The development of integrated conservation strategies based on environmental science and psychology: a case study of the freshwater pearl mussel

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ABSTRACT

The freshwater pearl mussel (FPM) is an iconic bivalve mollusc whose presence in rivers is assumed to indicate a healthy, bio-diverse ecosystem, capable of providing a range of goods and services. However, excessive sedimentation has been shown consistently to have detrimental effects on FPM, at both the juvenile and adult life stages. As a major source of diffuse river pollution, previous studies have shown erosion rates rising with increasing precipitation, suggesting also increased risk under wetter, future climates. So far, however, most erosion studies have been at the small plot scale and hence it is not possible to make predictions at the catchment scale where risk assessments for FPM are most relevant. Furthermore, little research has focussed on how work to remediate sediment delivery might affect public appreciation of rivers as highly valued landscape features. This research focussed on three typical FPM rivers in the UK: the Ehen catchment in Northern England; the Conwy in North Wales and the Dee in East Scotland and asked 1) How will climate change predictions for the period 2010 – 2039 affect soil erosion at the catchment scale? 2) What factors influence public attitudes towards rivers, the FPM, and mitigation measures to control sediment movement? and 3) Can habitat management for FPMs take into account climate-driven environmental change and social values when constructing conservation goals? In respect of the first aim, the Pan-European Soil Erosion Risk assessment model, PESERA, showed that whilst soil erosion rates increased with rising precipitation, land cover was a more dominant driver of erosion rates over the period studied (2010-2039). Despite being flatter, arable land had higher erosion rates than those from forested portions of each catchment, which were in regions of steeper topography. Secondly, based on a mixture of qualitative focus groups and quantitative surveys, the majority of people had positive attitudes toward rivers, both in a general and local sense. The FPM was not a well-known aquatic species but information about possible human or ecological beneficiaries of mitigation to control sediment delivery into rivers did not affect how acceptable these measures were perceived to be. Factors increasing acceptability of mitigation measures included natural looking scenes that were accessible. In contrast, concerns about impacts on agriculture and food production led to lower levels of acceptability. Finally, this research highlighted crossovers between FPM habitat needs and ideal river scenes from a public perspective and concluded that social values of riverscapes can be included in habitat management plans for the FPM, without compromising conservation goals. A case study exemplifying the methodology used to do this, using the Dee catchment, Scotland and future scenarios from the National Ecosystem Assessment showed that conservation measures in aid of the FPM can accommodate different land management priorities and societal needs. As one of the first studies to assess interactions between evidence from physical sciences, ecology and public perception for an iconic species, this research is expected to have far reaching consequences for public policy, land management practices and river conservation. At a policy level, this includes the ways in which environmental practices can accommodate the social values identified within this research to allow a more holistic approach to ecosystem management; for on the ground practitioners, this research will influence how ecologically important but socially unfamiliar species are managed and how the impacts of land management are assessed both temporally, (to include the impacts of future climate change), spatially, (to take account of catchment wide effects) and socially (to examine social acceptability of different management options).

LIST OF FIGURES, TABLES AND APPENDICES

CHAPTER SIX

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CHAPTER ONE:
GENERAL INTRODUCTION

The history of nature conservation in the UK can be dated back to the late 19th century when the first legislation was put in place to protect wild birds, the Wild Bird Protection Act 1872; private efforts to protect the landscape also began in the same era, with the National Trust for Places of Historic Interest and Natural Beauty (now known as the National Trust) established in 1895 (Oosthoek 2006). Driving these formalised conservation implements is the public's concern for the natural environment. For example, the founder of the National Trust, Cannon Harwick Rawnsley, did so subsequent to his founding of the Lake District Defence Society in 1876 in response to the Manchester Corporation's activities to dam Thirmere (Oosthoek 2006). Activities such as these mark the first record of public action as a result of a concern for human impacts on the natural environment.

Moving forward to the 20th century, terms such as biodiversity and ecology were in the main familiar only within the scientific community (Council of Europe 2004). The European Nature Conservation Year of 1970 thrust such terminology into the public sphere; public opinion became focussed on habitat loss at both a regional and global scale (Council of Europe 2004). At a European level, in response to both public and scientific concerns about the deterioration and fragmentation of a range of habitats and the resulting biodiversity losses, the Bern Convention was adopted by EU member states in 1982 (Coffey and Richartz 2003). This legislation specifically acknowledges the biological and social values of habitats and species:

'that wild flora and fauna constitute a natural heritage of aesthetic, scientific, cultural, recreational, economic and intrinsic value that needs to be preserved and handed on to future generations'
(Coffey and Richartz 2003)

Subsequent EU Council Directives for the protection of species and habitats alongside the Bern Convention remain the primary legal instruments of environmental conservation across Europe. At such a large, international scale, direct input into such policies by the lay-public is challenging. However, at a more local scale, public interest and attitudes can and do shape the use of the environment, of which there a several examples within a UK context. The UK walker's charity, the Ramblers, won their lengthy campaign for the right to roam across wild open countryside in England and Wales (The Ramblers 2014). The Countryside and Rights of Way Act 2000 sets out the legal right to walk across a variety of open-access landscape without having to stay on designated paths and tracks. A more recent example is in 2014 when, after increasing opposition in the UK by the public to onshore wind farms (Carrington 2012), the Conservative manifesto for the upcoming general election in 2015 includes provision for a more localised approach to granting planning permission for future terrestrial wind farms, in order to take into account the views of local residents (Kirkup 2014). Public interest in environmental management is not limited to the landscape level, but extends to specific habitats; the Royal Society for the Protection of Birds (RSPB); the World Wide Fund for Nature; the Anglers Trust and the Association of Rivers Trusts launched the 'Our Rivers' campaign in 2009. The campaign website included an interactive map where users could highlight issues facing their local rivers, providing an opportunity for the public to inform policy makers on the specific need of their local environment (RSPB 2009).

River conservation is practised by many agencies and charities in the UK, for example Rivers Trusts and the Environment Agency. The Water Framework Directive (WFD) provides the legislative backdrop for the management of rivers and inland waters in Europe and was formalised into UK law in 2003. Whilst legislation already existed which governed the conservation of biodiversity in terms of specific species or habitats (i.e. Wildlife and Countryside Act, 1981), the WFD was the first piece of legislation to explicitly include a requirement for public consultation within its remit. This inclusion formalised what is known as the consultative approach whereby non-experts, particularly local communities and stakeholders, have a voice in determining conservation objectives (Ericson 2006). The value of the consultative approach has long been recognised as a method of achieving greater conservation success through a more inclusive and acceptable decision making process (Pimbert and Pretty 1995). Such protocols elevate the social value of the environment through greater use of the natural environment (Tapsell *et al.* 1997; Tunstall *et al.* 2000) and indirectly increasing health and wellbeing benefits (White *et al.* 2010). However, few cases studies exist that demonstrate a methodology in which natural science and public consultation have been combined to facilitate ecologically and socially important environmental management.

Combining natural science and public consultation is not always easy and the success of such endeavours relies upon agreement between all those involved. It is well known that science and public attitudes are not always congruent with the obvious example being climate change, where factors such as trust and underlying personal values have played a pivotal role in determining public opinion (Lorenzoni *et al.* 2007). Even now, in the 21st century when the majority of the public feels climate change personally important (Whitmarsh 2011), there is little consensus about how to tackle it. However, unlike the issue of climate change, which is often seen as intangible and psychologically distant (Spence *et al.* 2011), rivers are seen as a positive landscape feature (Kaplan 1977; Tapsell *et al.*, 1997; Buijs 2009) and the detrimental impacts of climate change on rivers are often visually obvious with a much more direct impact on local communities (e.g. flooding). Many of the impacts of climate change on rivers would make them less appealing as a recreational resource, increase costs associated with potable water and negatively affect river biodiversity, reducing the ability for rivers to provide essential goods and services.

One such impact is sedimentation as a result of increased terrestrial erosion rates. Rivers provide the conduit by which eroded material is carried from the source of erosion to eventually be deposited in the ocean (Milliman and Meade 1983). It is estimated that 24 million tons of material is eroded from the Earth's surface annually (Montgomery 1961). Erosion rates as a result of water in the UK range from <1 t^{-1} ha^{-1} a^{-1} to >80 t^{-1} ha^{-1} a^{-1} (Rickson 2013). The impacts of soil erosion are both ecological (i.e. loss of soil carbon stores (Lal 2003, 2004), loss of soil biota (Pimentel *et al.* 1995) and detrimental impacts to aquatic ecosystems (Newcombe and Macdonald 1991; Skinner *et al.* 1997; Evans *et al.* 2006)) and economic (i.e. lost productivity and increased chemical fertiliser usage (POSTNote 2006)). Climate change predictions for much of the north of England, Wales and Scotland indicate a wetter, warmer climate with increased intensity and duration of rain events (UKCIP 2010). Much evidence suggests that under such conditions, erosion rates will increase (Boardman and Favismortlock 1993; Favis-Mortlock and Savabi 1996; Chaplot 2007; Ficklin *et al.* 2010). Areas likely to be most affected are those with steep topography or those with discontinuous ground cover, in particular arable land, which has been shown to have the highest rates of erosion (Rickson 2013). Erosion models have been much used to allow researchers to predict erosion rates as a result of changing environmental conditions. Earlier models (i.e., USLE and RUSLE) were based on soil types from the USA and so are less suitable for use in the UK (Wischmeier and Smith 1958; Wischmeier 1984). Alternatives, such as LISEM and EUROSEM are more complex and require greater volumes of data (De Roo and Offermans 1995; Morgan *et al.* 1998). In either case, such models are only really of use at the plot or field scale and have been mostly used on agricultural land. Given the catchment wide implications of soil erosion, large scale models, for example the Pan European Erosion Risk Assessment (PESERA) have been created which allow erosion risk to be modelled at the catchment scale (Kirkby *et al.* 2008). This approach allows the identification of vulnerable areas which enables a pro-active approach to tackling these, both on-site (i.e. changing agricultural practice to make the soil less likely to erode) and off-site (preventing eroded material entering rivers).

The risk to river habitats from erosion on arable land has already been recognised in England, where the Catchment Sensitive Farming programme, run by Natural England aims to reduce diffuse pollution from agricultural sources and make farm business savings (Natural England 2012). Agri-environment schemes, such as the Catchment Sensitive Farming programme, offer conservation bodies the opportunity to engage with landowners in situations where the conservation work needs the landowner's consent or action; linking ecological objectives with economic incentives. Engagement with the public (i.e. those without a clear economic benefit from river conservation) is extremely complex; research has identified multiple factors that contribute to environmental attitude formation and behavioural intentions and indicates a complex interaction of components such as values, knowledge, social norms and structural factors (Kollmuss and Agyeman 2002). Conservation organisation have historically focussed on knowledge provision based on the information deficit model, which states that information provision can lead to more environmentally conscious behaviour or more environmentally friendly attitudes (Burgess *et al.* 1998). In the case of specific habitat types, for example riverscapes, evidence suggests that rivers are valued landscape features for functional, cultural and aesthetics reasons (Kaplan *et al.* 1989; Dalrymple 2006; Buijs 2009). However, the values or knowledge held by the lay-person about specific species is understudied. Such a paucity of research makes species management challenging, especially in the present time of economic austerity when taxpayers' money funds schemes that may not match the values of the taxpayers themselves. Evidence suggests that the lay-person has a greater emotive connection with species that are morphologically similar to humans or those which human characteristics can be portrayed (Serpell 2004; Martín-López *et al.* 2007; Knight 2008). Hence, it is species such as polar bears and dolphins that are used to spearhead conservation campaigns. However, some research does suggest that the conservation of ecologically important species is acceptable by the public if the need for their conservation is understood (Czech *et al.* 1998; Tisdell and Wilson 2006). The terms 'indicator', 'keystone' or 'umbrella' species are used to describe species with strict habitat requirements and the presence of such species is indicative of good ecological quality; by focussing conservation efforts on such species ensures that the wider habitat is suitable for many other species. Keystone species may not be charismatic or familiar but if the effects of climate change can be mitigated well enough to protect these species, then overall river biodiversity will also benefit.

One example of an indicator species is the freshwater pearl mussel (FPM), an iconic British bivalve mollusc which plays a vital role as indicator species in upland rivers. Once fished to the brink of extinction for the pearls that they produce, FPMs are now heavily protected and as such their locations are often kept secret (for example, in Scotland). In doing so, the public have become increasingly unfamiliar with this species, ensuring that the conservation of this species has not been utilised as an opportunity for public engagement. However, in the River Clun, Shropshire, the opposite has occurred; engagement opportunities have been used to create a sense of importance to the species leading to a sense of pride within the community where this species is found. Local farmers now advocate on behalf of FPM conservation to other farmers due to the time and effort that has been put into promoting FPM habitat management that takes into account societal needs (Kelly 2011, pers. comm.).

The overarching aim of this research project is to assess whether habitat management plans for the FPM can be designed to take into account social values attributed to riverscapes and potential environmental change predictions. In doing so, a methodology will be established that combines natural science with the consultative approach which can be adapted for use with a range of species and habitats where needed. The research is split into three main sections and utilises a range of methodological approaches:

Section One attempts to answer the first research question of this thesis: How will climate change predictions for the period 2010 – 2039 affect soil erosion at the catchment scale? Here, erosion modelling, using the Pan European Soil Erosion Risk Assessment (PESERA) model, is implemented across three river catchments, chosen to represent the potential FPM habitat range in the UK. The effects of climate change and land use change on erosion rates relative to baseline conditions (1961-1990) is assessed for the period 2010-2039. The results of this section are documented in Chapter Three.

Section Two addresses the lack of previous research into the public perception of unfamiliar aquatic species and attitudes towards conservation objectives focussed on such species.

Section two uses both qualitative and quantitative methods, to answer the second research question: What factors influence public attitudes towards rivers, the FPM, and mitigation measures to control sediment movement? Mixed-method focus groups and a nationally representative survey are used to investigate attitudes to rivers, river species and erosion mitigation measures to support the FPM in light of potential climate change impacts. The results of this section are documented in Chapters Four and Five.

Section Three draws together the evidence from Sections One and Two and provides an example of management plans for the FPM that take into account potential habitat change and the attitudes and values associated with the FPM and possible mitigation measures to conserve the FPM. The final research question, addressed in this section, is: Can habitat management for FPMs take into account climate-driven environmental change and social values when constructing conservation goals? The results of this section, documented in Chapter Six, integrate the findings of the previous three chapters and provide practical recommendations for the conservation of the FPM.

For clarity, Chapter Two, figure 2.4 provides a schemetic representation of the relationships between the different components of this research.

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CHAPTER TWO:
LITERATURE REVIEW

2.1 Current Status of the Freshwater Pearl Mussel

Freshwater Pearl Mussels (*Margaritifera margaritifera*, Linnaeus, 1758), once the most abundant bivalve mollusc in European freshwaters (Araujo and Ramos 2001), are now an endangered species throughout its Holarctic distribution. As the name suggests, the Freshwater Pearl Mussel (FPM) is capable of producing pearls and there is evidence to suggest that FPMs have been continually exploited in the UK since pre-Roman times, and large-scale exploitation probably began in 16th century (Skinner *et al.* 2003). As a result of unsustainable practices FPM population declined to such an extent that in 1998 they were designated as a protected species in the UK (Figure 2.1). In Europe, the FPM is legally protected under the European Union Habitats Directive (Directive 92/43/EEC) and internationally they are classed as endangered and are recorded on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species. Despite this protection, declines in recruitment continue to be observed within previously healthy adult populations in northern England and Wales (Skinner *et al.* 2003; Jones 2011, pers. comm.). Scotland holds approximately half the global population (Cosgrove *et al.* 2000); however the FPM continues to be under threat throughout its entire geographic range (Skinner *et al.* 2003).

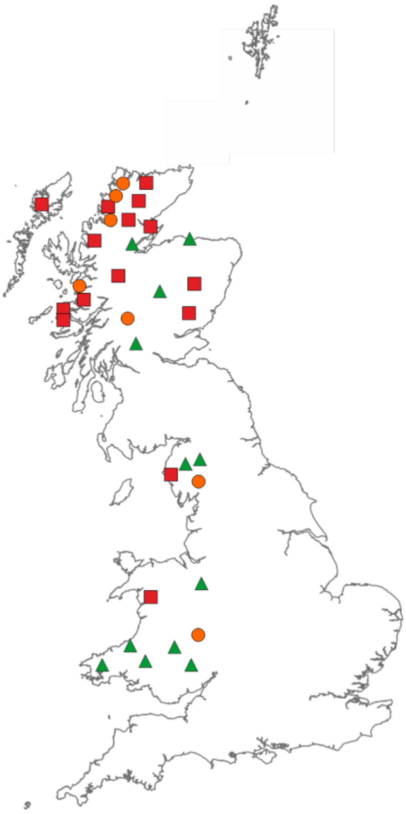

Figure 2.1: UK distribution Special Areas of Conservation (SACs) with populations of freshwater pearl mussels.

▲ Grade A/B – primary reason for European designation

■ Grade C – species present but not primary reason for designation

● Grade D – species present but not qualifying reason for designation

The early stages of the population decline of the FPM were undoubtedly the commercial exploitation for pearls (Cosgrove and Hastie 2001); approximately 3,000 mussels need to be opened to find just one pearl (Jackson 1925). Pearl fishers targeted larger, and therefore older, examples and research by Hastie (2006) shows that most of the mortality in 50+ mussels is due to fishing rather than natural causes, evidenced by characteristic knife marks on shells found at survey sites. In recent years, particularly since protection, population numbers have continued to plummet coupled with little or no recruitment (Skinner *et al.* 2003). It is apparent from the plethora of available literature that habitat characteristics have a large role to play in the continued decline of the FPM (Bauer 1986, 1988; Beasley and Roberts 1996; Cosgrove *et al.* 2000), with anthropogenic impacts on freshwaters leading to unsuitable conditions for the FPM. For example, the lack of human impact on a river in north west Russia has been attributed to the presence of a large viable population recently discovered (Ostrovsky and Popov 2011) and two of the remaining three Spanish FPM populations have been found in areas with little anthropogenic impact (Bauer 1986). Research from Cosgrove and Hastie (2001) shows the impact of river engineering work on populations of FPMs and attributes activities such as dredging and flood defence work as most threatening to populations due the destruction of suitable habitat caused by such works.

2.2 Habitat Requirements of the Freshwater Pearl Mussel

The life cycle of *Margaritifera margaritifera* is complex, involving a parasitic stage, a juvenile stage and an adult stage (Figure 2.2). Juvenile mussels have more specific habitat requirement than adults (Hastie *et al.* 2000a); consequently adults are found over a wider range of environmental parameters (Hastie *et al.* 2000a). The post-settlement juvenile phase has been identified as the most crucial life cycle stage of FPMs due to the ultra-sensitivities of juveniles to declines in physical habitat conditions (Hastie *et al.* 2000a; Skinner *et al.* 2003). Whilst buried in the sediment, juveniles are vulnerable to factors that alter the exchange between the interstitial pore spaces and the stream water which regulates the supply of oxygen and nutrients. Using redox potentials as a proxy of oxygen exchange, Geist and Auswalt (2007) only found juvenile FPMs in areas with little difference in redox potentials between stream water and the substrate. They conclude that poor quality sites (i.e. sites with large difference in redox potentials) with clogged interstitial pore spaces limit the exchange between the interstitial spaces and the stream water. Many of the factors that determine habitat suitability (see Table 2.1) directly or indirectly affect the free-flow of oxygen and nutrient through the interstitial pore spaces. Much work has focussed on determining the factors that impede nutrient and oxygen exchange through the interstices; yet few studies use current knowledge to predict future changes to sites for the FPM that are currently highly suitable, either at a reach or catchment scale.

There is still conflicting evidence as to the relative importance of different physical habitat characteristics in determining habitat suitability for the FPM. However, there is a large body of evidence that suggests substratum type and the presence of fine sediments to be detrimental to both adults and juvenile FPMs alike. Modelling work by Hastie *et al.* (2000a) shows bed substratum to be the best descriptor of habitat suitability for *M. margaritifera*; declines in numbers of FPM were found with decreasing size and increasing homogeneity of substratum. Hastie *et al.* (2000a) also found that boulder dominated substratum with small amounts of sand for burrowing were ideal habitats for juvenile mussels at the 1-10m reach scale and models that used bed substratum to predict FPM prevalence has success rate greater than 75% (Hastie *et al.* 2000a). Such conclusions about substratum made by Hastie *et al.* (2000) from his research in Scotland were replicated in Spain by Outeiro *et al.* (2008) who found mussel populations inhabiting similar substratum conditions, namely sand and gravel river beds. However, unlike Hastie *et al.* (2000), Outeria *et al.* (2008) indicates that proximity to river banks and shade to be significant predictors of mussel locations. These factors were present in Hastie's model, but it is possible that given Spain's higher summer temperatures, Spanish populations are more dependent on riparian shade than their Scottish counterparts.

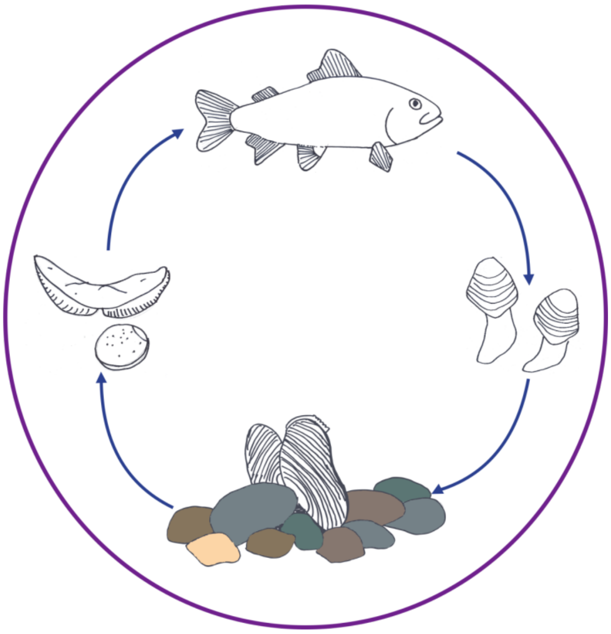

Figure 2.2: Life cycle of the freshwater pearl mussel
Female mussels (1) release larvae (glochidia) (2) which then need to attach to a salmonid host fish (3). After almost a year, the glochidia drop off the host and burrow into the substrate (4). Juvenile mussels reach sexual maturity at approximately 10 – 15 years old.

Österling *et al.* (2010) examined 24 FPM populations and found increases in turbidity and suspended sediment concentration were responsible for 58% of the recruitment failure and that the age of the youngest mussel was positively related to suspended sediment and turbidity. It has been documented that in highly turbid environs, adult mussels 'clam up' to prevent ingestion of high concentrations of suspended particulate matter, since this also prevents the mussels feeding. It is predicted that this could have detrimental effects growth rates, although this has not been empirically studied (Cooksley 2011, pers. comm.). Research on other species of freshwater mussel, including other member of the *Margaritifera* species, continues to highlight the significant effect of substratum type on mussel occurrence, with fewer mussels found in areas of smaller sediment size (Brainwood *et al.* 2006; Akiyama and Maruyama 2010) and the need for temporally stable substratum (Johnson and Brown 2000; Stone *et al.* 2004)

However, eutrophication and declines in water quality are also reason for reduction in mussel populations, and maximum concentration of nitrogen, phosphorus and calcium have been suggested (Table 2.1). Bauer (1988) found increasing level of biological oxygen demand (BOD), phosphate and calcium were negatively correlated with juvenile survival, although this research also indicates that since fertility persists once the pollutants are removed, recruitment should reoccur. This contrasts with the effects of excess sedimentation that causes mortality. Acidification of rivers can directly affect FPM population or indirectly through reduction in number of host fish (Degerman n.d); whilst some FPM populations have been reported in rivers with pH value as low as 5 or as high as 7.7, tolerable limits are thought to be pH levels of 6.2 to 7. Eutrophication as a result of increased phosphorus and nitrogen levels leading to increase in algal growth is thought to impede nutrient and oxygen exchange through the interstitial pore spaces (Moorkens 1999) and algal mats are thought to impede adults mussels feeding and the release of glochidia (Hastie *et al.* 2000b).

Environmental Parameter	**Effect on FPM's**	**Ideal Conditions**
Temperature	Higher water temperature leads to increased growth rates (Hruska 1992) Increased growth rate downstream, reduced growth rate upstream (Altnoder 1926; Wellman 1939) Growth related to latitude (Bauer 1992)	Shade: 60-100% (Moog *et al.* 1993)
BOD	Increased levels of BOD leads to decreasing survival rates of juveniles (Bauer 1988)	N/A
Flow rate	Flow rates high enough to remove sand leads to an inability of juvenile mussels to burrow (Purser 1985) Very fast rivers are too torrential for mussel survival (Young and Williams 1983; Hastie and Boon 2001) Flow is very important for FPM's, specifically flow at siphon levels, to allow gravel cleaning and food circulation (Killeen 2013)	Flow Rate: 0.25-0.75 m/s (Björk 1962; Hastie *et al.* 2000a) River Depth: over 0.5 m (Hendelberg 1960)
Substratum	Higher densities found where substrate have greater cover of cobble and gravel, thought to stabilise the substrata especially in times of flood (Young and Williams 1983; Purser 1985; Strayer and Ralley 1993; Chesney and Oliver 1998)	Areas of coarse sand and gravel, stabilised by large cobbles/boulders make ideal FPM habitat
Water Hardness/ Conductivity	Higher calcium ion concentrations (or increased water hardness) found in non-mussel rivers in comparison to mussel rivers (Björk 1962; Purser 1985; Lucey 1993; Beasley and Roberts 1996) High conductivity also indicative of pollution (Buddensiek 1995)	Conductivity: < 10 mS/m (Degerman n.d)
Eutrophication	Enrichment, particularly in the form of nitrogen and phosphorus, is detrimental to mussel success, (Bauer 1986, 1992; Valovirta 1998) FPM's often found in areas with little or no aquatic vegetation (Björk 1962)	Phosphorus: 15 micrograms/l in Sweden;(Lundstedt and Wennberg 1995; Söderberg 2008) <30 micrograms/l in Britain (Skinner *et al.* 2003) <5 micrograms/l in Ireland (Moorkens *et al.* 2007) Overall guideline of <10 micrograms/litre Nitrogen: 1 mg/l (Degerman n.d)

Environmental Parameter	Effect on FPM's	Ideal Conditions
Siltation	Siltation inhibits burrowing, clogs siphons and prevents interstitial nutrient and oxygen exchange (Buddensiek 1995; Arbuckle and Downing 2002) Turbidity higher in reaches without mussel recruitment (Arvidsson *et al.* 2006) Juveniles only found in areas with high redox potential in the substrate (Killeen 2013)	Turbidity: 1 FNU (Söderberg 2008) Proportion of fine grained inorganic material at bottom should be less than 25% in order for juvenile to survive (Ulvholt 2005; Österling 2006; Geist and Auerswald 2007) Redox losses at 5cm depth (Killeen 2013) <20% - good; 30% - declining; 35% - poor
Land Use	Higher mussel densities found in catchments with little human modification to channel bed or adjacent vegetation (Arbuckle and Downing 2002; Brainwood *et al.* 2006) Agriculture tends to lead to increased erosion and siltation (Arbuckle and Downing 2002) Physical habitat modifications have cause loss of FPM populations, such a pipe laying, bridge supports, channel realignment (Young and Williams 1983; Cosgrove and Hastie 2001)	

Table 2.1: Habitat requirements and recommendations for the freshwater pearl mussel.

Some research has posited that the presence of mussels in areas of rivers shaded by riparian vegetation is due to the reduction in the growth of algae in these areas; moreover, the presence of mussels in rivers with high flow rates is also thought to be due to the absence of filamentous algal cover in addition to reduce sedimentation compared to low flow areas, particularly in summer (Skinner *et al.* 2003). However, Buddensiek (1995) suggested that declines in water quality might favour juvenile mussels (who are pedal feeders until they reach approximately 4mm in size) by providing more food. Research in Spain which identified the presence of riparian vegetation and proximity to bank positively correlated with FPM presence but provide an alternative explanation for this (Outeiro *et al.* 2008). They suggest that the presence of FPM in such areas mimics the behaviour of juvenile salmonids that use shaded areas close to riverbanks to hide from predators; adult mussels in these areas are therefore more likely to have successful glochidial encystment.

The dependence of the FPM to a salmonid host for successful recruitment coupled with the decline in habitat for salmonids could be a factor in the corresponding decline in FPMs (Hastie and Cosgrove 2001). Research by Österling *et al.* (2008) indicated a tenuous link between host density and recruitment success by showing that juvenile density was positively related to glochidial trout encystment but also showed that mean glochidial infection did not differ between streams containing recruiting and non-recruiting populations. In later work by the same authors, trout density was not shown to be significantly different between recruiting and non-recruiting populations and there was no relationship found between trout density and the age of the youngest mussel (Österling *et al.* 2010). Hastie and Cosgrove (2001) comment that the pearl mussel-fish relationship may be symbiotic and certainly environmental parameters that provide suitable habitat for freshwater pearl mussels also provide suitable areas for salmonid breeding grounds (i.e. filter feeding adult mussels could prevent sediment deposition on salmon redds). Additional work by Hastie and Young (2001) investigated differences in glochidial infections between farmed and wild salmonid stocks in Scotland. It was found that older fish are less susceptible to infection than younger fish. There are numerous hypotheses that explain the difference in glochidial encystment between different age classes of fish. Behavioural differences affect where older and younger fish are found; younger fish are more often found in shallow riffles near mussel beds (although the depth at which mussels are found is dependent on whether the stream freezes during winter (Hendelberg 1960; Gittings *et al.* 1998; Valovirta 1998; Bauer 1987b; Cunjak and McGladdery 1991). In some Irish and Scottish streams, the older fish migrate and are not present when glochidia are released (Young and Williams 1984). However, the most widely accepted view is that older fish have an acquired immune response from previous infections which causes fish who have previously been infected with glochidia to reject encysted glochidia from a second infection, since glochidia have been shown to attach readily to older fish (Karna and Millemann 1978; Meyers *et al.* 1980; Young and Williams 1984; Bauer 1987a; Zuiganov *et al.* 1994). Hastie and Young (2001) also show that initial infection rates may be higher in older larger fish with greater gill surface area but that only approximately 5-10% of glochidia that were initially infected managed to metamorphose into juvenile and excyst successfully. Therefore, in water bodies with reduced salmonid recruitment the increased proportion of old to young fish may negatively affect glochidial encystment and hence FPM recruitment. If nothing else, this highlights the need of FPMs for high number of host fish and high production of glochidia to ensure successful recruitment to the juvenile stage.

2.3 Impacts on Habitat Suitability for Freshwater Pearl Mussels

At the catchment scale, much of the decline in suitable habitat for the FPM can be attributed to changes in land use and river management practices, leading to a decline in nutrient and oxygen exchange within the interstitial pore spaces of river bed substrate. Moorkens (1999) details twelve threats to the FPM in Ireland, and eight of these are related to land use change that increase eutrophication or sedimentation of rivers (leading to lower survival rates for juvenile mussels and fish species) or involve direct habitat destruction. For example, physical modification of rivers (for example river engineering works) have been attributed to the declines in 25 FPM population in Scotland (Cosgrove *et al.* 2000). River dredging not only destroys habitat, but removes entire mussel beds (Killeen *et al.* 1998) and hydroelectric schemes have also been shown to be detrimental to FPM populations as a result of the need to regulate flows (Zuiganov *et al.* 1994).

Extensive clearing of bankside vegetation connected with urbanisation or intensive agriculture has been associated with river reaches with no mussels, corroborating other studies in North America which found the same relationship (Arbuckle and Downing 2002; Brainwood *et al.* 2006). Rivers draining a higher proportion of agricultural land with narrower riparian margins have been shown to support far smaller mussel populations than rivers draining less agricultural land, where the distance between the river and any agricultural land is greater (Outeiro *et al.* 2008). Research by Arbuckle and Downing (2002) investigated the factors affecting mean mussel density and species richness in an agricultural setting and found a significant correlation with mean slope within the catchment, which led to greater sedimentation and bed instability.

The current body of literature as regards optimal habitat conditions for the FPM shows the importance of maintaining exchange through the interstitial pore spaces and indicates that excess sedimentation and eutrophication both contribute to blocking these pore spaces. Both eutrophication and sedimentation of waterways are inextricably linked; often the mobilisation of sediment exacerbates the transport of nitrogen and phosphorus (key chemicals involved in eutrophication of waterways) into the water column. Sedimentation is detrimental to each stage of the FPM life cycle and that of the salmonid fish upon which the FPM depends during the parasitic life cycle stage. Furthermore, anthropogenic actions are responsible for much of the sedimentation that is moved into watercourses through actions such as forestry, road building and agriculture (Waters 1995). Measure to reduce sediment influx may also have a preventative effect on eutrophication and at the same time have an economic impact by maintaining productive soils. Furthermore, implementing measures to reduce sediment mobilisation would facilitate better habitat conditions for FPMs. Despite the indication that catchment scale land management can directly affect the suitability of rivers for the FPM, few (if any) studies have investigated the impact of future changes to land use as a consequence of a changing climate, on habitat suitability for the FPM. Moreover, little research has quantitatively assessed the impact of changing land uses on potential habitat degradation for the FPM.

2.4 Land Use Controls of Erosion Processes

In the literature pertaining to soil erosion processes, the link between vegetative cover and vulnerability to erosion is well documented. Land under agricultural use is widely accepted as being vulnerable to erosion, because of the lack of continuous ground cover year round in comparison to forest or grassland, both shown to have low erosion risk (Le Bissonnais *et al.* 2002); moreover the most productive soils often have high silt content and are thus more easily eroded (Bakker *et al.* 2008). Plot scale experiments across Europe indicate that sheet and rill erosion rates are highest on bare land, followed by vineyards and then other agricultural lands; land under permanent cover show soil losses of up to an order of magnitude lower than arable land (Cerdan *et al.* 2010). Cerdan *et al.* (2010) estimate erosion rates of 1.2 t ha^{-1} a^{-1} across the whole European area; however on arable land the rate increases to 3.6 t ha^{-1} a^{-1}. In the UK, erosion rates on agricultural fields in England and Wales are estimated as between <1 $t\text{-}^{1}$ ha^{-1} a^{-1} (DEFRA 2009) to > 20 $t^{-1}h^{-1}$ a^{-1} on some vulnerable soil types (Evans 2002). In Scotland, rates in excess of 80 t^{-1} ha^{-1} yr^{-1} have been reported (SEPA 2001; Towers *et al.* 2006) although the average erosion rate is 1-2 t^{-1} Ha^{-1} a^{-1}.

The literature consistently agrees that the major influence on soil erosion rates over the recent past have been the rapid and large scale changes to land use, in particular agricultural land. Increases in agricultural drainage or farming intensity, moves from spring to autumn planted crops (thereby leaving bare soil in periods with most rainfall), and the type of crops planted (crops that need irrigation, increasing soil saturation, leading to higher erosion rates) are some of the reasons behind the continuing upward trend of soil erosion (Boardman and Favismortlock 1993; Böhm and Gerold 1995; Pimentel *et al.* 1995; Naden and Cooper 1999; Yang *et al.* 2003; Cebecauer and Hofierka 2008). Livestock grazing has also been identified as a cause of increasing erosion. Work by McHugh (2007) on upland areas in the UK shows that on sites where erosion was not occurring, the mitigating factor was the re-vegetation of previously bare soil.

Topography also plays a key role in soil erosion processes, which is of particular consequence to the FPM since they are most often found in upland reaches. However, topography appears to be somewhat secondary to the effects of current land use changes when comparisons are made between areas of similar elevation (Böhm and Gerold 1995; Pimentel *et al.* 1995; Fu *et al.* 2000; Asselman *et al.* 2003; Cebecauer and Hofierka 2008; Bartley *et al.* 2010). Cerdan *et al.* (2010) note that erosion rates on arable or bare land are related to topography but that this relationship is not as pronounced on land with permanent cover. When the extent of forested land is increased alongside a decrease in the slope of land used for farming, erosion rates decrease (Fu *et al.* 2000). It has been suggested that a spatial pattern of farmland – grassland – forest from valley to hill top would provide some measure of erosion protection (Fu *et al.* 2000), but this landscape pattern would ensure that the agricultural land was nearest to the river, which as previously discussed, was found to be detrimental to FPM populations. Such recommendations may be good advice in regions where economic pressures mean that agricultural practices (particularly arable farming) are being expanded to include areas of steeper topography. Research by Descroix *et al.* (2001) indicates that in mountainous areas, soil erosion and runoff can also be linked to stoniness, with rock fragments able to absorb the rain splash energy and lessen runoff. However this research took place in an arid upland region on Mexico, the result may not be applicable to UK upland regions where the soil moisture and vegetative cover is higher. Other industries such as forestry and construction also contribute to soil erosion; in the UK the literature suggests that these are less of a widespread issue and on a lesser scale and yet despite this, forestry operations, land drainage and road building are cited by Moorkens (1999) as significant threats to the FPM in Ireland.

2.5 Climate Change Impacts on Soil Erosion Rates

There is much evidence to suggest that where the predicted changes to climate involve increased temperature and rainfall, current rates of soil erosion will increase (Favis-Mortlock and Boardman 1995; Pruski and Nearing 2002a; Nearing *et al.* 2004; O'Neal *et al.* 2005). This has implications for food security and soil productivity (POSTNote 2006; Gong *et al.* 2013), carbon sequestration in soils (Lal 2003, 2004) and aquatic ecosystems and species like the FPM, since soil erosion has been identified as a major non-point pollutant of aquatic ecosystems (Skinner *et al.* 1997; Evans *et al.* 2006a). Predictions of increasing magnitude and intensities of rain events have been shown to cause increases to soil erosion rates (Favis-Mortlock and Boardman 1995; Favis-Mortlock and Guerra 1999; Nearing 2001; Pruski and Nearing 2002a; Nearing *et al.* 2005); conversely, climate scenarios where decreases in rainfall are predicted show a corresponding decrease in erosion events (Mullan *et al.* 2012). High intensity rainfall events, predicted to become more frequent, have also been shown to be highly erosive and can contribute a disproportionate amount to overall sediment yields (Ziadat and Taimeh 2013). Edwards and Owens (1991) examined 4,000 rainfall events over a 28-year period and reported that five events were responsible for 66% of the total erosion over the study period. Studies comparing the effects of climate variables (precipitation, temperature and CO_2 levels) have shown that whilst all three are implicated in changing erosion rates, it is precipitation levels that have the largest direct effect (Chaplot 2007; Ficklin *et al.* 2010). However, these studies focussed on relatively low elevation agricultural catchments in the USA and Spain, where the effect of snow melt is negligible. Studies conducted in Iceland in a region which has seen little anthropogenic land use change over the study period show that it is the temperature signal which controls the annual melt season which is the driver of erosion and river sediment loads (Lawler and Wright 1996). A critique of these studies is the scale of the work; few studies look at the catchment scale effects of changing climatic and land use conditions. Most focus on agricultural areas due to the economic importance of maintaining productive soils and few linkages are made to the potential off-site implications of increasing erosion rates, as found in Evans *et al.* (2006b) who linked catchment erosion rate to sediment delivery as part of an integrated project to increase habitat quality in relation to sediment supply.

