Environment Agency

Evidence

Ecosystem services assessment of buffer zone installation on the upper Bristol Avon,Wiltshire

Evidence Directorate

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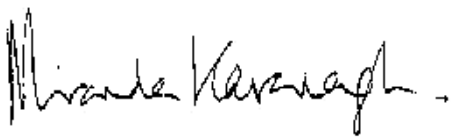

Miranda Kavanagh

Director of Evidence

Executive summary

This report outlines the background, methods, findings and learning following an assessment of the changes in ecosystem services stemming from the installation of a buffer zone on 330 metres of one bank of the upper Bristol Avon catchment, North Wiltshire. A buffer zone in this context is a strip of protected habitat between the top of the river bank and the river channel in which natural riparian and wetland habitat can regenerate, supporting wildlife and reducing sediment and potential pollutants running into the river from the surrounding land. This field boundary, immediately upstream of the village of Great Somerford in North Wiltshire, had been heavily poached by dairy cattle and was recognised as a priority for action to improve the habitat and reduce diffuse pollution from sediment and associated substances into the river.

This study sought to assess marginal changes arising from the installation of the buffer zone along this highly vulnerable field edge on the basis of its impact on ecosystem services. Ecosystem services comprise the breadth of benefits provided to society by ecosystems, many of which have formerly been substantially overlooked. They therefore provide an inclusive basis to consider the implications of development schemes or management activities for a full range of interconnected ecosystem functions, as well as their wider consequences for stakeholders. This aids development of an integrated case for safeguarding the environment founded not merely on inherent values but also clear societal benefits, including the stability of ecosystems necessary to secure the wellbeing of people, including present and future generations.

Concerned about the apparently severe impact of this poached river bank on fish populations and the wider river ecosystem, the Somerfords Fishing Association (SFA) began a process of dialogue with the landowner and the Environment Agency in early 2008 about creating a buffer zone on the edge of this problematic field. The buffer zone work was completed in August 2008 at a capital cost of £4,700.

Habitat re-vegetation and regeneration was almost immediate for the remainder of 2008, progressing throughout 2009 such that vegetative encroachment had stabilised the buffer-zoned bank and also narrowed the channel. This improved scour of the river bed and diversified flows and physical habitat, as well as attenuating sediment and other pollutants running off from the field. Regular visual inspection revealed a rapid restoration of a habitat critical for successful breeding and protection of both game and coarse fish species, as well as being beneficial to their invertebrate food and other wildlife. Critically, the greater complexity of channel-edge vegetative habitat provided not only improved spawning habitat for various species of coarse fishes and an improved source of invertebrate food, but also semi-static shallow water with cover. This is important as a ‘nursery area’, enabling juvenile fish to evade predators as well as warming rapidly in the summer to protect and accelerate the growth of fry, and which could provide refuges from both stronger flows and predation in higher winter flows. Anecdotal reports from residents and visiting anglers suggested a greater density of birds and other wildlife using the river reach, as well as vastly improved aesthetics.

Although driven by angling interests, this buffer zone project addressing a high-priority reach of the upper Bristol Avon was in reality about far more than fish stocks. Fish communities provided a focus for restoration of the wider health and functioning of the river reach, revealed by ecosystem services analysis to yield many associated benefits to society beyond those serving narrowly-defined angling interests.

Gross lifetime benefits from the buffer zoning project on the upper Bristol Avon are £144,860, representing a benefit-to-cost ratio of 31:1 and therefore exceptional value-for-money relative to the small initial investment. Fishery benefits alone were found to

have an annual benefit of £828, comprising 9.6% of gross annual ecosystem service benefits of the scheme, and a lifetime benefit of £13,989 which alone represents a benefit-to-cost ratio of 3.0:1 relative to the investment in fencing. Therefore, although angling interests (a combination of Environment Agency area fisheries staff and the Somerfords Fishing Association) were the instigators and primary drivers of this habitat improvements works, and anticipated angling returns alone justify the investment, the economic benefits to wider society achieved by taking an ecosystems approach yielded 90.4% of likely benefits to broader sectors of society.

In common with the findings of related ecosystem services studies of habitat-based enhancement projects, fish in this instance serve the role of 'iconic' conservation targets that support the delivery of far wider societal benefits. This reinforces the conclusions of a range of other studies exploring the benefits of environmental management founded on restoring the functioning of ecosystems and their functions, all of which suggest that substantial and long-lasting benefits are realised by wide sectors of society beyond the principal focus of the management interventions.

This study also strengthens the already robust case for the power of ecosystem services as a tool to help identify the breadth of issues and potential beneficiaries touched upon by environmental management schemes with, in this case, a broad range of 'collateral benefits' that may not have been part of the initial scheme design. By contrast, it also demonstrates the dangers of 'silo thinking', often enforced by organisational structures, mandates and/or budgets. Optimal societal value and sustainability of outcomes can occur only when a full range of impacts and benefits is considered simultaneously.

The benefits of targeted buffer zone installation on the upper Bristol Avon are clear and substantial, and the learning derived from this study is therefore relevant and transferable, with caution, to other environmental initiatives founded on restoration of river habitat, function and suitability for characteristic and iconic species. The lessons emerging are transferable with considerably less caution to the promotion of buffer zoning as a tool for improved river management and realisation of social benefits including, for example, as a measure appropriate to support achievement of 'good ecological status' requirements under the EU Water Framework Directive.

