction start in 2010 and a breach being made in 2011. The expected size of the breach would be 20 metres, but this would widen naturally to 40 metres over time with no need to constrain it (as was the case at Alkborough Flats) to protect navigation.

The Donna Nook site is already an SPA (under the EU Birds Directive), and there is a local RSPB site near Tetney Haven to the north of Donna Nook. East Lindsey District Council is very keen on ecotourism in the vicinity. Managed retreat on the Donna Nook site could make a major contribution to biodiversity and amenity/recreation. For example, a saline scape engineered into the land to be inundated could act as an additional magnet for birds. Bird hides are already being planned, together with footpaths across safe areas of the site. Furthermore, if the site were to become a year-round visitor attraction, it could draw in more funding with possibly up to 100,000 visitors. The habitat to be created will be similar to that on the existing saltmarsh and mudflat area directly to the north and beyond the sand dunes that form the

seaward boundary of the site, providing habitat for over-wintering birds, badgers and water voles which would also benefit from construction and management of channels on site. It is also proposed that raised little tern nesting sites be constructed in what will be a new saltmarsh/mudflat as compensation for losses elsewhere on the Humber Estuary. However, a practical constraint to optimising waterfowl habitat is that the Donna Nook RAF station is adjacent to the site, so it is important that large expanses of water are not allowed to stand for long periods as these might attract flocks of large birds such as Brent geese with consequences for aviation safety. The Environment Agency is also interested to discover if it might be possible to create further habitat for natterjack toads, which breed a little to the south of Donna Nook on one of only four or five known breeding sites in the whole of Great Britain.

However, the scheme is attracting significant opposition, with around 100 people attending local meetings which also attract the interests of local MPs and MEPs. Diverse issues raised by the public concerned about the Donna Nook managed realignment scheme include:

- Food security concerns, bolstered by rising agricultural land prices, fuel one of the biggest concerns at the loss of 140 hectares of agricultural land. Although this land is now owned by the Environment Agency, it is nonetheless Grade 1 land. Land loss is a major local issue that is hard to deal with, notwithstanding arguments about many other benefits flowing from land use as a result of managed realignment, and as compared to the prior overwhelming focus on provisioning services (the growing of crops).
- Although few people lose from this scheme, there are some 'losers' including one vocal farm labourer who has attracted a great deal of local empathy.
- Angry opposition is engendered by the sentiment that 'the river is now a kilometre closer'. People feel more vulnerable to flooding despite the design intent of the scheme to reduce flood risk.
- There are stakeholder concerns about the transmission of diseases with aquatic vectors including:
    - Malaria: the Environment Agency response is that this is carried by a certain type of mosquito which breeds in stagnant or fresh water, not in saline (salt) water. Therefore the saltmarsh habitat proposed would not provide suitable breeding habitat. Climate factors also mitigate against establishment of malaria.
    - Bluetongue: the Environment Agency response is that this animal disease is carried by a few species of midge flies. Very little is known of their life cycle but it is thought they may breed on plants or in damp places such as might be found in muddy fields. The evidence of their presence on saltmarsh is uncertain.
- Visitor management may be a problem: the planning consent will need to document how this will be addressed. However, there are many successful models upon which to base this (for example in the Frieston planning consent).
- The removal of the coastal footpath may also prove a problem; achieving

footpath closure can be a protracted process.

As part of a strategy to manage this groundswell of opposition, it is hoped that relevant aspects of the learning from Alkborough Flats – including the outcomes of the ecosystem services case study – can be transferred to Donna Nook.

The application of an engage–deliberate–decide (EDD) stakeholder process, in place of the more traditional decide–announce–defend (DAD) model, is also strongly advocated for Donna Nook (see Colbourne, in press), supported by the framework of ecosystem services as a transparent basis for stakeholder dialogue and consensus.

At site level, transferable to other sites such as Donna Nook, there are issues of how to demonstrate the 'winners and losers' within schemes based on distribution of ecosystem service benefits. In this case, there is a shift from provisioning services largely benefiting land managers across to wider public benefit from regulatory, cultural and supporting services (as described previously). We need to summarise this science to demonstrate in simple terms the wider value of the scheme at Alkborough Flats (and by implication Donna Nook) as a means to engage and persuade local people. The conclusion of this case study that provisioning services need not be net negative, and that there may be other significant types of net local benefits (through tourism, tea rooms, other forms of diversification, etc.), may be significant in supporting the uptake of managed realignment proposals at other sites.

The case study also provides important evidence upon which more inclusive deliberative processes may be founded, particularly reflecting the importance of engaging all relevant stakeholders in dialogue towards consensus about maximising the value of land management in future within the Humber Estuary Strategy. Lindsey Colbourne's excellent draft research (Colbourne, in press) on moving from DAD to EDD stakeholder engagement processes is particularly useful in this regard, and the framework of ecosystem services provides a transparent basis to support stakeholder dialogue.

3.5.3 Research priorities

A number of knowledge gaps become apparent in the execution of these quantification and valuation studies; these are integrated into the discussion in the front matter of this report.