Climate change is also believed to have indirect effects on erosion rates (Favis-Mortlock and Savabi 1996; Pruski and Nearing 2002a, b). Such indirect effects include: the increased growth of plants as a result of higher CO_2 levels and temperatures which in turn lead to increases in growing days and length of growing season (Boardman and Favismortlock 1993; Clark *et al.* 2010); and land use changes which can result in previously unsuitable land becoming agriculturally productive or changes to the type of crop being grown (Boardman and Favis-Mortlock 1993; Cebecauer and Hofierka 2008; Maeda *et al.* 2010). Land growing arable crops is shown to be most susceptible to erosion due to large variations in coverage throughout the year and tillage practices which actively increase organic matter decomposition thus reducing the soil's binding capacity and making it more susceptible to erosion by water, especially in hilly areas (Bryan 2000; Van Oost *et al.* 2000). Edwards and Owens (1991) showed that 92% of erosion from crop-rotated fields occurred during corn years with the remaining 8% in wheat years and little or no erosion when the field was left as meadow land. Whilst Owens and Walling (2002) were unable to find a connection between sedimentation rates and weather patterns in their study in the River Tweed, they did connect the introduction of land drainage, the conversion of grassland to arable to changes and afforestation to both increasing and decreasing erosion patterns. As temperatures increases so does the altitudinal limit at which crops can be cultivated (Boardman and Favismortlock 1993); in the UK this could mean that current areas of grassland may be replaced with crops on hill slopes in upland catchments. Given that erosion rates are highest in areas of steepest topography (Asselman *et al.* 2003; Cebecauer and Hofierka 2008; Maeda *et al.* 2010), growing cereals in fields with ever-increasing slope is likely to exacerbate soil losses from erosion.

Since rivers are the major conduit of eroded materials (Milliman and Meade 1983; Milliman and Syvitski 1992), work has been done to link suspended sediment loads of rivers with catchment erosion rates. A study by Ward *et al.* (2009) investigated multiple impacts on sediment loads within the Meuse catchment using historical data and climate change projections, with suspended sediment yield as a proxy for erosion. The results replicate that of previous research into climatic impacts on terrestrial erosion rates; namely that land use has a significant effect on sediment yields which can often be greater than the climate change signal. The importance of assessing both climate and land use impacts on erosion rates is vital in order to accurately reflect the full range of possible futures.

2.6 Climate Change Impacts on the Freshwater Pearl Mussel

Future climate scenarios based on changes to temperatures and precipitation levels may have a range of impacts on the FPM, and the evidence is not conclusive as to whether or not climate change will be detrimental to the FPM (Hastie *et al.* 2003). However, there has been little work conducted using climate change predictions to quantitatively assess how impacts such as increasing terrestrial erosion might affect habitat quality for the FPM. Much of the current thinking is based on mussel recruitment rates and the association with wet/dry and warm/cold years and direct impacts, such as mussels being washed away by high river flow rates (Hruska 1992; Mackie and Robert 1995; Hastie *et al.* 2003); however this fails to take into account catchment-wide responses to climate change predictions. The detrimental effects of the mobilisation of fine sediment to the FPM in combination with the likelihood of increased erosion rates than in regions of the UK still able to support FPM populations (as a result of current prediction of increasing precipitation levels) indicates unfavourable condition for the FPM in the future. Identifying current erosion hotspots and assessing how these would react to predicted changes to rainfall and temperature would allow an assessment of risk to the FPM, leading to early preventative interventions where appropriate.

2.6.1 Predicting Soil Erosion

Early attempts to parameterise erosion process for use in a modelling approach resulted in the USLE and updated RUSLE (Wischmeier and Smith 1958a,b, 1961, 1978). These equations were however based on soil characteristics and erodibility data from the USA and were not designed to be used on European soils. More recent models such as EUROSEM (Morgan *et al.* 1994), WEPP (Nearing *et al.* 1989), and LISEM (De Roo and Offermans 1995) explicitly incorporate some physical mechanisms of soil erosion (which USLE and RUSLE do not), but they tend to be limited to single rainfall events at field scale (De Roo and Offermans 1995; Morgan *et al.* 1998). They also require very specific data sets on soil type and topography, making them difficult to employ at catchment scale (Pieri *et al.* 2007; Kirkby *et al.* 2008; Licciardello *et al.* 2009). The Pan European Erosion Risk Assessment (PESERA) model is one of the few erosion models capable of predicting erosion rates at the catchment scale under different land use and climate change scenarios (Kirkby *et al.* 2008).

The PESERA model is a physically based soil erosion model which separates precipitation into monthly precipitation (including snow) that drives soil saturation and daily storm events that drive infiltration overland flow (runoff) and directly affect erosion rates (Figure 2.3) (Kirkby *et al.* 2008). The runoff threshold used to determine when runoff occurs is influence by both soil type and vegetation and runoff is represented by the processes of sheet and rill wash since these are the dominant processes in severe erosion events (Kirkby *et al.* 2008). Consequently, tillage erosion and rain splash are not considered within the PESERA model (Irvine and Kosmas 2007). PESERA uses mathematical equations to represent the physical parameters that affect soil erosion (Kirkby *et al.* 2008). As such, the model gives a snapshot in time of the erosion risk of a site which is representative of the input data and is adaptable to allow future scenarios to be evaluated (Kirkby *et al.* 2008).

Low frequency climate perturbations are used to derive baseline seasonal water balances and soil moisture deficits with inputs from vegetation and land use. Daily overland flow is estimated from excess rainfall above the runoff threshold and is therefore the connection between land use data and soil type and erosion (Kirkby *et al.* 2008). In PESERA the eroded soil is assumed to be travelling downslope and a major assumption of the model is that within each spatial unit there is a waterbody that the eroded material is directed towards (Baggaley, 2011, pers. comm.). Despite evidence to suggest that increased resolution would lead to better predictive output, care must be taken that the resolution does not increase to such an extent where this assumption is violated (Baggaley *et al.* 2010).

It has been recognised that the PESERA model has underestimated erosion at plot and catchment scales. It has been postulated that this is due to the inability of the model to account for individual storm events, which have been shown to significantly affect erosion (Tsara *et al.* 2005). Further research in the Mediterranean highlights the effect of bare soil within the PESERA model, in one example bare land accounted for 69% of the total sediment estimate for the catchment despite the area of bare soil accounting for only 15% of the total land area (Tsara *et al.* 2005). Since tillage erosion is not included within the model, landscapes that include vineyards have been shown to induce high errors into the PESERA model specifically due to the method of contour ploughing which can restrain runoff after ploughing (Tsara *et al.* 2005). One of the criticisms of the PESERA model is also one of its benefits; the reduced quantity of input data needed by its very nature can reduce the accuracy due to a 'one size fits all' approach in a model that was expressly designed to map erosion for the entire European Union, a vast area made up of distinctly different land use, soil type and precipitation regimes. However models with large volume of data input are time-consuming to run and can be overly specific to a spatial or temporal extent (Leavesley 1994). The PESERA model overcomes these difficulties by being fundamentally an erosion risk assessment model. Not only does this remove the need for validation but also smooth's over erroneously high or low yearly erosion values by allowing the user to highlight areas of high and low risk (Baggaley, 2011, pers. comm.) It appears that overall, the PESERA model is adept at predicting annual spatial variability of erosion and runoff over a range of climatic and land use variations, however short-term variations are not well captured (Licciardello *et al.* 2009). It seems that PESERA is useful for highlighting possible future erosion changes on spatial scales above 100m but the model tends to over and under estimate erosion at the extremes (Baggaley, 2011, pers. comm.).

In the United Kingdom, Baggaley *et al.* (2010) modelled soil erosion using PESERA on a 140 km^2 intensively arable catchment in east Scotland and evaluated the subsequent erosion predictions under different resolutions of input data. The resolution of the DTM used for the topographic component was found to be a significant limiting factor in prediction accuracy. Additionally, changing the precipitation input from a 30 year average to data from specific years showed large changes to the outputs, indicating that the PESERA model is sensitive to rainfall peaks and soil moisture deficits. The authors conclude that PESERA is able to predict soil erosion under different climate scenarios, but only if geospatial input data are available with sufficient resolution. For example, Baggaley *et al.* (2010) showed that the optimum combination was soils data at the 1:25,000 scale in combination with 100 m^2 resolution topographic data; the resulting soil erosion risk maps gave much more accurate spatial resolution of the erosion risk within the study area. Tsara *et al.* (2005) used the PESERA model to predict soil erosion in a 0.6 km^2 catchment in Greece, predominated by arable land, specifically winter wheat. Overall the findings indicated that PESERA provided satisfactory predictions of soil erosion in the study area, for use in a preliminary assessment. However, the model overestimates erosion in vineyards, likely as a result of contour ploughing which reduced surface runoff. The model also overestimated soil erosion in the wheat fields during winter with full cover because the cover values within the model are too low for a Mediterranean climate (Tsara *et al.* 2005). In Spain the PESERA model has been compared with other soil erosion models (*e.g.*, WATEM-SEDEM and SPADS) (de Vente *et al.* 2008). The study validated the modelling results using long-term sedimentation rates for 61 reservoirs, most of which were located along Spain's dry Mediterranean coastline. Both WATEM-SEDEM and SPADS outperformed PESERA in terms of accuracy, with PESERA consistently underestimating soil erosion for Mediterranean conditions. But the authors note that erosion processes which are not explicitly included within PESERA, such as gully-river channel erosion, may be important in this region, and this may explain the discrepancies within the PESERA predictions.

Since PESERA does not route eroded material through the river network, its use in predicting reservoir sediment would be limited, again acknowledged by the authors (de Vente *et al.* 2008). Licciardello *et al.* (2009) took a different approach and used plot scale data to evaluate the hydrological and erosion components of PESERA separately in the Netherlands (replicated plot areas of 40 m^2) and Italy (replicated plot areas of 20 m^2), each with different land use and climate characteristics. Despite finding that the model both over- and under-estimated runoff (at low and high rates respectively) and underestimated erosion rates 84% of the time (during months of observed low erosion rates), the authors note that the annual aggregate erosion and runoff rates do reflect the magnitude and spatial variability of soil erosion across the study sites. One reason postulated for the reduction in accuracy at the monthly temporal scale is that the daily time step used in precipitation data does not capture short-term rainfall events which modulate summer erosion event within the study areas. Finally, Esteves *et al.* (2012) used PESERA to evaluate conservation strategies for land degradation as a result of wildfires, in two fire prone regions of Portugal. This research modified the PESERA model to allow the inclusion of a fire ignition model within PESERA. The results indicate that PESERA has the potential to be modified in order to capture the episodic nature of wildfires which are unlike the regular agricultural cycle upon which the model is currently based. In its current state, the PESERA model predicted higher losses than were observed across all burning scenarios.

Whilst the literature agrees that PESERA is capable of reflecting the temporal and spatial distribution of erosion events (Baggaley *et al.* 2009; Licciardello *et al.* 2009), it is by design a risk assessment model and best suited to highlighting regions likely to be vulnerable to soil erosion under the conditions input into the model. Furthermore, it provides catchment scale modelling without the need for extensive input data sets, allowing local and national data to be combined and used comparatively easily. As such PESERA is an ideal tool for assessing erosion risk and investigating catchment response to changing climate and land use conditions. This is particularly relevant given the lack of extreme climatic or land use conditions present in the UK; the identification of erosion hotspots can then lead to targeted control measures.

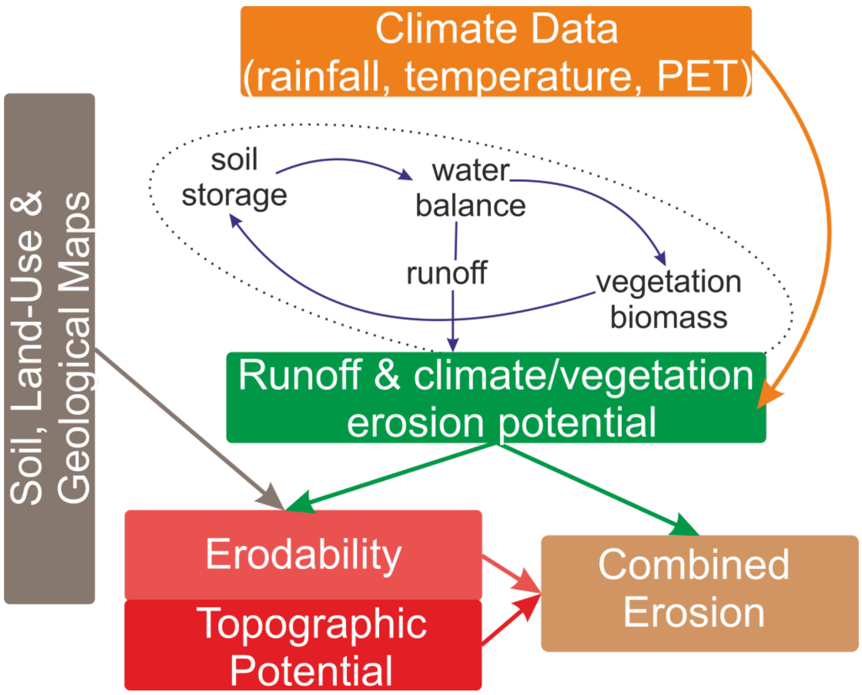

Figure 2.3: Schematic of PESERA model, showing inputs required to model erosion risk (Irvine and Kosmas, 2003)

2.7 Current Management for the Freshwater Pearl Mussel

Current approaches to the management of the FPM vary across the UK. In some regions, for example Scotland, the location of FPM population is confidential in an attempt to prevent illegal poaching. In other areas, such as the Shropshire Hills Area of Outstanding Natural Beauty (AONB) in England and the Balinderry Catchment in Northern Ireland, much work is done within the local community to foster greater understanding of the importance of the FPM in order to gain greater support for any conservation initiatives. In all examples, management work focusses on the enhancement of current habitat, focusing on water quality and physical habitat requirements of the FPM. Such approaches are supported at the regional and national scale by legislation, namely the Water Framework Directive. The Integrated Catchment Management (ICM) approach adopted within the WFD recognises that the catchment is a complex system made up of many different resources that interact (Bowden 1999) and provide many goods and services, from the more tangible goods such as freshwater provision, to elements linked to human health and wellbeing (Parkes and Panelli 2001). ICM is often issue driven and examples of an integrated approach focussing on the issue of habitat degradation as a result of excess sediment mobilisation within catchments include Ireland (Evans *et al.* 2006b) and Belgium (Verstraeten *et al.* 2002). In both examples, an integrated approach is used to identify the sediment sources which then allows the most appropriate solutions to be implemented. In Evans *et al.* (2006) the need for management was the decline in salmon numbers whereas in Verstraeten *et al.* (2002) the driver was soil loss from agricultural areas. However, neither example includes a social dimension into the process.

Both Evans *et al.* (2006) and Verstraeten *et al.* (2002) deal with issues surrounding soil erosion that are easily understood by the public; salmon is a familiar river fish species and economically as well as environmentally important and soil loss has consequences for food production and therefore local and national economies as well. With less familiar species such as the FPM whose contribution to the ecosystem goods and services of freshwater systems are less obvious, little is known about how accepting the public might be towards conservation measures needed to support such species. Coupled with a lack of understanding about the attitudes held by the public towards rivers as a landscape feature, it is difficult to predict how successful such an approach would be if the 'issue' driving management was the conservation of the FPM.

2.8 Public Attitudes towards River Conservation

The detrimental impacts of soil erosion processes can be constrained or alleviated by mitigation measures, such as re-planting riparian buffer strips. That DEFRA has produced guidance for the agricultural sector on how to minimise soil erosion and conservation agencies in the UK, such as Natural England, have schemes in place to subsidise such measures, indicates the importance of preventing soil erosion for both ecological and economic reasons. Furthermore, 78% of the UK public surveyed by DEFRA purport to being concerned about changes to the British countryside and losses of native animals and plants (DEFRA 2011). It is clear that public acceptability of any measures to combat soil losses is important, for several reasons: firstly, in deciding whether public money should subsidise the conservation of the FPM (i.e. a democratic or normative rationale); secondly, whether or not local schemes are implemented, and how these scheme would be implemented (i.e. an instrumental rationale); thirdly, in including public opinion in the decision making process (i.e. a substantive rationale) (Fiorino 1990). Increasingly public participation is viewed as crucial to the success of ecosystem restoration projects but a corresponding lack of knowledge surrounding how the public make value judgements in the case of biodiversity issues means questions have been asked about the efficacy of public engagement processes (Fischer and van der Wal 2007).

The values of water within the landscape can be broadly classed as: functional (i.e. related to the services rivers provide such as drinking water or irrigation (Gibbons 1986; Turner *et al.* 2004; Dalrymple 2006); cultural (i.e. traditional uses of water, in particular as a method of maintaining a link with historic practices (Buijs 2009; Birckhead *et al.* 2011) and aesthetic (i.e. the visual appearance of rivers and the associated landscape, influenced by both a person's background and use of the area (Kaplan 1977a; Shafer Jr and Brush 1977; Kaplan *et al.* 1989). It is impossible to regard these a three distinct values, each is interwoven in the other, for example the functional value of providing food is often intertwined with cultural aspects of how and where to fish, which is also likely to be intrinsically connected to the appearance of the riverscape.

In general, public attitudes towards river conservation are positive (Buijs 2009), but the implications of these values and attitudes for river conservation and watershed management are that public engagement at both the community and stakeholder level is vital (Tapsell *et al.* 1997; Eden *et al.* 1999; Tunstall *et al.* 2000): to avoid situations in which the management options used alter the perceived value of the river (Nassauer *et al.* 2001) and even undermine the ecological outcomes of the project (Spink *et al.* 2010). Visual attractiveness , water quality improvements and habitats for wildlife have all been shown to be important to communities in the midst of river management projects (Wagner 2008) and management options that are seen as 'balanced' or 'natural' are generally preferred (Fischer and van der Wal 2007). Fundamental changes in the perceived aesthetic, cultural or functional values of the landscape in question can disengage the public with the area and reduce the 'value' of the river (Wester-Herber 2004; Buijs 2009).

Research from the USA shows that in communities facing river management strategies, the more important values of the proposed schemes were water quality enhancement and habitat for wildlife (Wagner 2008). This implies that management strategies that are understood for their benefits to both humans and nature may be well-received, especially if they improve the 'naturalness' or aesthetic appeal of the environment in question (Fischer and van der Wal 2007; Wagner 2008). In light of the aesthetic value placed on riverscapes, the gap between scientific evidence and public perception can be large, as demonstrated by Chin *et al.* (2008) with respect to woody debris in rivers. The lack of understanding of the ecological value of wood in rivers is revealed by a majority of negative opinions about wood in rivers but the evidence suggests that education can alter people's views dramatically (Wyzga *et al.* 2009). Whilst this example focuses on woody debris it is likely that, given the importance of knowledge in assigning risk factors to ecosystems (McDaniels *et al.* 1995, 1996; McDaniels *et al.* 1997; Lazo *et al.* 2000) information or education could alter people's perceptions with regards to conservation and management needs. With the exception of woody debris, work by Junker and Buchecker (2007) shows that in general, the public perception of an aesthetically pleasing river and its perceived 'naturalness' is positively related to the river's improved ecological and morphological status, from a scientific perspective. These results also show that aesthetically pleasing scenes and the 'naturalness' of the river are intrinsically linked from a lay-person's perspective. However, Junker and Buchecker (2007) did not specifically look at key elements like woody debris, that are often perceived by a lay audience as being dangerous, thus giving rise to a negative feelings towards its presence (Wyzga 2009). Similar work showed that colour (both quantity and variety) and the absence of bare ground are also key to fostering a positive opinion of restoration projects (Hands and Brown 2002).

In general, research has shown that residents exhibit higher levels of concern and place greater importance on their local environment (Brody *et al.* 2004). What constitutes the 'local environment' oftentimes is that which is local to the individual (Catton and Dunlap 1978) and the perception of risks are also increased when the risk is deemed to affect the individual (Slovic *et al.* 1984). Local residents have been shown to use local natural amenities more; similarly, enhancing place-based experience and familiarity and place attachment (the emotional ties to a place, in part determined by long-term connections to the place (Altman and Low 1992) has been shown to enhance local environmental values (Vorkinn and Riese 2001). In studies that investigate the relationship of place attachment to local environmental concern, proximity to particular environmental features has been used as a measure of place attachment; proximity to water body has been shown to be a significant predictor of both familiarity and levels of knowledge about the environmental issues facing rivers (Brody *et al.* 2004). However, research by Halpenny (2006) also shows that localised environmental concern as a result of place attachment can spill over into general environmental concern. It is unclear if proximity influences increases in familiarity and knowledge, or vice versa, for example birdwatchers travel to specific locations to view a migratory bird, instigating a level of place attachment and increasing their sense of their 'local environment'. Therefore, a measure of proximity may prove useful to assessing knowledge and familiarity of river habitats.

There is often a disparity between scientific consensus and lay- person knowledge of habitats which leads to a difference in risk perception in relation to environmental threats. In research on the public perceptions of forest health by Patel *et al.* (1999), the issues most frequently mentioned were those that had direct implications for human well-being, for example air pollution and water quality. Little work has been done to examine perceptions of threats to freshwater ecosystems but in the marine context, public opinion is dominated by oil and sewerage pollution (Jefferson 2010). In both these examples the consequences have a clear (i.e., visible) cause and effect that is easy for the non-expert to identify. More complex issues such as biodiversity loss, or habitat fragmentation are more challenging to comprehend and often appear to be invisible to the public (Nassauer 1992). Whilst the literature is clear that rivers are a valued landscape feature, what is less clear is what components contribute to such value judgements about rivers. Additionally, little work has been done to assess the relative value of rivers in comparison to other landscape features, such as mountains or beaches.

2.9 Public Perceptions of Species

The policy backdrop of species and habitat conservation is based on ecosystem biodiversity, with legal designation (for example Special Protection Areas, Special Areas of Conservation and Sites of Special Scientific Interest) underpinned by the presence of threatened plant, animal or bird species or the habitats that support them. However, research based on the US Endangered Species Act highlights a correlation between legal protection and species charisma (Getzner 2002). This is in part due to the need for public support which is most often associated with aesthetics, human-like characteristics or high levels of familiarity (Kellert 1996).

2.9.1 Values associated with species

At a species level, species that elicit fear, irrational or otherwise (e.g. spiders), are perceived less positively (Knight 2008) than charismatic species upon which human characteristics can be conferred. Whilst the FPM is unlikely to elicit fear since it poses no threat to human health and is senescent, it is relatively unknown. In part this could be due to population declines reducing familiarity, but the actions of conservation agencies who deliberately keep the locations remaining UK FPM populations confidential have also helped to relegate this species into the unknown for much of the UK general public. As such it is difficult to assess how acceptable the public are of initiatives to support the FPM; little research has been undertaken to identify public perceptions of uncharismatic and unfamiliar species such as the FPM that would not be expected to elicit any extreme emotional response, either positive or negative. However, anecdotal evidence suggests that high levels of place attachment to one's local river may develop into feelings of pride in the presence of a rare and endangered species (Kelly 2011, pers. comm.).

During choice experiments with lay-persons, funds have been allocated to familiar species that were often least in need of support (Tisdell and Wilson 2006). This presents a difficult situation for conservation bodies that equally have a duty to protect unfamiliar and un-charismatic species as well as more familiar and charismatic ones. However, this is not a consistent finding. In work done by Czech and Kaussman (1999), despite taxonomic preferences for birds, mammals and plants at the expense of invertebrates and microorganisms, the most important factors in determining conservation importance were deemed to be ecological importance and rarity.

2.9.2 Species Knowledge

Knowledge can be a key factor in lay-persons' attitudes and is particularly relevant in the protection of unfamiliar and uncharismatic species (Martín-López *et al.* 2007). It has been shown that well-informed persons make choices based on ecological reasons whereas affective factors play a more significant role in the choices of less well-informed individuals, who tend to assess importance in terms of the familiar, the useful or the charismatic (Serpell 2004; Martín-López *et al.* 2007). This is particularly important with species that elicit fear and a study on sharks by Thompson and Mintzes (2002) shows a significant relationship between knowledge and values; scientific and naturalistic views were positively related to knowledge whilst utilitarian and negativistic views were shown to be negatively related to knowledge. Similar attempts successfully connected knowledge with attitudes in Lybecker *et al.* (2002) in relation to attitudes towards prairie dogs and in O'Leary *et al.* (2000) in relation to perceptions of afforestation in Ireland. The importance of knowledge and values on public attitudes towards species could be key to determine the conservation approach to the protection of less well-known species such as the FPM. However, little work has been done to investigate the relative importance of knowledge or values in determine lay-persons' attitudes to species, or how stakeholders and lay-persons differ in either knowledge or values in order to facilitate better engagement with the public and greater support for conservation work.

2.9.3 Experience and Place Identity

Personal experience of nature is also important in shaping an individual's values and knowledge in relation to the natural environment, be that as a result of the restorative effect of nature (Kaplan 1977b; Ulrich 1986; White *et al.* 2010) or related to aesthetics and the use of the environment for recreation (Petts 2007). Experiential contact leads to increased emotional connection to the natural environment and consequently the increase in desire to protect it (Miller 2005). Climate change scepticism has been shown to correlate with environmental attitudes, such that those with pro-ecological views are less likely to be sceptical about climate change (Vaske and Kobrin 2001; McCright 2010; Whitmarsh 2011). The emotional effect of the environment has also been shown to play a role in a person's attitudes towards the environment (Pooley and O'Connor 2000).

In the context of the environmental concern, environmental identity, defined as the degree to which the nature is included within an individual's concept of 'self' (Schultz 2001) is also believed to influence environmental concerns and emotional affinity with nature and itself has been shown to be a powerful predictor of concern (Kals *et al.* 1999). However, as illustrated by Devine Wright (2010) and Vander Horst (2007), the link between environmental behaviour and place identity is complex especially when proposed 'green' developments disrupts feelings of place identity, particularly the degree of positive place identity associated with rural landscapes.

2.9.4 Other Influences on Perceptions

Studies have shown that lay-persons engage both in both positive and negative ways with water in the environment and that socio-demographic factors such as gender, age, and education can all influence perceptions (Dietz *et al.* 1998; Dalrymple 2006; Swanwick 2009). Women have been shown to exhibit higher levels of environmental concern, perhaps in part due to their general greater perception of risk when compared to men (Bord and O'Connor 1997; Gustafsod 1998; O'Connor *et al.* 1999) and have also been shown to have higher level of place attachment than men (Hidalgo and Hernandez 2001). Increases in education level have also been shown to correlate with increased environmental concern (Liere and Dunlap 1980). However, the association with such socio-demographic factors, whilst reliable, have comparatively weaker associations with environmental concern than values, attitudes and beliefs (Dietz *et al.* 1998).

Of particular interest is the research that suggests a rural-urban difference in environmental concern since rivers are found in both but are perhaps more synonymous with rural locations. Published findings do not consistently show attitudinal or behavioural differences with respect to residential location (Van Liere and Dunlap 1981; Arcury and Christianson 1993). However, in those studies that do show a difference, environmental concern is higher in urban samples (Berenguer *et al.* 2005), especially at the local level hypothesised as being due to a greater exposure to environmental degradation (Tremblay and Dunlap 1977). Rural residents exhibit a greater level of environmental responsibility, due to an economic dependence on the environment (Berenguer *et al.* 2005) and have stronger utilitarian views of nature (Tremblay and Dunlap 1977). A better understanding of the socio-demographics variables that affect attitudes towards rivers and FPM is important in order to tailor engagement approach to best suit the audience

2.10 Key Knowledge Gaps

In summary, the key knowledge gaps identified within this review, which form the basis for the research conducted within this thesis, are:

Knowledge Gap 1: Whilst the climate change impacts on soil erosion on agricultural land have been well documented at the plot and field scale (Nearing *et al.* 2004; Pruski and Nearing 2002a; O'Neal *et al.* 2005; Favis-Mortlock and Boardman 1995) much less work has focussed on the catchment scale erosional response to climate change, particularly on the effect of land use and how such results can be used to target erosion control for the future.

Knowledge Gap 2: Public support for the conservation of charismatic species is well-known (Kellert 1996; Tisdell and Wilson 2006); some research has also shown that rarity and need also play a role in support (Czech *et al.* 1998). However, there is a lack of understanding on public attitudes toward less charismatic species (using the FPM as an example) and how this contributes to the acceptability of conservation measures needed to support the FPM. Additionally, the factors determining the perceived importance of less familiar species have not been explored, for example roles of knowledge and values.

Knowledge Gap 3: Whilst water in the natural environment has been shown to be important for well-being (White *et al.* 2010) and rivers are known to be a valued landscape feature (Kaplan 1977b) where conservation work is generally acceptable (Wagner 2008), little work shows what underpins this value judgement about rivers and how these values, alongside factors such as experience and knowledge impact the acceptability of conservation work.

Knowledge Gap 4: An integrated approach to catchment management is formally a part of the legislation governing water management in the UK and the use of a participatory approach as a means to preventing the diffuse pollution of water by soil focuses on the farming sector and uses economic incentives (Natural England 2012). Few examples provide a methodology for using a participatory approach within the context of conserving unfamiliar species facing habitat degradation as a result of climate change impacts.

These knowledge gaps are reflected in the three research questions that this body of research addresses:

1). How will climate change predictions for the period 2010 – 2039 affect soil erosion at the catchment scale?

2). What factors influence public attitudes towards rivers, the FPM, and mitigation measures to control sediment movement?

3). Can habitat management for FPMs take into account climate-driven environmental change and social values when constructing conservation goals?

Below, Figure 2.4 illustrates how these research questions will be approached and how the differing methodologies and the distinct components of this research will be integrated

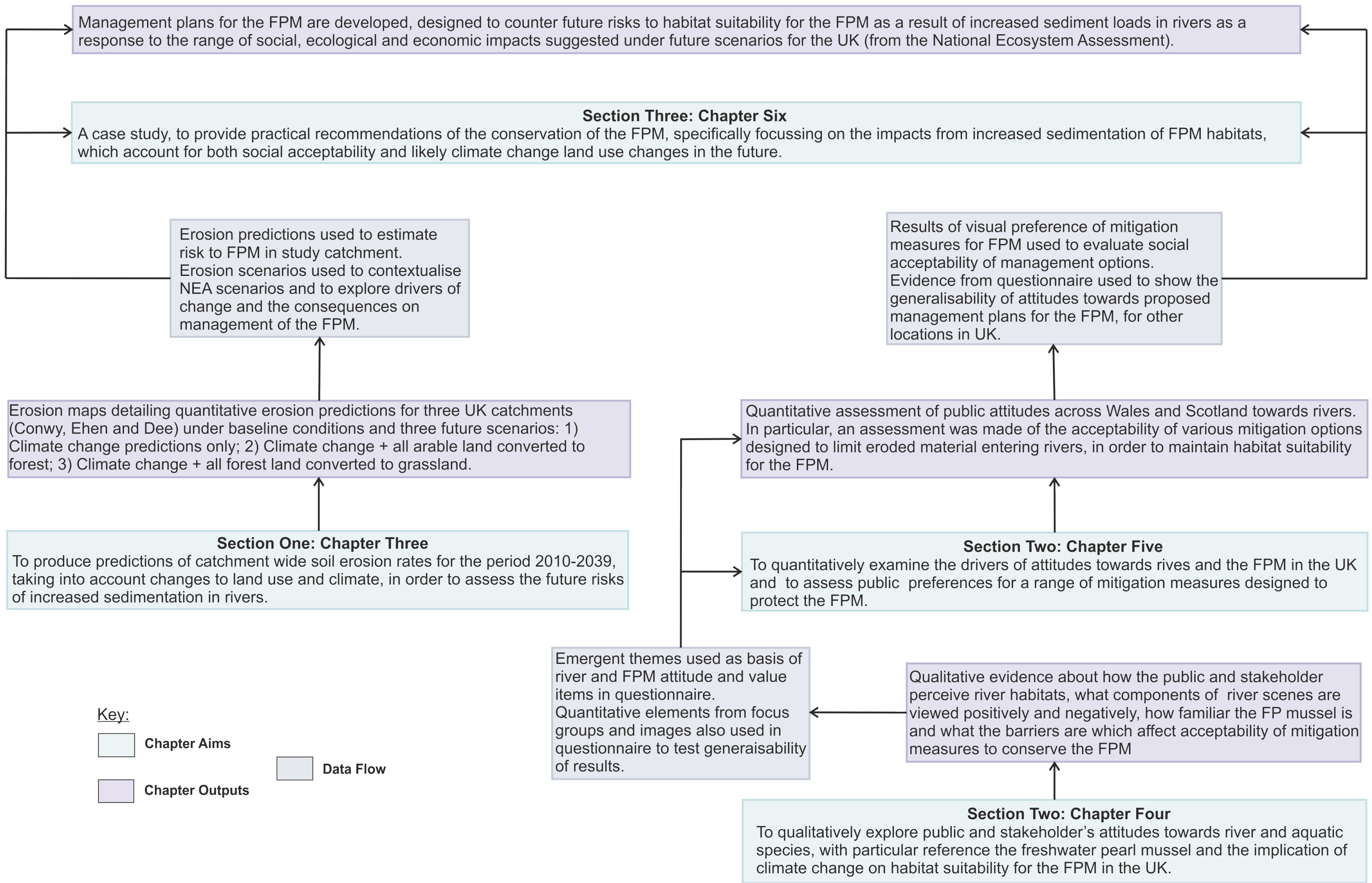

Figure 2.4: Schematic plan indicating how the chapters which comprise this thesis are connected and how the different components are integrated into Chapter Six to provide practical recommendations for FPM conservation and management.

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CHAPTER THREE:
DETERMINING CHANGES TO SOIL EROSION BY SHEET WASH IN RESPONSE TO CLIMATE CHANGE ACROSS GREAT BRITAIN[1]

Soil erosion is driven by topography, land use and climate; under a wetter climate it is anticipated that soil erosion will increase, particularly on land without year-round vegetative cover. In order to maintain productive soils and reduce off-site impacts of soil mobilisation (for example sedimentation of rivers), future scenarios at the catchment scale are necessary to assess whether topographic and land use conditions are such that a shift in climate will lead to widespread and accelerated soil loss. However, few studies thus far have evaluated erosion rates at this scale or quantitatively assessed the relative risk from different land use types. In this chapter, the impacts of potential climate change on catchment-wide soil erosion by sheet wash and rilling across the United Kingdom (UK) is assessed by employing the Pan-European Soil Erosion Risk Assessment (PESERA) model across three catchments in England, Scotland and Wales over the time period spanning 2010 – 2039, under three different land use scenarios. The results indicate that land use has the greater impact on catchment scale erosion rates in comparison to climate change, over the temporal period studied. In particular, arable land is shown to be up to three times more vulnerable to erosion that land under permanent vegetation, despite being found on areas of flatter topography. The advantage of a catchment-wide approach to predicting future erosion rates is that a more targeted approach to implementing preventative measures can be achieved.

[1] A modified version of this chapter will be published as:
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3.1 Background

Despite the fact that 60% of global present day erosion is attributed to human activity, Yang (2003) states that the future increases in soil erosion, predicted at approximately 17% are likely to be as a result of climate change. The literature consistently indicates that increasing rainfall will lead to increasing erosion (Favis-Mortlock and Boardman 1995; Pruski and Nearing 2002; O'Neal *et al.* 2005); however any future increases in soil movement will also be affected by land management decisions (Nearing *et al.* 2005; O'Neal *et al*. 2005; Notebaert *et al.* 2011). The general upward trend in the quantities of eroded material over the last 100 years correlates to large-scale changes to agricultural practices (e.g. move from spring sown to autumn sown crops), intensification of farming effort (more land under cultivation), increasing technological advances (allowing traditionally un-cultivatable land to be farmed, large-scale implementation of land drains after WWII) and changing political ideals (small plots converted to large fields via removal of trees & hedgerows) (Pimentel *et al.* 1995; Owens and Walling 2002; Cebecauer and Hofierka 2008). The implications of increased soil erosion rates are loss of productivity (POSTNote 2006; Gong *et al.* 2013), changes to soil carbon stores (Lal 2003, 2004) and off-site impacts to aquatic environments (Skinner *et al.* 1997; Evans *et al.* 2006).

How will climate change affect current trends in soil erosion rates for the period 2010-2039?

Although the United Kingdom is predicted to experience an increase in winter precipitation over the next 50 years (Met Office 2007; Osborn and Maraum 2008), including more extreme rainfall events, there is uncertainty regarding whether the increased rainfall will lead to increases in rates of soil erosion. Whilst predicted changes in precipitation will potentially cause erosion rates to increase, indirectly this will increase soil water availability and in combination with increasing air temperature, may extend plant growth rates and increase land cover both of which might act to limit soil erosion (Boardman and Favis-Mortlock 1993; Nearing *et al.* 2004). Mean annual erosion rates measured at the field scale show considerable variation, for example Evans (2002) calculated rates on agricultural land of 1.92

to 5.08 t ha^{-1} a^{-1}, whilst Morgan (1980) shows erosion rates of 0.23 to 10.9 t ha^{-1} a^{-1} with sandy soil more vulnerable to erosion than clay soil. Overall, erosion rates in the UK vary from 1 t^{-1} ha^{-1} a^{-1} to greater than 80 t^{-1} ha^{-1} a^{-1} in extreme cases (Rickson 2013). These results indicate considerable spatial and temporal variability in measurements of erosion rate, making predictions of future soil erosion difficult to quantify. Further, efforts to assess the impacts of climate change on soil erosion indicate a complex non-linear response to changes in precipitation, temperature and atmospheric-CO_2 concentrations (Favis-Mortlock and Boardman 1995). However, many studies have shown that erosion rates will increase with increasing precipitation (Boardman and Favis-Mortlock 1993; Favis-Mortlock and Boardman 1995; Nearing *et al.* 2005) or vice versa when climate change scenarios are used in isolation of land use changes (Mullan *et al.* 2012). Increases in the intensity and duration of storms has been shown to increase the likelihood of soil erosion under all land-cover types (Boardman 1990; Boardman and Favismortlock 1993; O'Neal *et al*. 2005). In spite of the uncertainty, predictions at the plot scale, based on global-scale climate models, indicate that rates of soil erosion will increase (Favis-Mortlock and Boardman 1995; Favis-Mortlock and Savabi 1996; O'Neal *et al*. 2005), particularly in steep regions with long slope lengths, and in those areas already susceptible to erosion (Favis-Mortlock and Savabi 1996).

Can land use changes ameliorate any change to erosion rates as a result of climate change over the period 2010-2039?