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The authors of this report are grateful to Andy Don (Environment Agency), Dave Whitehead (Somerfords Fishing Association) and Ron Parfitt (Angrove Farm) for supporting this ecosystem service assessment, and also to Bill Watts (Environment Agency) for input and critique of economic methods and assumptions. Also to Steve Thomas, Iain Turner and Melissa Clarkson (all Wessex Area of the Environment Agency) for review of this document.

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The purpose of this study was to assess marginal changes arising from the installation of this buffer zone along a highly vulnerable field edge. All improvements to the river ecosystem potentially affect broad societal constituencies, who benefit from the multiple ‘services’ provided by the river system. The ecosystem services approach helps identify the groups and communities connected with and potentially affected by these schemes.

1.1 About ecosystem services

‘Ecosystem services’ describes 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 people’s potential, and enjoyment of life. The essence of the ‘ecosystems approach’ – management of whole ecosystems and their benefits using the framework of ecosystem services – is to consider these multiple benefits simultaneously, so that the realisation of one benefit is not achieved at the cost of other benefits.

Our history of industrial development has largely overlooked many of these ecosystem services, founded instead on an ‘exploitation economics’ model focused on limited and generally immediate benefits to the exclusion of broader consequences. Current trends in ecosystem degradation demand greater recognition and improved stewardship of essential ecosystems if human wellbeing is not to be systematically undermined. Therefore, by definition, studies that select only a limited subset of ecosystem services, overlooking potential conflicts with others, are NOT consistent with the ecosystems approach, many merely using new terminology to perpetuate the outmoded ‘exploitation economics’ model.

Since the very concept of ecosystem services is based on the multiple benefits that ecosystems provide to society, it is inherently amenable to economic valuation. Environmental economics provide a common and transferable basis for assessing the different categories of benefits and disbenefits associated with the changes in

ecosystem services that come from interventions in environmental systems. We will consider economic approaches and their associated difficulties later in this introductory text. However, a key consideration to bear in mind is that if the services provided by ecosystems are not valued then, by extension, important aspects of those ecosystems themselves are inherently considered worthless in decision-making processes. This explains much of the unintended but systematic historical decline in ecosystems of all types and scales across the world.

The ecosystem services concept recognises and potentially provides a means to quantify benefits to society, allowing ecosystems to be brought into planning and other decision-making processes, linking ecological with social and economic considerations.

Many parallel strands of ecosystem services science have evolved since the late 1980s, and have proven effective in advancing the understanding and management of various ecosystem types in different places across the world. In order to provide a uniform basis to assess the status of all major global habitats across all of the world's bioregions, the UN's Millennium Ecosystem Assessment (MA, 2005) combined these diverse 'ecosystem services' typologies into a consistent classification scheme. The MA grouped ecosystem services into four main categories:

- 'Provisioning services' are those that can be extracted from ecosystems to support human needs, more or less synonymous with 'ecosystem goods' in some prior classification schemes, including such tangible assets as fresh water, food, fibre;
- 'Regulatory services' include those processes that regulate the natural environment, including the regulation of air quality, climate, water flows, erosion, pests;
- 'Cultural services' include diverse aspects of aesthetic, spiritual, recreational and other cultural values; and
- '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. They include services 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, greenhouse gas 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

Although neither perfect nor complete, the MA typology provides a broadly inter-comparable set of services across bioregions and ecosystem types. It exposes the complexity and diversity of interactions between society and natural systems, the knowledge gaps about how all ecosystem services are ‘produced’, and the need for methods to monitor them. It is also valid to use locally-appropriate addenda services where appropriate, as we will do in this study.

1.2 Buffer zone installation on the upper Bristol Avon

The Bristol Avon flows from two principal headwaters near Tetbury (Gloucestershire) and Luckington (Wiltshire), merging at Malmesbury and flowing through North Wiltshire and downstream through the cities of Bath and Bristol before discharging into the Bristol Channel at Avonmouth. The historic name of the county of Wiltshire was ‘the chalk and the cheese’, reflecting the chalk downland to the south of the county and the fertile clay-based dairy farming countries to the north. Although the principal headwaters and many upper tributaries of the Bristol Avon are influenced by the limestone geologies from which they rise, the river valley of the upper river below

Malmesbury largely flows across Oxford and Kimmeridge clays and has historically hosted many dairy farms.

Angrove Farm is one such dairy farm, with a network of owned and rented fields extending from Angrove Wood (Little Somerford) downstream as far as Great Somerford. The high bank and erosive edge of a large field on Angrove Farm upstream of Red Hatches weir and footbridge had long been recognised as highly vulnerable to erosion, formerly severely impacted by cattle poaching, and therefore a priority for riparian habitat improvement. An illustrative map of the relevant section of the Bristol Avon is provided in Figure 1.1.