Annex 1: Details of the case study workshop

The ecosystem services case study workshop took place in Natural England's London office, Ashdown House, on 11 December 2008. The agenda was:

Time and date: 10:00 for 10:30 to 15:30, Thursday 11 December 2008
Location: Natural England offices, Room 5, 6th Floor, Ashdown House, London SW1E 6DE
Purpose: Ecosystem service case studies: review, refinement and recommendations
Chair: Dr Mark Everard

10:00–10:30 Coffee and arrival

10:30–10:40 Welcome and introduction to the day

10:40–10:55 Orientation and overview of the case studies

The details of the case studies

10:55–11:55 Two working groups scrutinising the two case studies
- One person nominated to capture feedback (legibly, ideally on PC)

11:55–12:30 Plenary discussion of feedback
- Areas of agreement for each case study;
- Key points of learning from each case study; and
- Suggestions for finalising the two case studies.

12:30–13:15 Lunch

Lessons arising from the case studies

13:15–14:15 Lessons emerging from ecosystems thinking (builds on list in generic report)
- General lessons learned from both case studies;
- Strengths and weaknesses of this approach; and
- Emerging research priorities.

Further applications of the ecosystems approach

14:15–14:35 Plenary discussion surfacing further applications of this approach (building on the draft list in the generic report)

What next? (See worksheets)

14:35–14:55 In three working groups: how can we best present the outcomes of this work?

- Publication of the science base;
- Summary reporting for practitioners;
- Key points presentation for policy-makers?

14:55–15:15 Plenary feedback on emerging recommendations about taking forwards

Reflections on the day (See reflection sheet)

15:15–15:30 Reflections and lessons from today about promoting ecosystem services

- What went well?
- What could have gone better?

15:30 Thanks and depart

The meeting participants were:

Attending	
Mark Everard	Mark.Everard@environment-agency.gov.uk
Philip Winn	Philip.Winn@environment-agency.gov.uk
John Pygott	John.Pygott@environment-agency.gov.uk
Kathryn Monk	Kathryn.Monk@environment-agency.gov.uk
John Hopkins	John.Hopkins@naturalengland.org.uk
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Ronan Palmer	Ronan.Palmer@environment-agency.gov.uk
Roy Haines-Young	roy.haines-young@nottingham.ac.uk
Marion Potschin	marion.potschin@nottingham.ac.uk
Event coordination (with thanks)	
Sue Luckett	Sue.Luckett@environment-agency.gov.uk
Josh Duckett	Josh.Duckett@naturalengland.org.uk

Anonymous workshop feedback:

What was useful about today?	What went well?	What could have been done better? How could it have been improved?	How will you use the outcomes from today?
• Set aside a day to test my understanding of ecosystem services concept – Met a different group of people to those that I usually engage	• Introduction and discussions. Everyone participated effectively – good mix of participants	• Pretty good	• A way to evaluate justifications for my work as an ecologist
• Bringing together different interests	• Freeform application of agenda – ability to influence thinking of others (we hope)	• Bringing hard examples to the table. Explaining background to the work earlier on	• Towards the ecosystems project I'm managing and looking to back [at] the outcomes from senior management that I hope will come out
• Bringing together range of expertise and allowing free-flowing, open dialogue to discuss and explore range of issues related to ECS. Nice size group	• Good size. Good interaction. Good discussion	• Not much – discussion/feedback sessions always seemed difficult to keep to timescales in agenda – prob better that session allowed to flow	• Directly in PhD thinking, feedback to U of N FRESH
• Really useful to hear the ecosyst. services approach being debated on by a range of knowledgeable practitioners and policy influencers	• People all engaged with each other – all had plenty to say and seemed to develop ideas by bouncing suggestions among each other	• Maybe needed a bit more time as a big issue	• Applying ideas today to looking at case studies on ecosyst. services evaluation in Wales
• Obtain a working knowledge in terms of how the approach has been adopted in the 2 case studies. Mtg range of experts in field	• Workshops, plenary sessions	• Nothing to note. Bigger room perhaps	• Will endeavour to use concept in taking forward Cambrian Mountains Ecosystems work in Wales with WAG, CCW, EA and FC
• To get a broader/better understanding of ecosystem services. Good to network	• The discussion was very interactive	• Time control not a big issue	• Consider the issue of ecosystems in my work and monitor future inputs/outputs to ecosystems valuation
• Good to see colleagues in EA more on same wavelengths with NE	• Most of it	• Not sure	• Generally will make me happier to think about how NE and EA might link up. Tamar study will feed into my lobbying for a critical look at what has been achieved through Catchment Sensitive Farming
• Getting an overview of your (Mark's) work and including my (yes it's me!) Welsh colleagues in the circle	• The above	• Maybe mapping out an influencing strategy into which we could all feed and take away actions, knowing we can rely on these colleagues to help	• Expect to use your outputs and plan the above for Wales

End of Annex 1

Annex 2: Tamar 2000 and the Cornwall Rivers Project

This Annex provides further background details of the Tamar 2000 scheme, including its independent economic evaluation and an associated Tamar 2000 wetland study, in addition to the Cornwall Rivers Project.

A2.1 Overview of Tamar 2000

The purpose of the Tamar 2000 project, supported by funding from public funds (the Environment Agency and MAFF), private funds and the EU (EAGGF), was to improve the ecology of the River Tamar through advice to landowners and managers. This advice sought to improve river quality and ecology, while also boosting the rural economy by reduced agricultural inputs, diversification of farm businesses and promotion of tourism.