Land cover has been shown to be key in controlling erosion processes through overland flow through interception and improved stability of the soil surface by root growth. Increases in atmospheric CO_2 concentrations and atmospheric temperatures may improve rates of crop growth (Favis-Mortlock *et al.* 1991; Kimball *et al.* 1993), which reduces the period that ground cover is sparse and thus the period during which soil erosion is most likely to occur during precipitation events (Favis-Mortlock and Savabi 1996). Land use practices such as deforestation, mining, and agriculture can increase the proportion of soil that can be acted upon by water and thus have been shown to cause steep increases in erosion rates (Edwards and Owens 1991; Boardman and Favis-Mortlock 1993; Snelder and Bryan 1995; Naden and Cooper 1999; McHugh 2007; Hatfield *et al.* 2008; Bartley *et al.* 2010; Notebaert et al. 2011). Conversely, abandoned land has been shown to reduce in erosion vulnerability as permanent cover is re-established (Bakker *et al.* 2005; Bakker *et al.* 2008). For example, rates of soil loss are thought to be increasing across the United Kingdom because of agricultural intensification in the arable and livestock sectors (Evans and Cook 1986; Boardman 1990; Boardman and Favis-Mortlock 1993; Favis-Mortlock and Boardman 1995; Favis-Mortlock and Savabi 1996; O'Neal *et al*. 2005; McHugh 2007; Cebecauer and Hofierka 2008; Hatfield *et al*. 2008). As a result, mitigation strategies have led to funding initiatives to encourage the agricultural community to adopt practices that reduce erosion on site (DEFRA 2005, 2009; Evans 2010).

3.1.1 Chapter Aims

Thus far, there are few studies that consider the longer-term effects (i.e. greater than 2-5 years) of climate change on soil erosion, particularly at the catchment scale. Given the potentially devastating impacts of increased erosion rates to biodiversity, food and water resources and the economy, the PESERA model will be implemented to assess the potential impacts of regional climate change on soil erosion across three catchments in England, Scotland and Wales. This approach can be adapted to other regions with similar topographic and land use conditions that experience analogous climatic trends. Moreover, based on these results, site-specific research can then be conducted in order to minimise the impacts of soil erosion. In addition to identifying the principal controls on adjustments in soil erosion, the findings will provide land managers with vital information to justify the implementation of soil conservation strategies.

This will be achieved by addressing the following hypothesis:

1. How will climate change affect current trends in soil erosion rates for the period 2010-2039?

H1: Based on the work of Boardman and Favis-Mortlock (1993); Favis-Mortlock and Boardman (1995) and Nearing (2005) who show that soil erosion increases with increasing rainfall and Mullen *et al*. (2012) who showed that decreasing future precipitation led to a decrease in soil erosion at the plot and field scale, it is expected that erosion rates in all catchments will increase where precipitation levels are greater than current conditions.

H2: Based on work by Favis-Mortlock and Savabi (1996) who showed that sediment yields at erosion hotspots were exacerbated by climate change scenarios with increasing precipitation levels, it is expected that any current-day erosion hotspots will see the greatest increase in erosion rates.

2. Can land use changes ameliorate any change to erosion rates as a result of climate change over the period 2010-2039?

H£: Based on work by Morgan (1980) who showed erosion rates on arable land to be greater than other land use types, it is expected that erosion rates on arable land to be greater than erosion rates on land with year-round cover, such as grassland or forest.

3.2 Methodology

3.2.1 Study Sites

Catchments were chosen to ensure that a range of climatic and land use conditions were investigated. Although each catchment had a range of land use conditions and topographies that are representative of the United Kingdom, upland environments comprise significant portions of each site, which allowed the assessment of the potential influences of altitude and relief (Figure 3.1). Required data for model implementation were also readily available for each catchment at comparable resolutions.

3.2.1.1 Conwy Catchment, north Wales

The 55-km long River Conwy drains 627 km^2 of north Wales into the Irish Sea at the Conwy Estuary. The Conwy uplands extend into the Meignant Moor of Snowdonia National Park, a Special Area of Conservation designated under the European Union (EU) Habitats Directive. The catchment is characterised by steep slopes and flashy discharge (Environment Agency Wales 2010). The average annual discharge of the River Conwy is 19.0 $m^3 s^{-1}$, with a 95% exceedance discharge of 1.4 $m^3 s^{-1}$ and a 5% exceedance discharge of 46 $m^3 s^{-1}$ at the Cwmlanerch (EA No. 66011) gauging station for the period 1964-2011. Climate trends from 1961-1990 reveal a systematic increase in rainfall from the coast to the upland borders of the catchment, from 400 to nearly 2000 mm annually (UK Meteorological Office 2011). The climate data also indicate that precipitation events are most frequent during northern hemispheric autumn (September to November) and winter months (December to February). Over 40 days of sleet or snowfall is experienced on average in Snowdonia, to the southwest of the catchment, which decreases towards the coast, with snowfall along coastal areas rare in Wales. Mean winter and summer temperatures (at sea level) are 4.9 ^oC and 15.0 ^oC, respectively (UK Meteorological Office 2011). Climate change projections for the period between 2010 and 2039 indicate that summer and winter temperatures across Wales will increase on average by 1.4 and 1.3 ^oC, with an annual precipitation change of 0% belying a summer decrease of 7% and a winter increase of 7% based on 1961-1990 averages (UKCP09 2012).

Ordovician, Silurian and Cambrian igneous and sedimentary rocks underlie much of the Conwy catchment, which generally weather into brown podzolic soils, peats and gleys (NERC 2011). Dominated by the Snowdonia Mountains to the south and west, the highest elevation within the catchment is 1064 m above sea level. The lowlands to the north host the two major urban areas of Conwy and Llandudno, with a combined population of approximately 33,000 (NERC 2011). Overall, the Conwy catchment is rural, with the urban areas making up only 1.2% of the region. The dominant land use is pasture and grassland, accounting for 64%

of the catchment (Fuller *et al.* 2002) and supporting the primary contributor to the economy, cattle and sheep farming. Over 28% of the remaining land area is managed or natural forest (Fuller *et al*. 2002). The presence of peat bogs in the catchment at the headwaters of the River Conwy has prompted the inclusion of the Conwy in the UK Centre for Ecology and Hydrology's Carbon Catchments Programme, motivated by their susceptibility to erode and their importance in carbon sequestration. The National Trust is supporting a peatland restoration programme on its land in the same area.

3.2.1.2 Ehen Catchment, north-western England

The 27-km long River Ehen drains 225 km^2 of England's west coast into the Irish Sea, with headwaters in the Ennerdale Water, a deep glacial lake that also serves as a reservoir for several urban areas in the region. The eastern part of the catchment is within the Lake District National Park, where the areas of higher elevation are found, the highest altitude being 978 m above sea level. The average annual discharge of the river is 5.2 $m^3 s^{-1}$, with a 95% exceedance discharge of 0.94 $m^3 s^{-1}$ and a 5% exceedance discharge of 11.9 $m^3 s^{-1}$ at the Braystones (EA No. 74005) gauging station for the period 1974-2011. The River Ehen has a regulated flow regime, with a compensation flow set at 0.37 $m^3 s^{-1}$. Annual average precipitation is between 158 mm and 1250 mm across the catchment with much of the precipitation occurring during northern-hemispheric autumn and winter months. The mean seasonal summer to winter temperature range is approximately 10.7 ^oC, with winter mean temperatures of 3.8 ^oC and summer mean temperatures of 14.5 ^oC (UK Meteorological Office 2011). Climate change estimations (2010-2039) for North-west England show an annual mean change in precipitation of 0% with seasonal changes of -8% during the summer and 6% during winter based on 1961-1990 averages (UK Meteorological Office 2011). Temperatures are predicted to rise during both the summer and winter by 1.5 and 1.2^oC respectively.

Impervious Borrowdale volcanics underlie the upper portions of the catchment and Ordovician sedimentary rocks are found in the lower portions, forming podsolic soils, peats and gleys in the uplands and brown soils in the lowlands. The catchment has a population of approximately 43,000 with Whitehaven being the largest urban area. In total, urban areas account for 4.5% of the land use within the catchment, the majority of which is pasture and grassland (55%) and the remainder being arable (19.4%) or forested land (20.4%) (Fuller *et al*. 2002). Conservation work within the catchment has led to the end of managed coniferous forestry, thought to be a major instigator of soil erosion within the upper catchment (Killeen 2009).

3.2.1.3 Dee Catchment, north-eastern Scotland

The 140 km long River Dee drains 2100 km^2 of eastern Scotland into the North Sea at the Dee Estuary (Cooksley 2007; Baggaley *et al.* 2009). The headwaters of the River Dee are found in the Cairngorm massif in north-eastern Scotland, which forms part of the Cairngorm National Park (Cooksley 2007; Baggaley *et al*. 2009). The average annual discharge of the Dee is 47.12 $m^3 s^{-1}$, with a 95% exceedance discharge of 8.75 $m^3 s^{-1}$ and a 5% exceedance discharge of 95.42 $m^3 s^{-1}$ at the Park (SEPA No. 12002) gauging station for the period 1972-2011. The catchment receives approximately 810 to 2100 mm of precipitation annually, most of which falls in the winter months, 30% of it as snow (Cooksley 2007). The mean seasonal summer-winter temperature range at sea level is 10.8 ^{o}C, with mean winter temperature of 3.4 ^{o}C and mean summer temperature of 14.2 ^{o}C (UK Meteorological Office 2011). Climate predictions (2010-2039) for the east of Scotland show no annual change in precipitation relative to 1961-1990 averages, but they do indicate a 6% decrease in summer and 4% increase in winter (UK Meteorological Office 2011) precipitation levels. Temperatures in this region are predicted to rise by 1.5 ^{o}C during the summer and by 1.1 ^{o}C during the winter over the same period.

Heavily metamorphosed sediments from the Pre-Cambrian epoch flanked by igneous intrusive rocks of the Caledonian orogeny underlie the catchment, forming humic-iron podzolic soils in the lowlands and expansive areas of poorly drained blanket peat bogs and podzolic soils and peats in the uplands (Cooksley 2007; Baggaley *et al*. 2009). Most of the population within this catchment, a total of approximately 220,000, live in Aberdeen at the mouth of the River Dee. The dominant land uses are forest and moorland (71.2%). Arable land makes up 7.9% of the catchment, and pasture and grassland make up 17.5%, with sheep and dairy farming concentrated in the flatter lowlands (Fuller *et al*. 2002). The uplands have been identified as being particularly susceptible to erosion due to the prevalence of peaty soils (Towers 2006).

3.2.2 Description of the Pan European Soil Erosion Risk Assessment Model

PESERA was originally conceived to assess soil erosion rates across Europe at the kilometre scale (Kirkby *et al.* 2008). Model outputs provide monthly and annual prediction of potential soil transfer delivered to the channel network; it does not consider soil storage in the landscape or sediment transfer through the channel network. Further, PESERA only considers soil transfer by sheet wash and rilling and so may underestimate rates of soil flux where other soil transfer processes are important (e.g., rainsplash, gullying, mass wasting). Nonetheless, sheet wash and rilling are widespread and pervasive mechanisms of soil transfer that can be simply and explicitly linked to land use and climate variables, making predictions from PESERA useful to environmental policy and management (Licciardello *et al.* 2009).

An initial assumption of the model is that, during overland flow, sediment is transported at a rate equal to the flow's transport capacity per unit of flow width (*C*) (Kirkby et al., 2008), or:

$$C = kq^m \Lambda^n, \quad (1)$$

where *C* is measured in units of kg m^{-1} day^{-1}, *k* is a coefficient of soil erodibility with units that depend on the values of *m* and *n*, *q* is overland flow discharge per unit of flow width with units of L m^{-1} day^{-1}, and Λ is the local slope gradient. The values of *m* and *n* should depend on site-specific calibration based on field data, but we follow the example of Kirkby *et al*. (2008) and adopt values of 2 and 1 for *m* and *n* to facilitate the development of catchment-scale estimates of soil erosion. In this case, *k* takes on units of kg m day L^{-2}, and (1) reduces to:

$$C = k(rx)^2 \Lambda, \tag{2}$$

where *r* is the local runoff in units of L m^{-2} day^{-1} for each storm and *x* is the distance from the drainage divide in units of meters. The cumulative value of *C* that results from the frequency distribution of storm events that occur in a month can then be written as:

$$\sum C = kx^2 \Lambda \sum r^2, \tag{3}$$

Equation (3) is used in a relation that allows for estimates of the hillslope-length averaged sediment yield (*Y*) to the slope base, or:

$$Y = \frac{\sum C_b}{x_b} = kx_b \Lambda_b \sum r^2, \tag{4}$$

where *Y* is in units of kg m^{-2} day^{-1} and the subscript *b* denotes an evaluation at the hillslope base. Equation (4) does not consider fractions of sediment stored within the hillside during soil transfer, and, as stated, PESERA does not model soil transfer through the catchment network. The equation also does not consider the range of grain sizes that can be mobilized across the hillside, effectively treating all grain sizes as equally mobile. The application of (4) in PESERA occurs within a raster (*i.e.*, cell based) model of the landscape and requires spatially distributed values of *k* derived from soil classification data, estimates of local relief derived from a digital elevation model, and spatially distributed estimates of *r* derived from a biophysical model.

Details of the biophysical model used to determine *r* can be found in Kirkby *et al*. (2008), but, in summary, the calculation of *r* is based on a bucket model that states:

$$r = p(R - R_0), \tag{5}$$

where *p* is the proportion of subsequent rainfall that contributes to *r*, *R* is the total storm rainfall, and R_0 is the runoff threshold, or the maximum rainfall amount that can infiltrate into the soil. The value of R_0 is determined from soil classification data and estimates of the hydrological conditions within the near-surface soil. See Section 3.2.3.2 for a description of the soil classification data used in this study, but it is used in this context to account for the effects of surface roughness (*e.g*., the storage capacity of furrows), the soil water holding capacity, and soil crusting. For the hydrological conditions of the near-surface soil, PESERA essentially constructs a water balance for each storm event, estimating amounts of interception loss due to vegetation cover, evapotranspiration loss due to vegetation cover and climate conditions, and the loss due to the subsurface flow of infiltrated water modelled using TopModel (Bevan and Kirkby 1979). Vegetation is explicitly modelled by PESERA, which considers both natural and crop cover. Vegetation coverage evolves through time as a function of gross primary productivity and respiration driven by atmospheric temperature. PESERA can also adjust vegetation coverage through grazing and crop management. Atmospheric temperature is considered when modelling subsurface hydrology; for example, the depth of soil freezing is estimated and used to adjust the soil water holding capacity.

In its implementation, PESERA iterates model runs until a temporally stable output of soil erosion estimates is generated. The implementation also assumes that daily rainfall amounts follow a gamma distribution, using a probability density function based on input precipitation values to calculate daily rainfall, runoff and erosion for all possible storm events. In this study, the hydrological parameters generally stabilise more quickly (3-5 years) than the vegetation variables (10-50 years). Nonetheless, it is important to note that PESERA is limited by the resolution of the input data, with Baggaley *et al*. (2010) noting that the resolution of the digital terrain model (DTM) used for the topographic component was found to be a significant limiting factor in prediction accuracy. Moreover, PESERA has a tendency to inaccurately estimate erosion and runoff rates at the extreme ends of the spectrum (Licciardello *et al*. 2009). The predictive accuracy of PESERA is reduced in situations when there are localised factors that are not explicitly considered by the model, for example, Tsara *et al*. (2005) found that PESERA overestimated soil erosion in vineyards due to an inability of the model to account for the effects of contour ploughing and in wheat fields during winter with full cover because the cover values within the model are too low for a Mediterranean climates.

3.2.3 Input Data for PESERA Implementation

All model runs were at 100-m resolution with grazing intensity set to 50%. Grid squares in which land use was classified as water were made blank for all data sets and thus were not modelled. The time span of 1961-1990 was classed as the 'baseline' because this is the 30 year time period upon which the UK Climate Prediction 2009 (UKCP09) estimates are based. Table 3.1 outlines the data sets used in this study.

Data Type	Source	Catchment [1]Conwy	[2]Ehen	[3]Dee
Temperature	British Atmospheric Data Centre	Daily maximum/minimum gauge data, 1961 – 1991		
		gauges: 1141; 1180 & 17210	gauges: 1100	gauges: 163 & 147
Precipitation	British Atmospheric Data Centre	Daily rainfall gauge data, 1961 - 1991		
		gauges: 1148; 11488; 1149; 11494; 11517; 1101; 11366; 11385; 1141; 1153; 1154; 1155; 11601; 11730; 11785; 1180; 1186; 12218 & 17210	gauges: 1051; 12785; 12788; 12810; 12881 & 12891	gauges: 147; 148; 14903; 14978; 158 & 163
PET	UK Met Office	PET values for 10 major cover types, averaged over 1961-1991, at 40km grid resolution		
		MORECS grid: 113	MORECS grid: 83	MORECS grid: 37 & 38
Soil Type	National Soils Resources Institute[1,2] & James Hutton Institute[3]	Dominant soil type at 1km resolution and associated hydraulic and textural data		
Land Use	Centre for Ecology and Hydrology	Level 3 vector data containing broad habitat classification and sub-classifications (Fuller, 2000)		
Crop Data	Welsh Assembly Government[1,2] & James Hutton Institute[3]	Average crop planting dates.		
Topography	Mimas Landmap Service	25m Digital Elevation Model		

Table 3.1: Source data used within the PESERA model.

3.2.3.1 Climate Data

Precipitation data from each catchment was input into the PESERA Climate Template (Kirkby and Irvine n.d.), which computes the three monthly rainfall metrics for PESERA at each rain gauge site: mean monthly rainfall, mean rain per rain day, and the coefficient of variation of mean rain per rain day. Linear regressions of gauge elevation and rainfall were used to interpolate the station data between gauge sites, forming a contiguous grid across all three catchments. Rainfall gauges were grouped according to elevation (0-10 m; 11-100 m; 101-200 m; 201-300 m; 301-400 m & 401-500 m), and monthly and daily rainfall data were averaged across all gauges within each elevation group. These mean values for monthly and daily rainfall were then plotted against the upper value of each elevation group (i.e. 10 m; 100 m, 200 m, 300 m; 400 m & 500 m) from which a linear regression was fitted, giving an equation linking a rainfall metric (monthly or daily) to elevation. To calculate the coefficient of variation of mean rain per rain day across the whole catchment, the monthly coefficient of variation of mean rain per rain day data were first grouped into seasons (December to February – Winter; March to May – Spring; June to August – Summer; September to November – Autumn) before being averaged across all gauges within each elevation group, as described above for the monthly and daily rainfall metrics. In this manner, the linear regression equations for the three rainfall metrics (mean daily, mean monthly and monthly coefficient of variation of mean rain per rain day) were used with the catchment digital terrain model (DTM) to interpolate the gauged rainfall data across each catchment. Mean daily temperature and the daily temperature range were calculated from the weather stations in each catchment and then standardised by recalculating them at sea level using a lapse rate of 6 ^{o}C per 1000 m. Where catchments had more than one temperature gauge, the catchments were divided into equally spaced parcels with temperature values derived from the nearest weather station.

Climate predictions of future changes in precipitation and temperature for the period 2010 – 2039 were downloaded from the UK Climate Predictions (UKCP) User Interface (UKCP09 2012). In particular, data were downloaded for each calendar month under the low, medium and high emissions scenarios and at the 10%, 50% and 90% probability levels. The resolution of UKCP predictions is 40 km^2, and so each 100 m^2 grid square of each catchment was attributed to the correct UKCP grid number using the *extract value to points* tool in ArcGIS. The nearest land predictions were used for parcels of land within UKCP09 grid squares that were predominantly ocean. Temperature data were standardised by recalculating them at sea level using a lapse rate of 6 ^oC per 1000 m. The absolute change values from the UKCP09 data were then added to the baseline values for precipitation and temperature. No change was made to the coefficient of rainfall per rain day values since the monthly and daily rainfall values had all been manipulated by exactly the same amount the degree of change remained constant. Temperature range was adjusted using the absolute change values for minimum and maximum daily temperatures.

3.2.3.2 Soils Data

Dominant soil series in a 1 km^2 grid was used in conjunction with textural and hydraulic data to calculate the PESERA soil grids. For England and Wales, these data were obtained under licence from the National Soil Research Institute, Cranfield University and comprised NATMAP1000 (Land Information System 2011a), HORIZON FUNDEMENTALS (Land Information System 2011b), and HORIZON HYDRAULICS (Land Information System 2011c). NATMAP1000 is a spatial data set gridded to 1 km^2 giving relative percentage of soil series for England and Wales. This data set was drawn from work by Hodgeson (1979) and was used to determine the dominant soil series in each 100 m^2 of each catchment. The HORIZON FUNDAMENTALS data set contains textural (percentage sand, silt and clay) properties of four layers (topsoil, upper soil, upper subsoil, substrate) for each soil series. This tabular data set was designed to be used in conjunction with the NATMAP1000 spatial data and consists of a statistical summary of field data based on previous work by Hodgeson (1979). The HORIZON HYDRAULICS data set, also based on work by Hodgson (1979), contains water content for four layers (topsoil, upper soil, upper subsoil, substrate) for each soil series, calculated using pedo-transfer functions. This data set was used to give field capacity and saturated water capacity for each dominant soil series from the NATMAP 1000 data set. In both the HORIZON HYDRAULICS and HORIZON FUNDAMENTALS data sets, data are provided for four land use types: arable; ley grassland; permanent grassland and all other land uses. To ensure consistency in usage, texture and water content values for the arable land uses were used for grid squares defined as arable under the PESERA land use classification. Texture and water content values for the two grassland land use categories were averaged and used for all grid squares that were classed as pastures and grassland under the PESERA land use classes. Finally, texture and water content values for the other land use were used for all other PESERA land use types. The resolution used in this study (100 m^2) meant that the pedo-transfer rules used within the original PESERA implementation at 1km^2 resolution were not applicable. Instead, soil texture data (percentage sand, silt and clay) was used to calculate the crusting and erodibility metrics (Baggaley *et al*. 2010). Comparisons of field data and pedo-transfer functions for predicting saturated water capacity of soils with peaty horizons indicated that field capacity was approximately 15% less than saturated capacity. Therefore, in order to derive saturated water capacity from the field capacity data of peaty soils data from the National Soils Research Institute, an adjustment of +15% was made (Baggaley 2011, pers. comm.). The three metrics of soil water storage capacity were calculated based on documentation from the PESERA project (Gobin *et al.* 2003). For the Scottish catchment, no soils data were attributed to grid squares where the land use was defined as a water body (e.g., a lake). The second dominant soil type was used in instances where the dominant soil type was shown as a water body but the land use classification was terrestrial.

3.2.3.3 Land Use Data

In this study, Land Cover Map 2000 (LCM2000) was the source of land use data for all three catchments. LCM2000 is a classification of satellite image data obtained from the Landsat sensor as either summer or winter composite of single data images with a minimum mapable area of 0.5 ha (Fuller *et al*. 2002). It is important to note, however, that land cover may not directly correspond to land use depending on when the Landsat images were taken.

Fuller *et al*. (2002) carried out field surveys to assess the accuracy and found 88% repeatability at the lowest resolution. The land use classification is hierarchical and a Level 3 Vector dataset used in this research encompasses all British habitat types and variations at the highest resolution. Data for each catchment were stored as a point shapefile in an ArcMap 9.3 personal geodatabase where each point represented the centre of a 100 m^2 grid square. This allowed the LCM2000 land use at each point to be extracted using ArcMap 9.3. Land use data within PESERA were used to determine land cover and in the case of arable land, crop growth. The PESERA land use classes are based on the European CORINE land use classes, and so the LCM2000 classes had to be converted into CORINE land use classes. Such data manipulations were based on the procedure outlined by the UK Centre of Ecology and Hydrology (CEH 2011). In some cases, a direct conversion was not possible given the different scales of the LCM2000 and CORINE data. Finally, CORINE land use classes were converted to PESERA land use types based on monthly cover values for each land use type that reflects the plant growth simulations within the model. These were followed with the exception of the Forest/Woodland land type in the Scottish catchment, where cover was set to 99% as opposed to 100% to take in account the prevalence of eroded peat in the Scottish uplands (Baggaley 2011).

Potential evapotranspiration (PET) data was obtained from the Meteorological Office Rainfall and Evaporation Calculation System (MORECS) in tabular format based on average potential evapotranspiration across the period 1961-1990. The PET data were available for 18 land cover classes that were then converted to the equivalent PESERA land uses (see Appendix B for full details). The MORECS data are at 40 km resolution, and the grid squares used for each catchment are documented in Table 3.1. In the case of the Dee, ArcMap 9.3 was used to overlay the MORECS grid square map over the catchment map and assign the correct catchment segment to the corresponding MORECS grid square. Planting dates for crops were obtained from the Welsh Assembly Government and the James Hutton Institute.

3.2.3.4 Topography

The Landmap Digital Terrain Model (DTM), at 25 m^2 resolution, was used to derive DTMs at 100 m^2 resolution using the aggregate (mean) function in ArcMap 9.3. The Landmap DTM is an orthorectified version of the European Remote Sensing data obtained by two satellite missions, ERS1 and 2. The British DTM's were derived from the satellite datasets using inferometric techniques. The elevation metric used within PESERA is the standard deviation of points within a set radius with a modelling resolution of 100 m, set to 400 m (Baggaley 2011, pers. comm.).

3.2.4 Experimental Design

The UKCP09 climate change predictions used in this research (UK Climate Predictions 2012) represent probabilities of different future climates. They are an example of subjective probability, based on the available information and an assessment of the strength of the evidence (for example horse racing odds) as opposed to objective probability where all the possibilities are accounted for (for example rolls of a dice. At any given probability level, the prediction reflects the number of climate model runs that fell at or below the change value, rather than the chance of that exact change taking place in the future. The medium emission scenario used within the UKCP09 predictions are based on the carbon dioxide forecasts published by the International Panel on Climate Change's (IPCC) Special Report on Emissions Scenarios (IPCC 2000). The medium climate change scenario represents the situation in which CO_2 output and economic growth are balanced by relying on both fossil and non-fossil fuel sources of energy. PESERA model runs were performed using climate data from the 10%, 50% and 90% probability levels under the medium emissions scenarios, as well as a baseline run with climate data from the period 1961-1990. The lowest probability level, 10%, provided climate values (temperature and precipitation) that were considered the minimum change we are likely to experience. The mid-range predictions are obtained from the 50% probability levels, and the maximum levels, of which there is little chance of us exceeding these levels of change, were obtained using predictions at the 90% probability level. Within these result, the data gained through the use of climate predictions at the 10% probability level were termed the low climate change level; the medium climate change level was used for data obtained as a result of climate prediction at the 50% probability level and data as a result of using predictions from the 90% probability level is termed the high climate change scenario.

Adjustments in soil erosion due to changes in land use practices were modelled in three different scenarios: first, land use patterns across each catchment were held constant; second, forests present in each catchment were converted to pastures or grassland; and third, arable land was converted to a combination of coniferous and deciduous woodland. Each land use scenario was modelled in conjunction with climate change prediction at the 10%, 50% and 90% probability levels for the medium emissions scenario. While we acknowledge that such large-scale changes in land use are unlikely to occur, the modelling framework allowed us to document the sensitivity of soil-erosion predictions to land use across varying climate. In this study, the coverage or content of arable land was not altered because the available data on future projections of population growth, food demand, and crop availability were not available.

3.2.5 Statistical Analysis

The data was treated as matched data because the experimental design was a repeated measures approach; the erosion rate for each cell within the three catchments was calculated multiple times under different climate change and land use scenarios. The data was not normally distributed; therefore Wilcoxon Matched-Paired tests were conducted on the un-transformed model outputs, using SPSS Version 20.

3.3 Results

H1. How will climate change affect current trends in soil erosion rates for the period 2010-2039?

3.3.1 Climatic conditions across the catchments

In general, UKCP09 climate change predictions indicated that average annual precipitation should increase systematically as a function of the magnitude of CO_2 emissions over the 2010-2039 time period modelled in this study: precipitation across each catchment is lowest in the low climate change scenario and highest in the high climate change scenario (Figure 3.2). Interestingly, average annual precipitation was predicted to decrease in the low climate change scenario relative to the 1960-1991 baseline by roughly 14.5% across the Dee and Conwy catchments and by roughly 13% across the Ehen catchment. Each of the catchments are predicted to experience a marginal increase in average annual precipitation in the medium climate change scenario relative to baseline conditions, by 0.1% across the Conwy, 0.9% across the Dee, and 2% across the Ehen. Average annual precipitation was predicted to significantly increase across each catchment in the high climate change scenario relative to baseline conditions, by 17.4% across the Conwy, 18.9% across the Dee, and 19.5% across the Ehen.

Each of the emission levels lead to increases in average annual air temperatures for the three catchments, with temperatures increasing in line with the magnitude of the emissions level (Figure 3.3). In PESERA, air temperature governs the type of precipitation (rain or snow). Across all catchments, the predicted monthly rise in temperatures from January to May was less than from June to December (Figure 3.3). Under the low climate change scenario, average annual air temperatures were predicted to increase by 0.34 ^{o}C across the Dee catchment, by 0.41 ^{o}C across the Conwy catchment, and by 0.42 ^{o}C across the Ehen. The medium climate change scenario produces predicted increases of 1.30 ^{o}C across the Dee, 1.28 ^{o}C across the Conwy, and 1.31 ^{o}C across the Ehen. The high climate change scenario produces predicted increases of 2.35 °C across the Dee, 2.24 °C across the Conwy, and 2.27 °C across the Ehen.

3.3.2 Soil erosion predictions based on baseline conditions

The majority of the baseline PESERA erosion rates across the three study catchments are between 0.05 and 1 t ha^{-1} a^{-1} (Fig. 3.3), consistent with baseline measurements made elsewhere in Britain (Rickson 2013). Erosion rates in the Dee are more variable than the other two catchments because of steeper topography, higher precipitation, and to a lesser extent differences in land use and soil characteristics. PESERA does not estimate catchment sediment yields, rather calculates erosion rates at individual points within a catchment. Therefore, the central tendency of the distribution of erosion rates at each point in the landscape approximates the average sediment yield from the catchments. Modelled erosion rates for all of the catchments have a strongly right-skewed distribution that is heavily influenced by high erosion rates calculated on steep slopes. Therefore, mean annual erosion rates calculated by averaging individual erosion values at each pixel appear to by unrealistically high. Mean annual erosion rates for the Dee were 0.71 t ha^{-1} a^{-1}, more than twice as high as the baselines for other regions in the United Kingdom. The Ehen (0.28 t ha^{-1} a^{-1}) and Conwy (0.24 t ha^{-1} a^{-1}) mean annual erosion rates were considerably lower than the Dee. The median and interquartile range of individual erosion rate measurements of 0.20 ± 0.09 t ha^{-1} a^{-1} for the Conwy, 0.21 ± 0.14 t ha^{-1} a^{-1} for the Ehen, and 0.20 ± 0.10 t ha^{-1} a^{-1} for the Dee. These median erosion rates are consistent with sediment yields from other catchments in Britain and suggest that the model output is reproducing the magnitude of erosion of these catchments.

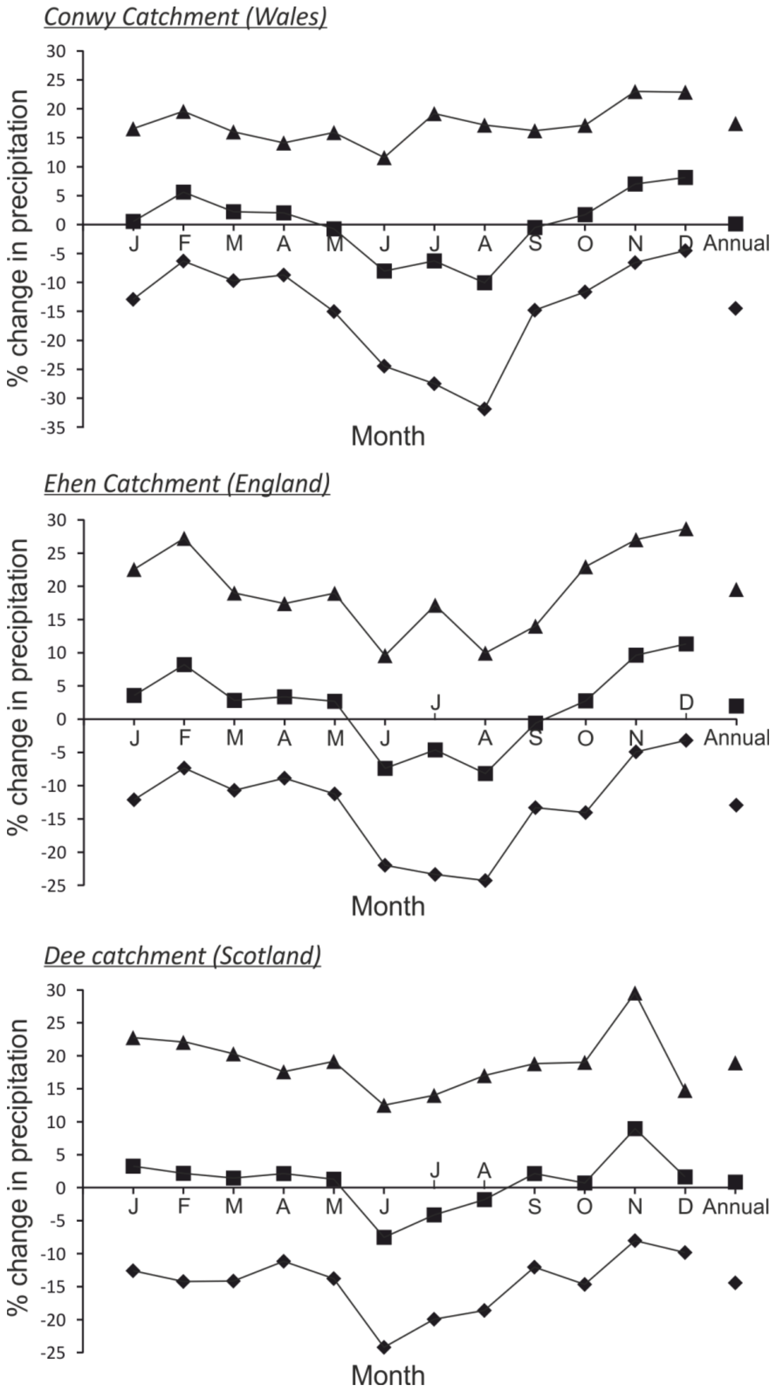

Figure 3.2: Mean monthly and annual precipitation changes used within the PESERA model
The predictions for each catchment are based on UKCP09 projections for the temporal period 2010-2039 using the medium emissions scenario. The graphs show the percentage change expected on 1961-1990 averages.

◆ = Low climate change scenario (10% probability level)
■ =Medium climate change scenario (50% probability level)
▲ =High climate change level (90% probability level)

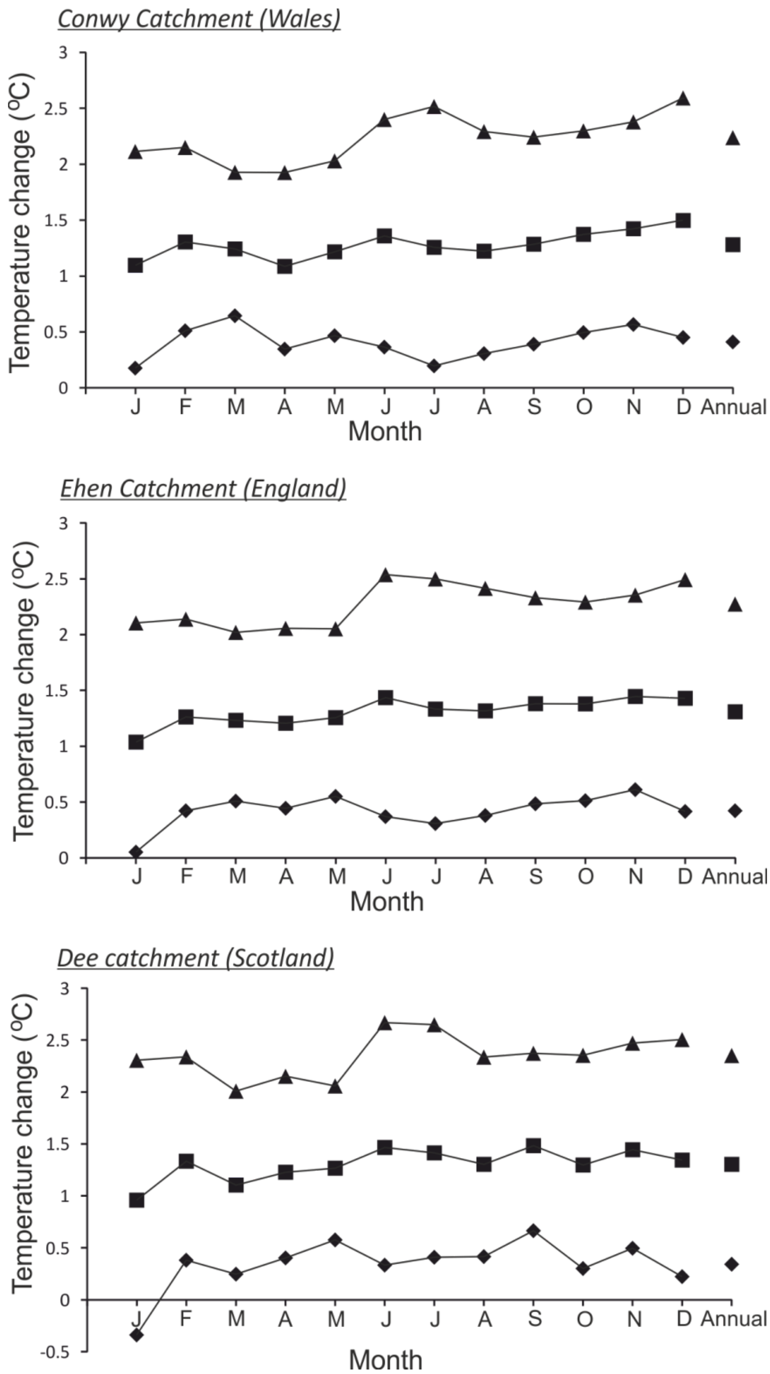

Figure 3.3: Mean monthly and annual temperature changes used within the PESERA model. The predictions for each catchment are based on UKCP09 projections for the temporal period 2010n 2039 using the medium emissions scenario. The temperature graphs show the actual change (^{o}C) expected to the 1961-1990 means.