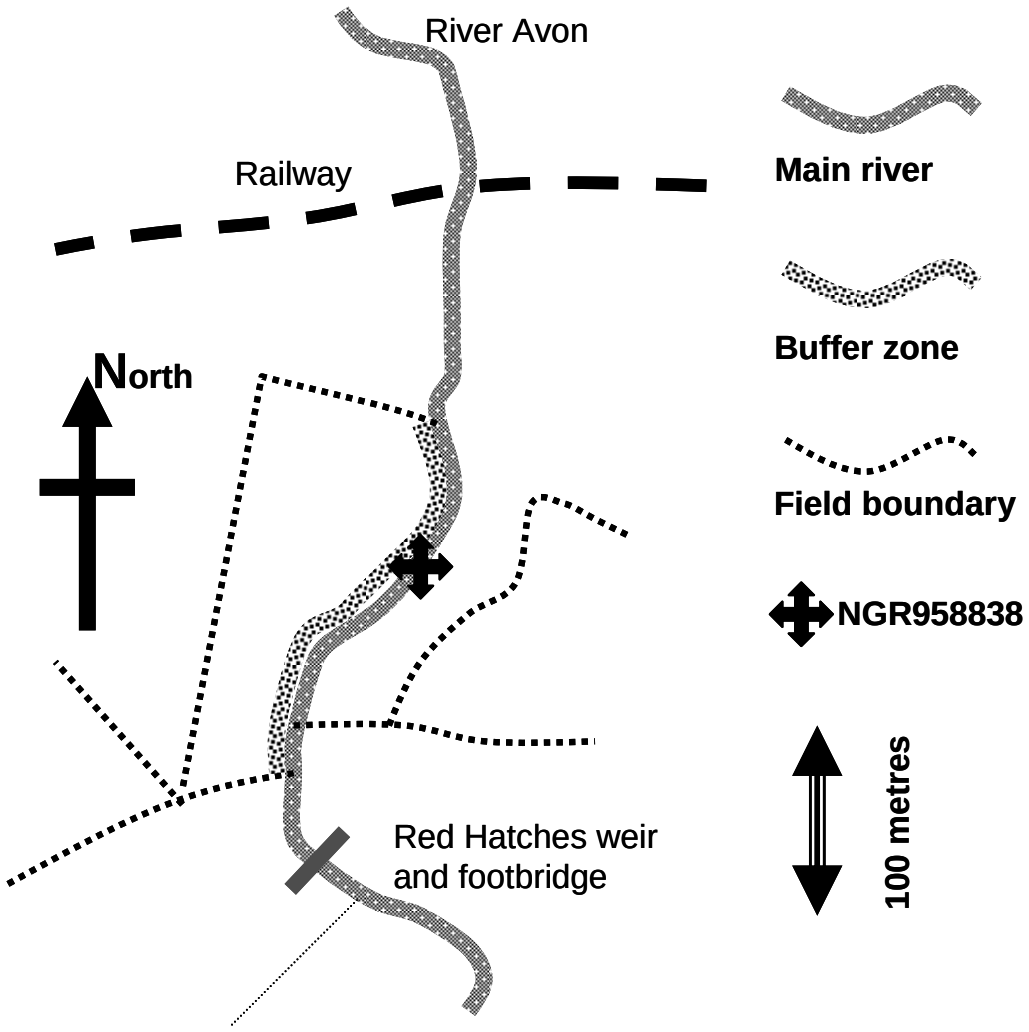

Figure 1.1: Part of the upper Bristol Avon including the buffer zoned field.

Concerned about the apparently severe impact of this poached river bank on the fishery and the wider river ecosystem, the Somerfords Fishing Association (SFA) began a process of dialogue with the landowner (Angrove Farm) and the Environment Agency (led by Andy Don) in early 2008 about creating a buffer zone at the edge of this problematic field. Permissions were obtained from the landowner as well as the Environment Agency, which also provided funds to support the work. The buffer zone design entailed fencing off the entire 330 metres of the badly-poached and eroding field edge, with the provision of one gate for disabled access in addition to three styles for angling access and two access points for controlled cattle drinking. The fencing was

made from visually attractive split timber, comprising two horizontal bars attached to posts at regular intervals some 3 metres from the bank top and with a high lower bar enabling cows to crop grass beyond the fence line. This meant that the farmer lost no effective field area, advantageous for grazing purposes but also to protect subsidy claims. This work was completed in August 2008 at a capital cost of £4,700.

Habitat revegetation and regeneration was almost immediate, with significant spread of reeds (mainly *Glyceria maxima* and *Sparganium erectum*), associated herbaceous plants (including *Persicaria maculosa*) and willow saplings during the remainder of the 2008 growing season. Strong growth occurred throughout 2009 such that vegetative encroachment had stabilised the buffer-zoned bank and also narrowed the channel in places to approximately half of its original width promoting river bed scour. Whereas substantial loads of sediment and associated nutrients had previously been entering the river, the river margin was now trapping any silt emanating from overland flow from the field. Gravels were exposed on the better-flushed river bed, as well as a notable sinuosity of flow and a visibly improved diversity of channel habitat.

Visual inspection, on at least a monthly basis, revealed a rapid restoration of habitat critical for the successful breeding and protection of both game and coarse fish species. More open gravel structures and locally-increased flows suited game fish (stocked brown and rainbow trout as well as grayling). The greater complexity of channel-edge vegetative habitat provided not only improved spawning habitat for many species of coarse fish and an enhanced source of invertebrate food but also, critically, semi-static shallow water with cover to evade predators. Such areas would warm rapidly in the summer to protect and accelerate the growth of fry, and could provide refuge from both stronger flows and predators during higher winter flows.

Although no quantitative counts were undertaken, anecdotal reports from a number of residents and visiting anglers suggested a greater density of kingfishers and grey wagtails (bird species which both typically benefit from improved river habitat) and at least one otter was sighted in the winter of 2009. The visual impact on the fishery, adding significantly to the quality of the angling experience as well as passive enjoyment by bird-watchers, walkers and others, was significant.