Tamar 2000 was delivered through a team of advisors targeting farming businesses across the catchment and covering the costs of development of a total of 117 whole farm plans seeking simultaneous economic and environmental opportunities through recommended beneficial actions. Recommended actions included measures to reduce fertiliser use, to compost farm yard manure (FYM), under-sowing of maize, ditch clearing on a rotational basis (saving digger days), water separation and water savings (using roof water, separating dirty and clean, etc.), and hedge cutting (change from annual to biannual). Also, more mainstream economic recommendations were made including diversification of the farm to deliver tourist facilities. Allied to these plans, advisors also helped farm managers access relevant sources of funding to implement schemes such as buffer zoning, roof water separation, and energy- and water-saving technologies. A major purpose of the advice was to achieve direct cost savings as well as increased profit from farm diversification.

A2.2 Summary of the Tamar 2000 economic evaluation study

Late in the Tamar 2000 project cycle, an economic study was undertaken to evaluate the benefits and costs of proposed actions (Tusa, 2000). There were two acknowledged shortcomings to this assessment: (1) EU rules required only economic evaluation (jobs and regional economy, overlooking wider benefits); and (2) it had to be based on assumption of uptake of recommendations due to funding constraints necessitating completion prior to project end. Nevertheless, acknowledging these constraints, the Tusa (2000) study provides valuable evidence of likely impacts of the Tamar 2000 project.

The Tusa (2000) evaluation was based on advice and its uptake on 30 farms, selected to be representative of the 117 farms within the catchment for which a

whole farm plan had been completed and relevant data had been gathered. Criteria used for this systematic random procedure included ‘Farm Size’, ‘Principal Enterprise’ and 'Farm Advisor'. The sample was chosen with respect to the farm population structure across the catchment, with 29% small farms (under 40 hectares), 35% medium farms (between 40 and 80 hectares) and the remaining 36% large farms (80 hectares and over) selected for further study. Across the catchment as a whole, farm size varied significantly between extremes of 3.5 hectares and 214 hectares. Farms were also selected for study in representative proportions across the catchment for the ‘Principal Enterprise’ category, grouped in the seven main categories of livestock, arable, equestrian, tourism (and livestock), smallholding, and different combinations of these categories.

Tusa (2000) evaluated both direct benefits, largely accruing to participant farmers and corresponding to direct use values in environmental economics terms (e.g. Turner et al., 1994), and indirect benefits for a broader set of stakeholders (described below) resulting from application of project recommendations.

Benefits were calculated on the basis of both observed and anticipated uptake. Direct and indirect benefits covered diverse factors including the letting of cottages with fishing or barns for residential use, and stabling blocks, and bed and breakfast. All direct and indirect benefits were calculated as annualised values per sample. Fishing, including the sale of fish and exploitation of coarse and game fish stocks through angling, were significant, as was shooting. Thinning and coppicing operations yielded benefits, as did wetland benefits and erosion reduction. Indirect benefits were accrued to different degrees by a range of stakeholders including farmers, tourists and anglers, and at different levels including:

- local community level, ranging from employment benefits to community commitment for improving environmental conditions;
- national-level benefits such as meeting national targets such as UK Biodiversity Action Plan targets; and
- international-level benefits including facilitating compliance with international agreements to which the UK is signatory to (such as the Ramsar Convention).

Evaluation of benefits, such as water quality protection or enhancement consequent from the reduction in diffuse pollution, is a complex topic. However, the multiple potential benefits accrue via drinking water supply, fishing, recreational activities, agriculture, industry, ‘general environmental value’, industrial use and property values. Tusa (2000) took as a proxy the annual reduction in water treatment costs at the Gunnislake water treatment plant (the Tamar River is the main raw water supply for Plymouth and South Devon) due to water quality improvement or increased consumer satisfaction (or both). Nevertheless, the indirect value of water quality improvement could be quite significant, as some previous case studies have proved. Newsome and Stephen (1999) explored procedures for valuing the benefits attributable to improved surface water quality, matching the rather easier determination of the costs of control measures in improvement schemes. The benefit of surface water quality

improvement in the River Gwenfro in North Wales, which is a predominantly rural test catchment (as is the Tamar), was estimated between £6.5 million and £25 million. However, this figure is not transferable to the Tamar for the purpose of ecosystem service assessment as it is built up from a range of parameters that, in effect, cover multiple ecosystem services. Nevertheless, we can use these constituent valuations as proxy for some ecosystem services.

Contingent valuation studies in catchments across the world, assessed via 'willingness to pay' (WTP) methods to improve water quality in several case studies was between $39.6 and $130.6 per household (Cameron and Eglin, 1997), $196 annual WTP in 1997 dollars (Smith et al.,1983), $252 (Loomis et al., 2000) and even $526 Loomis (1987). These values seek to express recreational and water quality aspects as well as existence value (the amount of money an individual would pay to know that a particular environmental asset is conserved) and bequest value (the amount of money an individual would pay to preserve today an environmental asset that may be enjoyed in the same condition by future generations).