◆ = Low climate change scenario (10% probability level)

■ =Medium climate change scenario (50% probability level)

▲ =High climate change level (90% probability level)

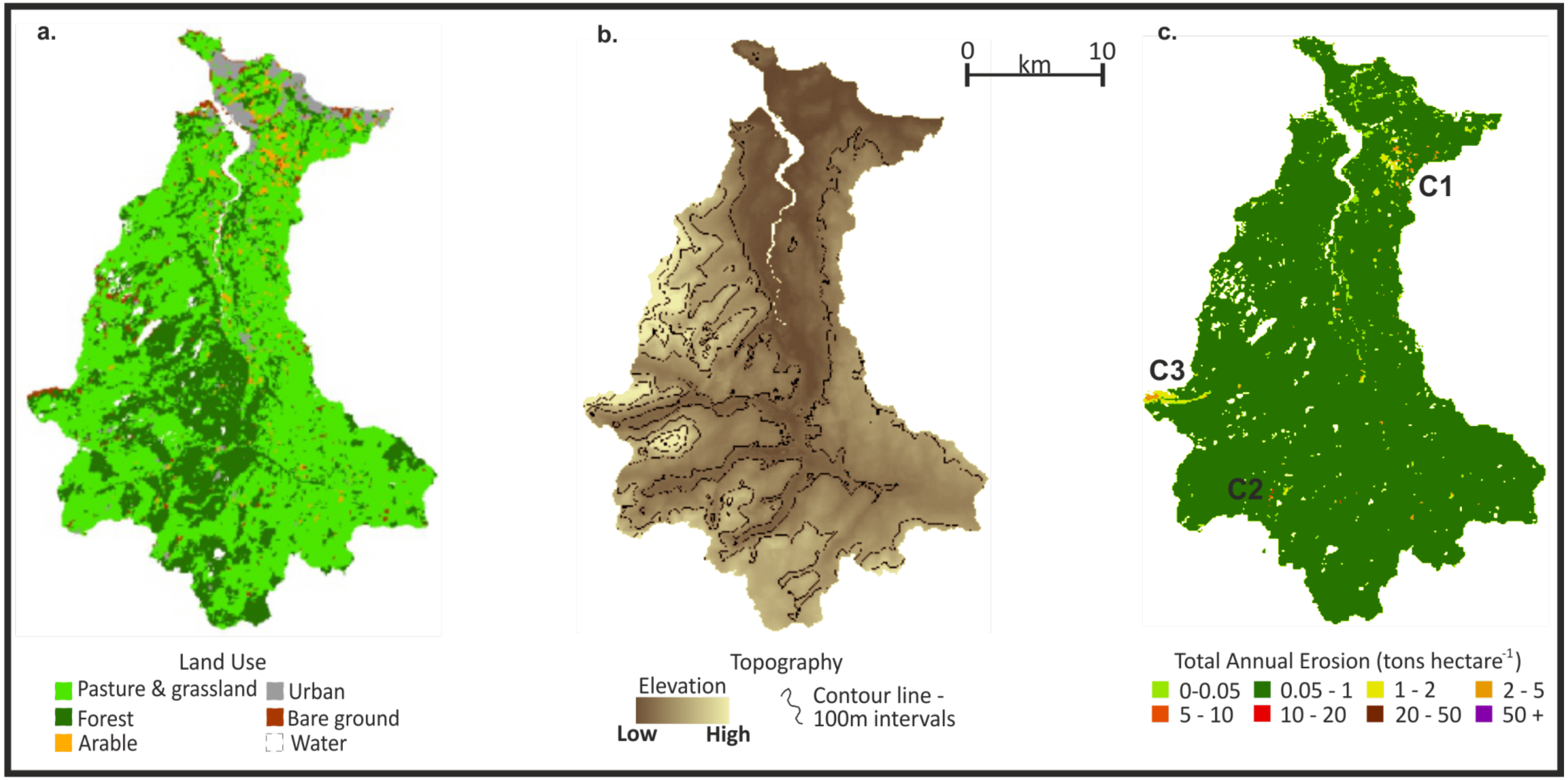

Figure 3.4: Land use, topographic and baseline PESERA erosion maps for the Conwy catchment, Wales.
Map a. shows the land use within the Conwy catchment, based on land use classifications described within the PESERA model.
Map b. is topographic map of the Conwy catchment with contour lines at 100 m.
Map c. is the baseline PESERA erosion prediction, for the Conwy catchment, using climate averages over the period 1961-1990, with hotspots C1-C3 marked.

The Conwy is a formerly glaciated catchment that is predominantly rural, with 64% of the catchment area containing pasture. Forestry is the second most important land use (28% of catchment area) and is concentrated towards the headwaters of the catchment. The remaining 8% of the catchment area is divided between small patches of arable and bare land and the urban areas of Conwy and Llandudno. Most of the catchment was shown to be eroding at 0.05-1 t ha^{-1} a^{-1} consistent with being under permanent, year-round cover: the median catchment erosion rate is 0.2 ± 0.09 t ha^{-1} a^{-1} There were very few hotspots of higher erosion highlighted by points C1 and C2 (Figure 3.4, insert c). C1 is found in the largest patch of arable land in the catchment, located on higher topography close to the outlet of the river. The combination of land use and a soil that is particularly vulnerable to crusting and erosion mean that erosion in this patch was between 1 and 2 t ha^{-1} a^{-1}. C2 had the highest local erosion rates in the catchment (up to 5 t ha^{-1} a^{-1}) reflective of a combination of steep topography and bare, erodible soils. Erosion rates at C2 were 2-3 orders of magnitude higher than the steep, pasture-dominated opposite side of the valley, suggesting that in this case land use rather than steep topography is controlling soil erosion.

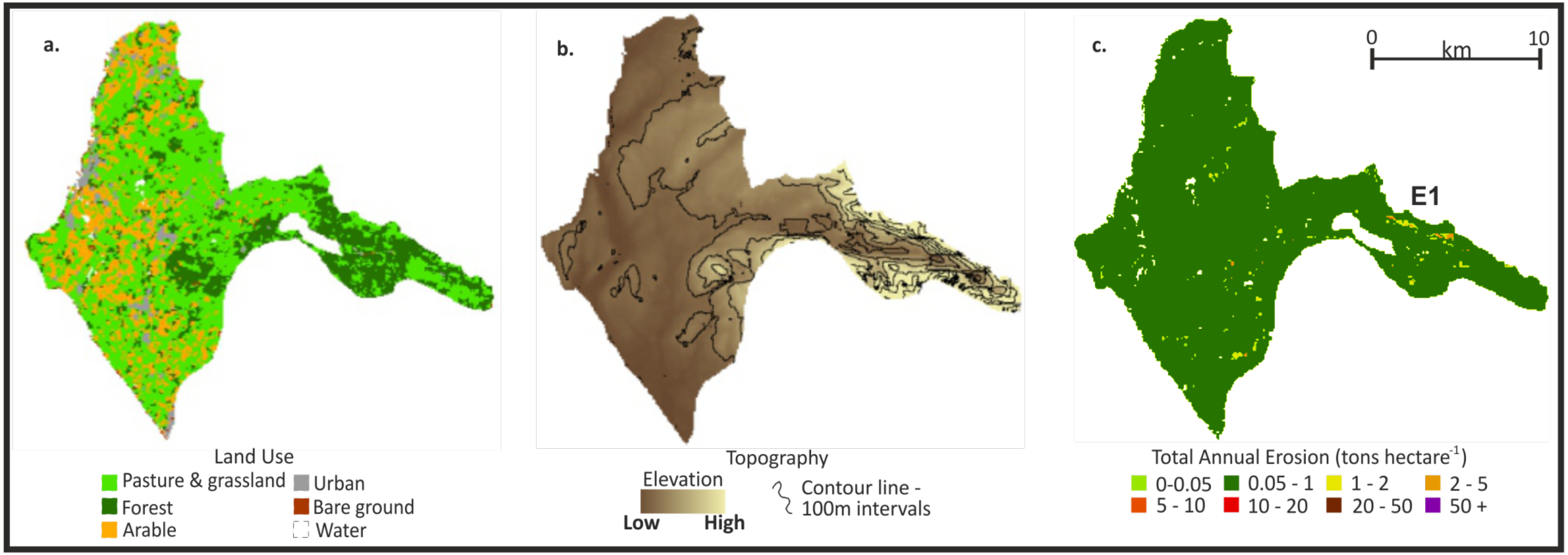

Figure 3.5: Land use, topographic and baseline PESERA erosion maps for the Ehen catchment, England.
Map a. shows the land use within the Ehen catchment, based on land use classifications described within the PESERA model.
Map b. is topographic map of the Ehen catchment with contour lines at 100 m.
Map c. is the baseline PESERA erosion prediction, for the Conwy catchment, using climate averages over the period 1961-1990, with hotspots E1 marked.

The Ehen had the highest median erosion rates of the three catchments, despite having a lower relief, of 0.21 ± 0.14 t ha^{-1} a^{-1}. The Ehen has by far the greatest proportion of arable land of the three study catchments (19%) and the lowest proportion of permanent, year-round cover (75% of the catchment is pasture and forest). The only patches of high erosion rates (up to 2 t ha^{-1} a^{-1}) were found in the steep, pasture- and forest-dominated headwater topography. The erosion hotspot highlighted by E1 (Figure 3.5), occured on steep topography with permanent cover, however a particularly erodible soil at this location significantly increases erosion rate.

Modelled erosion rates for the Dee are considerably more variable than the other catchments. The median erosion rate of 0.20 ± 0.1 t ha^{-1} a^{-1} is the same as for the Conwy despite steeper topography and higher precipitation rates. Forest comprises 71% of the Dee catchment, and is concentrated in the catchment headwaters. Arable land makes up 8% of the catchment and is concentrated near the mouth of the river and is interspersed with pasture, which makes up 17% of the catchment. Erosion hotspots D1, D2, and D4 (Figure 3.6) were all found in steep, forested topography and had the highest erosion rates (up to 20 t ha^{-1} a^{-1}) measured in this study. The key difference between these three locations and adjacent patches of steep topography is again the presence of soil that is vulnerable to crust formation. The increase in the proportion of arable land around D3 produced erosion rates of up to 10 t ha^{-1} a^{-1}.

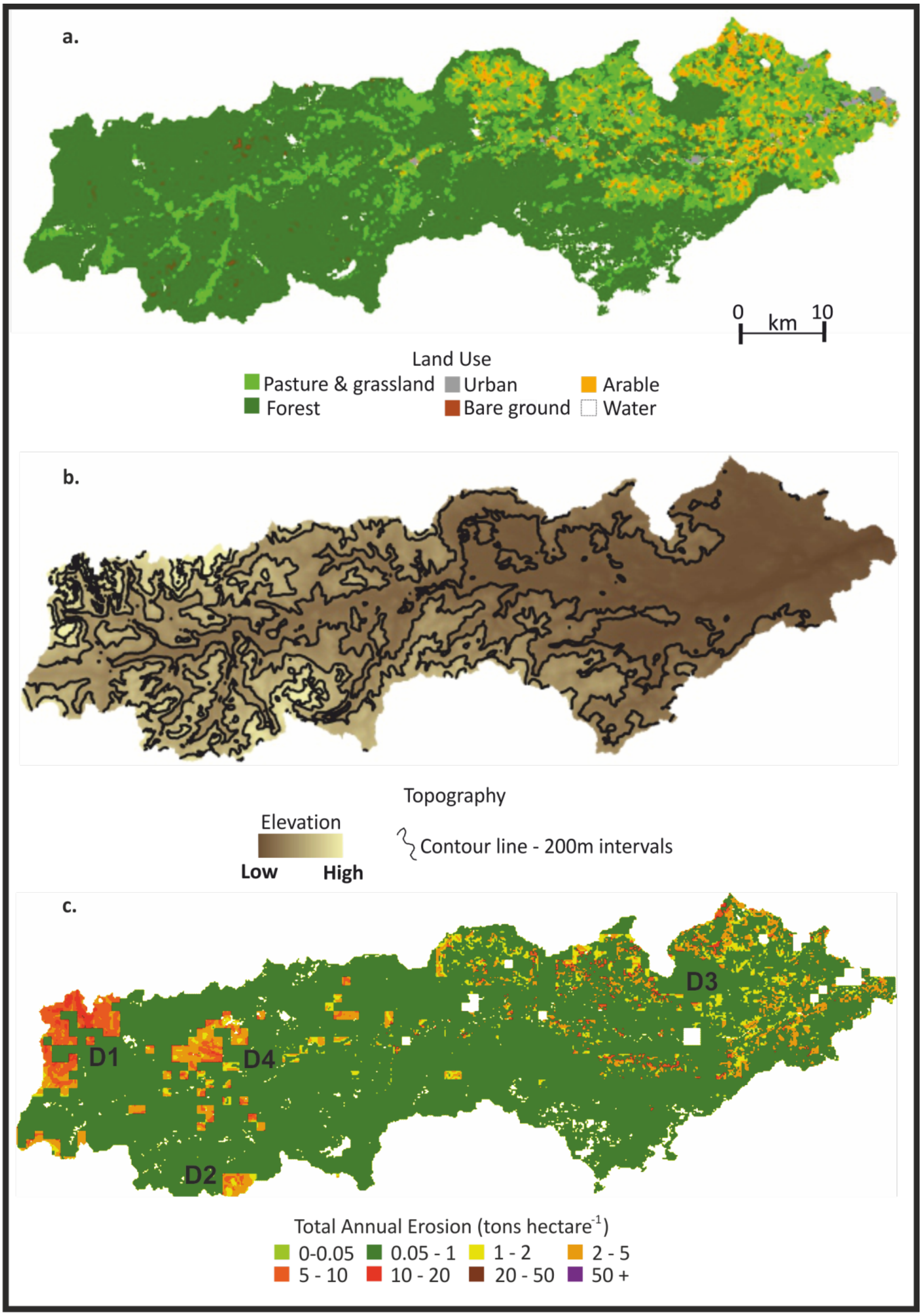

Figure 3.6: Land use, topographic and baseline PESERA erosion maps for the Dee catchment, Scotland. Map a. shows the land use within the Dee catchment, based on land use classifications described within the PESERA model. Map b. is topographic map of the Dee catchment with contour lines at 200 m. Map c. is the baseline PESERA erosion prediction, for the Dee catchment, using climate averages over the period 1961-1990, with hotspots D1-D4 marked.

3.3.3 Climate Change Effect Relative to Baseline Conditions

The effect of changes in precipitation and temperature were investigated, based on the 10%, 50%, and 90% probabilities from the UKCP09 medium emissions scenario (hereafter termed the low, medium, and high scenarios) on each of the three catchments whilst maintaining land use as in baseline conditions (Land Use scenario 1). Counter intuitively, these results suggest that in all climate change scenarios there is a small to no decrease in the median annual sediment yield. In all of the catchments the mean annual sediment yield increased for the medium and high climate change scenarios. This suggests that the extremely erodible portions of the landscape such as arable and bare lands and vulnerable soils are eroding much faster.

The median erosion rates predicted for the Conwy catchment (Figure 3.7) under the low, medium and high climate change scenarios (0.15 ± 0.09 t ha^{-1} a^{-1} ; 0.015 ± 0.09 t ha^{-1} a^{-1} and 0.19 ± 0.09 t ha^{-1} a^{-1} respectively) did not differ significantly from the baseline median (z = -151.59; -109.18 and -14.33 respectively, $p<0.05$) The PESERA model predicted that the majority of the Conwy catchment would have a sediment yield of 0.05 – 1 t ha^{-1} a^{-1} across all three climate change scenarios. However, the forested sections of the valley bottom are predicted to erode more slowly, at less than 0.05 t ha^{-1} a^{-1}, which is a decrease on baseline conditions. The erosion hotspots C1 and C2 both increased in magnitude, with a greater proportion of both eroding at 2-5 t ha^{-1} a^{-1} under the high climate change scenario. This change is reflected in the mean sediment yield predictions, which increased from the low to high climate change scenario; under the high scenario the mean sediment yields were greater than the baseline predictions.

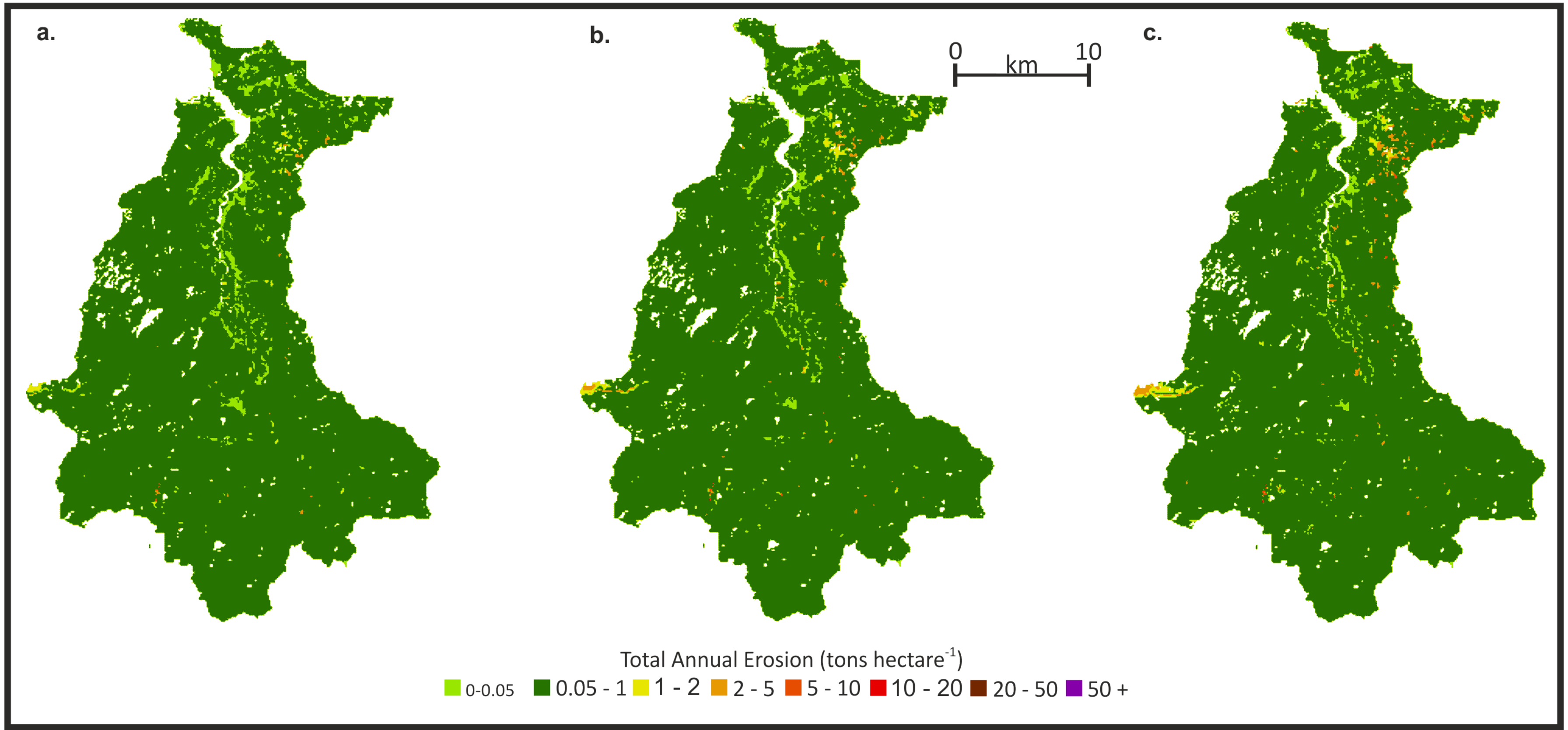

Figure 3.7: PESERA model outputs for the Conwy (Wales) catchment, at 100 m resolution, showing total annual erosion (tons hectare$^{E\ 1}$year$^{E\ 1}$).
Outputs a. b. and c. are model outputs using UKCP09 climate change projections (precipitation and temperature) under the medium emissions scenario, at the10%, 50% and 90% probability levels respectively, with no change to land use (Land Use Scenario 1).

Across the Ehen catchment (Figure 3.8), the median sediment yields are consistent across the three climate change scenarios (0.18 ± 0.15 t ha^{-1} a^{-1}; 0.18 ± 0.15 t ha^{-1} a^{-1} and 0.18 ± 0.21 t ha^{-1} a^{-1}), with increasing variability under the high scenario. Across each of the scenarios, the model outcomes showed that sediment yields would be 0.05 – 1 t ha^{-1} a^{-1}; however there were patches of arable land in areas of flatter topography where the sediment yield rose to 1-2 t ha^{-1} a^{-1}. These patches increased from the low to high climate change scenario, as did the size of hotspot E1 which showed the highest sediment yield under the high scenario of 2-5 t ha^{-1} a^{-1}. All the climate change scenarios were significantly different to the baseline output (low: z = -104.13; medium: z = -31.98; high: z = -16.44, all $p<0.05$) and, in comparison to the baseline, the high scenario has noticeably increased erosion rates on arable land which increases in steepness to the north of the catchment.

The Dee catchment (Figure 3.9) continued to exhibit high yet variable erosion rates; the median erosion rates were 0.18 ± 0.09 t ha^{-1} a^{-1}; 0.19 ± 0.13 t ha^{-1} a^{-1} and 0.21 ± 0.21 t ha^{-1} a^{-1} across the low, medium and high climate change scenarios respectively (Figure 3.9). Under the low scenario, less of the arable land at the mouth of the catchment (hotspot D3) was predicted to erode at rates of 2-5 t ha^{-1} a^{-1} in comparison to the medium and high scenarios. At hotspot D1, in the steepest section of the catchment, a higher proportion of this area was predicted to erode at 2-5 t ha^{-1} a^{-1} under the low scenario; in contrast, under the high scenario, the majority of this hotspot was predicted to erode at a rate of 10-20 t ha^{-1} a^{-1}, the highest erosion rate seen across all the study catchments. Such results lead to greater mean sediment yields for these scenarios than the baseline. All the climate change scenarios were statistically significantly different from the baseline (low: z = -288.80; medium: z = -13.28; high: z = -186.48, all $p<0.05$), and the mean erosion rate for the medium and high scenarios were greater than the mean sediment yield of the baseline

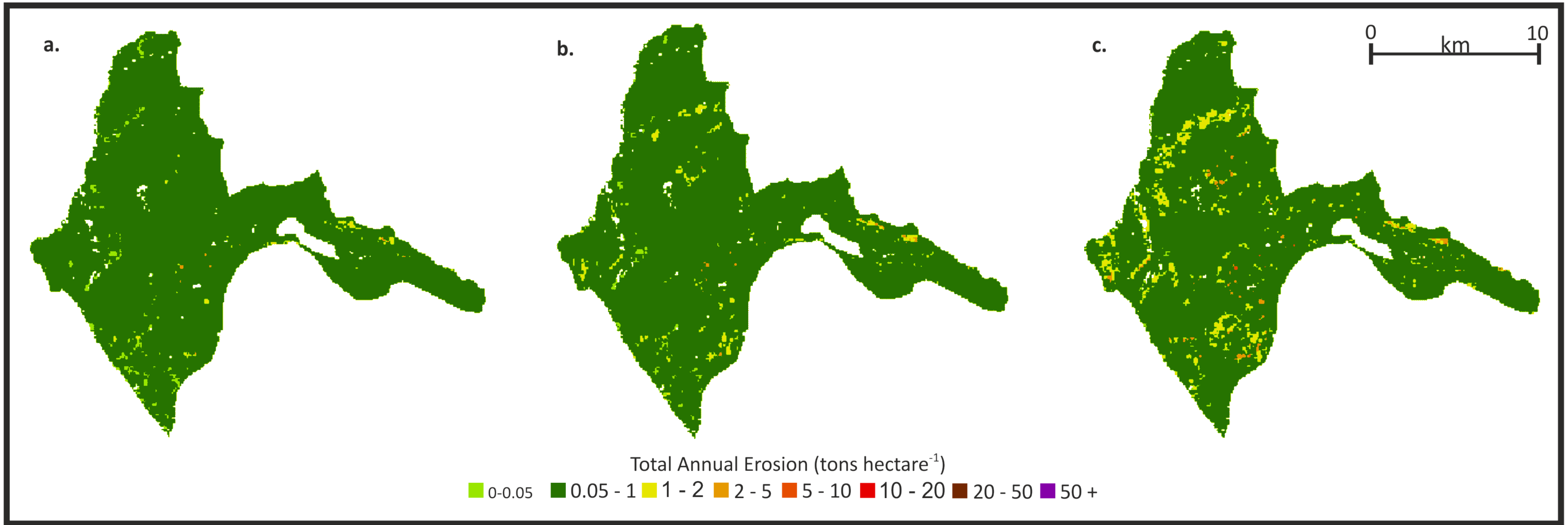

Figure 3.8: PESERA model outputs for the Ehen (England) catchment, at 100 m resolution, showing total annual erosion (tons hectare^{-1}year^{-1}).
Outputs a. b. and c. are model outputs using UKCP09 climate change projections (precipitation and temperature) under the medium emissions scenario, at the10%, 50% and 90% probability levels respectively, with no change to land use (Land Use Scenario 1).

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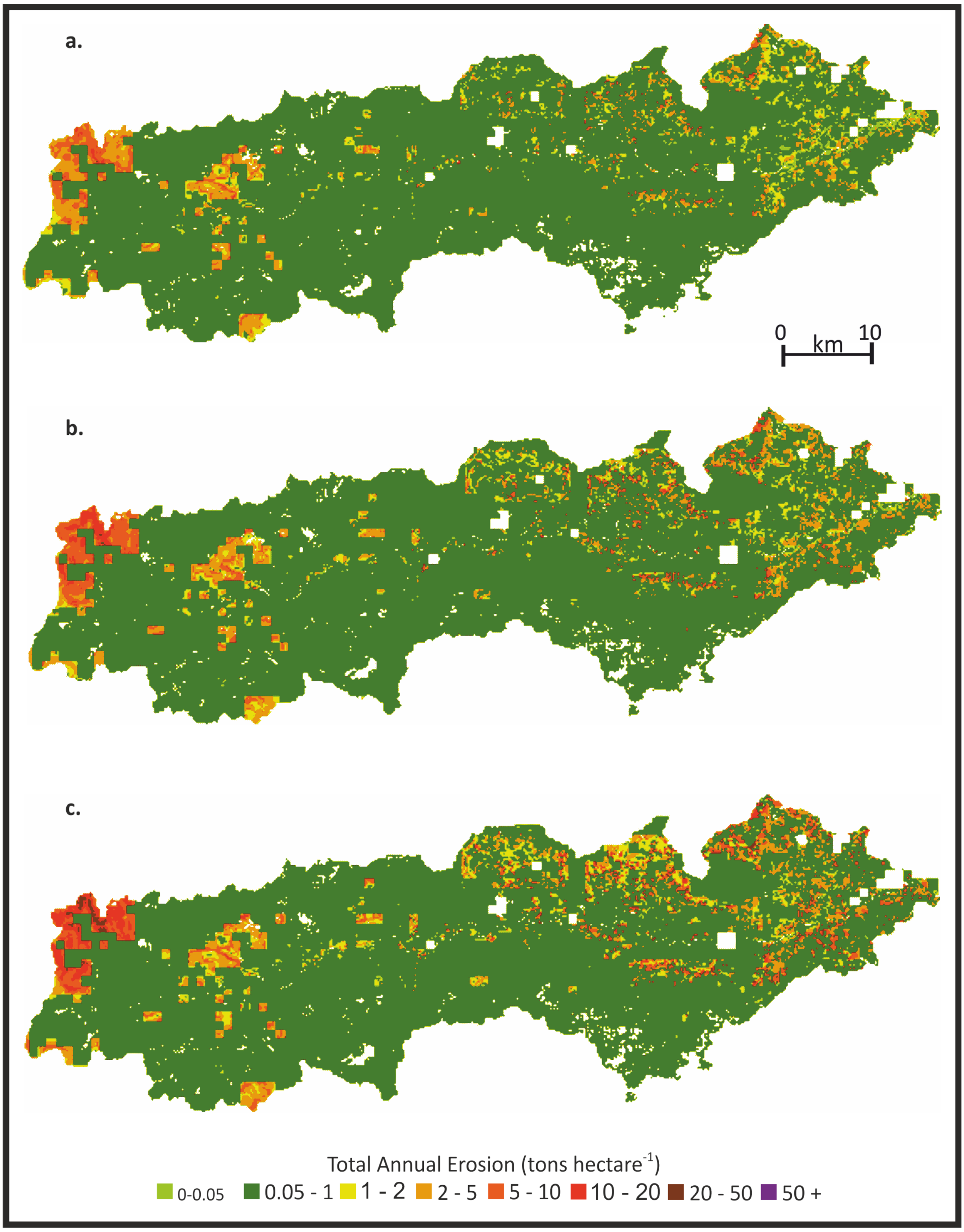

Figure 3.9: PESERA model outputs for the Dee (Scotland) catchment, at 100 m resolution, showing total annual erosion (tons hectare$^{E\ 1}$year$^{E\ 1}$).

Outputs a. b. and c. are model outputs using UKCP09 climate change projections (precipitation and temperature) under the medium emissions scenario, at the10%, 50% and 90% probability levels respectively, with no change to land use (Land Use Scenario 1).

H2. Can land use changes ameliorate any change to erosion rates as a result of climate change over the period 2010-2039?

3.3.4 Land Use Effects Relative to Baseline Conditions

In order to investigate the combined effects of climate change and catchment wide land use change on sediment yields, the quantity of arable, pasture and forested regions across all three study catchments were manipulated; comparisons were then made with the baseline and climate change only scenario (LU1) results. In land use scenario 2 (LU2), all arable land in the catchment was replaced by mixed forest and under land use scenario 3 (LU3), all forest was converted to pastures. At the same time, the medium climate change precipitation and temperature data was used (i.e. temperature and precipation data from the 50% probability level under the medium emissions scenario).

3.3.4.1 Land Use Scenario 2

The median sediment yield predicted by PESERA for all three catchments under LU2 was less than both the baseline and the medium climate change scenario alone (LU1), reflecting the reduction in arable land across the three catchments. Catchments with the largest proportion of arable land show the greatest decrease in sediment yield as a result of the arable to forest conversion in this scenario. All the model outputs for this scenario were significantly different to both the baseline outputs (Conwy z = -120.53; Ehen z = -99.00; Dee z = -129.40, all $p<0.05$) and those for the medium climate change scenario (Conwy z =-28.80; Ehen z = -56.54; Dee z = -110.40, all $p<0.05$).

The Conwy catchment has the lowest proportion of arable land; the LU2 scenario only increased the forest proportion by 1.8%. The median sediment yield for this catchment nder the LU2 scenario was 0.18 ± 0.08 t ha^{-1} a^{-1}, the same as the median sediment yield under the medium climate change scenario (LU1) alone and a small decrease on the baseline sediment yield. Under this scenario, hotspot C1 showed a marked reduction in sediment yield to 0-0.05 t ha^{-1} a^{-1} whilst hotspot C2 didnot change. This effect is reflected in the mean sediment yield

(0.18 t ha^{-1} a^{-1}) as a result of the change in land use at hotspot C1 from arable to forest (Figure 3.10, insert b).

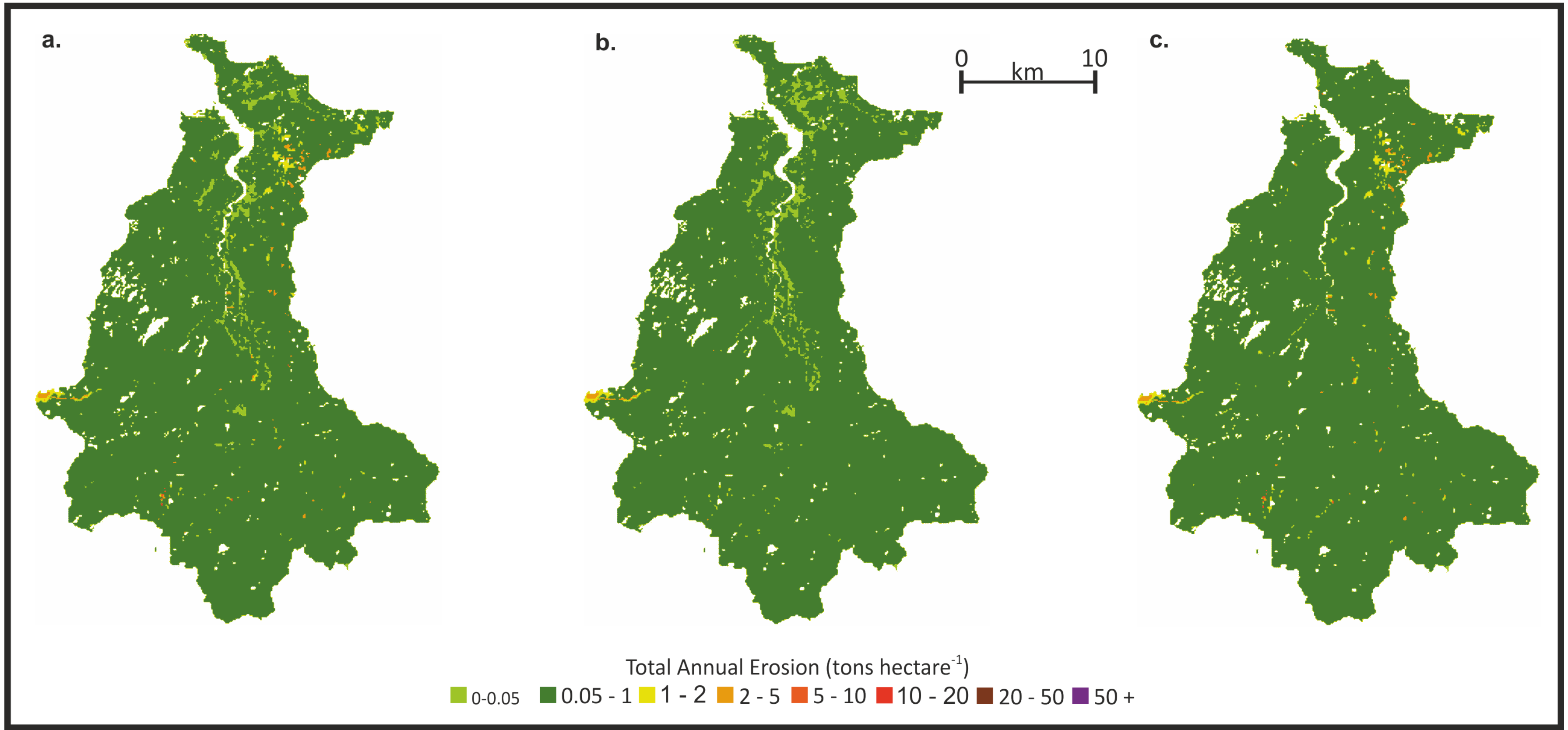

Figure 3.10: PESERA model outputs for the Conwy (Wales) catchment, at 100 m resolution, showing total annual erosion (tons hectare$^{E\ 1}$year$^{E\ 1}$).
Output a. is the erosion rate predicted under the medium emission scenario at the 50% probability level (for reference).
Output b. is the erosion rate under the medium emission scenario at the 50% probability level, additionally all the arable land in the catchment has been converted to forest (Land Use scenario 2).
Output c. is the erosion rate under the medium emission scenario at the 50% probability level, and all the forested land within the catchment has been converted to pastures and grassland (Land Use Scenario 3).

The forested proportion of the Ehen catchment increases to 19% under the LU2 scenario, indicative of the fact that the Ehen catchment has the highest proportion of arable land of the three study catchments. The median sediment yield was 0.18 ± 0.06 t ha^{-1} a^{-1} under LU2, which was both a reduction on the baseline and on the medium emission scenario (LU1) but also showed a reduction in variability. having the lowest sediment yield of 0-0.05 t ha^{-1} a^{-1}, as forest replaced arable land. The sediment yield at hotspot E1 remained unchanged; despite this, the mean erosion rate under this land use droped to 0.18 t ha^{-1} a^{-1} likely as a result of the reduced erosion on the converted arable-to-forest land (Figure 3.11, insert b).

Under the LU2 scenario, forest in the Dee catchment was increased by 8% and the median sediment yield was less than both the medium emission scenario and the baseline at 0.18 ± 0.11 t ha^{-1} a^{-1}. Hotspots D2 and D3 remain unchanged, like both the Conwy and the Ehen these are on pasture or forested land which were unaffected by this land use scenario. However, there was a marked decrease in the sediment yield at hotspot D3 where the model outputs showed that the majority was eroding at 0.05 – 1 t ha^{-1} a^{-1}, as a result of the conversion of arable land to forest (as illustrated in both the Conwy and the Ehen). The resultant reduction in mean sediment yield under this scenario (to 0.52 t ha^{-1} a^{-1}) exemplified the effect that a relatively small proportion of the catchment dedicated to arable land can have on catchment sediment yields (Figure 3.12, insert b).

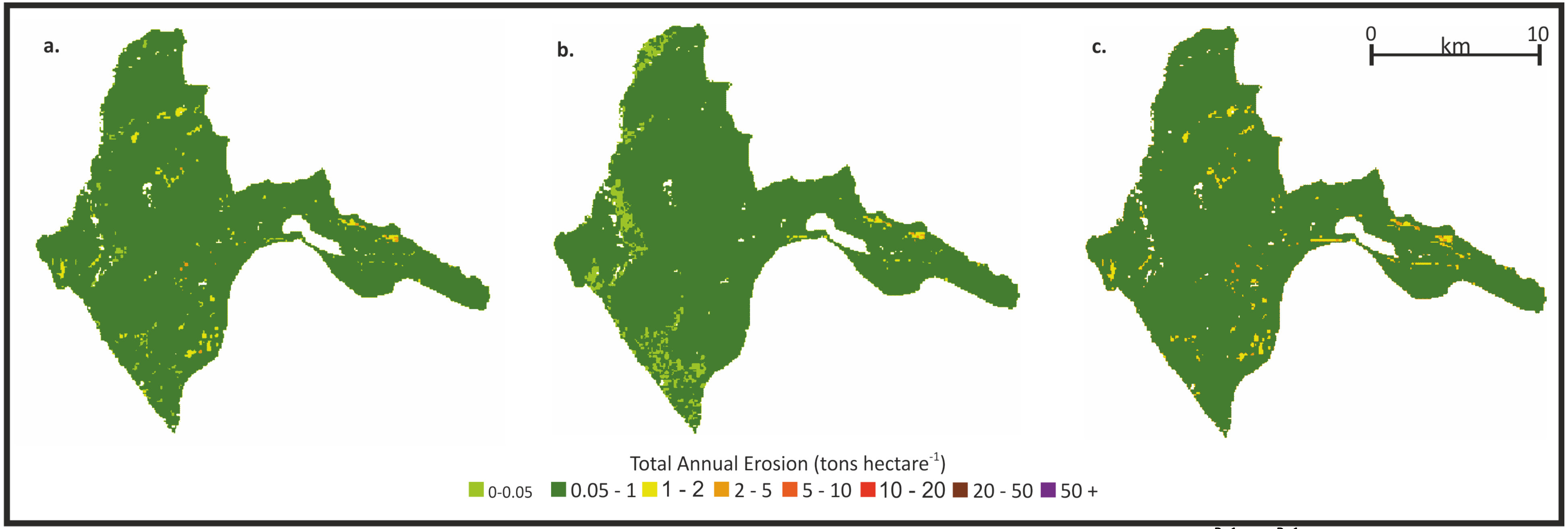

Figure 3.11: PESERA model outputs for the Ehen (Scotland) catchment, at 100 m resolution, showing total annual erosion (tons hectare^{-1}year^{-1}).
Output a. is the erosion rate predicted under the medium emission scenario at the 50% probability level (for reference)
Output b. is the erosion rate under the medium emission scenario at the 50% probability level, additionally all the arable land in the catchment has been converted to forest (Land Use scenario 2).
Output c. is the erosion rate under the medium emission scenario at the 50% probability level, and all the forested land within the catchment has been converted to pastures and grassland (Land Use Scenario 3).