Habitat improvements resulting from this buffer zoning work are illustrated in Figures 1.2 and 1.3.

Figure 1.2: Habitat change on straight section of river at field edge.

Figure 1.3: Habitat change at top bend of field edge.

1.3 Determination of ecosystem service impacts

Based on monthly site visits to this and adjacent reaches of the upper Bristol Avon, as well as discussion with visiting anglers and local residents, a limited set of stakeholders (see the acknowledgements in this report) was engaged in assessing how the various ecosystem services were affected, given the state of regeneration achieved by January 2010.

The works were targeted largely at improving the quality of existing habitat, rather than a transition between habitat types. In the economics literature, most studies from which transferable values could be derived do not deal with quanta of improvement, focusing instead on complete habitat re-creation and other capital works. This creates some difficulties when determining ecosystem impacts on a more subjective basis.

However, the project team sought to weight the likely impacts of restoration work on the basis of the MA classification of ecosystem services, and using the Defra (2007) 'likelihood of impact' weighting score which is reproduced in Table 2.

Table 1.2: Defra 2007 'likelihood of impact' weighting system.

Score	Assessment of effect
++	Potential significant positive effect
+	Potential positive effect
O	Negligible effect
-	Potential negative effect
--	Potential significant negative effect
?	Gaps in evidence / contention

1.4 Monetisation of ecosystem service impacts

Environmental economics provides a common and transferable basis for assessing the different categories of benefits and disbenefits associated with changes in ecosystem services that come from interventions in environmental systems. The ecosystem services themselves are largely amenable to economic valuation as they relate to different categories of human benefit. 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 meaning, 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 (actual or projected), provides insight into the tendency and scale of changes. Marginal values are therefore helpful in informing analysis and decisions.

Identification of total 'baseline' values for the different categories of ecosystem service would not merely be a daunting task but would also be ultimately likely to result in subjective values, given the many necessary assumptions and the inevitable data gaps. For this reason, the 'baseline' value was taken to be zero (except where marginal values were based on an uplift of existing value), with pre-intervention status acting as a point from which the relative benefits and disbenefits of the buffer zone were calculated.

Where possible, values are ‘transferred’ from other relevant studies, although some values are deduced on the basis of a number of stated assumptions related to real or surrogate markets. However, we have already highlighted the practical difficulty of a sparse economics literature from which transferable values could be derived to assess marginal improvement of existing habitat rather than gross habitat displacement or restoration. The economic benefits of most ecosystem services are calculated on the basis of a range of stated assumptions linked to surrogate market prices and drawn from related ‘willingness to pay’ surveys. Values transferred from other studies into this analysis are cited in the analysis in Annex 1. Transferred values are NOT corrected to current price levels in this case study as this would give a spurious impression of the precision of the estimate and underpinning assumptions; the values derived in this analysis serve adequately for illustrative purposes of relative magnitude and direction.

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 to determine lifetime values. 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 would in any case be contentious in that it rests upon many assumptions.

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

Specific methods, assumptions and transferred values applied to each ecosystem service are described in Annex 1.

2 Results of the ecosystem services assessment of buffer zoning on the upper Bristol Avon

This section summarises the key findings of the detailed analysis of impacts of buffer zoning of the field edge on the upper Bristol Avon (Annex 1).

2.1 Assessment of marginal benefits from buffer zoning on the upper Bristol Avon

Drawing upon the detailed analysis in Annex 1, the following summary values were derived for this buffer zone case study.

Table 2.1: Summary of results for buffer zoning on the upper Bristol Avon.

MA ecosystem service category	Annual benefit assessed	Notes
Provisioning services	**£508**	£400 for 'fresh water' and £108 for savings on 'food' production
Regulatory services	**£1,840**	£240 in 'climate regulation', with £1,600 on 'erosion regulation' (£1,000 for costs of soil loss from the field and £600 for removal from river)
Cultural services	**£4,633**	£2,975 from 'recreation and tourism' (of which £828 is angling benefit and £2,147 is tourism), £208 as an addendum service of local amenity and informal enjoyment, and £1,450 (32%) for social relations (largely volunteer activities)
Supporting services	**£1,618**	All related to costs averted in 'provision of habitat'
Gross annual ecosystem services benefits	**£8,599**	

These benefits accrue from a modest initial gross investment of £4,700 (including VAT) capital costs, overlooking the Environment Agency staff costs entailed in the necessary permissions and also volunteer input from people associated with the Somerfords Fishing Association to enable the scheme to proceed.

When the cumulative annual ecosystem services benefits of £8,599 are compounded over 25 years with a discount rate of 3.5%, this equates to a gross scheme benefit of £144,860.

If we divide the gross lifetime scheme benefit (£144,860) by the initial gross investment (£4,700 including VAT), buffer zone implementation on this field by the upper Bristol Avon yields a substantial benefit-to-cost ratio of 31:1.