Excluding the highest value, which differs significantly from the other studies, it could be assumed that the willingness to pay to improve the water quality could be between $39.6 and $252.0 per year, per household. In terms of the 30 farms in the Tamar 2000 sample, this represents an annual value between £742.50 and £4,725. Extrapolating for the whole catchment (500 farms), the water quality value could be from £12,375 to £78,750. This value is probably an underestimate, as there are thousands of other people – in addition to the farmers and their families – interested in the water quality improvement, including anglers, tourists and water consumers in Plymouth.

Soil erosion and nutrient loss are also hard to evaluate. Tamar 2000 project recommendations to control erosion included fencing of vulnerable riverbank, river corridor restoration, re-planting and provision of livestock drinking access, and river corridor woodland regeneration or re-planting. Reduction in the soil loss to the river can be expected to lead to a range of other benefits, for example improved natural habitats (particularly for fish), and reduction of dredging in estuaries. Tusa quotes literature suggesting a net reduction in soil erosion across the catchment of between 1168.5 and 3259.5 tonnes per year, with values of £2.19 per tonne (value of productivity loss) ranging up to £40 per tonne (transport cost of returning the soil from the estuary to source). Taking a median value of £20 per hectare, this equates to a catchment total of between £23,370 and £47,190, of which 30.6% (corresponding to 188 ha of 615 ha of river corridor restored) can be attributed to Phase II of the Tamar 2000 project.

The overall benefits were substantial, and were found to be clustered into three groups: (1) agriculture and other savings (by majority direct); (2) tourism and barn renting, fishing and shooting (substantially direct); and (3) woodland management, wetland restoration, water quality and parallel public funds (all indirect). Tourism comprised about 50% of the total benefits.

The Tusa (2000) study shows the average annual net direct benefit per sampled farm business (estimated at £2,700). This is equivalent to a total of £27,000 per farm business over the 10-year planning horizon, or to £19,924 per

farm business if the stream of costs and benefits over the planning period are discounted at 6%. A comparison of this benefit with the average cost to the Westcountry Rivers Trust of delivering a farm business plan equal to £2,200 (including advisors' salaries, expenses and overheads and grants), demonstrates the cost effectiveness of advisors' time.

Extrapolating from this targeted subset study, the net results of the Tamar 2000 project identified restoration of 615 hectares of river corridor and the identification and control of 67 sites of accelerated erosion through measures agreed with farmers. Net direct and indirect benefits across the catchment are summarised in the table below, noting that Tusa was not able to evaluate all benefits so this will be an underestimate.

In summary, Tusa's (2000) evaluation of Tamar 2000 concluded that Phase II total costs of £600,700 were distributed between 1999 (£300,700) and 2000 (£300,000). On the basis of detailed evaluation of direct and indirect benefits, Tusa (2000) calculated that the benefit/cost ratios of Tamar 2000 Phase II were:

Benefit/cost ratio	Direct benefit/cost	Indirect benefit/cost	Total benefit/cost
without discounting	4.3	3.9	8.2
with discounting (6%)	3.4	3.0	6.4

These returns to farm businesses were significant, particularly in the light of the greater importance of agriculture to the South West than to many other regions of the UK. (*An Environmental Prospectus for South West England Report* produced by a partnership of organisations and published by the RSPB in 1999 records that farming contributes to 4% of regional Gross Domestic Product (GDP) in the South West compared to a 2% average for the UK, with the environment contributing 100,000 jobs and £1.6 billion to the South West's economy, representing over 4% of employment.)

Interestingly, there was no significant correlation between the amount of direct benefits experienced by the farmer and the farm type or size.

Tusa's summing up of direct and indirect benefits accruing from following targeted advice are summarised in the table below:

Action	Direct benefits	Indirect benefits
Fertiliser reduction	Eight of the sample farms decided to reduce or eliminate fertilisers, leading to an average annual total saving of £93,579, representing £312 per farm, per year.	Reduction in fertilisers will lead to an increase in both surface and groundwater quality. It is very difficult to attach monetary values to the positive effects on wildlife, endangered species, and native plants, beneficial insects, livestock, crops and operator health (Lohr et al., 1999) and therefore these are only mentioned and not quantified.
Composting farm yard manure (FYM)	**This r**esulted in an annual saving of £330 due to three tractor days saved per year.	Allows for more appropriate timing of spreading and utilisation of nutrient content, reduces need for mineral fertilisers, reduces emissions of NH_4, eliminates disease and weed risk. Hard to quantify.