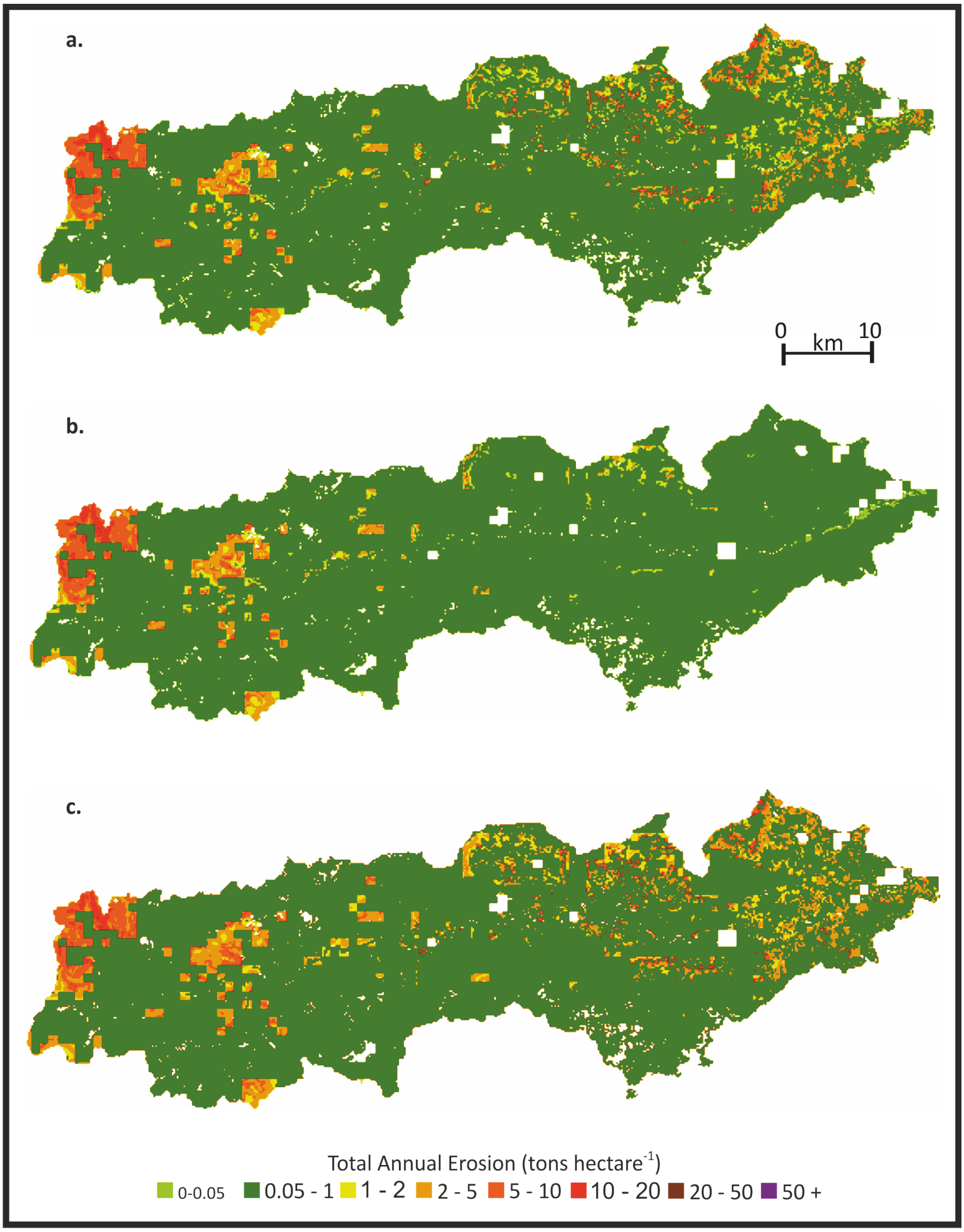

Figure 3.12: PESERA model outputs for the Dee (Scotland) catchment, at 100 m resolution, showing total annual erosion (tons hectare^{-1}year^{-1}).

Output a. is the erosion rate predicted under the medium emission scenario at the 50% probability level (for reference)

Output b. is the erosion rate under the medium emission scenario at the 50% probability level, additionally all the arable land in the catchment has been converted to forest (Land Use scenario 2).

Output c. is the erosion rate under the medium emission scenario at the 50% probability level, and all the forested land within the catchment has been converted to pastures and grassland (Land Use Scenario 3).

3.3.4.2 Land Use Scenario 3

In scenario, LU3, the effects of converting all forest land to pasture were investigated; this maintained year round cover but altered the morphology of the cover type. Again, as with LU2, the climate data used was from the medium climate change scenario (i.e. the temperature and precipitation data used were from the 50% probability level under the medium emissions scenario), and all modelled outcomes were significantly different from the baseline (Conwy $z = -71.64$; Ehen $z = -14.83$; Dee $z = -74.43$, all $p<0.05$); the medium climate scenario alone (Conwy $z = -81.27$; Ehen $z = -34.16$; Dee $z = -92.29$, all $p<0.05$) and the results from LU2 (Conwy $z = 87.93$; Ehen $z = -71.36$; Dee $z = -145.73$, all $p<0.05$). A greater proportion of each catchment increased in sediment yield (in comparison to baseline erosion rates) under the LU3 land use conversion than either LU2 or the medium climate change scenario. Figure 3.13 represents the changes in land use modelled using the percentage of forest in each scenario.

The majority the Conwy catchment showed a sediment yield of 0.05 – 1 t ha^{-1} a^{-1} under LU3, with a 28% increase in pastures under this land use scenario. The median sediment yield was 0.18 ± 0.10 t ha^{-1} a^{-1}; in particular the sediment yield in the centre of the catchment was predicted to have an erosion rate of 0.05-1 t ha^{-1} a^{-1} , representing an increase in comparison to LU2, the medium climate change scenario alone and to a certain extent, the baseline. The land use type in hotspot C1 remained unaltered, thus the erosion rate here is identical to that under the medium climate change scenario (LU1) and LU2 (Figure 3.10, insert c).

The LU3 land use change has little effect on the Ehen catchment since it had the lowest proportion of forest across all three study catchments (20%). The median sediment yield was the same as the medium climate change emission scenario alone but slightly higher than that predicted under LU2, at 0.18 ± 0.16 t ha^{-1} a^{-1}. The hotspot E1 is unchanged by the LU3 land use scenario given that this area is predominantly pastured. That the sediment yield from the Ehen catchment did not change under LU3 indicates that both forests and pastures provide comparable protection of the soil from the erosive action of rainfall (Figure 3.11, insert c).

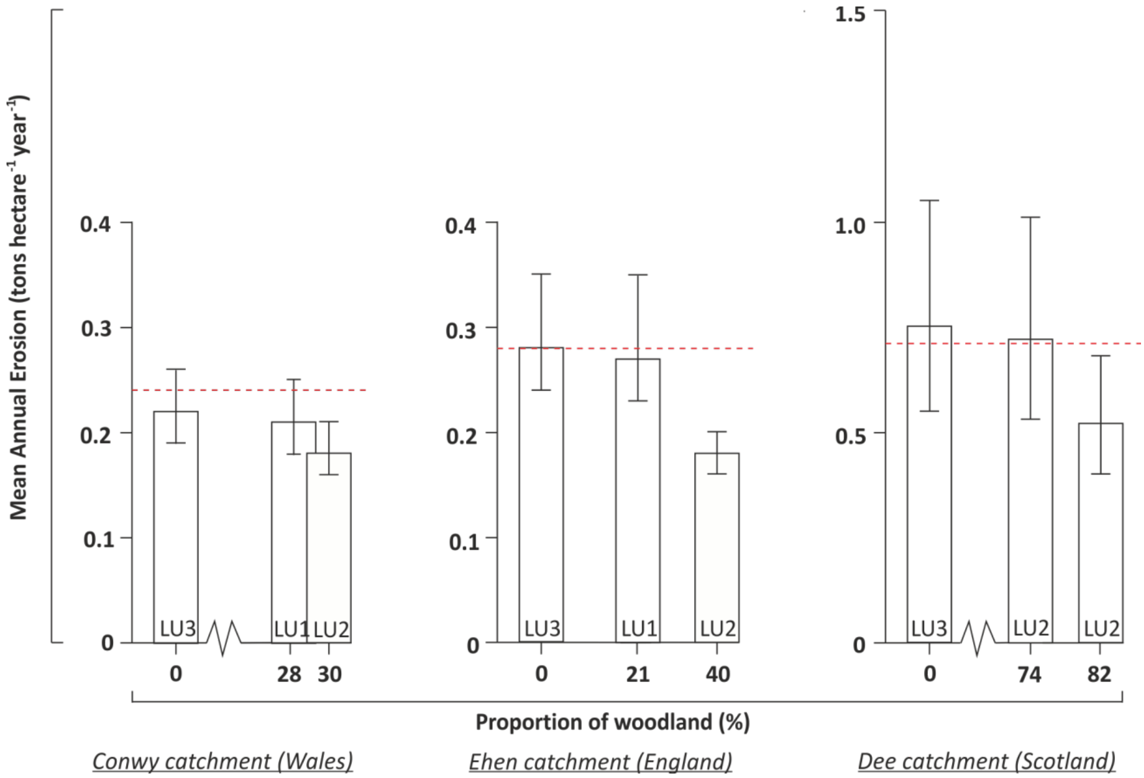

Figure 3.12: Bar graphs showing the change to mean annual catchment erosion (t ha-1 a-1) with respect to the proportion of forest within each catchment, as predicted by the PESERA model.
The climate change data used are from UKCP09 under the medium emission scenario at the 50% probability level. Error bars show the results at the 10% and 90% probability levels.
Original land use data based on Land Cover Map 2000, figures underneath bars indicate percentage of forest within each catchment under each scenario.
shows baseline mean erosion, based on climate averages from 1961-1990 and land use from 2000 (LCM2000).
LU1, 2 and 3 show the effects of the climate change data under different land use scenarios: LU1 - no land use change; LU2 - all arable land converted to forest, and LU3 - all forest converted to pastures and grassland.

The Dee has the highest proportion of forest and in the LU3 scenario therefore, with the 71% increase in pasture, the median sediment yield was greater than the climate change scenario alone (LU1) at 0.20 ± 0.11 t ha^{-1} a^{-1}. However, the sediment yield of the four hotspots was unaltered in comparison to the medium climate change scenario; it is likely that despite this land use conversion maintaining year round cover, the underlying soil properties and topography are dominating the erosion process in these regions (Figure 3.12, insert c).

3.3.5 Changes to dominate land use types under Land Use Scenario 1.

Finally, the effect of the three climate change scenarios on the three dominant land use types within each catchment were investigated: arable; forest and pasture (Table 3.2). The output from each climate change scenario was significantly different from the baseline and the other climate change scenarios (Table 3.3). In general the arable land use was constrained to regions of flatter topography; despite this, median sediment yields on this land use were the highest, for example arable land in the Dee under the high climate scenario generated erosion rates of up to 3.39 ± 4.34 t ha^{-1} a^{-1}. The medium and high climate change scenarios showed an increase on the baseline erosion rates, across all catchments. In the Conwy and the Dee catchments the median sediment yields under the high climate change scenarios were almost twice as large as the baseline.

Pasture land across the three study catchments was predominantly found in areas of moderate topography. Only in the Dee catchment under the high climate change scenario did the median sediment yield for this land use type exceed the baseline. All of the catchments showed increasing median sediment yields from low to high climate scenarios. It is of note that the median sediment yields for all three catchments are considerable lower than the median values for arable land, despite an increase in topographic variability. It appears that the slight increase in slope on pasture lands is outweighed by the year round cover generated by grass.

In all three catchments, the forest land use type was found in the areas of steepest topography, yet the median sediment yields were amongst the lowest of all three land uses, for example in the Dee catchment under the high climate change scenario the median sediment yield was 0.20 ± 0.12 t ha^{-1} a^{-1}. This replicates the trend seen under the pasture land use type. Across all three catchments, sediment yields under the forest scenario did not exceed the baseline median; in the Conwy catchment the median sediment yield under the high scenario was less than the median baseline sediment yield. Only the high climate change scenario resulted in an increase to median baseline sediment yields. The prevalence of erosion hotspots in forested land use in the Dee catchment are likely a result of extremely steep topography in combination with a highly erodible peat soil type.

a. Conwy Catchment

	Topographic Variability[1]	BL	Low	Medium	High
Arable	20.08 ± 9.93	0.92 ± 1.07	0.66 ± 0.76	1.00 ± 1.17	1.57 ± 1.75
Pastures	27.58 ± 17.68	0.20 ± 0.08	0.15 ± 0.08	0.16 ± 0.08	0.19 ± 0.09
Forest	33.11 ± 19.94	0.18 ± 0.09	0.13 ± 0.08	0.13 ± 0.11	0.15 ± 0.10

b. Ehen Catchment

	Topographic Variability[1]	BL	Low	Medium	High
Arable	11.24 ± 5.95	0.41 ± 0.22	0.36 ± 0.13	0.47 ± 0.29	0.70 ± 0.56
Pastures	19.60 ±34.44	0.20 ± 0.05	0.15 ± 0.03	0.15 ± 0.03	0.15 ± 0.04
Forest	44.23 ± 34.69	0.19 ± 0.11	0.15 ± 0.10	0.16 ± 0.11	0.19 ± 0.16

c. Dee Catchment

	Topographic Variability[1]	BL	Low	Medium	High
Arable	11.34±6.61	1.84 ± 2.21	1.38 ± 1.57	2.08 ± 2.57	3.39 ± 4.34
Pastures	16.86 ± 12.36	0.20 ± 0.10	0.18 ± 0.05	0.20 ± 0.12	0.24 ± 0.34
Forest	32.59 ± 18.58	0.18 ± 0.04	0.18 ± 0.08	0.18 ± 0.10	0.20 ± 0.12

Table 3.2: Comparison of changes to baseline median total annual erosion (tons hectare^{-1}) ± IQR by land use in each catchment, based on PESERA model outputs.
The model runs used climate change projections (for the period 2010-2039) under the medium emission scenario. These three land uses represent the three dominant land uses within the catchment, (based on PESERA land use classes): arable; forest and pastures & grassland.
[1]Mean topographic variability is based on the measure of topography as used by the PESERA model, whereby the standard deviation of elevation data within a set radius (400m) as the measure of topography.

a. Conwy Catchment

	BL – Low	BL – Medium	BL – High	Medium – Low	Low – High	Medium - High
Arable	-27.898	-27.777	-28.544	-28.313	-28.570	-28.113
Pasture	-125.296	-100.333	-19.900	-87.440	-110.917	-98.216
Forest	-79.015	-59.015	-13.183	-53.836	-79.382	-62.566

b. Ehen Catchment

	BL – Low	BL – Medium	BL – High	Medium – Low	Low – High	Medium - High
Arable	-54.794	-55.901	-56.366	-55.961	-56.360	-56.364
Pasture	-80.040	-75.707	-49.814	-21.671	-36.867	-30.299
Forest	-41.884	-27.098	-1.389 *ns*	-27.722	-41.603	-29.112

c. Dee Catchment

	BL – Low	BL – Medium	BL – High	Medium – Low	Low – High	Medium - High
Arable	-108.077	-109.857	-108.666	-108.837	-109.843	-109.579
Pasture	-150.266	-95.509	-22.829	-123.495	-138.963	-127.740
Forest	220.501	73.774	114.537	-185.228	-230.022	-210.334

Table 3.3: Statistical comparisons of erosion rates predicted under the three climate scenarios for the three major land use types.

Wilcoxen Signed Rank tests between the erosion predictions for the three major land uses (arable; forest and pastures) under each climate scenario (low, medium and high) reveal significant differences at all levels to the baseline.

Unless otherwise stated, all results p<0.001 l

3.4 Discussion

Much work predicting erosion rates under future climate scenarios uses climate predictions in which precipitation levels increase, both in intensity and magnitude (Favis-Mortlock and Boardman 1995; Nearing *et al*. 2005; O'Neal *et al*. 2005). Indeed, many studies have concluded that it is an increase in intensity that will drive the predicted increases in erosion rates (Pruski and Nearing 2002; Nearing *et al*. 2005; Arnaez *et al.* 2007), as a result of the interaction between erosion and antecedent soil moisture conditions (Luk 1985; Ziadat and Taimeh 2013), although the climatic data used in some instances can be out-dated (Soil and Water Conservation Society 2003). The climate scenarios used in this study, obtained from the UKCP09 data (UKCP09 2012) show that under the low climate change scenario (the 10% probability level), precipitation levels across the year will be lower than the 1961-1990 baseline, leading to reduced rates of catchment-wide soil erosion as a result. Similarly, in work by Mullan *et al.* (2012) decreases in erosion rates were also observed under climate scenarios which predicted less rainfall than current levels. Precipitation patterns under the medium climate change scenario (50% probability level) reveal a trend towards wetter winters and drier summers, with mean annual precipitation similar to baseline conditions. Accordingly, mean catchment-wide erosion rates were similar to the baseline rates, with erosion rates across all land uses lower during summer than winter. The high climate change scenario (the 90% probability level) has precipitation increasing across all months compared to the baseline, and consequently, mean-erosion rates across all catchments increased. These results compared well with predictions that have been previously reported, that increased annual precipitation should lead to increased and widespread soil erosion (Evans and Cook 1986; Evans 1990; Boardman and Favis-Mortlock 1993; Favis-Mortlock and Savabi 1996; Boardman and Favis-Mortlock 2001; Nearing *et al*. 2005). For example, other studies have predicted a 0.85% increase in rates of soil erosion for every 1% increase in precipitation (Pruski and Nearing 2002) and up to a 150% increase in erosion on arable land with a 10% increase in winter precipitation (Favis-Mortlock and Boardman 1995). Similar to work by Favis-Mortlock and Savabi (1996), the PESERA modelled increases in soil erosion under the high climate change scenario were not spatially contiguous across the catchments; regions which are already vulnerable to erosion show the greatest increase. There are, however, substantial proportions of the upland portions within the three catchments that are under permanent (i.e. year-round) vegetation cover where erosion decreases relative to baseline conditions, even at the high (90%) probability level.

These results confirm the increased vulnerability of arable land to soil erosion and the ameliorating effect of land use in the process, even under situations of increasing rainfall (Van Rompaey *et al.* 2002; Nearing *et al*. 2004; Bakker *et al*. 2005; Nearing *et al*. 2005; Bakker *et al*. 2008). The results indicated that, in these three catchments, land cover was the principal control on the susceptibility of soil to rilling and erosion by sheet wash. The results also indicated that the greatest susceptibility occurred on arable land where cover is not constant year-round, consistent with other empirical studies (Boardman and Favis-Mortlock 1993; Favis-Mortlock and Boardman 1995; Favis-Mortlock and Savabi 1996; Boardman and Favis-Mortlock 2001; O'Neal *et al*. 2005). In each model scenario, increases to erosion rates as a result of precipitation increases were proportionately much smaller on woodland or pasture where cover was high throughout the year. Permanent land cover has been shown to increase the spatial variability of the soil infiltration capacity by the introduction or organicmatter and plant roots (Bonell 1993; Cammeraat 2002); the resultant discontinuous runoff rates mean that significant overland flow is thereby prevented (Cammeraat 2002; Cerdan *et al.* 2004).

The PESERA results also demonstrated that locations at high elevations with steep slopes are incredibly susceptible to soil erosion by sheet wash and rilling, even with year-round vegetative cover. Under modern climate conditions, steep upland areas in each of the catchments are predicted to experience very high erosion rates in excess of the tolerable soil erosion rate of 1.4 t ha^{-1} a^{-1} for Britain (Verheijen *et al.* 2009). Further, land use changes, such as the conversion of woodland to pastureland, showed a small shift to an increase in mean-annual erosion rates, likely due to the reduction in slope stability that lower growing vegetation imparts in comparison to forested slopes (Stokes 2010). These results highlight the continuing need to maintain the forested slopes within each catchment and control forestry operations where applicable. The results of this study suggest that some sites in the upland areas of these catchments, where erosion is high even at current baseline climate conditions, cover should be maintained at all times already advocated through guidance from the UK Forestry Commission. The use of selective felling operations as opposed to clear-felling to ensure continuous cover and well managed road networks help reduce soil compaction in managed woodlands (Stokes 2010).

Whilst it is acknowledged that PESERA has been documented as only being able to approximately predict rates of soil erosion, the rates predicted here are not unrealistic. Indeed, the mean catchment erosion rates for arable land predicted under baseline conditions in this study are within the range of erosion rates for arable land within the United Kingdom as defined by UK Department for Environment, Food and Rural Affairs (DEFRA) for England and Wales and by the Scottish Environment Protection Agency (SEPA) for Scotland (Rickson 2013) and the tolerable erosion rates for Europe (Verheijen *et al*. 2009). The mean erosion rates for woodland and pastures are also similar to erosion rates for these land use types across Europe. Erosion is the mechanism by which soil particles enter water courses; the results discussed in this study indicate that climate change is likely to increase the erosion of arable land, therefore rivers draining such land uses are likely to see an increase in sediment. A recent study by Rickson (2013) showed that mitigation measures such as buffer strips, wetland/detention ponds and mulching/crop residue management are effective at constraining runoff and erosion, all of which can be implemented at a farm scale.

The vulnerability of agricultural land to soil erosion has led to a plethora of advice and recommendations for farmers and land owners both in the United Kingdom and further afield. Guidance issued by both DEFRA and the SEPA encourages soil protection throughout autumn and winter on arable farms by restricting runoff, especially whilst irrigating and adjusting livestock numbers to maintain a permanent grass cover across grazed fields and by increasing topsoil stability by the application of organic matter and keeping land drains in good condition (DEFRA 2005, 2009). Best practice guidelines from SEPA specifically state that areas of farmland known to be particularly at risk from soil erosion should be kept grassed at all times (SEPA n.d. a, b), and both DEFRA and SEPA acknowledge both the economic and environmental cost of erosion (SEPA 2001; DEFRA 2009). In the United Kingdom and European Union, the recommendations are not legally binding, however, and there is no legislation that directly protects soils. Despite changes to the EU Agricultural Policy in 2005 that meant landowners and farmers had to adhere to Standards of Good Agricultural and Environmental Condition, which included reducing erosion and runoff, there is no legislation to ensure that soil erosion is kept under a tolerable limit (Evans 2010; Natural England n.d.). Whilst schemes such as the UK Catchment Sensitive Farming Delivery Initiative (set up to provide one-to-one advice to farmers in catchment known to be adversely affected by sedimentation and nutrient enrichment) are improving soil-protection measures, given that these results demonstrated that soil erosion by sheet wash and rilling will likely only increase across arable lands, voluntary schemes may not be sufficient to prevent or constrain additional increases in runoff and soil erosion. In recognition of this, the European Union proposed a Soils Framework Directive to address threats to soils across Europe, but this has yet to be ratified and adopted as legislation across all member states.

The ecological implications of increased sedimentation on the biodiversity of freshwater ecosystems can be severe (Wood and Armitage 1997). For example, changes to turbidly, light penetration and biological oxygen demand caused by increased loading of fine particulates can cause deleterious impacts to fish behaviour and spawning (Alabaster and Lloyd 1982; Theurer *et al.* 1998; Stopps *et al.* 2012). Reduced numbers of invertebrates have also been associated with increased within-channel sedimentation (Newcombe and Macdonald 1991; Wood and Armitage 1997). Further, the transport of pesticides and nutrients adsorbed onto soil particles can cause increased algal growth and eutrophication of water bodies (Dampney *et al.* 2002). In recognition of this, European legislation (the Freshwater Fish Directive) has set upper limits for suspended sediment loads in order to avoid detrimentally impacting fish populations.

An example of the deleterious effects of sedimentation on invertebrates is the potential impacts of fine sediment on freshwater pearl mussels (FPM) (*Margaritifera margaritifera L.*), an endangered bivalve mollusc native to Great Britain and found across Europe. The freshwater pearl mussel is a vital component of freshwater ecosystems and filters up to 50 litres of water each day (Degerman n.d), maintaining a clean water supply not just for other species but also for humans who use the rivers for recreation or to abstract drinking water. The FPM is most vulnerable to excessive sedimentation as a juvenile when it spends several years within the substrate of the river bed, relying solely on the exchange of nutrients and oxygen through the interstitial pore spaces (Skinner *et al.* 2003; Degerman n.d). Increased sediment load block these pores effectively suffocating the juvenile mussels and once they emerge as adults increased turbidity prevent them being able to filter feed (Degerman n.d). The continued decline of this species, subsequent to its legal protection, is indicative of the continued decline of water quality in freshwater systems, which includes increased sediment loads. Allowing erosion to increase into the future will inevitably mean that species such as the freshwater pearl mussel would see a reduction of suitable habitats.

3.5 Conclusions

The aims of this research were to identify the drivers of soil erosion by sheet wash and rilling across three catchments in the United Kingdom over the time period 2010-2039, utilising the most recent predictions of climate change scenarios. The results supported prior results, suggesting that land use and topography play distinct roles in controlling erosion, potential ensuring that much of Britain will not experience dramatic changes to erosion rates due to climate change. Under the medium climate change scenario and under current land use conditions, no catchment was predicted to see mean erosion rates greater than the baseline. However, land use changes are inevitable due to increased population growth and the altitude at which crops can be grown increases due to warmer seasonal temperatures. This research has shown that arable land will experience increases in erosion rates over and above other land use types with increasing precipitation and temperature levels, in spite of the flatter topography of arable land within each catchment. Nonetheless, despite the year round cover that woodlands provide, steep forested topography was predicted to experience the maximum erosion rates, far above the catchment-wide values. Within these regions, the role of topography in fostering soil loss can be exacerbated or ameliorated by changes to land use.

The key finding from this research is that climate change is likely to exacerbate already vulnerable areas within catchments, but may not immediately increase catchment-wide erosion rates. The implication of this finding is firstly that strategies currently being undertaken to target erosion-prone areas (e.g., arable land) are likely to continue to be of use over the coming 30 years. Secondly, tight controls of land use change in upland regions (e.g., preventing the displacement of woodland by grassland or arable land) will become increasingly necessary to prevent the maximum erosion rates from increasing in magnitude and spatial distribution. Finally, the trends described here are consistent across all three of the study sites, leading to the conclusion that other catchments with comparable precipitation and temperature regimes may experience similar patterns into the future. Whilst this model allows glimpse of future erosion rates, there are limitations based on what the climate-scenarios allow. Precipitation rates are likely to increase in both amount and intensity, and yet this modelling approach only allows limited perturbations of precipitation patterns. More work in the future is needed to accurately model changes to the intensity of precipitation events to understand the likely impact of this. Additionally, in order to assess changes to erosion rates from future land use scenarios it would be necessary to manipulate land use in a manner more reflective of likely land use futures. This, alongside modelling changes to precipitation intensity, would give a more precise picture of future erosion rates upon which management decisions can be made.

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3.3.4.2 Land Use Scenario 3

In scenario, LU3, the effects of converting all forest land to pasture were investigated; this maintained year round cover but altered the morphology of the cover type. Again, as with LU2, the climate data used was from the medium climate change scenario (i.e. the temperature and precipitation data used were from the 50% probability level under the medium emissions scenario), and all modelled outcomes were significantly different from the baseline (Conwy $z = -71.64$; Ehen $z = -14.83$; Dee $z = -74.43$, all $p<0.05$); the medium climate scenario alone (Conwy $z = -81.27$; Ehen $z = -34.16$; Dee $z = -92.29$, all $p<0.05$) and the results from LU2 (Conwy $z = 87.93$; Ehen $z = -71.36$; Dee $z = -145.73$, all $p<0.05$). A greater proportion of each catchment increased in sediment yield (in comparison to baseline erosion rates) under the LU3 land use conversion than either LU2 or the medium climate change scenario. Figure 3.13 represents the changes in land use modelled using the percentage of forest in each scenario.

The majority the Conwy catchment showed a sediment yield of 0.05 – 1 t ha^{-1} a^{-1} under LU3, with a 28% increase in pastures under this land use scenario. The median sediment yield was 0.18 ± 0.10 t ha^{-1} a^{-1}; in particular the sediment yield in the centre of the catchment was predicted to have an erosion rate of 0.05-1 t ha^{-1} a^{-1} , representing an increase in comparison to LU2, the medium climate change scenario alone and to a certain extent, the baseline. The land use type in hotspot C1 remained unaltered, thus the erosion rate here is identical to that under the medium climate change scenario (LU1) and LU2 (Figure 3.10, insert c).

The LU3 land use change has little effect on the Ehen catchment since it had the lowest proportion of forest across all three study catchments (20%). The median sediment yield was the same as the medium climate change emission scenario alone but slightly higher than that predicted under LU2, at 0.18 ± 0.16 t ha^{-1} a^{-1}. The hotspot E1 is unchanged by the LU3 land use scenario given that this area is predominantly pastured. That the sediment yield from the Ehen catchment did not change under LU3 indicates that both forests and pastures provide comparable protection of the soil from the erosive action of rainfall (Figure 3.11, insert c).

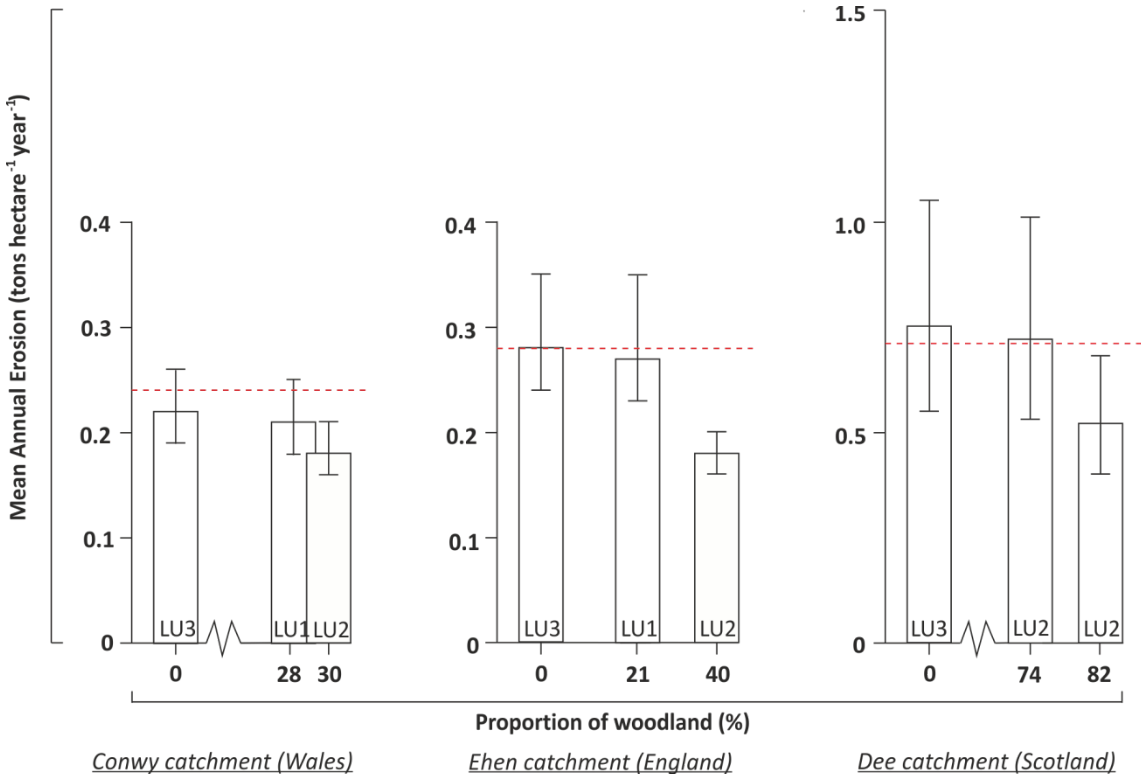

Figure 3.13: Bar graphs showing the change to mean annual catchment erosion (t ha-1 a-1) with respect to the proportion of forest within each catchment, as predicted by the PESERA model.
The climate change data used are from UKCP09 under the medium emission scenario at the 50% probability level. Error bars show the results at the 10% and 90% probability levels.
Original land use data based on Land Cover Map 2000, figures underneath bars indicate percentage of forest within each catchment under each scenario.
shows baseline mean erosion, based on climate averages from 1961-1990 and land use from 2000 (LCM2000).
LU1, 2 and 3 show the effects of the climate change data under different land use scenarios: LU1 - no land use change; LU2 - all arable land converted to forest, and LU3 - all forest converted to pastures and grassland.

The Dee has the highest proportion of forest and in the LU3 scenario therefore, with the 71% increase in pasture, the median sediment yield was greater than the climate change scenario alone (LU1) at 0.20 ± 0.11 t ha^{-1} a^{-1}. However, the sediment yield of the four hotspots was unaltered in comparison to the medium climate change scenario; it is likely that despite this land use conversion maintaining year round cover, the underlying soil properties and topography are dominating the erosion process in these regions (Figure 3.12, insert c).

3.3.5 Changes to dominate land use types under Land Use Scenario 1.

Finally, the effect of the three climate change scenarios on the three dominant land use types within each catchment were investigated: arable; forest and pasture (Table 3.2). The output from each climate change scenario was significantly different from the baseline and the other climate change scenarios (Table 3.3). In general the arable land use was constrained to regions of flatter topography; despite this, median sediment yields on this land use were the highest, for example arable land in the Dee under the high climate scenario generated erosion rates of up to 3.39 ± 4.34 t ha^{-1} a^{-1}. The medium and high climate change scenarios showed an increase on the baseline erosion rates, across all catchments. In the Conwy and the Dee catchments the median sediment yields under the high climate change scenarios were almost twice as large as the baseline.

Pasture land across the three study catchments was predominantly found in areas of moderate topography. Only in the Dee catchment under the high climate change scenario did the median sediment yield for this land use type exceed the baseline. All of the catchments showed increasing median sediment yields from low to high climate scenarios. It is of note that the median sediment yields for all three catchments are considerable lower than the median values for arable land, despite an increase in topographic variability. It appears that the slight increase in slope on pasture lands is outweighed by the year round cover generated by grass.

In all three catchments, the forest land use type was found in the areas of steepest topography, yet the median sediment yields were amongst the lowest of all three land uses, for example in the Dee catchment under the high climate change scenario the median sediment yield was 0.20 ± 0.12 t ha^{-1} a^{-1}. This replicates the trend seen under the pasture land use type. Across all three catchments, sediment yields under the forest scenario did not exceed the baseline median; in the Conwy catchment the median sediment yield under the high scenario was less than the median baseline sediment yield. Only the high climate change scenario resulted in an increase to median baseline sediment yields. The prevalence of erosion hotspots in forested land use in the Dee catchment are likely a result of extremely steep topography in combination with a highly erodible peat soil type.

a. Conwy Catchment

	Topographic Variability[1]	BL	Low	Medium	High
Arable	20.08 ± 9.93	0.92 ± 1.07	0.66 ± 0.76	1.00 ± 1.17	1.57 ± 1.75
Pastures	27.58 ± 17.68	0.20 ± 0.08	0.15 ± 0.08	0.16 ± 0.08	0.19 ± 0.09
Forest	33.11 ± 19.94	0.18 ± 0.09	0.13 ± 0.08	0.13 ± 0.11	0.15 ± 0.10

b. Ehen Catchment

	Topographic Variability[1]	BL	Low	Medium	High
Arable	11.24 ± 5.95	0.41 ± 0.22	0.36 ± 0.13	0.47 ± 0.29	0.70 ± 0.56
Pastures	19.60 ±34.44	0.20 ± 0.05	0.15 ± 0.03	0.15 ± 0.03	0.15 ± 0.04
Forest	44.23 ± 34.69	0.19 ± 0.11	0.15 ± 0.10	0.16 ± 0.11	0.19 ± 0.16

c. Dee Catchment

	Topographic Variability[1]	BL	Low	Medium	High
Arable	11.34±6.61	1.84 ± 2.21	1.38 ± 1.57	2.08 ± 2.57	3.39 ± 4.34
Pastures	16.86 ± 12.36	0.20 ± 0.10	0.18 ± 0.05	0.20 ± 0.12	0.24 ± 0.34
Forest	32.59 ± 18.58	0.18 ± 0.04	0.18 ± 0.08	0.18 ± 0.10	0.20 ± 0.12

Table 3.2: Comparison of changes to baseline median total annual erosion (tons hectare^{-1}) ± IQR by land use in each catchment, based on PESERA model outputs.
The model runs used climate change projections (for the period 2010-2039) under the medium emission scenario. These three land uses represent the three dominant land uses within the catchment, (based on PESERA land use classes): arable; forest and pastures & grassland.
[1]Mean topographic variability is based on the measure of topography as used by the PESERA model, whereby the standard deviation of elevation data within a set radius (400m) as the measure of topography.

a. Conwy Catchment

	BL – Low	BL – Medium	BL – High	Medium – Low	Low – High	Medium - High
Arable	-27.898	-27.777	-28.544	-28.313	-28.570	-28.113
Pasture	-125.296	-100.333	-19.900	-87.440	-110.917	-98.216
Forest	-79.015	-59.015	-13.183	-53.836	-79.382	-62.566

b. Ehen Catchment

	BL – Low	BL – Medium	BL – High	Medium – Low	Low – High	Medium - High
Arable	-54.794	-55.901	-56.366	-55.961	-56.360	-56.364
Pasture	-80.040	-75.707	-49.814	-21.671	-36.867	-30.299
Forest	-41.884	-27.098	-1.389 *ns*	-27.722	-41.603	-29.112

c. Dee Catchment

	BL – Low	BL – Medium	BL – High	Medium – Low	Low – High	Medium - High
Arable	-108.077	-109.857	-108.666	-108.837	-109.843	-109.579
Pasture	-150.266	-95.509	-22.829	-123.495	-138.963	-127.740
Forest	220.501	73.774	114.537	-185.228	-230.022	-210.334

Table 3.3: Statistical comparisons of erosion rates predicted under the three climate scenarios for the three major land use types.
Wilcoxen Signed Rank tests between the erosion predictions for the three major land uses (arable; forest and pastures) under each climate scenario (low, medium and high) reveal significant differences at all levels to the baseline.
Unless otherwise stated, all results p<0.001 l

3.4 Discussion

Much work predicting erosion rates under future climate scenarios uses climate predictions in which precipitation levels increase, both in intensity and magnitude (Favis-Mortlock and Boardman 1995; Nearing *et al*. 2005; O'Neal *et al*. 2005). Indeed, many studies have concluded that it is an increase in intensity that will drive the predicted increases in erosion rates (Pruski and Nearing 2002; Nearing *et al*. 2005; Arnaez *et al.* 2007), as a result of the interaction between erosion and antecedent soil moisture conditions (Luk 1985; Ziadat and Taimeh 2013), although the climatic data used in some instances can be out-dated (Soil and Water Conservation Society 2003). The climate scenarios used in this study, obtained from the UKCP09 data (UKCP09 2012) show that under the low climate change scenario (the 10% probability level), precipitation levels across the year will be lower than the 1961-1990 baseline, leading to reduced rates of catchment-wide soil erosion as a result. Similarly, in work by Mullan *et al.* (2012) decreases in erosion rates were also observed under climate scenarios which predicted less rainfall than current levels. Precipitation patterns under the medium climate change scenario (50% probability level) reveal a trend towards wetter winters and drier summers, with mean annual precipitation similar to baseline conditions. Accordingly, mean catchment-wide erosion rates were similar to the baseline rates, with erosion rates across all land uses lower during summer than winter. The high climate change scenario (the 90% probability level) has precipitation increasing across all months compared to the baseline, and consequently, mean-erosion rates across all catchments increased. These results compared well with predictions that have been previously reported, that increased annual precipitation should lead to increased and widespread soil erosion (Evans and Cook 1986; Evans 1990; Boardman and Favis-Mortlock 1993; Favis-Mortlock and Savabi 1996; Boardman and Favis-Mortlock 2001; Nearing *et al*. 2005). For example, other studies have predicted a 0.85% increase in rates of soil erosion for every 1% increase in precipitation (Pruski and Nearing 2002) and up to a 150% increase in erosion on arable land with a 10% increase in winter precipitation (Favis-Mortlock and Boardman 1995). Similar to work by Favis-Mortlock and Savabi (1996), the PESERA modelled increases in soil erosion under the high climate change scenario were not spatially contiguous across the catchments; regions which are already vulnerable to erosion show the greatest increase. There are, however, substantial proportions of the upland portions within the three catchments that are under permanent (i.e. year-round) vegetation cover where erosion decreases relative to baseline conditions, even at the high (90%) probability level.