Although all assumptions and transferred values used in this study are based on established methods, the value most likely to be contested is the disproportionately high sum calculated for the ecotourism component of the 'recreation and tourism' benefit (an annual benefit of £2,147 or 25% of the gross annual benefit). Although we stand by the value derived on the basis of the principles stated in Annex 1, there is a case that a lack of easy public access and no immediate 'honeypot' sites (overlooking for now the immediate proximity of the field to the heritage monument of the Brunel railway arch bridge) renders this an overestimate. Nevertheless, excluding the ecotourism value still yields a gross annual benefit across remaining ecosystem services of £6,462, a gross 25 year/3.5% discount rate lifetime value of £108,851, and a significant benefit-to-cost value of 23:1.

The annual benefit to recreational angling of £828 is, interestingly, only 9.6% of the gross annual ecosystem service benefits (£8,599). Nevertheless, the scheme is justified on angling economic uplift alone as, if we compare a gross 25 years, 3.5% discount rate for recreational angling benefits alone (a lifetime value of £13,949), this still yields a substantial benefit-to-cost ratio of nearly 3.0:1.

Thus, although angling interests (a combination of Environment Agency fisheries staff and the Somerfords Fishing Association) were the instigators and primary drivers of this habitat improvements works, the economic benefits to wider society account for 90.4% of the not inconsiderable likely benefits.

3 Lessons learned from the ecosystem services assessment of buffer zoning on the upper Bristol Avon

Although driven by angling club interests, this buffer zone project, addressing a high-priority erosion risk reach of the upper Bristol Avon, is in reality about far more than fish stocks. Rather, game and coarse fish serve as indicators of a river relieved of a severe impact and restored to improved health and function. This, in turn, then yields many associated benefits to society beyond those for which the fishing club and the fisheries budgets of the Environment Agency are principally focused.

As highlighted in the analysis of results above, gross lifetime benefits from the buffer zoning project on the upper Bristol Avon are £144,860, representing exceptional value-for-money (a benefit-to-cost ratio of 31:1) for the modest investment in fencing of £4,700. Even if the uplift to tourism (25% of gross benefit) is discounted, this still yields a gross lifetime benefit of £108,861 and a significant benefit-to-cost value of 23:1.

This ecosystem services analysis also underlines the conclusion of a review by Everard (in press) on *The potential contribution of freshwater fishery management to societal wellbeing*, tracking a transition in the management of freshwater fisheries from an outmoded approach based on habitat clearance towards novel approaches founded on sensitive habitat and ecosystem regeneration. In the case of this buffer zone project on the upper Bristol Avon, the annual benefit to recreational angling of £828 contributes to only 9.6% of the gross annual ecosystem service benefits of the scheme. The buffer zone scheme is more than justified on the basis of the economic uplift from recreational angling alone, as the lifetime benefit (£13,989 over 25 years with a discount rate of 3.5%) still yields a substantial benefit-to-cost ratio of 3.0:1. Therefore, although angling interests (a combination of Environment Agency fisheries staff and the Somerfords Fishing Association) were the instigators and primary drivers of this habitat improvements works, the economic benefits to wider society account for 90.4% of likely benefits.

Since habitat-based restoration is not intended primarily to boost production of commodities, the modest annual benefit of £508 for provisioning services (representing only 6% of the gross annual benefits of which £400 is for costs averted from provision of fresh water) is unsurprising. By comparison, cultural services yield a substantial 54% of quantifiable annual benefits, whilst regulatory and supporting services account for 21% and 19% respectively.

In common with the findings of an ecosystem services analysis of a sea trout restoration project on the River Glaven in North Norfolk (Everard, 2010), the high cultural values and building of social capital around this ecosystem-based enhancement initiative has served to bring different constituencies together around common goals. Both the Glaven and Bristol Avon schemes bear comparison to similar ecosystem-based river enhancement schemes such as the constitution in 1986 of the Thames Salmon Trust as a registered charity (reconstituted in 2005 as the Thames Rivers Restoration Trust), with the ambitious aim of bringing about regeneration of the river such that salmon would again be able to run the river. The salmon was iconic of a river restored to full health, appealing to far wider constituencies than those interested in fishing for the (then non-existent) Thames salmon. The sea trout was found to serve this same iconic role in the River Glaven system, emblematic of a river restored to its

natural vitality. So too on the upper Bristol Avon, regenerated fish stocks are regarded as a desirable consequence of relief of pressures upon, and recovery of, the river ecosystem with all of its wider associated benefits. Reinforcing the conclusions of ecosystem services analyses of habitat restoration on the River Tamar (Everard, 2009), the River Glaven (Everard, 2010) and as a generic principle of progressive freshwater fishery management practices that seek to work with and enhance natural regeneration processes (Everard, in press), ecosystem restoration is generally found to result in net benefits or neutral impacts across all ecosystem service types.

Although there is always a risk of 'double counting' ecosystem-derived benefits in complex socio-ecological systems, the methods deployed in this study were consistent with best practice elsewhere, based on clearly-stated assumptions and conservative values, and sought to minimise the potential for this type of error. Given the magnitude of deduced benefits compared with the costs of the intervention, any error introduced by inadvertent double-counting would in fact have only a minimal effect on the resulting benefit-to-cost calculations, demonstrating that the overall conclusions of the study are robust. A research gap did, however, emerge, which was the lack of economic studies to date with transferable economic values relating to habitat improvement as opposed to replacement; this gap may be significant in determining the economic aspects of measures to implement the EU Water Framework Directive.