Undersowing maize	The two farms applying this recommendation had a net profit of £6.20 and £6.70 per acre (£15.31 and £16.56 per hectare), depending on the type of the soil, leading to an average annual saving in the sample of £1,607.60.	Leads to an increase in savings of 40p per acre in retaining soil productivity (based on Boardman, 1990; Evans 1993, Evans 1994; Nix 1998), representing an average annual saving of £1,607.60 in the 30-farm sample.
Fencing	None assessed	Fencing along riverbanks and different type of wetland areas creates an estimated annual saving of £720, as a result of reduced stock losses and reduced vet bills for injury treatment of the livestock.
Ditch clearing on rotational basis	Due to the change in the ditch-clearing regime one or more digger days are saved annually, which means a total annual save in the sample of £188.	Improvements in water quality, reduced sediment loss to natural watercourses, attenuation of flows and improved wildlife habitat. Hard to quantify.
Water separation and water savings	Using the roof water, keeping the clean and dirty water separated, or leak reduction and alternative water supplies all together account for an annual saving at the sample level of £4,120 (or £137.33 average annual saving per farm).	Contributes to the water quality improvement. Additionally, another potential indirect benefit of applying this recommendation is a possible fine avoided by implementing the diversion of dirty water – estimated annual savings of £500.
Hedge cutting	The change from annual to biannual rotation basis saves one tractor day, meaning £110 per year.	Improvements in landscape, wildlife/habitat. Hard to quantify.
Tourism conversion	**Cottage with fishing**. Cottages leased for £550 per week for an estimated 15 weeks account for an income of £8,250 per year. **Letting barn residentially**. (Less the conversion costs) accounts for the highest increase in farm income – £12,250 each year. **Stabling block**. In conjunction with tourism brings an estimated extra £2,400 per year. **B&B**. The net income of £3,360 per year was calculated based on the estimated £14 per day net income per room for an estimated 33% rate of occupancy (120 days per year).	The increase in tourism in the area benefits not only the farmers but also the local community, through the daytime spending in the local shops, pubs, etc. The average daytime expenditure per visitor in a rural area is £5.10 (Environment Agency, 1996), leading to a total annual sum of £4,692. Furthermore, along with the overnight visitors there is also expected that there will be an increase in day visitors in the next 3–5 years, linked to the improvement in the environmental conditions, landscape, habitats, salmon, etc. The biggest part of this increase in tourism will most likely be due to the increase in angling activity (due to an expected increase in salmon population). To avoid double-counting, this increase was accounted for under 'fishing'.
Fishing	**Fish for sale**. Sales from the existing fish stock correspond to an average annual net benefit of £8,269. **Coarse fishery**. Accounts for an increase in the annual income of farms of £2,240. **Game fishing/angling**. A new opportunity for an increase in benefits from game fishing or angling is to enter 'Angling 2000'. The actual incomes and the predicted ones lead to an estimated annual net benefit of £1,055.	The improvement of 79 reaches of river giving salmonid fishes easier access to upstream spawning sites less impacted by sedimentation, and the removal of 23 obstructions to fish migration along with the improvement in water quality and riparian and in-stream habitat will all lead to an increase in the salmon and trout population. It will be neither a rapid nor an easy process to quantify.
Shooting	The two farms from the sample which decided to provide shooting drives will	None assessed.

	have a total estimate annual net income from this activity of £420 per year.	
Woodlands	**Thinning operations** generate net annual benefits of £900 per year. **Coppicing** leads to a net estimated £1,611 per year fire wood, on a rotational basis.	Managers of public forests often seek to establish timber-related revenues as well as ensuring that biodiversity is protected and that a natural setting for outdoor recreation is provided (market and non-market goods).
Wetlands		Most ecosystem services associated with wetlands are not used directly but rather indirectly, supporting human and ecosystem wellbeing. Derived from the work of Constanza et al. (1997), the value of created wetlands in the Tamar catchment due to the project recommendations are calculated by Tusa, but these combine a range of benefits that are not readily disaggregated.
Parallel public funding	Five farms from the sample of 30 (out of 117) had already joined or were about to finalise agri-environment agreements as a result of the advice provided by project advisors (an indirect benefit of the project). The total value of this parallel public funding was £17,721.64 per year. Most of this is targeted at woodland.	
Other direct benefits	£3,700 per year per sample represents savings in animal housing costs in winter respectively, £230 per year per sample energy audit savings due to the advisor recommendations.	
Employment	Full-time and part-time jobs in tourism, woodland management and other sectors, consequent from uptake of advisor recommendations.	Full-time and part-time jobs in tourism, woodland management and other sectors.

A2.3 The Tamar 2000 wetland study

To support the Tamar 2000 work, a separate wetlands report was produced exploring the historical and current extent of wetlands in the catchment and the implications of their restoration (Hogan et al., 2000). This reflects the fact that wetlands are among the world's most important environmental resources, representing around 6% of the global land area (Maltby and Turner, 1983) despite generating about 15% of the world's ecosystem services and natural capital value (Costanza et al., 1997). Wetlands remain poorly understood and are often abused or neglected, yet may offer keys to the restoration of important ecosystem functions within catchment systems including those delivering tangible benefits to society – fisheries, flood control, protection of water quality, erosion control and so forth, with identifiable economic values.

Changing agricultural practices have made significant inroads into the wetlands of the Tamar system, with a survey by the Devon Wildlife Trust (1992) suggesting that 92% of wetlands present in 1900 in South West England had been lost to this cause. The Tamar's wetlands were identified as contributing a range of beneficial ecosystem services including improving water quality (with knock-on benefits for fisheries and the general health of the river corridor), a water supply for stock, reduction of downstream flood risk, maintenance of river levels during dry seasons, supporting summer grazing, wildlife conservation benefits including habitat for rare plants and animals, rough ground for game

shooting, providing important elements of the landscape, contributing to the overall beauty of the countryside and providing some of the special characteristics of the locality, providing an educational resource for schools and other groups, supporting alternative sources of income such as biofuels, and the preservation of pollen and archaeological remains forming a record of past landscapes and human activities.