These results confirm the increased vulnerability of arable land to soil erosion and the ameliorating effect of land use in the process, even under situations of increasing rainfall (Van Rompaey *et al.* 2002; Nearing *et al*. 2004; Bakker *et al*. 2005; Nearing *et al*. 2005; Bakker *et al*. 2008). The results indicated that, in these three catchments, land cover was the principal control on the susceptibility of soil to rilling and erosion by sheet wash. The results also indicated that the greatest susceptibility occurred on arable land where cover is not constant year-round, consistent with other empirical studies (Boardman and Favis-Mortlock 1993; Favis-Mortlock and Boardman 1995; Favis-Mortlock and Savabi 1996; Boardman and Favis-Mortlock 2001; O'Neal *et al*. 2005). In each model scenario, increases to erosion rates as a result of precipitation increases were proportionately much smaller on woodland or pasture where cover was high throughout the year. Permanent land cover has been shown to increase the spatial variability of the soil infiltration capacity by the introduction or organicmatter and plant roots (Bonell 1993; Cammeraat 2002); the resultant discontinuous runoff rates mean that significant overland flow is thereby prevented (Cammeraat 2002; Cerdan *et al.* 2004).

The PESERA results also demonstrated that locations at high elevations with steep slopes are incredibly susceptible to soil erosion by sheet wash and rilling, even with year-round vegetative cover. Under modern climate conditions, steep upland areas in each of the catchments are predicted to experience very high erosion rates in excess of the tolerable soil erosion rate of 1.4 t ha^{-1} a^{-1} for Britain (Verheijen *et al.* 2009). Further, land use changes, such as the conversion of woodland to pastureland, showed a small shift to an increase in mean-annual erosion rates, likely due to the reduction in slope stability that lower growing vegetation imparts in comparison to forested slopes (Stokes 2010). These results highlight the continuing need to maintain the forested slopes within each catchment and control forestry operations where applicable. The results of this study suggest that some sites in the upland areas of these catchments, where erosion is high even at current baseline climate conditions, cover should be maintained at all times already advocated through guidance from the UK Forestry Commission. The use of selective felling operations as opposed to clear-felling to ensure continuous cover and well managed road networks help reduce soil compaction in managed woodlands (Stokes 2010).

Whilst it is acknowledged that PESERA has been documented as only being able to approximately predict rates of soil erosion, the rates predicted here are not unrealistic. Indeed, the mean catchment erosion rates for arable land predicted under baseline conditions in this study are within the range of erosion rates for arable land within the United Kingdom as defined by UK Department for Environment, Food and Rural Affairs (DEFRA) for England and Wales and by the Scottish Environment Protection Agency (SEPA) for Scotland (Rickson 2013) and the tolerable erosion rates for Europe (Verheijen *et al*. 2009). The mean erosion rates for woodland and pastures are also similar to erosion rates for these land use types across Europe. Erosion is the mechanism by which soil particles enter water courses; the results discussed in this study indicate that climate change is likely to increase the erosion of arable land, therefore rivers draining such land uses are likely to see an increase in sediment. A recent study by Rickson (2013) showed that mitigation measures such as buffer strips, wetland/detention ponds and mulching/crop residue management are effective at constraining runoff and erosion, all of which can be implemented at a farm scale.

The vulnerability of agricultural land to soil erosion has led to a plethora of advice and recommendations for farmers and land owners both in the United Kingdom and further afield. Guidance issued by both DEFRA and the SEPA encourages soil protection throughout autumn and winter on arable farms by restricting runoff, especially whilst irrigating and adjusting livestock numbers to maintain a permanent grass cover across grazed fields and by increasing topsoil stability by the application of organic matter and keeping land drains in good condition (DEFRA 2005, 2009). Best practice guidelines from SEPA specifically state that areas of farmland known to be particularly at risk from soil erosion should be kept grassed at all times (SEPA n.d. a, b), and both DEFRA and SEPA acknowledge both the economic and environmental cost of erosion (SEPA 2001; DEFRA 2009). In the United Kingdom and European Union, the recommendations are not legally binding, however, and there is no legislation that directly protects soils. Despite changes to the EU Agricultural Policy in 2005 that meant landowners and farmers had to adhere to Standards of Good Agricultural and Environmental Condition, which included reducing erosion and runoff, there is no legislation to ensure that soil erosion is kept under a tolerable limit (Evans 2010; Natural England n.d.). Whilst schemes such as the UK Catchment Sensitive Farming Delivery Initiative (set up to provide one-to-one advice to farmers in catchment known to be adversely affected by sedimentation and nutrient enrichment) are improving soil-protection measures, given that these results demonstrated that soil erosion by sheet wash and rilling will likely only increase across arable lands, voluntary schemes may not be sufficient to prevent or constrain additional increases in runoff and soil erosion. In recognition of this, the European Union proposed a Soils Framework Directive to address threats to soils across Europe, but this has yet to be ratified and adopted as legislation across all member states.

The ecological implications of increased sedimentation on the biodiversity of freshwater ecosystems can be severe (Wood and Armitage 1997). For example, changes to turbidly, light penetration and biological oxygen demand caused by increased loading of fine particulates can cause deleterious impacts to fish behaviour and spawning (Alabaster and Lloyd 1982; Theurer *et al.* 1998; Stopps *et al.* 2012). Reduced numbers of invertebrates have also been associated with increased within-channel sedimentation (Newcombe and Macdonald 1991; Wood and Armitage 1997). Further, the transport of pesticides and nutrients adsorbed onto soil particles can cause increased algal growth and eutrophication of water bodies (Dampney *et al.* 2002). In recognition of this, European legislation (the Freshwater Fish Directive) has set upper limits for suspended sediment loads in order to avoid detrimentally impacting fish populations.

An example of the deleterious effects of sedimentation on invertebrates is the potential impacts of fine sediment on freshwater pearl mussels (FPM) (*Margaritifera margaritifera L.*), an endangered bivalve mollusc native to Great Britain and found across Europe. The freshwater pearl mussel is a vital component of freshwater ecosystems and filters up to 50 litres of water each day (Degerman n.d), maintaining a clean water supply not just for other species but also for humans who use the rivers for recreation or to abstract drinking water. The FPM is most vulnerable to excessive sedimentation as a juvenile when it spends several years within the substrate of the river bed, relying solely on the exchange of nutrients and oxygen through the interstitial pore spaces (Skinner *et al.* 2003; Degerman n.d). Increased sediment load block these pores effectively suffocating the juvenile mussels and once they emerge as adults increased turbidity prevent them being able to filter feed (Degerman n.d). The continued decline of this species, subsequent to its legal protection, is indicative of the continued decline of water quality in freshwater systems, which includes increased sediment loads. Allowing erosion to increase into the future will inevitably mean that species such as the freshwater pearl mussel would see a reduction of suitable habitats.

3.5 Conclusions

The aims of this research were to identify the drivers of soil erosion by sheet wash and rilling across three catchments in the United Kingdom over the time period 2010-2039, utilising the most recent predictions of climate change scenarios. The results supported prior results, suggesting that land use and topography play distinct roles in controlling erosion, potential ensuring that much of Britain will not experience dramatic changes to erosion rates due to climate change. Under the medium climate change scenario and under current land use conditions, no catchment was predicted to see mean erosion rates greater than the baseline. However, land use changes are inevitable due to increased population growth and the altitude at which crops can be grown increases due to warmer seasonal temperatures. This research has shown that arable land will experience increases in erosion rates over and above other land use types with increasing precipitation and temperature levels, in spite of the flatter topography of arable land within each catchment. Nonetheless, despite the year round cover that woodlands provide, steep forested topography was predicted to experience the maximum erosion rates, far above the catchment-wide values. Within these regions, the role of topography in fostering soil loss can be exacerbated or ameliorated by changes to land use.

The key finding from this research is that climate change is likely to exacerbate already vulnerable areas within catchments, but may not immediately increase catchment-wide erosion rates. The implication of this finding is firstly that strategies currently being undertaken to target erosion-prone areas (e.g., arable land) are likely to continue to be of use over the coming 30 years. Secondly, tight controls of land use change in upland regions (e.g., preventing the displacement of woodland by grassland or arable land) will become increasingly necessary to prevent the maximum erosion rates from increasing in magnitude and spatial distribution. Finally, the trends described here are consistent across all three of the study sites, leading to the conclusion that other catchments with comparable precipitation and temperature regimes may experience similar patterns into the future. Whilst this model allows glimpse of future erosion rates, there are limitations based on what the climate-scenarios allow. Precipitation rates are likely to increase in both amount and intensity, and yet this modelling approach only allows limited perturbations of precipitation patterns. More work in the future is needed to accurately model changes to the intensity of precipitation events to understand the likely impact of this. Additionally, in order to assess changes to erosion rates from future land use scenarios it would be necessary to manipulate land use in a manner more reflective of likely land use futures. This, alongside modelling changes to precipitation intensity, would give a more precise picture of future erosion rates upon which management decisions can be made.

3.6 References

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CHAPTER FOUR:
EXPLORING PUBLIC AND STAKEHOLDER PERCEPTIONS OF UK RIVERS, SPECIES AND CONSERVATION OPTIONS[1]

Rivers play an important role in the natural landscape, both for the range of biodiversity they support as well as the goods and services they provide, for example freshwater supplies, but they also play an important social role. Historically used for travel and the movement of goods, rivers remain valued for their intrinsic qualities and have long been the subject of poetry, prose and songs. Despite this, there is little research that specifically looks at why rivers are valued by the public, what risks are perceived to threaten rivers in the future and what (if any) trade-offs in terms of riverscape aesthetics are considered appropriate in order to conserve specific species. This chapter uses a deliberative approach within mixed-methods focus groups to begin to understand lay-persons' perceptions of rivers and provides the backdrop for a more in-depth qualitative analysis which is found in Chapter 3. The results indicate that the lay-public and stakeholders have similar concepts of the ideal riverscape, with perceptions of naturalness inversely related to accessibility (i.e. the more natural a river scene is perceived, the less accessible it appears to be). In general, rivers without visible man made elements such as fences were preferred. These results will aid river conservation practitioners to avoid circumstances where river management leads to a lesser valuation of the river by end-users.

4.1 Background

Historically legislation to protect and enhance river environments has focussed on ecological restoration and has largely ignored any social dimensions, such as cultural (Buijs 2009; Birckhead *et al.* 2011) or aesthetic values (Kaplan 1977; Shafer Jr and Brush 1977; Kaplan *et al.* 1989) the rivers elicit. Little previous work has been carried out on the public's attitudes

[1] Particular acknowledgements in this chapter go to members of the Cardiff Community Panel and the staff, volunteers and local residents of the Balinderry River Enhancement Association for participating so enthusiastically in the mixed-methods focus groups that form the basis of this chapter.

towards specific habitats in the UK. Whilst there is evidence to suggest that rivers elicit high aesthetic values, there has been a piecemeal approach to the research that attempts to explain attitudes towards rivers or specific types of environment in a general sense. Given the vulnerabilities of river habitats to climate change (Ormerod 2009) and the inevitability of increased conservation effort needed in order to protect river habitats from climate change, it seems logical to pursue this research. The Water Framework Directive explicitly encourages public participation in water resource management; to do this effectively the public's expectations and understanding of the process must be understood and managed. In doing so, the risks of misunderstanding and unrealistic expectations can be minimised, reducing the likelihood of dissatisfaction of the end result and mistrust in the process itself (Wester-Herber 2004; Hovik *et al.* 2010). Elucidating how the public feels about river habitats and understanding how far they would be willing to compromise for the conservation of particular species will allow such work to meet ecological, cultural and aesthetic needs.

What role do rivers play in the public consciousness and what risks are perceived to impact rivers in the future?

The value placed on water within the landscape, particularly rivers, has long been recognised within the field of environmental psychology (Kaplan 1977; Kaltenborn and Bjerke 2002) particularly in terms of their restorative effect (Kaplan 1977; Ulrich 1986; White *et al.* 2010) as well as more intrinsic qualities related to aesthetics and their use as a place for leisure activities (Petts 2007), which can all enhance a person's feelings of place attachment to this particular landscape feature. However, what is less well-documented is the public's preference towards types of water scenes, with a focus on rivers; nor has there been dedicated research to understand lay persons' perceptions of future risks to such habitats. In general, conservation work targeted at improving wildlife is often well received, even those with strong sense of place attachment that has the potential to be compromised have been seen to accept changes to achieve ecological aims (Tapsell 1995; Eden *et al.* 1999; Tunstall *et* *al.* 2000) but this is not guaranteed and depends on the pre-existing use and concepts associated with the river (Buijs 2009). For example, woody debris in rivers is often perceived as being dangerous and in need of removal by the public when in ecological terms it represents an important aquatic habitat type (Wyzga *et al.* 2009). This misconception highlights issues faced in conservation or restoration, often understood by the public to describe attempts to turn back the clock and return the environment to the supposed pristine state of a bygone era (Moore-Colyer and Scott 2005). Yet the reality of modern day river management is somewhat different; climate change impacts and increasing pressures for flood protection in both urban and rural areas can be in conflict with a desire to increase biodiversity and overcome decades of the human manipulation of river channels. Flooding is a key concern of the public as regards climate change impacts (Whitmarsh 2011) but there are other possible, but less obvious risks, such as the availability of water for agricultural purposes and an increased cost of providing potable water.

What factors influence the public's opinion of rivers and aquatic species?

The study of landscape aesthetics appeared in the 1970's and aimed to predict visual preference from physical landscape features; subsequently policy makers and land managers have identified such a concept as a useful conservation tool since public support for conservation is linked to favourable landscape appearances (Nassauer *et al.* 2001; Junker and Buchecker 2008). Factors such as the complexity of the scene and the type of land cover were recognised as being key to understanding which landscapes are preferred (Kaplan 1977; Shafer Jr and Brush 1977; Kaplan 1979, 1982; Kaplan *et al*. 1989). Whilst much river conservation work is met with public approval (Tapsell *et al.* 1997; Tunstall *et al*. 2000), little work has been undertaken to identify why river landscapes are preferred and to understand what elements of such scenes elicit high or low levels of preference. An understanding of this would enable conservation campaigns to be more targeted; currently a common approach is to use umbrella or flagship species whose preservation also positively contribute to the conservation of other species and indeed entire habitats. Charismatic and familiar species have long been used as flagship species in order to motivate the lay-person to change behaviour, such as choosing line caught tuna to reduce dolphin by-catch (Simberloff 1998), but oftentimes those species that need the most help are unfamiliar or un charismatic. Whilst research suggests that the public are most likely to conserve higher order species, with human-like morphology that is familiar, there is also evidence to suggest that knowledge about the need for conservation support is also a driver to encourage support (Tisdell and Wilson 2006). In the UK, many uncharismatic river species are under threat, and so understanding how opinions of aquatic species are formulated will be beneficial in constructing conservation campaigns aimed at support.

To what extent are the public willing to support the conservation of the freshwater pearl mussel, an important but less well-known freshwater species?

The freshwater pearl mussel is an example of an uncharismatic river species that is of fundamental importance to the rivers in which it is found. Historically fished to the brink of extinction, populations of this bivalve mollusc have not increased after the ban on pearl fishing was introduced in 1998 and its subsequent national and European protection under Annex 2 of the EU Habitats Directive. This species is detrimentally affected by the presence of fine sediments within the river bed, preferring clean gravely substrates (Hastie *et al.* 2000; Hastie and Young 2003; Osterling *et al.* 2008; Osterling *et al.* 2010). Measures to reduce the influx of fine grained material can require changes to farming practices such as preventing livestock accessing rivers and planting in-field margins, all of which require landowners' consent and therefore their support for such schemes. Some of the mitigation measures will alter the aesthetics of river landscapes, possibly threatening place attachment. The success of conservation measures also requires the support of the general public (Silvano *et al.* 2005) Understanding whether or not the public is willing to compromise in order to achieve a favourable outcome for the FPM will contribute to how rivers are managed for the conservation of this and other uncharismatic species in the future.

4.1.1 Chapter Aims

Rivers are particularly vulnerable to the deleterious impacts of climate change; in order to protect aquatic habitats species, conservation projects and river management will become increasingly necessary. However, rivers have a value in the public eye that is distinct from their ecological importance, for example cultural or aesthetic values, which are a potential source of conflict in river management schemes designed primarily for ecological reasons. This chapter seeks to better understand how the public perceive rivers using focus groups. This qualitative methodology will facilitate discussion with participants about topics relating to the current impacts and future risks that are associated with river habitats; what element constitute ideal riverscapes and identify attitudes toward at-risk species. As an exploratory study, this qualitative methodology is appropriate because it provides an opportunity to examine the underlying values and attitudes associated with perceptions., through reflection and discussion between participants and the facilitator. The results from these workshops will then be integrated into the quantitative approach used in Chapter five.

The topics for discussion will be as follows:

What role do rivers play in the public consciousness and what risks are perceived to impact rivers in the future?

This topic is broad and covered a word association exercise to elicit both positive and negative association with rivers. Participants also discussed how often they actively visited a river and what rivers meant to them, prompting topics such as place attachment and why rivers are or are not important. The facilitators asked participants about their local river and how participants felt about its current state. This topic was then moved on to discuss how rivers might change in the future with prompts to elicit opinions on what risks the participants saw as most significant to rivers, how participants felt climate change would affect rivers, specifically risks from flooding, provision of drinking water, biodiversity, if these were not mentioned spontaneously. Additionally, this topic included questions on the responsibility for river conservation.

What factors influence the public's opinion of rivers and aquatic species?

Through the use of the photo sorting exercise participants were encouraged to discuss what elements of the river photos led them to assumptions about the health, safety, naturalness and accessibility of the scenes. When the topic was moved onto attitudes toward the conservation importance of specific freshwater species, the discussion focused on relative importance and the factors that determined this assessment, such as the provenance of the species, the familiarity of the species and any emotional connection with the species. Discussions surrounding the relative importance of specific habitats focused on dividing financial contributions to support each as a way to encourage the participants to discuss which habitat would hypothetically receive the greatest and least proportion of the fund, thus revealing the underlying drivers behind the allocation of funds.

To what extent are the public willing to support the conservation of the freshwater pearl mussel, an important but less well-known freshwater species?

The FPM will have been introduced in the previous section, following on from which conservation options presented will all be with respect to the conservation FPM's. Participants will be encouraged to discuss any additional reasons for their opinions on these measures taking into account the aim of the measures is specifically to conserve the FPM.

4.2 Methodology

4.2.1 Sampling

The three focus groups took place in early 2012 and 2013 with participants recruited from the Cardiff Community Panel and from the stakeholder database at the Balinderry River Enhancement Association, Northern Ireland. These two sources represent two distinct groups of publics: the first are persons with no formal contact with rivers nor do they rely on the river for economic purposes. The participants from this group live in urban or suburban areas and participated in focus groups one, two and three. These participants might walk by rivers en route to the shops or use paths that run alongside rivers to walk the dog, but contact is limited and informal. The second group are a more informed public living in rural areas with some degree of contact with the river conservation work that the Balinderry River Enhancement Association (BREA) undertakes. Such contact can take the form of volunteering with the BREA, using the Balinderry river for recreational purposes (e.g. fishing) or commercial reasons (e.g. quarrying) on simply participating in the community meetings that BREA holds to discuss forthcoming projects. These individuals participate in focus groups four, five and six.

Groups 1-3. The Cardiff Community Panel is a database with contact details for individuals who are willing to participate in research conducted by researchers within Cardiff University's School of Psychology. Initial contact was made by email and the title of the focus group was 'Public Attitudes to Rivers and their Conservation' with follow up telephone calls made a week later. A nationally representative group in terms of age, gender and socio-economic status were initially approached in order to capture as wide a range of viewpoints as possible (Table 4.1).

Groups 4-6. In Northern Ireland, the participants were selected from a list of attendees at a community meeting held by BREA to discuss the forthcoming FPM conservation programme of works. As with the Cardiff participants, initial contact was made by email and this was followed up by a telephone call approximately one week later. Participants were chosen to represent the range of interests each had in BREA and the Balinderry River, in order to accurately reflect the views of stakeholders in this catchment (Table 4.1).

In total 20 individuals participated in six focus groups, 11 in the Cardiff group, hereafter referred to as the 'public' group and 9 in the Northern Ireland, hereafter referred to as the 'stakeholder' group. Consent forms were given to participants to sign at the beginning of each group and debrief forms containing contact details of the facilitator and supervisor were distributed at the end of each session. Video and audio recording were made of all focus groups, with participants' permission; each focus group lasted approximately 90 -120 minutes.

The aim of these deliberative workshops are not to be representative in the statistical sense, rather generalisability is possible by ensuring that range of viewpoints are captured as a result of the sampling criteria employed. Given that there was no difference in attitudes between Welsh and Scottish participants (see Chapter Six for further details) the conclusions from this chapter can be generalised across the UK and classed as representative of the range of views held by UK residents. That said, the study was designed to be exploratory and therefore the sample size was small; whilst this must be taken into account with regards to the conclusions that can be drawn, it is important to note that the commonality of themes expressed throughout the focus groups indicate data saturation and it is likely that undertaking further focus groups would not yield substantial amounts of new data.

Focus Group	Participant Reference	Age	Gender	Employment Details	Group Dynamic
FG1	A	18-25	F	Administrator and volunteer at Cardiff Museum	Participants B and E had a tendency to dominate the discussions, D was reticent to express an opinion. Due to the size of the group, participants were split for the photo sorting exercise (Group 1(1) – A, B & D; Group 1(2) – C & E)
	B	55-66	M	Retired	
	C	35-45	M	Un-Employed, former Town Planner	
	D	35-45	M	Musician	
	E	45-55	F	Dietician	
FG2	F	45-55	F	Former Geography teacher	No dominant individual
	G	18-25	M	Student	
	H	45-55	M	Mature Student	
FG3	I	55-65	M	Retired, former Engineer	Participants J dominated all discussions, participants I and K deferred (reluctantly) to J, particularly in the photo sorting exercise.
	J	18-25	F	Student	
	K	55-65	F	Lecturer and volunteer with local conservation group	
FG4	L	35-45	M	Son of the BREA Manager	No dominant individual
	M	35-45	F	Ecological Consultant for a local quarry	
	N	18-25	F	Student	
FG5	O	35-45	M	Unemployed, volunteer for BREA	Participant O dominated discussion because of the length of the response to many of the questions. However, this did not prevent participant P and Q from expressing conflicting opinions.
	P	65-75	M	Retired Farmer	
	Q	35-45	M	Volunteer for BREA	
FG6	R	35-45	M	Quarry Owner	Participant R dominated the discussion due to the position held in the local community. This meant that both participant S and T tended to defer to the opinion of R; however, this was not as apparent in the photo sorting exercise.
	S	35-45	M	Quarry employee	
	T	45-55	M	Owns fishing tackle shop	

Table 4.1: Socio-demographics and groups dynamics of focus group participants.

4.2.2 Format

An outline plan of the focus groups was drawn up to ensure that all participants were asked the same questions in the same order to allow comparability (Appendix 4.1). The subject of the focus group was introduced by the facilitator and participants were asked to fill in a brief questionnaire detailing river proximity and frequency of visits to rivers (see Appendix 4.2). A brainstorming exercise was used to focus participants' attention on rivers in the UK and a general discussion followed to gather opinion on rivers in the UK, how they have changed and the potential effects of climate change.

Participants were then split into sub-groups of two or three for a photo sorting exercise where participants were asked to rank 18 photographs between four pairs of descriptors:

1. Natural – Unnatural
2. Accessible – Inaccessible
3. Safe – Dangerous
4. Healthy – Unhealthy

No definitions were provided and participants were asked to collectively come to an agreement on the rank of each photo in an attempt to capture any areas of disagreement. Given the six of the group, participants in FG1 were split into two for this exercise, hereafter referred to as FG1(1) and FG1(2).

A familiarity exercise followed the photo sort, with images of six freshwater species shown to participants, with both their common name and Latin name (see Appendix 4.3). Participants were asked to discuss these species in terms of familiarity, whether the species were native to the UK and conservation preference. The choice of species was based on work by Jefferson (2010) and was designed to reflect the variation of species found in UK rivers, taking into account taxonomy, conservation status and aesthetic appeal.

1. Kingfisher (*Alcedo atthis*)
2. Common otter (*Lutra lutra)*
3. Weeping willow *(Salix x sepulcralis)*
4. Japanese knotweed (*Fallopia japonica*)
5. Great diving beetle (*Dytiscus marginalis*)
6. Freshwater pearl mussel (*Margaritifera margaritifera)*

The facilitator then introduced the freshwater pearl mussel, its importance within river ecosystems and the threat fine sediments posed to its future (Appendix 4.4). Participants were then shown three sets of images showing three possible mitigation measures that could be employed to conserve freshwater pearl mussels (Appendix 4.5); participants were encouraged to discuss which they preferred and why.

Finally, participants were asked generally who should be responsible for river conservation and where the finances should come from. The discussion finished with participants completing a pie chart to show how they felt funding should be split between five conservation areas and discussing their results (see Appendix 4.6). The five areas given were:

1. Marine
2. Rivers and lakes
3. Forests
4. Other land including moorlands
5. Historic Buildings

4.2.3 Materials

Photos for the initial sorting exercise were chosen to reflect a variety of river conditions, and were provided by the River Restoration Centre. The methodology for choosing photographs was based on that found in Wyzga *et al*. (2009) and White *et al*. (2010). Photographs were chosen to reflect a variety of typical river scenes in the UK, which included rivers of varying sizes, urban rivers, rural rivers, rural rivers with visible human influence (e.g. channelling or infrastructure such as bridges) and river with varying degrees of in-channel and bankside vegetation. Descriptive words used for the sorting exercise were found within the literature on landscape aesthetics (Kaplan *et al*. 1989) and evaluations of previous river restoration projects in the UK (Fordham *et al.* 1991; Tunstall *et al*. 2000).

The images used to discuss conservation options for the freshwater pearl mussel were based on measures to prevent fine sediments being transported into rivers and came from UK Government policy advice for preventing erosion (DEFRA 2005; Rickson *et al.* 2010).

All supporting material used for the focus groups can be found in the Appendices which includes a brief presentation given to the participants (Appendix 4.3). Specific information about the FPM was given to participants, to ensure that all participants had a basic understanding of the importance of FPM. The briefing focused on the following points:

The FPM is:

- Endangered & protected throughout geographic range
- Indicator species for river health
- Long lived & senescent

Threats to the FPM:

- Historically, largest impact was pearl fishing, especially in Welsh and Scottish rivers.
- Currently, agricultural practices and changes in water quality are major conservation issues.
- Major factor in continued decline is fine sediment in water.

4.2.4 Data Analysis

4.2.4.1 Qualitative

All of the focus groups were transcribed and anonymised. Thematic analyses of the resulting transcripts was then conducted in order to identify themes and patterns within and between transcripts (Miles and Huberman 1994).

4.2.4.2 Quantitative

In order to assess the different scores attributed to the river photographs across the four sorts a modified Euclidean distance calculation was conducted. The difference between pairs of scores was calculated, squared, totalled and the square root taken for each photo. This then gave a value that represented the degree of similarity in the score each photo had received across each sort, with photos that were scored the same having a lower value than that of a photo that received different scores from each group. These results were used to create box and whisker plots for each category allowing comparison of spread, indicating categories where participants had similar opinions, to be made.

To assess the degree of correlation between results a Spearman's Rank Correlation was performed using the statistical software SPSS 16.0, which compared the ranks of each photos across different sorts, both between groups (i.e. public vs. stakeholders) and within groups.

4.3 Results & Discussion

What role do rivers play in the public consciousness and what risks are perceived to impact rivers in the future?

4.3.1 General Views on Rivers

Across the six focus groups, discussions surrounding riverscapes elicited positive feelings with adjectives such as peaceful, exciting, relaxing and attractive being used to describe rivers, reflecting the importance of river as a landscape feature not only for any direct use but "merely for its presence" (Kaplan 1977) by both the public and stakeholders.

"it's just a really nice place to go" **F, FG2**

"just the point of view of enjoying the sound of the river and the peacefulness" **T, FG6**

"I always look down on the river when I pass, it's very attractive to see the sunlight" **B, FG1**.

In response to questions about how often participants visit rivers; there was little difference between the Cardiff and the Northern Ireland groups which might be a reflection of the small sample size (Table 4.2). Whilst it might be expected that members of the stakeholder group (where rivers could be expected to hold a greater significance) might visit rivers more often, this did not appear to be the case. The greater significance of rivers to members of the stakeholder group does not necessarily mean that those participants would actively choose to visit a river more often, simply that rivers play a greater role in their day-to-day life. For example, in FG6 the participants T and R work in a local quarry, which depends on abstraction licenses to use river water in the quarrying operations; this does not necessarily mean that participants R and T would be more or less likely to visit a river. Conversely, in Cardiff where green spaces are limited, the Taff and the Ely could play a greater role in residents contact with nature, leading to more frequent visits.

Frequency of river visits	Lay-Public (Cardiff)	Stakeholders (NI)
Daily	9.1%	22.2%
Once or twice a week	36.4%	33.3%
Once or twice a month	27.2%	33.3%
Once or twice a year	0%	11.1%
Only when on holiday abroad	18.2%	0%

Table 4.2: Comparison of the frequency of river visits between lay-public and stakeholder

The range of words that participants associated with rivers during the brainstorming activity can be found in Table 4.3 and have been broadly categorised as follows:

Visual – e.g. reflections, words that represent images of rivers

Auditory - e.g. noises of wildlife, typical noises or sounds by rivers

Affective – e.g. calming, the emotions that rivers elicit

River Uses – e.g. leisure. How rivers are used, both present past and future

Environmental – e.g. litter, environmental issues and impacts that affect rivers

Familiarity – e.g. river holidays, or childhood memories, ways in which rivers are a familiar landscape

River Infrastructure – e.g. bridges, man-made framework surrounding river networks

Visual	Auditory	Affective	River Uses	Environmental	Familiarity	River Infrastructure
Murky[1]	Confluences[3]	Relaxing[2]	Fishing[2,4,5]	Part of ecological system[2]	History esp. in cities[2]	Canal Transport[2]
Muddy[1]	Whirlpools[3]	Peaceful[2]	Kayaking[2,4,]	Improving awareness[2]	Norfolk holiday [3]	Bridges[3,5]
Shopping trolleys[1]	Ripples[3]	Tranquil[1]	Canoeing[2, 4,5]	Wildlife[2,5]	Riverside Pubs[3]	Locks[3]
Bright[1]	Lapping sounds[3]	Excitement[3]	Leisure/Recreation[2,6]	Flooding (farmland, houses)[2]	History – line mills[5]	Watermills[3]
Patterns in water[3]	Bubbling sounds[3]	Soothing[3]	Energy generation[2, 5]	Flood defences[2]	Location[6]	Weirs/Dams[3,5]
Whirlpools[3]		Calm[3]	Long boats[3]	Insurance[2]	History[6]	Boundaries[5]
Confluences[3]		Serene[3]	Walkways[3]	Global warming[2]	Rises & falls[6]	Drains[5]
Photography[3]		Awe[3]	Punting (Oxford)[3]	Pollution[2,3]	Flows to[6]	
Reflections[3]		Beauty[3]	Photography[3]	Litter[1]	Lake District/Scotland[6]	
Ripples[3]			Amenities[5]	Flooding[1,4,5]	Childhood[4]	
Natural[1]				River banks[1,5]		
				Otters[1]		
				Water[3,4,5,6]		
				Kingfisher[3]		
				Salmon[3,5]		
				Oxbow lakes[3]		
				Ducks[3]		
				Fish[34,,5,6]		
				Contryside[3]		
				Education[5]		
				Giant Hogweed[5]		
				Cattle in rivers[5]		
				Vegetation[6]		
				Birds[5]		
				Streams/Tributaries[5]		
				Woodland[5]		
				Flow rate[6]		
				Size[6]		
				Nauture[4]		
				FPM's[4]		

Table 4.3: Results from river brainstorming exercise where participants were asked to say words that they associated with rivers.
Categorisation was conducted post-hoc: [1] = Focus Group 1 (Cardiff); [2] = Focus Group 2 (Cardiff); [3] = Focus Group 3 (Cardiff); [4] = Focus Group 4 (NI); [5] = Focus Group 5 (NI); [6] = Focus Group 6 (NI)

The majority of words fall into the environment category; most of the words were positive and centred around plants and animals that would be likely to be seen near or in a river. However, within the environmental category, flooding and pollution were two words that were repeated across more than one focus group. Many specific species were mentioned, but the Freshwater Pearl Mussel only came up only in one of the stakeholder groups (FG4). The choice of words under the affective category reflects well-being emotions, typically those found in literature documenting the restorative effect of the natural environment (Ulrich 1986; Frumkin 2001; Bratman *et al.* 2012) which was also touched in the discussion surrounding healthy rivers - "because we will feel happy in places where you know something else was healthy" **J, FG3**. The over-arching positivity associated with river environments in this study reflects the literature which documents landscape with water as having an increased effect on personal well-being than that of a natural vegetated scene alone (Ulrich 1986). Many of the words in the visual and auditory categories overlap and appear in both categories because they describe both river images and sounds. In general there was a division with the words from the public groups and those from the stakeholder groups; affective descriptions of rivers were most often elicited from the public groups whereas the stakeholder groups mentioned rivers as being important for their sense of place. Group 3 (public) and 5 (stakeholder) had a greater focus on river infrastructure than any of the other groups.

Familiarity of and place attachment to the river environment was a theme that ran throughout the discourse, initially appearing in response to questions about participants' nearest river and then developing to inform participants' views on how rivers have changed and even the health and accessibility of a river. However, there appears to be a distinction between the public and stakeholder groups; the public refered to familiarity, such as childhood memories whereas the stakeholder participants spoke about rivers giving communities a sense of place and being integral to the culture of local areas, both in terms of townland boundaries (akin to parish boundaries in England and Wales) and also through songs and stories.

“and where I was brought up I was always around rivers so I suppose it reminds me of that” **H, FG2**

“when I was younger . . there was a stream where I lived . . . and I used to go and play down there . . but then since the little river seemed to grow a lot more nettles . . . maybe I just can’t remember what it was like” **A, FG1**

“you know, people having an affinity with their river, you know it is included in songs and paintings and it is a part of any local culture” **L, FG4**

Positive opinions of the river environment are higher in those individuals who feel a strong attachment to this type of landscape feature, as found by Keane (1990); both public and stakeholder participants valued rivers and attributed positive feelings and thoughts towards rivers, with similar levels of concern about pollution being voiced in both groups. It might also be true that, like Devine-Wright’s work (2010) those actions that might detrimentally affect this type of feature would result in a more negative reaction from those with a strong place attachment. This can be seen in the discourse further on in FG2 when participant ‘G’ was vehemently opposed to the use of metal to stabilise river banks because of the perceived consequences of metals in the water that he recalled from his childhood. Additionally, the idea that the use of concrete in river restoration works would reduce the naturalness of the work expressed by some participants in the stakeholder and lay-persons groups highlights the challenge when designing work that has to appeal to the users as well as providing ecological or geomorphological outcomes.

4.3.2 Current River States

Overall, the majority of participants across all groups felt that they had seen positive changes to the current state of UK rivers and hoped that this would continue into the future. The reasons behind this improvement were wide ranging; in the stakeholder group who were from an agricultural area, the reasons focussed on a perceived reduction in agricultural intensification and less channelling of rivers in combination with the work of the local rivers trust, the Balinderry River Enhancement Association. In contrast, the decline of coal mining was perceived as removing a significant polluter of rivers from the public groups, who were all from the Cardiff area, in close proximity to the coal mining region of South Wales.

"now certainly our river, I live in a mining village an apparently 20 years ago, 30 years ago it was totally uninhabitable for wildlife and now we've got otters and you now we, everything in it indicates it is doing really well" **F, FG2**

"in a way the last 50 years have perhaps shown an improvement, we've stopped burning coal very much and there's less pollution from industry. . . so the Taff is now basically a clean river whereas it was a filthy river not so long ago" **B, FG1**

One of the aspects of rivers that was universally perceived as having declined in recent times was vegetation growth which was seen as excessive and detrimental to the visual aesthetics normally attributed to rivers and was mentioned across several groups:

"any sort of shrub or trees are allowed to grow . . .sooner or later you won't be able to see the river at all I suspect" **B, FG1**

"Since I was younger a lot more rivers seem a lot more overgrown" **A, FG1**

"you see the hedgerows along the banks . . grown over, very hard to walk along the banks" **T**, **FG6**

Certain restoration attempts were also viewed in a negative light with concerns over the reasoning behind the project; however there was an acknowledgement that the work had encouraged visitors to the area:

"I feel that some of it is just because they've been given the money to do it, some of it is a bit intrusive . . lots of tarmac through an area that was previously woodland . .the river is much the same but the surrounding, as I say it's very nice that it's very accessible and it's nice to see it being enjoyed, it was quite nice before but they've maintained it" **F, FG2**

Participants in FG1 expressed frustration at the inertia with which they felt river conservation had suffered. Participants believed that whilst work has been needed for some time it has only recently been acted upon:

"I think there seems to be a move towards doing something . . .you know, restoring the habitat, people are finally seem[ing] to realise it's important to do it" **E, FG1**

Conversely, in FG3 one participant believed that there was a large amount of river restoration work currently happening whilst another was not so positive, highlighting differing perceptions between urban and rural rivers.

"I think we are paying far more attention, almost everywhere I go I see attention being paid to cleaning up rivers, to look and be more user friendly" **I, FG3** “my own kind of perception is more towards like London, like the Thames and everything like that so I kind of, maybe not as optimistic as I should be” **K, FG3**

The current method of protecting rivers by designating them as protected site (e.g. Sites of Special Scientific Interest) was seen as a positive method of conserving them, again reflecting the value that the public place on rivers as a landscape feature (Kaplan 1977; Purcell *et al.* 1994).

“I think having an area like National Parks and special areas of scientific interest and areas like that have protected a lot of the rivers” **G, FG2**

In fact, in FG4, 5 and 6 participants spontaneously mentioned legislation as a way of ensuring compliance in protecting rivers; that this was not mentioned in the public groups is perhaps indicative of their lack of awareness of the legislation relating to controlling runoff from farms, industry and septic tanks which tends to be applicable to those in rural communities.