However, as observed in the case study of sea trout restoration on the River Glaven (Everard, 2010) and options for coastal defences in Wareham Harbour (Defra, 2007), monetisation is often not necessary to justify continued investment in habitat enhancement. Where qualitative analysis, based for example on the Defra (2007) valuation guide weighting system deployed in this study, suggests the likelihood of positive benefits that are significant and evident to a wide range of stakeholders, monetisation may be superfluous. The occurrence of 'Potential significant positive effect', 'Potential positive effect' and neutral impact scores for ecosystem service impacts in Annex 1, and the absence of any negative impacts, suggests that this type of a buffer zoning approach applied in sensitive locations (such as this field margin on the upper Bristol Avon) is likely to be justified without the expense and time delay of monetisation. This study, brief and unsupported by a budget for bespoke surveys as it is, therefore provides an unambiguous endorsement of buffer zoning of vulnerable sites as a contribution to river ecology and the angling and many other substantial and long-lasting benefits that it yields to wide sectors of society.

Given a budget for this work, we would ideally have liked to have undertaken more stakeholder engagement to ensure that all affected views were represented and that, therefore, no ecosystem services were overlooked or underrepresented. This approach would be consistent with evolving good practice in the mainstreaming of collaboration with communities and stakeholders in flood risk management and other environmental decision-making, as mandated by the UNECE Aarhus Convention of 1998 (UNECE Aarhus Convention, 1998) and supported by a report on mainstreaming stakeholder engagement in flood risk management produced for the Environment Agency (Colbourne, 2009).

Other issues yet to be researched include the scale of the contribution of local initiatives of this nature, some of which may be diminished over relatively small distances (for example fall-out of sediment) but others of which may have considerably wider ramifications across the catchment (for example recruitment of fish, support for other wildlife and a contribution to river water quality) and more broadly (such as though enhancement of air quality or regulation of climate-change gases).

This study also strengthens the already robust case for the power of ecosystem services as a tool to help identify the breadth of issues and potential beneficiaries touched upon by environmental management schemes with, in this case, a broad range of 'collateral benefits' that may not have been part of the initial scheme design.

By contrast, it also demonstrates the dangers of ‘silo thinking’, often enforced by organisational structures, mandates and/or budgets. Optimal societal value and sustainability of outcomes can occur only when a full range of impacts and benefits is considered simultaneously.

The benefits of buffer zone installation on the upper Bristol Avon are clear and substantial, and the learning derived from this study is therefore relevant and transferable, with caution, to other environmental initiatives founded on restoration of river habitat, function and suitability for characteristic and iconic species. It is transferable with considerably less caution to the promotion of buffer zoning as a tool for improved river management and realisation of social benefits including, for example, as a measure appropriate to support achievement of ‘good ecological status’ requirements under the EU Water Framework Directive.

Annex 1: Assessment of buffer zoning on the upper Bristol Avon

This Annex contains detailed considerations of ecosystem services impacts of buffer zoning on the upper Bristol Avon. Methods, assumptions and deduced transferred values are outlined in Tables A1.1–A1.4 below, respectively for provisioning, regulatory, cultural and supporting services.

Table A1.1: Provisioning service impacts of buffer zoning on the upper Bristol Avon.

Weighting (++, +, 0, -, --, ?)	Quantification?	Monetisation?
Provisioning services		
Fresh water **+**	Improved habitat will enhance the supply of fresh water, both in terms of quantity and quality. Dairy farming pollution is a significant cause for concern about risks of *Cryptosporidium* contamination, which is notoriously difficult to remove from water abstracted for potable supply. Cattle poaching river margins also contaminate rivers with organic matter and nutrients. In the early 1990s, a programme of buffer zoning sponsored by the regional utility Wessex Water had proven helpful in relieving this problem in water draining from the upper Bristol Avon. This field margin had formerly been acknowledged as a high-risk source of contamination	There are numerous water abstraction points lower downstream on the Bristol Avon, both for irrigation and to serve public treated supply, which will benefit from protection of water quality and quality. Assuming these benefits are lost to wider pollution beyond Chippenham (the first town [c]10 kilometres downstream) and a 0.2% cost saving on treatment costs of water abstracted between the field and the town (assumed as £200,000), this yields an annual benefit of £400 **Annual value = £400**
Food (e.g. crops, fruit, fish, etc.) **+**	As 'catch and release' fishing is assumed, benefits for fishing and for shooting are covered as cultural services rather than double-counted as 'food' benefits. However, savings to the farm for food production are considered significant, particularly for savings on disease control in stock	Assuming that stock disease management accounts for a modest 5% of the benefits to the per farm 'food' benefit of £2,158.29 determined in the River Tamar case study (Everard, 2009), this yields an annual benefit of £108 **Annual value = £108**
Fibre and fuel (e.g. timber, wool, etc.) **0**	There is a visual regeneration of wet carr and reeds, but no market for this service. Likewise there is no impact on arable and stock (i.e. sheep) fibre production	**Annual value = £0**
Genetic resources (used for crop/stock breeding and biotechnology) **0/+**	It is likely that genetic diversity, potentially exploitable in future, will be protected or enhanced. However, the scale of this is likely to be small or neutral	**Annual value = £0**
Biochemicals, natural medicines, pharmaceuticals **0/+**	It is likely that biochemical diversity, potentially exploitable in future, will be protected or enhanced but the scale of this is likely to be small or neutral	**Annual value = £0**
Ornamental resources (e.g. shells, flowers, etc.) **0**	None known	**Annual value = £0**
Gross annual 'provisioning services' benefits =		**£508**

Table A1.2: Regulatory service impacts of buffer zoning on the upper Bristol Avon.