A2.4 The Cornwall Rivers Project and its valuation

The Tamar 2000 project led on to a broader EU-funded Cornwall Rivers Project, extending principles established in the Tamar 2000 study. An evaluation report for the Cornwall Rivers Project, Bishop Fleming Chartered Accountants (2004, page 7) noted that 'The Cornwall Rivers Project is directed towards the rehabilitation of the key rivers and their catchments across the whole of the Cornwall Objective One area. The overall aim of the project is to engage and empower local communities to manage land use in a sustainable way to protect and enhance Cornwall's rivers. The initiative was developed in order to expand the work carried out by the Westcountry Rivers Project Phase 1 on the Taw and Torridge catchments, as well as the Trust's Tamar 2000 SUPPORT project'.

This successor to Tamar 2000 used the same basic methods in a three-year (2002–2004), £1.8 million programme of work partly funded by Defra and the EU (EAGGF) under the Objective One Programme. (See the WRT 2003 document *Cornwall Rivers Project: Review of Project Activities and Progress*.) The Cornwall Rivers Project was directed towards the rehabilitation of the key rivers and their catchments across the Cornwall Objective One area. The project contributes towards the full strategic objectives of the Objective One programme:

- to increase absolute prosperity;
- to support agricultural adjustment;
- to support communities faced with change; and
- to enhance regional distinctiveness.

Cornwall is recognised as having an environment of high quality, with one in three jobs believed to depend upon it. Damage to the mainly rural catchment areas of some of the rivers of Cornwall has resulted from changing land use patterns over the past 30 years or so, which have unintentionally combined to degrade natural ecosystems. Specifically, diffuse pollution poses a particular threat that is recognised universally as being very difficult to trace and control.

The bottom-up, catchment-scale approach adopted by the Westcountry Rivers Trust is a practical example of how an integrated partnership approach can be implemented to enhance and maintain environmental quality for both people and wildlife, at the same time providing increased revenues/lower costs and sustained employment. Economic and sustainable land and water practices together create a more prosperous and high value environmental legacy.

A crucial achievement was production of 666 farm management plans for land managers across the ten catchments is in line with the expected profile.

Although only one tributary of the Tamar (the River Inny) formed part of the series of ten rivers targeted by the Cornwall Rivers Project, the project is significant in providing further methods for evaluating benefits from the Tamar 2000 project including a post-project evaluation undertaken by Bishop Fleming Chartered Accountants (2004). This provides some transferable benefit evaluations which help to overcome the two major shortcomings of the Tusa (2000): a focus on economic impact only, and assessment founded on projected rather than actual uptake of advice to farm businesses.

One of the legacies of the Tamar 2000 project was Angling 2000, set up as a millennium initiative in Devon and since expanded through the Cornwall Rivers Project. Angling 2000 is a token-based system opening day ticket angling access and returning its benefits to participating fishery owners. The decline in accessible and affordable day ticket water, combined with the increasing demand for wild salmonid fishing, enabled the scheme to flourish. Including Devon, the number of beats in the scheme grew from 11 to 20 in 2003, the number of anglers on the database grew from 172 to 1,237, and revenue generated by the scheme and returned to farmers and riparian owners to aid with restoration and engagement grew to almost £500 per beat.

Returns from Angling 2000 in 2003 provided a measure of the wild fish stocks in participating rivers. The widely perceived decline in wild trout was found not to have occurred on scheme waters. Catches in 2003 indicated 2,759 wild trout (with only 35 killed), with an additional 148 grayling, 40 sea trout, 2 salmon and a few escapee rainbow trout.

With the Angling 2000 scheme demonstrating the value of the fishery, farmers are embracing it as an alternative source of income and looking proactively to manage their waters for the benefit of the fish stocks. One farmer has invested the returns from the scheme into habitat improvements recommended by the Trust and has seen visits increase four-fold and catches increase from 4.1 trout per angler in 2001 to 14.1 trout per angler in 2003, with the largest fish increasing from 12 to 16 inches (30 to 40 cm) in the same period.

Angling 2000 returns assessed in 2003 indicated that the scheme had resulted in nearly 300 overnight stays from visiting fishermen, helping to support the local economy. This is good news for the fishermen, the farmer and, most importantly, the fish.

The Cornwall Rivers Project included community and education work strands, which were also evaluated by the Bishop Fleming report. Public awareness of the importance of water resources and related habitat issues and engagement of the wider community in the conservation and enjoyment of heritage is an important objective of the project. As consumers of water and producers of waste, we all contribute to the problems. With a greater understanding of the issues, we can all be part of the solution. The form of community involvement was varied. A total of 11 conducted river walks were undertaken in 2002 and 2003, which enabled the Trust's advisors to explain and show the life within a river at first hand. General talks and presentations have been given to 27 groups, including the Royal Cornwall Show. A demonstration site at South

Penquite (near Blisland) was completed and others (Golitha Falls, Cotehele Estate, Enfield Park Camelford and Grampound) were still to be completed in 2003. Educational signage was organised by a project partner, who also finalised an interactive educational CD for primary school children and a community information pack. Technical presentations setting out the benefits of catchment-scale management and GIS had also been given to nine professional/technical conferences attended by over 1,000 delegates. In addition to normal newsletters, the Trust also promoted the project on its website at http://www.cornwallriversproject.org.uk/.