P: Just thinking that silage effluent was a big problem in the 90’s
O: its super improved like
P: It’s improved because there is sort of a zero tolerance of it and that has increased the care that farmers take **(FG5)**

The participants from the stakeholder groups did not mention a distinction between urban and rural rivers, but members of the public groups did. Increased public awareness in cities was given as the reason for the idea that urban rivers have become healthier despite being considered generally more polluted than their rural counterparts, according to participants from the public groups, although this idea was not consistent across all participants.

“ . . so, I think the condition of them, because of the awareness, seems to be improving” **F, FG2**

“the ones that are generally near cities and industrial areas I have the impression that they got very polluted and now people are more aware as to the effect on the local environment . . even the Thames I think which was a pretty dirty river I now having fish in it” **H, FG2**

G: I don’t know of any [rivers] that are polluted but I don’t live in a big city
Facilitator: It seems like you are assuming rivers in cities are more polluted than those in the country
G: Yeah **(FG2)**

"I don't know if it is genuinely the rivers themselves, that are different . . because of their surrounding it gives you a different impression" **K, FG3**

In contrast, rural rivers were unanimously thought to be at greatest risk. Participants from the public groups felt that they were less well monitored whilst runoff from farms was considered to be a significant pollutant risk by both the public and stakeholder participants.

"I would imagine that cities are very conscious of it where there must be a lot of smaller rivers that have runoff from farming and things that perhaps aren't monitored as carefully" **F, FG2**

Across both groups, pollution was seen as the greatest risk to rivers, although the participants in (stakeholder) groups 5 and 6 elaborated on this, mentioning chemical runoff from agriculture, increased chemical use in the home that enters the sewage system and industry, particularly the quarry industry which is significant in that part of Northern Ireland. In FG1 litter was seen as a form of pollution, but in all other FGs this distinction was not made.

"I'd like to distinguish pollution from litter in a way which can be pollution as well but the amount of stuff which is just junk it should really be in a bin" **B, FG1**

Participants in FG3 held strong beliefs about indicators of unhealthy rivers. Rivers "chocked up with weeds" **I, FG3** and "stagnant, smelly, muddy water" **J, FG3** were believed to be negative and actions to "clean up the river" were viewed positively in that it "looks much better" **I, FG3**. In FG5 and 6, the changing focus of conservation work, from a historic focus on clearing and dredging rivers to the current method of less destructive river management led some to some participants assuming that the perceived increase in flooding was directly attributable to this change in management practices.

Q: over the years they silt up and grows a lot of trees and stuff, obstructing
Facilitator: And that causes flooding?
Q: Yes it does.

One participant explicitly mentioned that change is a fundamental part of the nature of rivers; the influence of humans on this intrinsic quality of river was only perceived as negative if there was a financial incentive behind the impact.

"I think river are constantly changing . .and maybe it is a good thing or a bad thing that mankind is kind of meddling with it . . I mean if it's to conserve wildlife or. . . then it's a good thing, if it's just for making money or whatever that's not good" **D, FG1**

Participants' preference for flowing water and their association of still water with stagnation, aligns with work done by Brown & Daniel (1991) who showed that scenic beauty of water-based landscaped peaked when the discharge was 31-42m^3 s^{-1}. This perhaps reflects an inherent expectation that rivers move or flow and that those whose flow is slow or impeded by vegetation are seen as unhealthy and needing help. Anecdotal evidence from the farming community in Northern Ireland also suggests that the presence of in-river vegetation is also linked to a perception of increased flood risk which helps to explain the negative impression of excess vegetation in the river perceive by some participants.

One view held by the public participants was that there had not been enough conservation of rivers. This opinion reflected the high importance participants attributed to river environments in conjunction with their perception of the level of pollution of rivers. There was also an underlying feeling that there had been a lack of public participation in terms of any restoration work that may have been done. In spite of this, the three rivers that the public participants quoted as being their closest river (Taff, Ely & Rhymney) have associated Action Plans with the most recent being published in 2010 and all with aims to improve the river environment and involving stakeholder including local residents (Cardiff Council 2012) In later comments, when the responsibly for conservation was being discussed the same participants clearly expressed a wish for local residents to be actively involved in restoration activities, highlighting the expectation of involvement previously documented (Tunstall *et al*. 2000; Junker *et al.* 2007). In comparison, there was no mention of a lack of local involvement from the stakeholder groups; indeed the Ballinderry River Enhancement Programme has been recognised for its efforts to engage with the local community (Keys 2012, pers. comm.).

4.3.3 Responsibility for River Conservation

The universal answer to this question was the government, who were believed to have the resources and power to put measures in place and ensure that they are enforced. There was a strong feeling that the involvement of local people, stakeholders and charitable organisations would ensure that local knowledge would not be ignored and residents' opinions would be included before decisions were made. The government was seen as the appropriate body to take the lead, in case there is need for legislation "people don't want to do things voluntarily" **C, FG1** although it was also felt that everyone had the responsibility to ensure rivers were protected.

"I think it would be important the government works with other charities and conservation people who maybe have different experiences, who can help, although the government people may be responsible but they shouldn't ignore everyone else that can help them" **A, FG1**

In terms of financing restoration work, the groups were split between those that felt increases in taxation, possibly local taxation, would be acceptable as long as people understood why it was necessary - "might help people to realise that rivers do need looking after" **B, FG1**

Those who were firmly against raising taxes felt that the money should be re-distributed from other government sectors, in combination with using volunteers - "I feel that the budget of money is there, but it's the distribution that is wrong" **R, FG6**. Education was also seen as key to changing people's attitudes, making increased taxes acceptable and encouraging individuals to appreciate nature more - "I think if people were educated they would feel more responsible and be more responsible" **O, FG5**. Young people who were perceived as having less and less contact with the outdoors - "education is the key to all this" **I, FG3**. Finally, several participants felt that industry should contribute financially to conservation projects, particularly those that are responsible for declines in river quality and that the ethos of pollution of being acceptable if you can afford the fines should be stamped out. In particular, participants from FG6 felt very strongly that there should be amendments to the quarry industry's standard operating procedures to encourage better conservation of rivers and increased awareness about the consequences from industry. The two participants who voiced this were also the ones who felt that the major of polluters were industry and are both involved in the quarry industry themselves.

4.3.4 Rivers in the Future

Across all groups there was a unanimous desire for rivers to continue improving into the future and to return to the perceived pristine state of a bygone age, although in the public groups it was recognised that this aim might be unrealistic and would only be achieved through intervention.

H: I would hope that they would actually get better
Facilitator: And what do you mean by getting better what would you class as a better river?
H: Well, one that is not polluted, has a good variety of wildlife . . I think that all adds up to the satisfaction of the people that use it **(FG2)**

"I think it's really, for myself, it's almost something that you've given up on, you would love to have clean water and things like that but you'd have to be a total idealist to think it's ever going to get back to . . . I think it's going to take intervention to increase it [biodiversity] . . .it's about us remedying the damage we've done" **D, FG1.**

In FG5, there was an emphasis placed on increased awareness about how much we rely on rivers, for both drinking water and for industry, which meant that the incentive for continuing to look after rivers was also economic and health-related in nature.

"That river flows into Lough Neagh, is it 40% of Northern Ireland get their drinking water from it, so 40% of Northern Ireland are dependent on that river . . . you need clean water for industries, especially the modern industries . .that would be a selling point for Northern Ireland" **O, FG5**

Smaller streams and tributaries were also viewed as more vulnerable to human impacts, such as culverting, than larger rivers in stakeholder group, FG6. This was due to such projects being able to be carried out by homeowners and not being visible to the relevant authorities.

"maybe not so much main rivers but tributaries are going to change" **T, FG6**

"I think planning and building control should pay more heed to it" **R, FG6**

In the three public groups, there were strong positive opinions about the use of rivers for electricity generation in the future; in the stakeholder groups the use of rivers for energy generation was not mentioned. Whilst it was recognised that this must not be to the detriment of river ecosystems it was felt that river were an under-used resource and examples were cited from Scotland and New Zealand where hydropower operations were viewed in a very positive light.

"I think in principle it's a brilliant idea, in practice there's lots of pro's and con's for it but I think the idea of using rivers, my family are form New Zealand and hydroelectric power is huge out there . . .I think as a resource for energy they are completely unexploited" **F, FG2**

"*I was going to say, where I come from we supplied through hydroelectric power a lot of the grid to England for years, it seems to work very nicely*" **H, FG2**

Facilitator: *And would you like to see water used for energy?*
K: *Yes, definitely, I quite like sort of renewable energy source and things like that* (FG3)
J: *There's a lot of opposition because of the ecosystems around them, surely there must be a way of positioning it in a way that minimises the effect to the wildlife*
Facilitator: *And is protecting the ecosystem important to you?*
J: *Yeah, because you can't say well build this to minimise global warming and then kind of you know protect the earth when you are destroying something at the same time* **(FG2)**

However, there was a degree of negativity towards hydropower expressed when one participant called it "some big giant thing that is making electric" and said that alongside hydropower, rivers should be given a purpose by encouraging leisure usage - "you make it into something with more of a purpose so people could go there maybe do water sports" **G, FG2**

Participants from FG1 and 2 felt that it was important that rivers were used and that by increasing the social awareness of rivers, that rivers would be better looked after. It was also suggested that in the future, rivers would be used predominately for pleasure.

"If you're going to make it a nice place to go, you're going to have to make people want to go there" **A, FG1**

"I would imagine that those of them [rivers] that are involved in leisure would tend to have more of a social impact in terms of getting them cleaner and nice and those that are involved in industry I would imagine have problems" **F, FG2**

"Because of something is accessible and people care about it they are more likely to do something to conserve it" **A, FG1**

Facilitator: So it's important that people use and enjoy it [the river]?
H: Oh, yes, absolutely **(FG2)**

"I think the main uses of rivers will be pleasure and boating, walking punting that sort of thing" **I, FG3**

Participants from FG2 also put forward the idea of using canals again as a means of transportation to ease the burden of the roads and to provide a lower pollution option to moving goods around the country.

"I wonder given the carbon effects of road traffic whether we can use canals again in terms of moving things around" **H, FG2**

An interesting view was expressed by a participant in FG3 that in the future rivers and the outdoors in general would be primarily enjoyed by the older generation as a result of young people being disinterested in nature as a result of new technologies (taken to mean computers and games consoles).

"I think amongst young people don't really enjoy nature and the countryside . . . people will get more pleasure out of rivers, maybe like older people but younger people perhaps not" **K, FG3**

The view of this participant resulted in her advocating strongly for education as a method of conservation to attempt to explain to young people the importance of rivers as part of the environment.

In the stakeholder groups this need for rivers to be useful was not expressed, instead there was more of a focus on the sense of community they brought - "to townlands and different areas and stuff you do, rivers give a sense of place to that" **L, FG4.**

The desire to see rivers being used to generate electricity and as a greener option for transportation is reflective of the support from the public for renewable energy, documented as being the public's preferred choice of energy generation (POSTNote 2007). However, in principle support and in practice opposition by local residents (van der Horst 2007) could also explain the more negative response when turbines were described as "some big giant thing" by one public participant, although the participant's experience with hydropower was not clear. NIMBYism (Devine-Wright and Howes 2010) perhaps explains why hydropower schemes were not mentioned in any of the stakeholder groups. Place attachment to a particular environment can result in strong negative emotions in response to changes or alterations, especially if it is perceived that these changes will alter the intrinsic qualities of the environment to which the person has formed an attachment (Buijs 2009). This may well explain why the stakeholder groups only mentioned river and power generation in relation to historic uses for mills, since the linen industry was very important to the economic history of Northern Ireland.

In this section and in the previous 'Current Rivers' discourse, there was a general desire to see rivers restored to a previous point in history which was perceived to be a "rural idyll" where rivers were seemingly clean, healthy and untouched by humans (Eden *et al*. 1999; Moore-Colyer and Scott 2005). Whether this is a realistic or achievable goal given the pressure face by river engineers and conservationists to enhance integrity and ecology whilst at the same time maintaining flood defences and providing cost effective options which need little management, remains to be seen (Tapsell 1995). However comments within these groups exemplify the literature which emphasises the need for expectations of river restoration programmes to be managed, lest the end results be disappointing in the public's eye and reduce future support for such projects (Junker *et al*. 2007; Petts 2007).

4.3.5 Rivers & Climate Change

Flooding and increased rainfall were the only climate change impacts on rivers that participants mentioned unprompted across all six groups. In FG2 flooding of farmland was mentioned alongside houses and in FG6 there was the opinion that fields are flooded much more quickly these days and that climate change will exacerbate this. Drought was also recognised as a consequence of climate change in the stakeholder focus groups but this was perceived as a problem that would not be experienced in Northern Ireland.

"I think it's just too wet for something like that to happen!" **M, FG4** “another one near me [river] does flood a lot and it flood farm land like stable and there’s houses on the other side and there’s damage to those houses as well” **G, FG2**

In FG3 a more pragmatic approach to flooding was voiced, indicating that adaptation to such events would mean the effects were lessened and that technology would provide the solution to the issue of flooding:

“I guess there are many counties in the world where flooding has become a way of life . . and they have adapted to that . .normally when it flood they cope with it because they are used to it . .as those changes occur we are going to have to adapt to many things” **I, FG3**

“we need to come up with new technologies and use other things that other countries have used to kind of adapt to it” **K, FG3**

“if we knew it was going to happen we would then obviously make changes in the way that we do things” **J, FG3**

In FG5, it was mentioned that the infrastructure to supply homes and business with fresh water would need updating with increased rainfall through climate change, leading to increased water bills. However, this point of view was likely the result of the negative experience these stakeholders have had with the sewage and water treatment works downstream in Cookstown and the perception of the detrimental impact this has had on the river as a result of the lack of finance.

“to increase infrastructure and the pipes and stuff they are going to have to spend more money” **Q, FG5**

Mention was made in both FG1 and FG2 about building on floodplains and how this could exacerbate the impact of rivers flooding:

“there was some complaint about funding for flood defenses but nothing acknowledging the fact that by building on floodplains you are opening up the problems anyway” **F, FG2**

When prompted, the climate change impacts on river biodiversity provoked a discussion about the increased presence of invasive species as the waters warm and how seasonal changes of water availability might become out of synch with species life cycles.

“this year during that heavy rain at the time the fish were moving up, even the bigger of them weren’t making it” **T, FG6** destroying all the natural biodiversity . . because you've got more warmer water creatures coming in apparently" **D, FG1**.

However, there was also the opinion that nature might be able to adapt, dependant on the speed of the change - "I'm a firm believer in nature's ability to fix things . . . . it depends on how fast the change happens" **L, FG4**

Despite this, biodiversity loss as a result of climate change alone was not perceived as a significant issue from the lay-public's perspective, rather in combination with other impacts; there was also a degree of confusion as to the impacts of climate change on river habitats and species. In FG2 wildlife being washed away was a concern with more rain and high flow rates; in FG3 higher flow rates were suggested as having a positive outcome by removing weeds and pollution in the rivers.

"If you've got a lot more water flowing down, surely it will wash a lot, maybe plants or other wildlife out?" **G, FG2**

"if we do get benefits from climate change one of them will be an increase in the flow of waters in the river . . . we will see rivers cleaned up more than they have been . . more water flowing down the river will clear out a lot of the weed and pollution that grows" **I, FG3**

Within the majority of the focus groups, both lay-public and stakeholder, the effect on the provision of potable water through climate change was not at the forefront of participants' minds. However when prompted, one participant saw it as an issue for river ecosystems rather than affecting the amount of freshwater available for human consumption.

"*I think there are dangers there, particularly with increasing populations in some areas which don't have enough other sources of water trying to extract more water from the river and endangering the bio-systems of the river*" **B, FG1.**

However, in FG5, the link between rivers and potable water was clearly stated - *"The river flows into Lough Neagh . .40% of Northern Ireland gets their drinking water from it, so 40% of Northern Ireland are dependent on that river"* **O, FG5.**

The fact that the major concern of participants, when asked to consider the effect of climate change on rivers, was increased flood risk is likely due to the tangible impact flooding has, both at a local, regional and national scale. Additionally, the links between climate change and flooding as described in the media would also act to bring this impact to the forefront of public consciousness (Gavin *et al.* 2011). Experience of flooding has been linked to changing perceptions of climate change and behaviour alteration (Spence *et al.* 2011) and many participants had first-hand experience of floods; however this cause and effect linkage has not been consistently found (Whitmarsh 2008).

The lack of other risks to rivers associated with a changing climate could be attributed to two factors. The first is a lack of knowledge – whilst several participants used language that indicated a level of expertise in relation to rivers and the environment, for example ox-bow lake, meanders, ecosystems, and also made mention of jobs or voluntary work which gave them contact with this kind of environment, such as teachers and conservation volunteers, none of the participants were an 'expert'. The finer mechanisms of how a changing climate could affect rivers and the vulnerability of such habitats to this scale of change (Durance and Ormerod 2007; Heino *et al.* 2009; Durance and Ormerod 2010) are rarely documented in lay-persons' terms and thus this information is unlikely to be accessible to the majority of the population (Lewan and Soderqvist 2002). This is corroborated by the fact that the consequences to fresh water supplies were identified by those stakeholders who had the closest connection to the Balinderry River Enhancement Association. Secondly, there appears to be a disconnect between rivers and humans. Aside for their value at an aesthetic level rivers are no longer vital for food or transportation as they were once; rivers are more of a pleasure rather than a necessity. Even the provision of drinking water is several steps removed from its source thanks to plumbing and taps! Therefore when asked about the impacts of climate change it is difficult for the public, and even some stakeholders, with less of a link between, for example, rivers and the provision of water, to envisage how this might change in the future. Indeed, the stakeholder who relied on river water for his business was in the minority when it came to describing why rivers are important; the majority of replies centred on intrinsic qualities.

In spite of this, concerns for biodiversity loss due to climate change were relatively high but only when prompted, across both groups. Examples focus on loss of species either due to increased flow rates as a result of higher precipitation levels, or because of invasive species extending their northward range. This negative attitude towards invasive species is not consistently proved in the literature which suggests a gradation of acceptability of invasive species. Evidence suggests that charismatic or attractive such as the buddleia or Canada goose (Rotheram 2005; Sharp *et al.* 2011) are more acceptable which can complicate the implementation of schemes to eradicate such species. Indeed, the literature shows that conflict can ensue between the public and policy makers when dealing with invasive species (Maguire 2004).

What factors influence the public's opinion of rivers and aquatic species?

4.3.6 Species Poster

Of the six aquatic species shown on the poster, the kingfisher, the otter and the weeping willow were readily recognised and the otter and kingfisher provoked positive emotive responses typical to other charismatic mega fauna - "I think seeing the otter, its rather cute" **J, FG3.** In contrast, the following comment referring to Japanese knotweed clearly shows that species that were perceived as non-native were all viewed negatively and associated with causing damage to native species and ecosystems;

"crowding out native species" **E, FG1**

"I've always been told that you can't get rid of it, so I've always had a negative impression of it" **G, FG2**

"I would be surprised if it was native 'cause it's causing such a problem" **F, FG2**

"It's an invasive species and they are trying to get rid of it**" M, FG4**

Opinions were divided over exactly which species were non-native. FPM's were mistaken for zebra mussels in one focus group but in the stakeholder groups the FPM was well recognised - "and I've seen those down in the hatchery (BREA)" **S, FG6**. The great diving beetle, a native British invertebrate, was seen as possibly being native - "I know that there are a lot of interesting insects that we do get in our waters that maybe people just aren't aware of" **A, FG1** but was not as familiar - "do you know that in any of my kick sampling[2] or whatever, I don't think I have ever brought up a great diving beetle" **M, FG4**. Participants appeared to find it difficult to distinguish non-native species, names e.g. Japanese knotweed provide some clues - "it's not Ulster knotweed" **L, FG1** but aside from any direct experience or knowledge, participants had no reference points to enable them to determine whether an unfamiliar species was native to UK rivers.

"I'm assuming that this is not a natural plant in the UK cause this is called Japanese knotweed" **H, FG2**

"because that is called Japanese I would say no, the name gives it away" **I, FG3**

"I would suggest that because I have never heard of any of these that they can't be native" **J, FG3**

In addition, in the stakeholder group carried out in Northern Ireland where willow is native, but weeping willow is not, many of the participants knew this - "the weeping willow is probably not [native] either" **Q, FG5.**

Reflecting the emotive response to the charismatic species, conservation priorities for these six focussed on the otter and the kingfisher - "I think that it [otter] is a lovely creature" **S, FG6**. Other reasons for these species being protected included the perception that otters needed more help than kingfishers - "maybe the kingfisher can fend for itself more, it looks quite robust" **J, FG3** and that otter and kingfishers, to the participants, best exemplified river species - "I think they are both kind of associated with the rivers and things like that [Kingfisher & Otter]" **K, FG3.** It was believed that as the river are "cleaned up" species that were previously lost would return; the example given was the otter whose presence was believed to be an indicator species for river health.

[2] Kick-sampling or stream sampling involves the sampler agitating the stream bottom using his/her foot for three minutes in a region just upstream of a 1m mesh pond net. Any species disturbed will be carried downstream and caught in the net.

"I was only reading the other day that there's more otters returning than ever before and they're seen sort of as the bench mark of a healthy river" **I, FG3**

In addition the great diving beetle, if it was native, would be considered for protection because it is recognised that it is important to conserve the whole ecosystem - "even though it is a beetle" **D, FG1**.

"Obviously there is a flow on effect if otters are conserved . . .you can't just conserve the otter without conserving his habitat and by conserving the habitat therefore ipso facto if I conserve the otter I've got to conserve all those other things" **I, FG3.**

In addition one participant recognised that the aesthetic reason to conserve otters should not be to the detriment of other species - "because they fit into the ecosystem of the river" **T, FG6**

Attitudes to invasive species management have been shown to be influenced by individual value judgements and knowledge (Fischer and van der Wal 2007; Sharp *et al*. 2011). In work by Fischer and van der Wal (2007), naturalness and balance were significant predictor values towards the management options for controlling the invasive species, the tree mallow. Their results also show that provenance is not the main issue but rather the action of the invasive species in altering the natural balance of the area. This in part explains the reactions to perceived invasive species found in this study, where the damage done to other species was cited as the reason they should be removed.

4.3.7 Photo Sort

4.3.7.1 Naturalness

Across all groups, naturalness was defined as unaltered by humans - "the way God intended" **P, FG5,** with no human-made structures visible, or obvious human-made interference. The presence of green vegetation, sinuous rivers, and remote areas increased the impression of naturalness. In contrast, reinforced banks, straight canal-like rivers and urban environs were universally perceived as less natural. There was also a link between beauty and naturalness - "all the pretty ones down this [natural] end please**" J, FG3**

In the stakeholder groups, there was a greater degree of knowledge as to what might have happened to rivers historically to cause the perceived un-naturalness, for example, excavation or dredging of the river bed. This probably reflects a collective memory of amount of drainage work that was done in rural areas in the post-second world war period that continued for many years, whereas in the public group attention was focussed on the shape of rivers and visible structures, perhaps a result of bank reinforcement and channelling done in urbanised areas to reduce the risk of flooding.

4.3.7.2 Accessibility

Accessibility of the river was dependent on the mode of transport in combination with how far away the river was believed to be, for the members of the public groups.

"the more in the wilderness it is the harder it is for me to get to it" **D, FG1** (non-driver)

In addition, both groups mentioned factors such as paths running alongside the river and the appearance of humans in the pictures, for example in urban rivers, made the rivers seem more accessible whereas large amounts of vegetation or thick forest reduced the accessibility - "It's very overgrown, so I don't think you could actually be able to get, but I don't know" **A, FG1.**

The stakeholder group also mentioned access in terms of whether they would be allowed to access the river if it was on farmland, and therefore private land.

"The thing about farmers in some cases don't like people just wandering about" **P, FG5**

4.3.7.3 Healthiness

Participants found this category the most challenging; public participants in particular felt as though they didn't have enough knowledge or expertise to make such judgements. However, in general terms, rivers that contain rubbish or pollution, either visible or potential such as runoff from agricultural areas, those pictures that only contain one species of plant and those with slow moving or still water were classed as unhealthy, by both the public and stakeholders. Rivers in urban areas were classed as unhealthy simply because they were urban by several participants, irrespective of any other factors - "because it's full of syringes and shopping trolleys" **D, FG1** describing a photo in which no shopping trolleys or syringes were visible. Again, as with the natural category, stakeholders were far more specific about what might have caused the river to become unhealthy, for example nitrates, silage effluent, and the geographical location of the river reach i.e. upland rivers were perceived as more healthy with less opportunities to have become polluted.

No overt link was made between naturalness and healthiness. One participant explicitly stated that the two could be distinct - "It could still be healthy; it may not look natural but that doesn't mean it's not healthy" **A, FG1**

4.3.7.4 Safety

This category was perhaps the most contested, with little consensus within or between groups. Fences along rivers were taken as an indicator of danger but also as a measure to increase safety. Use of the river for water sports were taken as an indicator of fast flowing water and therefore dangerous; or alternatively as a safe river because people were using it. From the public groups urban rivers were seen as safe due to the availability of people for help if needed, but also as a danger because of the presence of rubbish in the river and the danger posed by people "to throw you in" **D, FG1.**

Vegetation in the water was perceived much more often by the public as a hazard due to entanglement and steep sides would make the river more difficult to get out of, however - "what reason would you have to get in" **B, FG1.** An association was made in one group about river restoration making rivers potentially more dangerous by increasing flow rates.

" . . a paradox, because as you improve the rivers and make better, more fast flowing or whatever and encourage people to use the facilities then it comes with it the danger of how do you stop them jumping in or falling in the water" **H, FG2.**

It became clear that many of the pictures that were ranked as being more natural were often preferred over the urban, less natural images. Whilst Kaplan *et al*. (1989) show that physical attributes of rivers, such as slope and naturalness, did not have predictive power, their work was not focussed on comparing urban and rural compositions. It is likely that the restorative properties of the natural environment as discussed previously are a factor in the preference for more natural scenes, with participants able to imagine themselves in this environment and the positive emotions that it would elicit.

Historically, wilderness was seen as dangerous and the type of place people got lost in (Cronon 1995). In the more recent past, the idea of wilderness has changed to be somewhere untouched by humans and a place to be preserved (Warner 2008). The link in this research between naturalness and accessibility is likely a combination of these two ideas of wilderness augmented by some of the concepts of Kaplan *et al*. (1989) considering ease of movement and preference for specific land cover types.

It became apparent through this research that the idea of a safe river is particularly personal and related to many factors aside from physical indicators related to river itself. There is little academic research available to compare this to; Tapsell *et al*. (1997) linked perceptions of safety to flood risk but this was not apparent in this study. Many factors such as physical barriers to access were perceived as being both a marker of safety but also as an indicator of danger (why would barriers be there if the area was safe). It is challenging to distil this information into a single reason but it appears that contextualising the comments would be an appropriate method. Individuals who were confident being in the 'outdoors', particularly those who were confident swimmers, felt safer across a larger range of pictures. Those who were nervous swimmers or who were thinking of the safety of others, for example children on a school trip, were more likely to see hidden dangers and to perceive more risk in the photographs.

4.3.8 Quantitative Results

In order to assess how levels of similarity in the photo sort exercise varied between each of the sub-groups from the public and stakeholder groups, each photo was given a single value, equal to the sum of the square of each of the differences in score between each sub-group. Thus a value of zero indicates that the photo was scored identically between each sub-group, and with increasing score, the photo would have been scored increasingly differently between each sub-group. The eight photographs which were placed at the top (most) and bottom (least) under each sorting category for the public and stakeholder groups are shown in figures 4.1 and 4.2.

Of the four sorting categories (naturalness, accessibility, safety and healthiness) naturalness and accessibility scores had the smallest range within both the public and stakeholder groups, with the most similar mean values as well (Figure 4.3). This indicates that the four public groups (FG1 was split into two sub-groups for the sorting exercise) and the three stakeholder groups each ranked the photographs more similarly under these two categories than under the safety and healthiness categories. This reflects the qualitative results for this section, with participants having clear definition of naturalness and accessibility, within each sub-group of public or stakeholder participants identifying the same factors that made a photo more natural or more accessible. Comparing the public and stakeholder results it can be seen that whilst the interquartile range indicates that the three sub-groups within the stakeholder group ranked the photographs more similarly than the public, the extended range under the naturalness category seen for the stakeholder group shows that there was a higher level of dissimilarity at this end of the range than is seen under the public group.

Looking at Figure 4.1, it can be seen that both all of public and stakeholder groups were unanimous in their choice of most natural photograph; this was the only category that had 100% agreement both within and between groups. Both groups also chose similar photos for least natural (Figure 4.2), with elements such as urban surroundings dominating the choice of the public groups whereas the stakeholder groups also including factors such as whether the river had naturally formed which relates to their familiarity with things such as drainage ditches and dredged river channels. Under the accessibility category, again there was a striking similarity between choice of most accessible picture, with both the public and stakeholder groups focussing on pictures that were urban or appeared to put the river in a recreational setting, for example in a park.

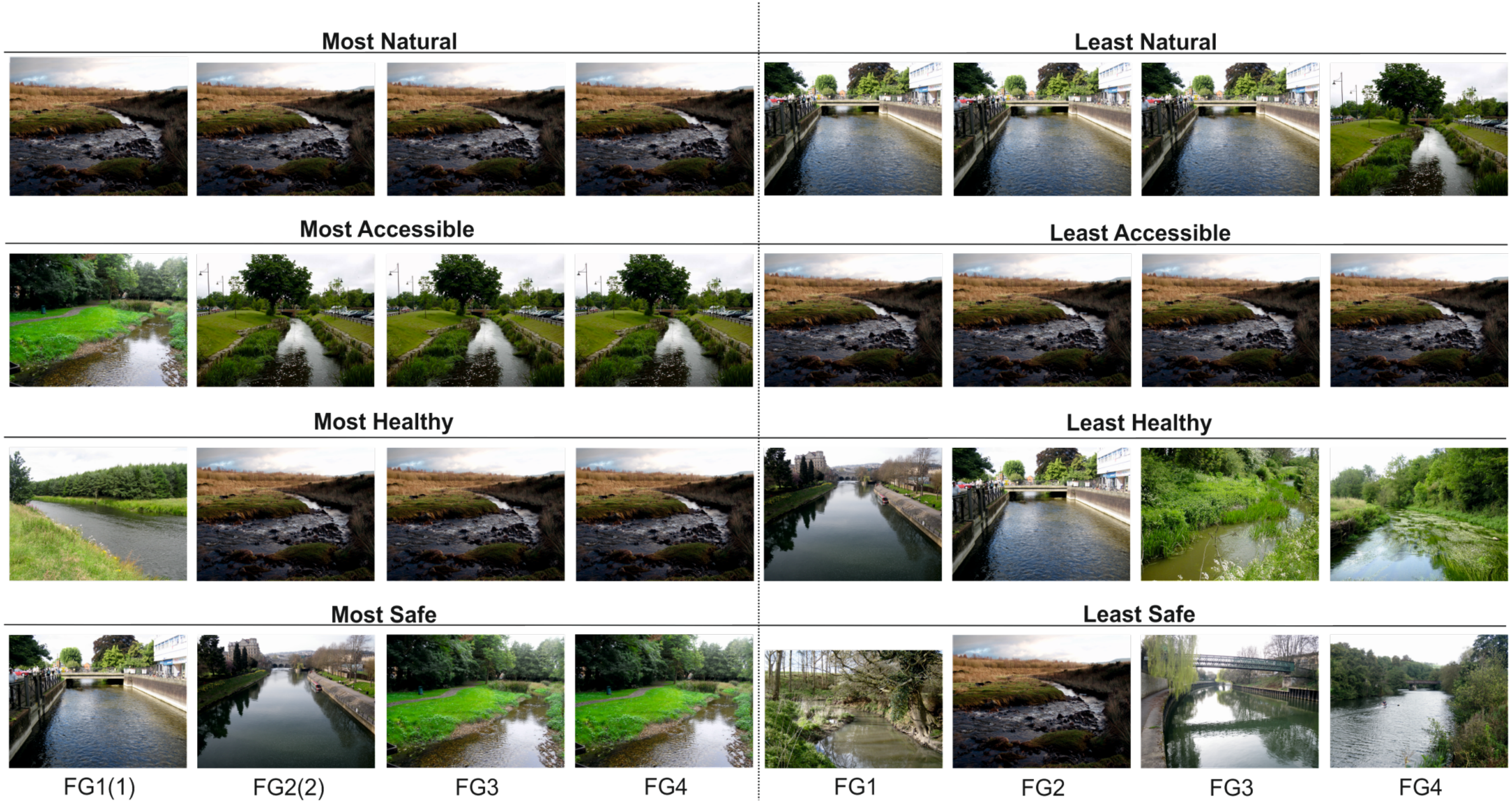

Figure 4.1: The photographs ranked at positions 1 (most) and 18 (least) under the four sorting categories for the four lay-public groups.
Focus Group1 was split into two sup-groups for this activity: FG1(1) and FG1(2)

Figure 4.2: The photographs ranked at positions 1 (most) and 18 (least) under the four sorting categories for the three stakeholder groups.

In contrast, the choice of least accessible picture polarised the two groups; by focussing on how difficult it might be to get to the location of the river, the public group were unanimous in their choice which reflects the remote nature of the river. Whilst the stakeholder groups were in agreement in their choices of least accessible image, they instead assessed how easy it would be to get to the river's edge and the choice of image reflects this, showing a river surrounded by dense vegetation (Figure 4.3).

The healthiness and safety categories show a much greater level of dissimilarity when the public results are compared to the stakeholders' (Figure 4.3); of the two, the healthiness category elicited the highest degree of dissimilarity amongst the lay-public whereas the stakeholder group showed similar results for both healthiness and safety. The qualitative results above reflect this, indicating that the public participants found it difficult to assess health with no clear indicators being established.

Under the most healthy category, there was a high degree of consensus between the public and stakeholder groups in image choice; this also appears to connect to the choice of most natural with the same image that was chosen as most natural (i.e. image 1, see figures 4.1 and 4.2) also being chosen as the most healthy in all but one sorts. The choice of least healthy however was much more divided, with the public choosing urban pictures of those images which had dense bank vegetation and visible aquatic vegetation. However, the stakeholder choice of least healthy was aligned with their choice of least natural and featured rivers with what they perceived as questionable water quality or that had been artificially created or maintained.

There were multiple factors that influenced perceptions of safety, that did not all consistently represent safety or danger across all groups. The choices made by the public and stakeholder groups in relation to most and least safe highlighted the difference in reasoning between the groups. The public groups were polarised between those who felt safer in an urban setting with more help available and those that felt less safe in a remote rural setting; hence the choice of least safe reflects both these views. In contrast, the stakeholder group focussed on how easy is was to get to the river in conjunction with any safety measure in place and so chose an urban scene with a path along a potentially deep river with no railings. The most safe image choices in the stakeholder groups were shallow small rivers that were considered safe for a child, one of which was classed as the least safe by the lay-public in FG2 (see Figure 4.1). In contrast, the public groups chose images which either depicted a shallow river in a park like setting or a river with railing running alongside it.

In order to assess the relationships between the ranks attributed to the photos under different categories, correlation analysis was conducted. The naturalness and accessibility categories show a relationship within both the public and stakeholder groups, with high effect sizes (Cohen 1988) (Table 4.4).

Correlation Coefficients

		Naturalness	
		Public	**Stakeholders**
Accessibility	**Public**	-.622**	
	Stakeholders		-.308*

Table 4.4: Spearman's Rank correlations between the ranks attributed to the 18 photographs under the naturalness and accessibility categories, split by lay-public and stakeholder groups.

Looking further into the link between accessibility and naturalness, it can be seen that for both the public results and the stakeholder results, naturalness scores decrease (becoming more natural) as accessibility scores increase (i.e. become less accessible). This relationship is stronger for the public results than for the stakeholder, with 39% of the variability of the accessibility score explained by the variance in the naturalness score for the public compared with only 9% for the stakeholders, indicated by Figure 4.4.

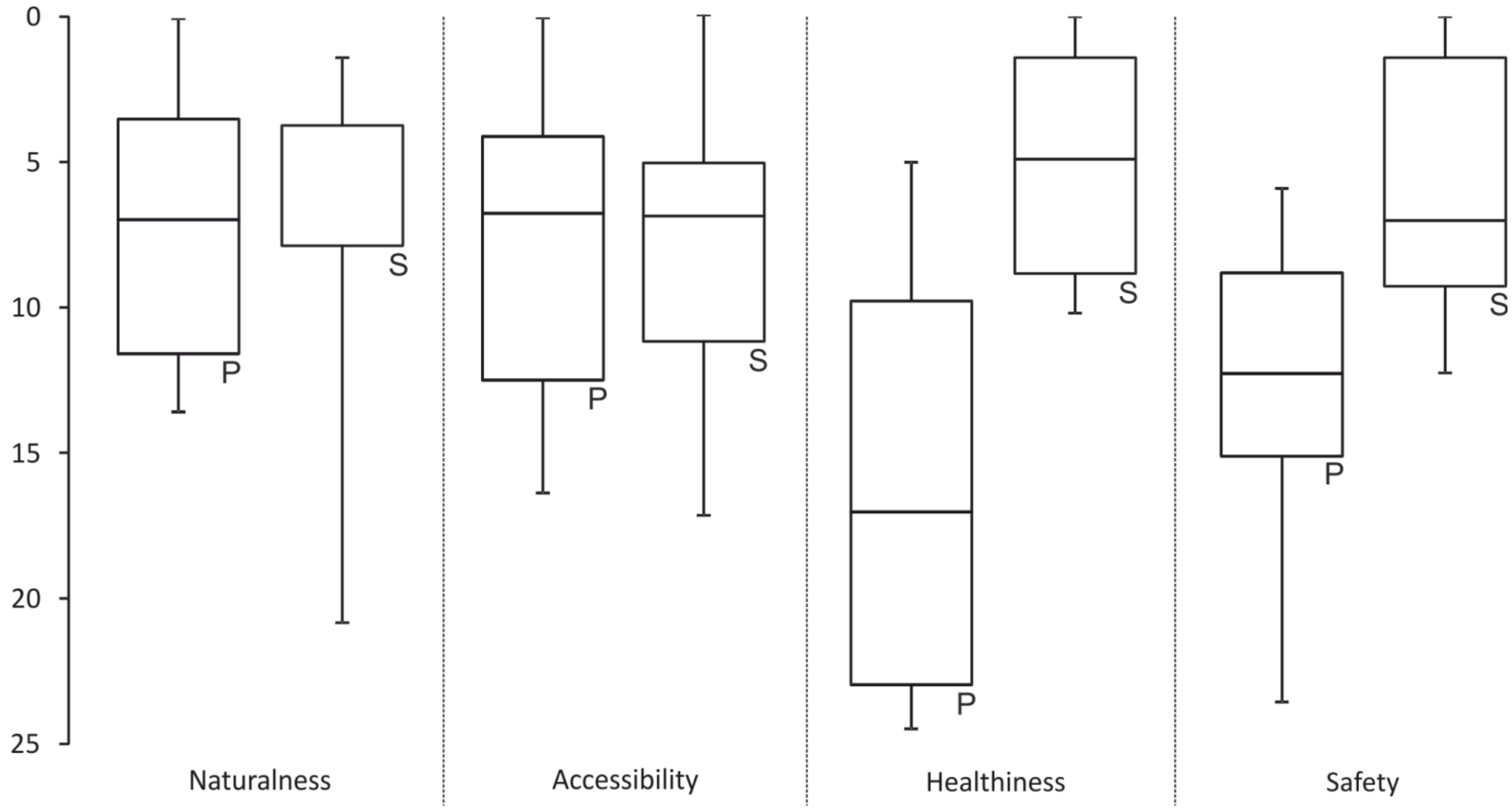

Figure 4.3: Box and whisker plots illustrating the degree of similarity of photo scores between the lay-public and stakeholder groups.
Under each category (naturalness, accessibility, healthiness and safety) the differences in the ranks attributed to each photography within each sub-group (P =lay-public; S = stakeholder) were calculated to give a single score per photography which represent the degree of similarity in ranking that each photo scored, with photos that were ranked identically across the sup groups scoring 0. Thus, categories with a large range represent categories in which there was a higher degree of dissimilarity in the rank attributed to the same photo across either the stakeholder or public sub groups.