Weighting (++, +, 0, -, --, ?)	Quantification?	Monetisation?
Regulatory services		
Air quality regulation **0/+**	Improved habitat is likely to enhance settlement of aerial particulates and metabolism of pollutants such as SOx, NOx and ozone. However, the scale of interventions is small and, owing to good existing air quality, the quantum of gains to beneficiaries are small	**Annual value = £0**
Climate regulation (local temperature/precipitation, GHG sequestration, etc.) **+**	Improved habitat (rewetted river margins, wetland encroachment and development of carr) is likely to enhance sequestration of carbon and also provide positive benefits for local microclimate which may be locally significant, if hard to quantify. However, more sustainable catchments will also require less management interventions, which provides a basis for quantification	Rewetting of river margin habitat within the buffer zone including development of carr is likely to sequester carbon. Assuming a modest on hectare of riparian habitats making a transition from values in the literature for permanent grassland towards those derived for wetted, carbon-accreting soils or to wet woodland, and transferring values from the Everard (2009) study of the Tamar catchment (itself transferring in values from the a prior Swimmer (2007) report) using a marginal cost of carbon of £27 per tonne, this yields an annual ecosystem service benefit value of £240 **Annual value = £240**
Water regulation (timing and scale of run-off, flooding, etc.) **+**	Improved habitat is likely to provide a more natural hydrology. However, the scale of this is small, so it is not possible to make robust assumptions for flood risk to property. Also, benefits of improved hydrology for fish and other river wildlife are assessed as 'recreation and tourism' and 'provision of habitat' services respectively	Not assessed in order to avoid double-counting with other benefits **Annual value = £0**
Natural hazard regulation (i.e. storm protection) **+**	This benefit is likely to track that for hydrology, though quantification is more problematic	This is not valued in order to avoid double-counting; assumed to be rolled in with 'Water regulation' above **Annual value = £0**
Pest regulation **0/+**	Whilst enhanced habitat is likely to support populations of natural predators of crop and other pests, quantification of this benefit is complex	There are complexities in valuing this benefit, but we ascribe it a zero value to avoid any double-counting with the

		service of 'food' above **Annual value = £0**
Disease regulation **0/+**	Buffer zoning excludes cattle from much of the river, reducing transfer of pathogens into the water as well as 'treating' microorganisms already in the water column	Not valued in order to avoid double-counting with food (provisioning) services **Annual value = £0**
Erosion regulation **0/+**	Buffer zoning substantially reduced erosion from this field margin. This has habitat benefits in the river which are not evaluated here in order to avoid double-counting with the services of 'recreation and tourism' and 'habitat for wildlife'. However, it is important to evaluate the benefits of both soil protection and aversion of siltation of the river system	It is assumed that 1 tonne of soil is lost per annum at a shadow value of £1,000 Costs averted from removing silt from the river are used here as a surrogate market for siltation impacts on the river. Using costs applied in the River Glaven case study (Everard, 2010) and assuming this equates to 5 man/machine days (@ £350 staff costs + £150 machine costs + £40 [round trip from home of 100 miles @ 40p per mile] travel to work) + £300 costs of machine haulage to/from site = £600 **Annual value = £1,600**
Water purification and waste treatment **0/+**	More natural hydrology and better connection with floodplain is likely to enhance water purification and waste treatment	'Fresh water' benefits are not valued here as this final service is already assessed as a provisioning service **Annual value = £0**
Pollination **0/+**	Enhanced habitat is likely to support stronger populations of natural pollinators, though quantification of this benefit is complex	In this rural catchment, natural pollinators are not believed to be limiting so the marginal impact would be negligible **Annual value = £0**
Gross annual 'regulatory services' benefits =		**£1,840**

Table A1.3: Cultural service impacts of buffer zoning on the upper Bristol Avon.

Weighting (++, +, 0, -, --, ?)	Quantification?	Monetisation?
Cultural services		
Cultural heritage **0**	Heritage infrastructure downstream may be affected by siltation, but it is assumed that this value is covered by the desilting surrogate market costs applied in assessing erosion regulation above	**Annual value = £0**
Recreation and tourism **++**	Enhanced fish stocks will have some impact on recreational angling (which is not double-counted with the service of 'food' as 'catch-and-release' fishing is assumed). Further benefits accrue from enhanced wildlife and river aesthetics promoting bird-watching, photography and informal recreation, and regional tourism enhanced by the improved environment in this reach of river immediately downstream and in clear sight of an archaeological-important Brunel arched bridge across the river valley	Angling benefits are assessed as a very modest 2% uplift in angling to the SFA, assuming 160 paying members @ £230 per annum and 20 honorary members deriving equivalent value, yielding an annual benefit of £828 Wildlife-related recreation and eco-tourism is less easy to value but, the following assumptions are applied: (a) there is a 2% uplift of ecotourism benefits on a 1km^2 'catchment' around the buffered reach of river; (b) the Countryside Agency (1998) estimated that rural tourism in the English countryside (130,410 km^2) is worth nearly £14 billion a year; and (c) the Brunel arch bridge may disproportionately enhance tourism value but this is neutralised by lack of access. This yields an annual tourism benefit of £2,147 Implications for uplifts to the value of local property, likely to me small if significant, are not valued **Annual value = £2,975**
Addendum service: Local amenity and informal enjoyment **+**	This 'addendum service' to the basic MA suite has been used on the River Glaven case study (Everard, 2010) to	Assuming that 1 person per week might otherwise drive 10 miles