The conclusion of the Bishop Fleming Chartered Accountants (March 2004) evaluation report was interesting in this regard as principles relevant to out-turn of the Tamar 2000 work can be derived. The Bishop Fleming report found that:

- The Trust worked mainly with farming businesses (and some angling clubs). 666 farm management plans were professionally written to highlight environmental and economic opportunities for each farm or landowner. Optional grants delivered as part of (free) production of management plans, with around of 25% of farm plans resulting in a formal contracted grant offer. 10 catchments were selected across Cornwall due to funding (Camel and Allen, Cober and Looe Pool, East and West Looe, Fal and Tresillian, Fowey and Lerryn, Inny, Lynher and Tiddy, Neet and Strat, Ottery, and Seaton). Selected in conjunction with the Environment Agency.

- Audited returns assessed across all targets and secondary benefits included:

    - Objective One programme as a whole delivered on intentions (priority measure 4.6, 'promoting the station and development of rural areas')
    - Gains for water quality
    - Benefits for wildlife habitat
    - Reduced flooding risk
    - Improved angling
    - Stimulated rural tourism
    - Enhanced public education (schools, community and youth groups, website, newsletter)

- The Trust showed a good understanding of farm business needs, improving targeting of recommendations and their effective uptake by farm businesses.

- A quote on page four of the Bishop Fleming report from one of the Trust's customers noted that, "The West Country Rivers Trust and Cornwall Rivers Project has proved the link between river environment and business, and has achieved significant improvements in both".

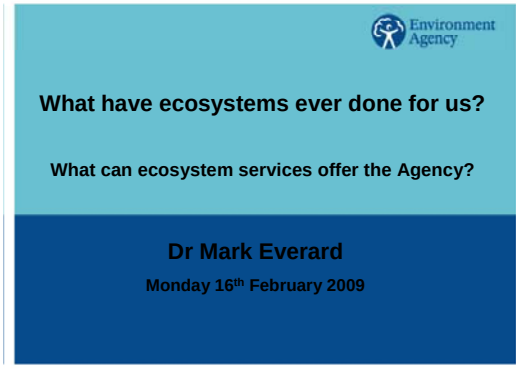
- The programme made links to other sources of support.

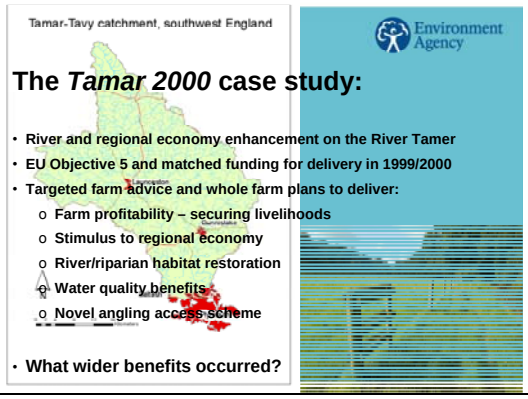
- Declining river health has followed 30 years of changing land use patterns, undermining sustainable use of natural resources whilst also failing to provide a sustainable income to the real community

- These conclusions were drawn from 41% responses (148) from a customer survey and 100% responses (20) from a stakeholder survey.

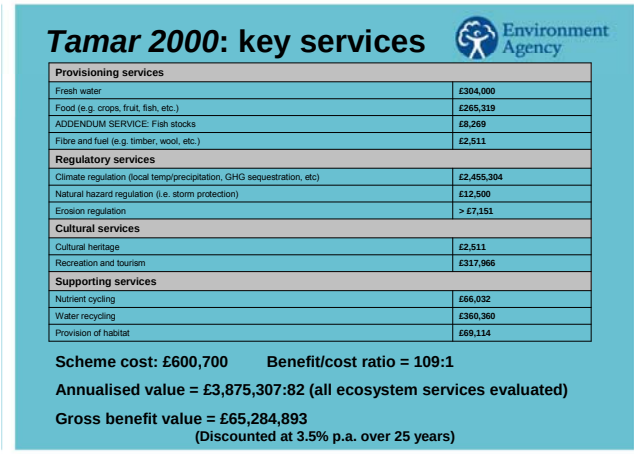
End of Annex 2

Annex 3: Copy of presentation summarising project findings

Slide No.1:	Supporting notes:
	• This presentation is based on a summary of results from the two ecosystem services case studies conducted in late 2008: o Catchment scale: Tamar 2000 project (Westcountry Rivers Trust); and o Site scale: The Alkborough Flats managed realignment scheme • Two key points here are: • Return on investment in ecosystem protection/restoration includes not only target benefits but also, when explored with the full suite of (MA) ecosystem services, much wider societal value; and • Benefits are ecological but also underpin wider dimensions of social and economic human benefits – a very important message indeed!

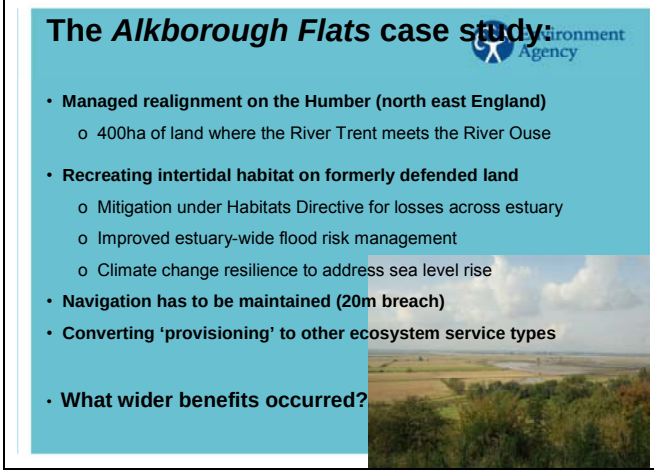
Slide No.2:	Supporting notes:
	• None

Slide No.3:

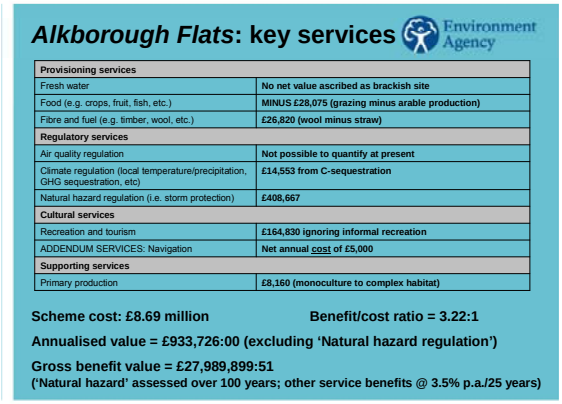


Supporting notes:

- Tamar 2000 had significant annualised benefits beyond improvement in direct benefits to provisioning services via farm advice. Significant figures here include:
  - Provisioning service gains included e.g. ≈ £265k (food) and ≈ £304k (fresh water)
  - Regulatory service gains included e.g. ≈ £2,455k (climate regulation – carbon storage)
  - Cultural service gains included e.g. ≈ £318k (recreation and tourism)
  - Supporting service gains included e.g. ≈ £69k (provision of habitat) and ≈ £360k (water recycling)
- The benefit to cost ratio of 109 is very large indeed (verified by Agency economists) reflecting the substantial and diverse societal benefits that can flow from restoring functional catchment ecosystems, often beyond a narrower set that may have formed the basis for the project proposal.

Slide No.4:	Supporting notes:
	• None

Slide No.5:



Supporting notes:

- A surprising finding from the Alkborough Flats case study was that the assumed decline in *provisioning* services did not occur after the site was put under the new land management regime post-realignment to deliver broader *regulatory* and *supporting* services.

- Net annual *provisioning services* impacts are overall neutral or slightly positive, as:
    - Net annual *(provisioning)* food production (arable loss + gain in grazed stock) ≈ £28k LOSS… but…
    - Net annual *(provisioning)* fibre production (wool minus loss of straw) ≈ £27k GAIN

- Substantial annualised *regulatory* benefits included:
    - Climate Regulation ≈ £15k
    - Note that 'Natural Hazard regulation' was not calculated as an annualised figure as the PAR recognised long-lived benefits (£12.26 million) but also a very long lifetime of benefit. Hence, this was assessed over 100 years at variable discount rate

- Substantial annualised *cultural* benefits included…
    - Recreation and tourism ≈ £165k

- Substantial annualised *supporting* benefits included…
    - Provision of habitat ≈ £749k

Slide No.6:	Supporting notes:
	• Both case studies – Tamar 2000 and Alkborough Flats – identify benefits (and some negative impacts) across all categories of ecosystem services, with benefits accruing to multiple beneficiaries both local to the site (i.e. food) and more remote (i.e. climate change). • In all cases, there are both direct and indirect benefits of many types, as well as some associated losses, affecting diverse stakeholders in different ways • Some benefits (and disbenefits) are intended and some are not. • We have the potential to optimise public value across this breadth of ecosystems services in the precise design and targeting of many management interventions • Benefits may best be achieved by internalising the ecosystems approach into operation tools such as SEA, FRM assessment, etc.

Slide No.7:	Supporting notes:
	• Individual services (fresh water, food, climate regulation, spiritual value, etc.) relate to issues with which lay people can readily identify. This helps us explain the multiple potential benefits of our work. • Demonstrating and identifying the breadth of services helps us communicate how multiple impacts arise from our work, and the interconnections within the environment and between its beneficiaries. • Dialogue about the range of services helps work with people to think differently about problems and their potential solutions, innovating for multiple benefits rather than merely making 'trade offs' in a narrow set of options.

- Critically, this helps people understand that 'nature' is not merely 'nice to have', but rather that safeguarding the environment is essential to securing a collective future for al societal interests.
- Ecosystem services offer a readily-understood framework for collective and consensual decision-making with sustainable development and optimal public benefit as a focus.
- Helps the Environment Agency communicate the many benefits arising from its activities, and to collaborate with partner organisations and other stakeholders towards their achievement.
- It is important to convert valuation methods into operational practice, which requires consensus about best valuation methods as well as accessible and relevant benefit transfer databases
- The three major research gaps identified by the two case studies were quantification of:
    - Complex climate change issues: the relative rates of carbon sequestration/oxidation, methanogenesis, nitrous oxide occurring in different soil moisture/redox/salinity
    - Contribution of saltmarsh/floodplain to fish recruitment
    - Air/water interactions affecting air quality and microclimate: PM10s, SOx, O3, etc., but also temperature, moisture, wind speed, etc.
- Helps us show how ecosystems underpin societal (including economic) wellbeing

These potential benefits **can be supported and developed throughout 2009/10**

End of Annex 3

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