	capture benefits for local people that might not be adequately captured under the category of 'tourism'. However, given that the field is some walk from neighbouring villages and not directly accessible by vehicle as a 'honeypot' site, the benefit is assumed to be small but, as a surrogate for 'aesthetic value' below, is ascribed a monetary value. In addition, the fence between the river and the field was reported to have encouraged use of this buffered field margin by walkers concerned about crossing a field containing cows	@ 40p per mile for an alternative, attractive river walk alternative to this reach of the upper Bristol Avon in its poached state, this yields a marginal annual benefit of £208 **Annual value = £208**
Aesthetic value **0**	It is assumed for the purposes of this study that these values are captured by the 'local amenity and informal enjoyment' service above	**Annual value = £0**
Spiritual and religious value **?**	None identified	**Annual value = £0**
Inspiration of art, folklore, architecture, etc. **?**	None identified; any enhancement assumed to be captured under 'recreation and tourism' and 'local amenity and informal enjoyment'	**Annual value = £0**
Social relations (e.g. fishing, grazing or cropping communities) **++**	The buffer zone project has served as a focal point for the SFA, the Environment Agency and the farmer to undertake a joint project of habitat restoration for the benefit of both anglers and local residents. To assess this benefit robustly, we would need to undertake a full social audit, for which we lack resources. Valuation of the building of social capital amongst the key stakeholders in this reach of river is complex, and so the surrogate market approach applied here is to seek to value volunteer activity Disabled access via a gate through the buffer zone fencing was integral to the design and this will play a role in social inclusion. Although this has a value, it is one that is difficult to assess but it is assumed that it is captured in the value derived by angling club members accessing the water (see 'recreation and tourism' above)	A surrogate value for this service is building of social capital derived from the level of volunteer activity in the catchment. A review by O'Gorman, Bann and Caldwell (2009) of the *The Benefits of Inland Waterways* to UK Government provided valuation of volunteers of unskilled @ £50/day, skilled @ £150/day and professional @ £350/day. Assuming the SFA put in 7 days (assumed here as 1 unskilled, 5 skilled and 1 professional), the farmer 1 day (skilled) and the Environment Agency 1 day (assumed for this purpose as equivalent to skilled), this yields a total of £1,450. Since this coordination has been maintained towards monitoring and enhancement of the upper Bristol Avon, it is low estimate is assumed to represent an annual value **Annual value = £1,450**
Gross annual 'cultural services' benefits =		**£4,633**

Table A1.4: Supporting service impacts of buffer zoning on the upper Bristol Avon.

Weighting (++, +, 0, -, --, ?)	Quantification?	Monetisation?
Supporting services		
Soil formation **+**	Improved habitat is also likely to enhance soil formation, which may be locally significant	Soil-forming processes from the re-wetting of reconnected floodplains are of undoubted value, but this is not monetised here so as to avoid double-counting with the service of 'soil erosion' **Annual value = £0**
Primary production **+**	Improved habitat is likely to enhance primary production and photosynthesis, but quantifying this is complex	Assumed beneficial but at a level likely to be lost in uncertainties of assessment, and marginal benefits assumed small in an area already enjoying a healthy environment **Annual value = £0**
Nutrient cycling **+**	Improved habitat is likely to enhance nutrient cycling, but quantifying this is complex	Assumed beneficial but at a level likely to be lost in uncertainties of assessment, and already discussed above in the context of 'fresh water' **Annual value = £0**
Water recycling **+**	Improved habitat is likely to enhance water recycling, but quantifying this is complex	Assumed beneficial but at a level likely to be lost in uncertainties of assessment, and also not valued as considered captured in the final service of 'water regulation' **Annual value = £0**
Photosynthesis (production of atmospheric oxygen) **+**	Improved habitat is likely to enhance primary production and photosynthesis, but quantifying this is complex	Assumed beneficial but at a level likely to be lost in uncertainties of assessment, and marginal benefits assumed small in an area already enjoying a healthy environment **Annual value = £0**
Provision of habitat **++**	Resilience of fish stocks presents a clear benefit, but values are captured under the 'final service' of recreational angling. This reach of the Bristol Avon is not covered by statutory nature conservation designations but is host to bullheads (*Cottus gobio*). Control of	Bullheads are being lost from many southern British rivers. This localised restoration work is assumed to avert the need for active management (1

	sIltation from the former severe erosion on this field boundary is likely to be advantageous for bullheads and many other species of plants and animals for a considerable distance downstream. Also, like all 'water bodies', measures are necessary to secure 'good ecological status' under the EU Water Framework Directive (WFD)	man/digger days + haulage costs on a five-yearly cycle) to clean habitat or undertake bespoke projects, yielding an annual value of £168 Taking the contribution of the buffer zone to river management for WFD purposes, to which volunteer and voluntary sector contribution make a substantial contribution, this supporting service is valued as an equivalent addition of volunteer input (for the 'social relations' service) of £1,450 per annum **Annual value = £1,618**
Gross annual 'supporting services' benefits =		**£1,618** (all 'provision of habitat)

End of Annex 1

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