At first this might seem that the public may perceive obstacles to access where the stakeholder, with more hands-on river experience, may not. Rather, the qualitative results and photo ranks suggest simply that the two groups were focussing on slightly different meanings of the term accessibility. Whilst the public discussed concepts such as how easy it would be to travel to some of the rivers (for example using public transport) as well as how easy or difficult it appeared to get to the edge of the river, the stakeholder groups predominantly used the latter classification. For example, photograph 1 (natural category, figures 4.1 and 4.2) was universally agreed upon by all groups to be the most natural; the lay-public also decided that it would be the least accessible given its rural nature (i.e. considering how easy it would be get to river itself). In contrast, it was ranked as being very accessible, and moderately accessible, by stakeholder groups considering how easy it would be to get to the edge of the river once you were in the location.

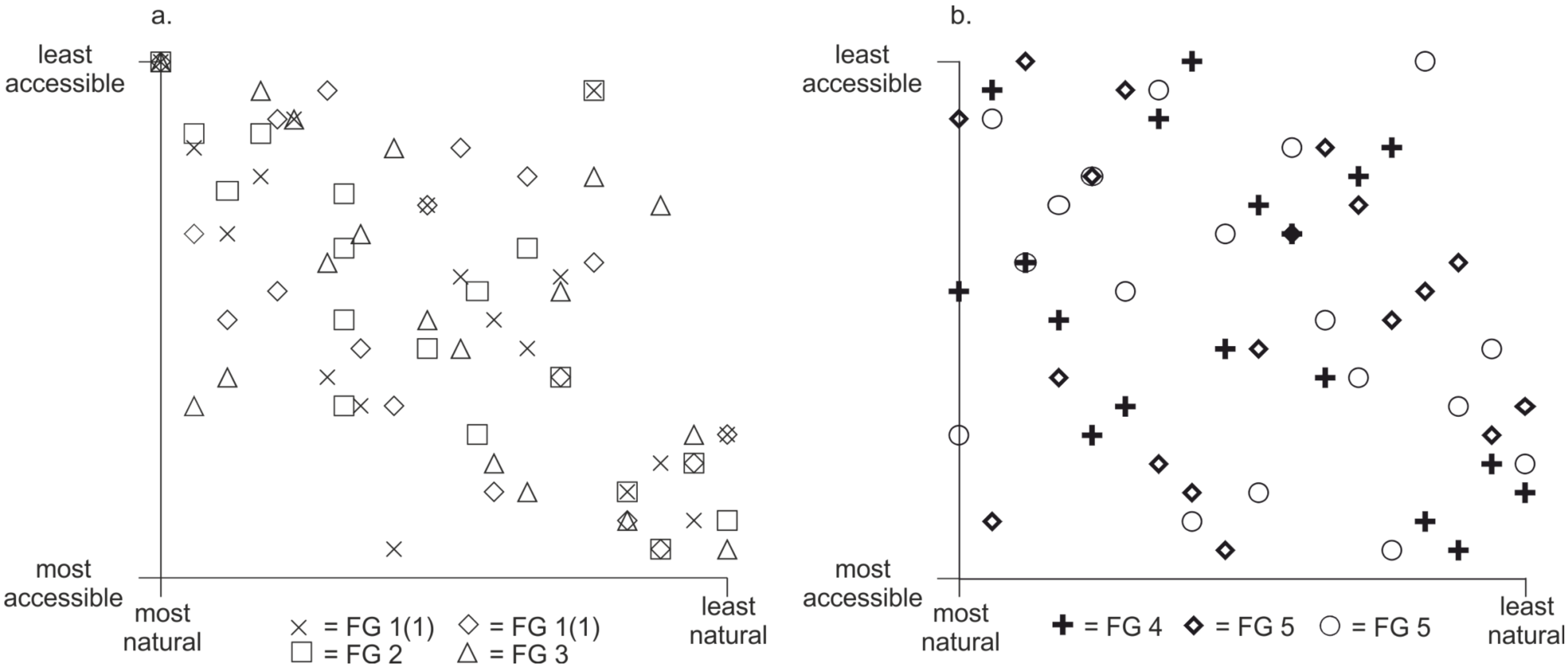

Figure 4.4: Scatter graph showing the relationship between naturalness and accessibility, split by group
a. = public groups; b. = stakeholder groups

4.3.9 Conservation Priorities

As a general trend, three of the four nature categories (marine, rivers & lakes and forests) were given proportionally more in this exercise (Figure 4.5). Other land received slightly less, whereas historic building was given significantly less, overall. There was no significant difference between the proportion of funds attributed to each category by the lay-public participants compared to the stakeholder participants (Marine and Seas $t(18) = .4$; Rivers and Lakes $t(18) = -.76$; Forests and Woodland $t(9.9) = .42$; Other Land $t(18) = -.70$; Historic Buildings $t(14.48) = .50$ all *ns*).

Historic Buildings were felt to be important because of their contribution to culture and learning - "I think it's important to remember our culture as well" **A, FG1.** In addition, one of the stakeholder groups mentioned that unlike the natural categories which could take of themselves, historic buildings needed to be maintained. Conversely it was felt that they have been given substantial contributions in the past and are also able to generate money though activities such as entrance fees - "stuff like castles generate loads of money anyway" **E, FG1** and "*I believe they are already quite well funded*" **J, FG3**.

Forests were seen as important due to their role in reducing climate change, absorbing CO_2 - "one of the biggest factor with global warming is the production of carbon in the atmosphere . . doing away with the forest in Brazil" **Q, FG5** and as a source of raw materials "there's a commercial aspect of the forestry" **R, FG6**. Many participants gave equal amount to forest, marine and river & lakes because it was felt that these are interrelated, for example that within forests you also find rivers and lakes.

The two aquatic habitats, marine and seas and rivers and lakes, together received the majority of the hypothetical funding. Whilst many participants struggled to justify giving more to these two than forests - "I've kind of got equal for marine, rivers and forest" **J, FG3**, reasons for giving more to rivers and lakes included the importance of freshwater to humans - "it's probably going to be more expensive than oil in terms of a resource" **H, FG2**. Those that gave proportionally less to marine and seas indicated that the marine environment could make its own revenue through commercial fisheries, which is a similar reason for less funding to historic buildings. Conversely, those that gave more to the marine sector did so because of the size of the marine environment and the higher degree of need - "I know that it [marine] needs a lot of attention" **M, FG4.**

It was mentioned that whilst meadows and moorlands are less attractive they are still important for insects and so they also need protecting - "you need those [meadows and moorlands] for the bees and the butterflies" **E, FG1**. The 'other land' was only given a higher proportion of funds than the other three natural options by two participants in both the stakeholder and lay-person focus groups, perhaps a reflection of the terminology used. After the focus group, one participant mentioned that the title 'other land' made this category appear less important.

The opinion that attractive areas are conserved at the expense of less attractive ones which are just as important was also raised, which supports earlier finding about perceptions of naturalness. This reflects the finding of Junker and Buchecker (2008) who found that aesthetic preference of river scenes was strongly linked to perceived ecological quality, reflecting an understanding within the public of the importance of rivers ecology.

E: yeah, it's like marshy swamp land, you need that as well and yet that's not as attractive, look at the Severn Estuary at Newport it looks muddy and horrible but you need it don't you?
C: Yeah, there was almost a case for not building the Cardiff barrage cause it was such an important ecological feature
B: I'm one of those funny people who thought the mudflats were quite beautiful at low tide **(FG1).**

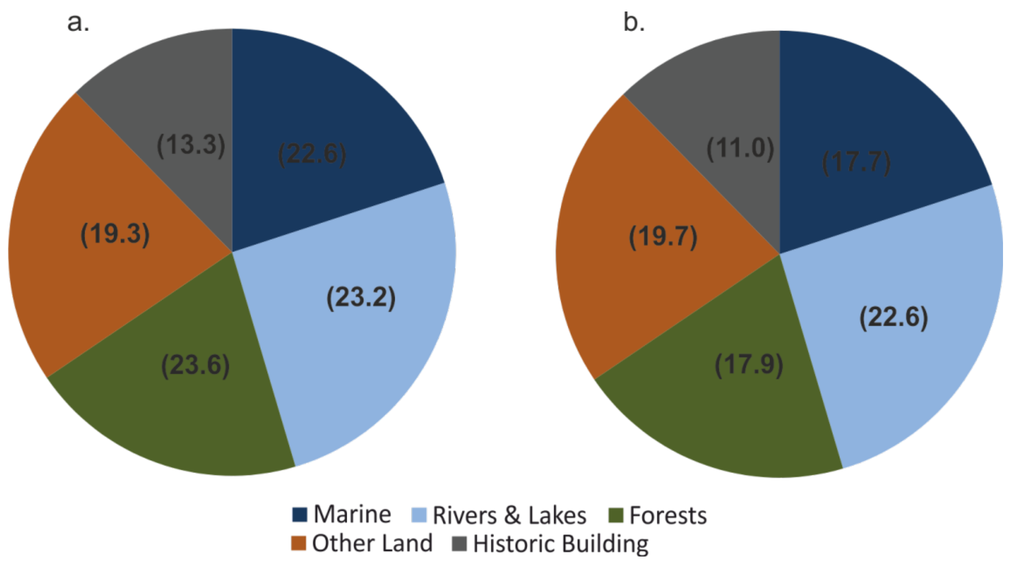

Figure 4.5: Pie charts showing the attribution of funds for conservation priorities. Numbers in parenthesis represent the percentages attributed to each sector.
a. = public groups b. stakeholder groups

4.3.10 Conservation Options for the Freshwater Pearl Mussel

To what extent are the public willing to support the conservation of the freshwater pearl mussel, an important but less well known freshwater species?

Overall, participants were in favour of conservation methods for the FPM and were willing to compromise between images that were aesthetically pleasing and those that had more conservation merit. Initially, these measures were discussed purely as a method to reduce erosion for the conservation of FPM's and no comments were made as to whether these methods were appropriate for the conservation of just one species. Whilst participants recognised the term indicator species, they did not appreciate that the FPM was an indicator species until this information had been given to them, after which they understood that by conserving the FPM, many others will benefit. When prompted, participants did mention value for money "create as much value as possible for what you are doing" **H, FG2** and that conservation measures which are beneficial for multiple species are better.

"if it's an indicator of the health of the river then I would like to see them in every river and if that means you have to do a lot of work behind the scenes in other areas to make an environment that the pearl mussel is going to survive [in] that's also a good thing from my point of view" **I, FG3** "and through the work that is done here, by protecting the FPM, Mr Otter benefits and Mr Kingfisher benefits from it as well" **N, FG4**

4.3.10.1 Picture Set 1: Changing Land Use (Appendix 4.5)

Across all focus groups participants' least favourite picture in terms of aesthetics was of the arable farmland, with the exception of two stakeholders from group 6 who expressed views that arable land was a fundamental part of life in their area - "being able to see the land cultivated like that, part of the natural way of life" **T, FG6**

Despite the lesser aesthetic value of arable land, there was a general consensus that an attempt to reduce the amount of land used for arable farming would be impracticable and illogical; the first indication that other values compete with aesthetics in order to define a person's overall attitude towards the landscape. It was mentioned that farmers had specific reasons behind choice of crop including location and market prices; concerns were raised over the subsidies needed to change farming practices and how this would affect food production. Mention was made of alternative farming techniques that could be used to reduce runoff and sediment transport with examples being cited such as contour ploughing and terracing. Farming being primarily a business was also mentioned and that any conservation measures must reflect this, but reducing arable land was also seen by one participant as a method to reduce the runoff of fertilisers as well as sediment.

"poor farmers, are battered with so much . . . using some arable land for grazing might be economically, well you would have to change your whole farm" **F, FG2**

"But I think they [farmers] would generally be supportive [of conservation] provided that it wasn't detrimental to their livelihood" **H, FG2**

"so its food and farmers need to make a living, it's part and parcel of the whole agricultural scene" **P, FG5**

In FG6, the fact that arable land provides food meant for stakeholders that irrespective of aesthetic preference, arable has to be accepted and this should take priority over conservation:

"heading towards scrubland would be good, but that's not the only factor that has to be taken into account . . . the farmer has to get the crops produced and we have to eat so that would be the priority" **S, FG6**

The groups were split between those that favoured the grazed hill slope picture and those that preferred the forest. Reasons for preference of the grazed hill slope were that participants could see themselves being able to walk through that landscape which was more ordered than the forest and the colours were attractive "*nice walk in the countryside*" **A, FG1**, which links to the concept of legibility in landscape preference in Kaplan and Kaplan's work (1989); however, some participants thought that the grazed picture looked featureless, again providing a link to ideas of scene complexity by Kaplan and Kaplan (1989). The forest picture was described as scruffy and concerns were raised that it looked like a Forestry Commission plantation which had negative connotations due to a perceived lack of appropriate management, with one participant feeling as if the image represented a dangerous environment. One participant thought that more native trees had been planted in the foreground which he felt was better environmentally than the coniferous tree in the background whilst another preferred this landscape because it - "benefits everything . . clean water, biodiversity and flooding" **O, FG5,** and finally one participant (a farmer) felt that the scrubland was "barren and infertile" **F, FG5**

"It's because it looks like Forestry Commission and I'm always a bit suspicious about it, how well managed it would be and how useful it would be" **F, FG2**

"because you can trip over, its bit sort of like wild . . looks a bit treacherous" **J, FG3**

Overall, it seemed that the change from arable land to woodland posed too many unanswerable questions and issues for any overall decision with regards to the conservation of the FPM to be made, with little difference in opinions between the public and stakeholders except for a greater preference for arable land in the stakeholder group, possibly as a result of more familiarity with this kind of landscape. However one participant, who saw the forest as dangerous and thus preferred the grazed hill slope image, suggested a compromise - "I would go for a combination, with maybe little barriers of scrub land" **J, FG3**

4.3.10.2 Picture Set 2: Cattle Access to Rivers (Appendix 4.5)

The overwhelming majority of public participants felt that cattle had an intrinsic right to access rivers. This extended further than being simply access to water as participants were made aware that alternative watering arrangements would be made. No specific reason was voiced for this, aside from one participant who felt that cattle were not treated well and that this restriction would exacerbate this – "I think that cows are treated really badly, the way they are farmed is not natural really" **E, FG1**. In the stakeholder groups, there was still a preference for cattle in the river, although this was more for aesthetic reasons - "It does look nice, the cows in the river" **N, FG4**. There was an exception, the farmer in FG5 - "it's necessary in the way that you have a river that could prove dangerous [to the cows], also to contain your stock, so again necessary from an animal disease point of view" **P, FG5.** However in general the livestock drink was seen as a compromise, giving the cattle limited access to the river and acting to reduce sediment loading whilst at the same time being more aesthetically pleasing than the fenced alternative - "it's a compromise isn't it, allowing that cattle to access the river and also it's done nicely" **D, FG1.**

The image containing the barbed wire was seen negatively by most participants; it indicated danger and in FG2 was seen as a temporary measure - "the situation where the banks have been eroded because of bad practice so they are recovering then that's [barbed wire] good" **H, FG2**. However, if there had been more vegetation around the barbed wire, in effect to disguise it, then opinions were not so negative, one particular participant in the stakeholder groups suggested the vegetation could "open up a sort of wildlife corridor" **Q, FG5**. In terms of its usage in conservation, this would have to be determined by its efficacy in comparison to alternative methods. Only one participant preferred this picture for aesthetic reasons, feeling that "the idea of nature taking over appeals" **C, FG1**, in reference to his idea that over time vegetation would fill the gap between the fence and the river, although in separate discussions it was found that he was unable to swim and was nervous around water.

4.3.10.3 Picture Set 3: Bank Re-Vegetation (Appendix 4.5)

Of all the sediment control options, this elicited the most positive responses for reasons such as - "habitat for bees and butterflies" **D, FG1** and "provides [visual] interest across several seasons" **M, FG1**. However, in opposition this picture was also seen as less accessible than picture set two promoting feeling that picture set three would involve difficulty in walking alongside the river.

"you were talking about it growing over . . and then I though that's a shame because then you won't see the wicker . . . you could more or less walk along it or moor a boat next to it [re-vegetated bank image, picture set 2]" **J, FG3**

The use of a natural material for the bank support was supported; however in FG3 participants were clear that their opinion of the picture would be different if the wicker was replaced by concrete - "I wouldn't like to see concrete, under any circumstances" **I, FG3.** In FG1 and 6 there was a more pragmatic approach in that as long as the area was healthy for plants and the end result was the same it didn't matter what the starting material was.

"well, if it wasn't detrimental, as long as it didn't defeat the purpose that is was intended for, you could probably live with it" **S, FG6**

In FG2 there was strong opposition for any metal being used by one participant who had previous experience of what he perceived to be metal contamination of rivers - "I just feel like because of the minerals in the metal could seep out into the soil" **G, FG2**. A member of FG4 mentioned that is would probably cost more if concrete was used in place of a more natural material.

Despite a paucity of work surrounding the aesthetics of specific management options, and even less on preference associated with management options to support a specific species, there is a wealth of literature surrounding landscape aesthetics in general with many conclusions that are relevant to this current work. The work of Kaplan *et al*. (1979, 1982; 1989) use four domains to successfully predict landscape preference and their results reflect the general trends found in this study. Characteristics such as openness, defined as the amount of space in the picture, and locomotion, the ease of moving through the image unhindered, combined reflect the preference of the grazed pasture picture in the first group of erosion control measures, where participants felt that they could imagine themselves walking through that type of landscape. In contrast, the forest image was not seen as attractive – whilst this image was undoubtedly more complex (i.e. it contained more elements within the scene), researchers found that an intermediate level of complexity is generally favoured (Shafer Jr and Brush 1977). Mystery is a significant predictor of preference, defined as the promise of novel but related information, for example a winding road or a meandering river (Kaplan *et al*. 1989). The forest photo did not possess an auspicious combination of these elements being a broad swath of trees, with no visible means of accessing the forest easily with no variety of land cover types within the frame and a reduced legibility, in terms of being able to find one's way there and back. Participants' choices in this exercise were consistent with the work of Kaplan *et al*. (1989), which showed certain land cover types, including agriculture and scrubland were significant negative predictors of preference.

These variables can also help to explain the preference of the re-vegetated bank images within picture set three. Participants generally preferred the re-vegetated bank, an image with less direct human influence. Whilst degree of human influence was not explicitly investigated by Kaplan and Kaplan (1989), Ulrich (1986) showed that vegetated scenes were preferred over urban scenes and urban scenes with vegetation (i.e. trees) had increased preference ratings over urban images without vegetation. The image of the re-vegetated bank was also more complex in that it contained a number of different elements and perhaps in combination with the weather, encouraged exploration and had an element of mystery. The image of the bare bank with willow support structures does have an increased openness and smoothness which Kaplan and Kaplan (1989) show to be good predictors of perception since they are linked closely to locomotion, which explains the comments made that this photo was perceived by some as being more accessible. However this photo lacked elements such as an element of mystery to encourage exploration which could explain why fewer participants favoured this image.

The images surrounding the reduction of livestock poaching as a method to control sediment transport into rivers were perceived predominantly with an animal welfare viewpoint from the groups containing an active farmer, as opposed to the other five groups which were mainly focussed aesthetic appearance. Animal welfare, in particular that related to farm animals and their husbandry, has received much attention over recent decades. Post-war demand for cheaper food has led to increases in farmed stock sometimes at the expense of husbandry techniques (Maria 2006). This has led to concerns about welfare and combined with a popular belief that Britain is a nation of animal lovers (BBC. 2000) it is unsurprising that these images provoked discourse about the rights that cattle have to access rivers. That said, most participants chose the livestock drink as their preferred method because it represented a compromise and did not appear to be detrimental to livestock living conditions. It is interesting to note that the participant who preferred the barbed wire image was quite fearful of water and so it is likely that this represented a safety measure in his opinion. Comments about "*nature taking over*" also mimic this participant's preference of the forested scene, which perhaps indicates further a preference for wilderness-type environments.

4.4 Conclusions

This research set out to understand the attitudes of two distinct groups towards rivers: the lay public with less active involvement in river conservation, and stakeholders from the Balinderry River Enhancement Project area who have been exposed to conservation projects on their river over the last 10 years. Likely impacts of climate change in the future will undoubtedly mean more work will be needed to protect both river biodiversity and maintain the goods and services that rivers provide. But rivers are also valued for intrinsic qualities; in order to ensure that conservation planning takes into account social elements we must understand exactly what it is about rivers that is so valued, what risks are associated with rivers now and in the future and how conservation importance is assessed in terms of specific species to allow more targeted conservation communication which appropriately advocates their relevance and necessity within river ecosystems.

The protection of uncharismatic species is supported even when compromises to visual aesthetics are needed

This research indicates that the public are willing to support and compromise on mitigation measures that are not always aesthetically pleasing in order to protect a passive, inactive species such as the freshwater pearl mussel, but more so after the significant role (i.e. as an indicator species) of the freshwater pearl mussel (FMP) was revealed. Prior to this, the species was not well recognised in comparison to other freshwater species by public participants and in one case, it was mistaken for an invasive bivalve and believed to be causing damage to the aquatic environment. In contrast, stakeholder participants who had worked closely with the BREA were aware of and could recognise the FPM. Even though the FPM was not well recognised by the public their willingness to conserve it is likely to be in part due to the importance placed on riverscapes as a whole; this is corroborated by the change in opinion about the freshwater pearl mussel as their relevance to freshwater environment was made clear.

There is a relationship between perception of naturalness and perception of accessibility

Throughout this research is has been shown that rivers continue to play an important role in the landscape, both for recreational uses and intrinsic well-being associated with nature. As found in Buijs (2009) and Devine-Wright and Howes (2010) and in this study, place attachment plays a significant role in the perceptions of riverscapes, both current and historical, and misunderstandings of the importance of this by policy-makers has been seen to result in reduced support for restoration schemes, clearly seen in the public discourse within this research. The importance of accessibility in encouraging and allowing people to appreciate the river environment coupled with the lay-public desire for rivers to be utilised, either recreationally or for energy generation, should be used to inform land managers and conservation authorities involved in river management. However, to avoid conflict with local residents, project managers also need an appreciation of the connectivity between perceptions of naturalness and accessibility, lest naturalness be reduced in order to increase access. It is important to note that accessibility through the lens of the stakeholder was constrained by the type of land that the river ran though, for example farmed land would automatically mean that access was prohibited. This needs to be taken into account since land managers or owners will vary in levels of enthusiasm for conservation work taking place on 'their land' Overall, the domains of landscape aesthetics first put forward 30 years ago (Kaplan 1979; Kaplan *et al*. 1989) as powerful predictors of preference such as mystery, openness and land cover types still continue to be relevant today, seen in both the photo sorting exercise and the mitigation preferences discourse, which gives a good idea of what the ideal river is, in both the eyes of the public and stakeholders.

There is a strong desire for rivers to be clean and to stay clean

River in the recent past are seen as being polluted, particularly urban rivers, but works done to improve the quality of rivers are also recognised and currently rivers are seen as improving with a desire expressed for this trend to continue into the future. However the cause of the pollution is understood differently between stakeholders and the public which appears to reflect the degree of local awareness about rivers. For example, the stakeholder groups had much more specific examples of pollution incidents and were able to attribute causes of pollution more readily than the lay-public, whose perceptions were more generalised.

The impact of climate change on rivers is less well understood. Flooding was a major concern for many of the participants in this study and any other impacts are less well understood consistent with previous climate change perception research (Whitmarsh 2008; Whitmarsh 2011). However, flooding was not solely seen as resulting from climate change impacts; the human actions of building upon flood plains in the public groups and the move away from artificially de-silting river beds in the stakeholder groups, were very much at the forefront of participants' minds as a causative agent in increasing the magnitude of flooding events. From the public's discussion it appears that the effects of climate change on invasive species was of slight concern but in general, impacts as a result of climate change were viewed as detrimental to the human appreciation of the river as opposed to negatively effecting the river ecosystem. This bears similarity to findings by Tapsell *et al.* (1997) where urban residents felt that restoration schemes were primarily designed to be of benefit to local residents and their rural counterparts believed that restoration was designed to be of benefit to the rivers itself.

This research has taken a step forward in understanding general perceptions about riverscapes in the UK but perhaps more significantly, it has revealed the dominance of aesthetic values in attitudes towards rivers. This is particularly important to consider if future conservation priorities mean changes to way that rivers look. Whilst there were differences observed between attitudes and opinions of the public groups and stakeholder groups, these were for the most part restricted to a more in-depth knowledge about the causes of detrimental impacts to rivers and differences to the place attachment facilitated by rivers alongside a better understanding of how health, safety and accessibility are related to river scenes. Perceptions of what constitutes a desirable river scene or who should be responsible for river conservation and opinions about conservation importance of species and management options were very similar between the groups. It appears that there is a clear and universal opinion about how rivers should look and likewise what elements are perceived in a negative light, such as pollution. The importance of accessibility reinforces the value that rivers have in the landscape, although there was tension between this dimension and naturalness; for many participants, naturalness and accessibility are seen as opposing descriptors. This was particularly apparent during the discussions in Northern Ireland where it was vividly recalled that 'The Troubles' (a colloquial term for the conflict in Northern Ireland) had restricted access to rivers due to curfews, which were no longer in place.

Overall, this research suggests that indicator species do not have to be charismatic for the public to support work towards their conservation, particularly within the river environment, a landscape feature which is universally appreciated. The importance of local knowledge and the use of volunteers within such restoration projects is perceived as being a way of ensuring projects include the local community whilst at the same time being centrally managed by government, perceived as having the finances to fund and authority to legislate where necessary to ensure the continued improvement of what is seen as a vital national resource. But, the natural tendency is to protect charismatic species, therefore if uncharismatic examples are to be used communication is vital to inform the public about the importance of the indicator species chosen. If the survival of the indicator can be linked to the survival of other, charismatic species then this approach may be more effective.

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Appendix 4.1: Outline Plan for Focus Groups

Section	Activity	Description	Equipment Needed	Duration
1	Welcome/Consent Forms	Welcoming participants into room, explaining consent forms, collecting signed consent forms	Printed consent forms plus spares, name badges for participants and facilitators, pens	5 mins
2	Introduction	Brief intro into focus group activities, what to expect, the aims of the research	PowerPoint presentation, projector, laptop	10 mins
3	River Use/Awareness	Paper exercise, participants to fill in details regarding use of rivers and distance to nearest river	Printed question sheets, pens	5 mins
4	River Use/Awareness	Discussion of answers, beginning with brainstorming exercise to answer the question "what words do you think of when I say the word river". Ask about participants sues of rivers and when they last visited a river.	Flip chart & pens	10 mins
5	Rivers in the Future	Discussion surrounding how rivers might change in the future. Prompt to find out what risks the participants see as most significant to river, how to participants feel climate change will effect rivers, prompt for thoughts on flooding, provision of drinking water, biodiversity,	None	10 mins
6	River Photographs	Group split in 2, participants asked to rank riverscape photographs according to descriptors. Facilitators to record rankings and promote discussion to illicit disagreements. At the end, ask which photographs show scenes which most need improvement and discuss.	Photo scoring sheet, photographs, pens, post-it notes, 2 copies of descriptor pairs	30 mins
7	Species Questions	Using approx. 6 UK river species (including FWPM's) discuss which species participants are familiar with, which species participants believe are found in UK rivers.	PowerPoint of species pictures, laptop, projector, background information about species	15 mins

Appendix 4.2: River Use Questionnaire

River Uses Questions

Home Postcode ☐☐☐☐ ☐☐☐

Distance to nearest river (approx).. miles / km (please circle)

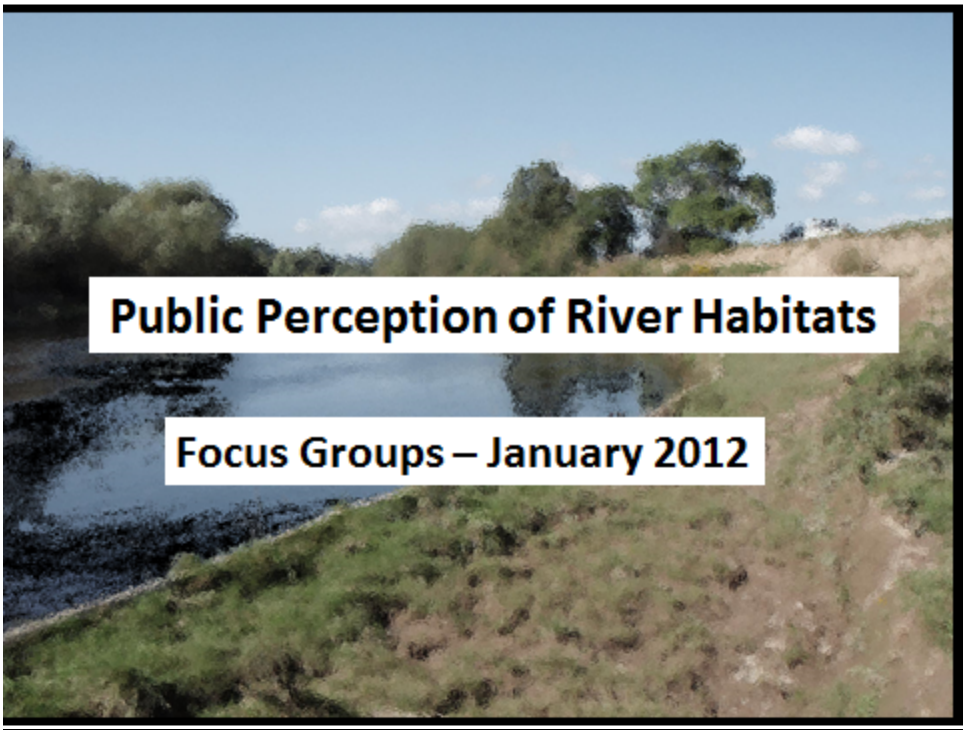
Name of nearest river:

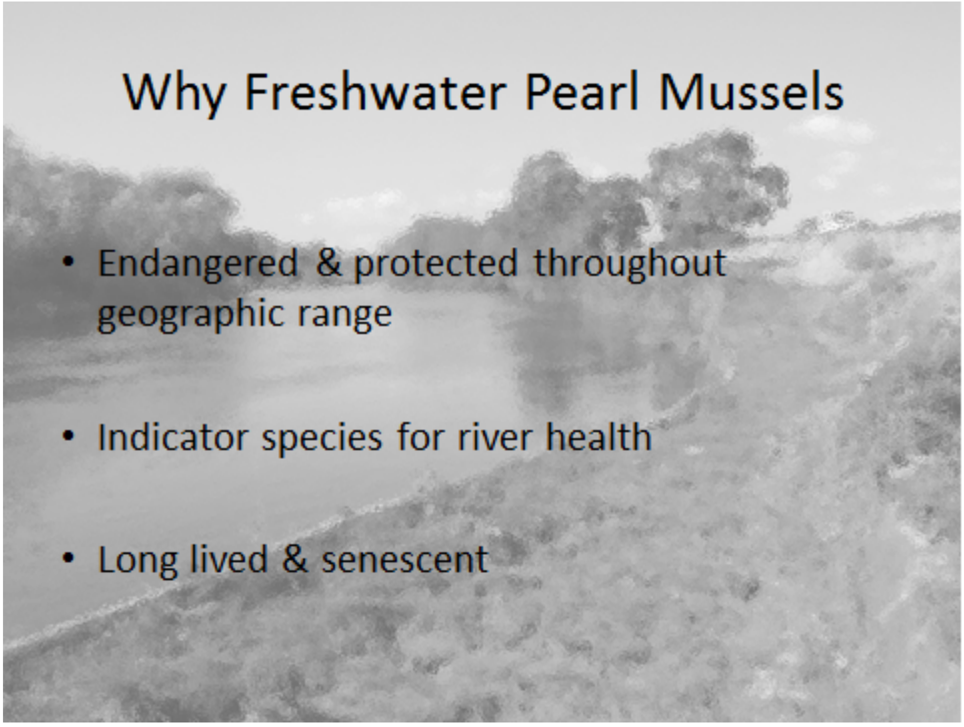
What activities do you regularly do near/in rivers? Please tick all that apply

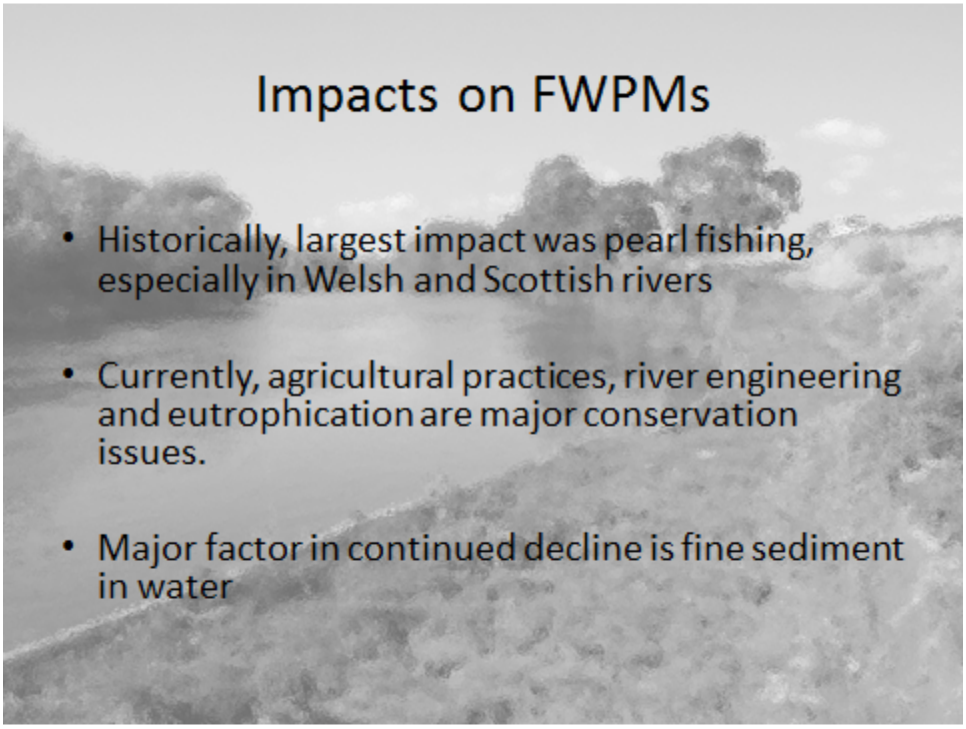
Walking
Running
Cycling
Swimming
Canoeing/Kayaking
Fishing
Conservation work

Appendix 4.3: Species Poster

Appendix 4.4: Focus Group Presentation




Why Freshwater Pearl Mussels
• Endangered & protected throughout geographic range
• Indicator species for river health
• Long lived & senescent


Impacts on FWPMs
• Historically, largest impact was pearl fishing, especially in Welsh and Scottish rivers
• Currently, agricultural practices, river engineering and eutrophication are major conservation issues.
• Major factor in continued decline is fine sediment in water

Appendix 4.5: Picture Sets for FPM Conservation

Picture Set 1

Picture Set 2:

Appendix 4.5 Cont.: Picture Sets for FPM Conservation

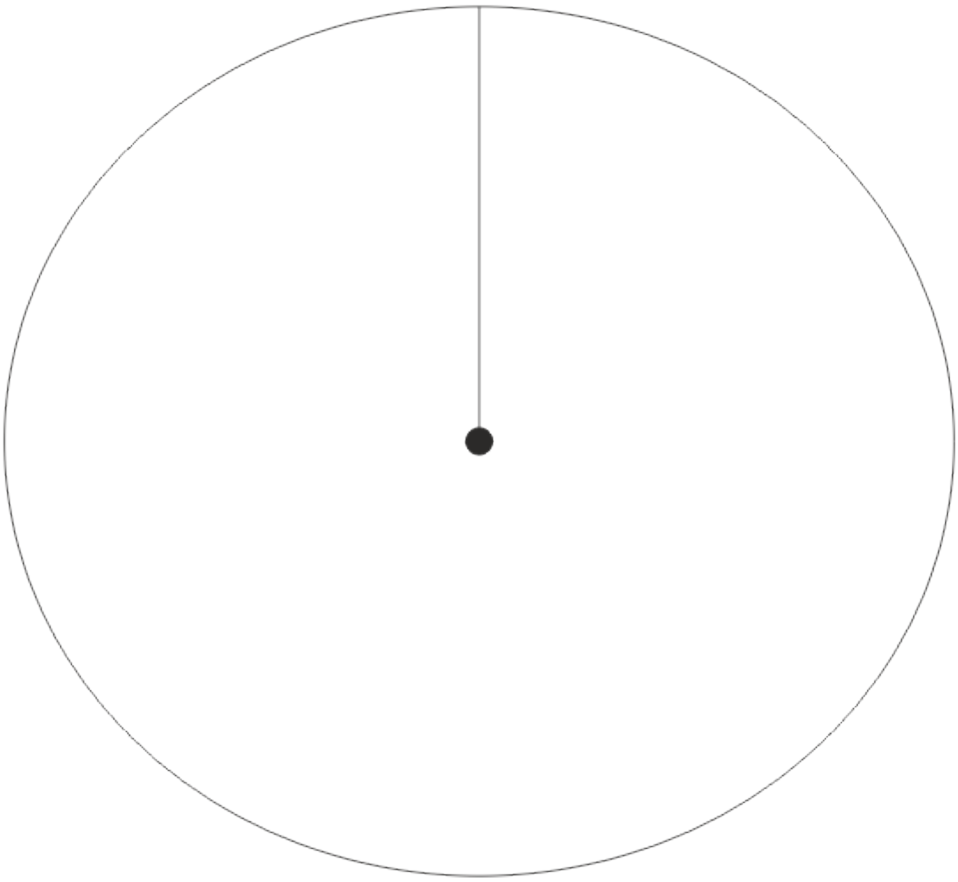
Picture Set 3:

Appendix 4.6: Conservation Priorities Pie Chart

Conservation Priorities Pie Chart

Section 9: Using the following headings, please divide the circle to show how you feel the that the funding for UK conservation should be divided:

1. Marine
2. Rivers & Lakes
3. Forests
4. Other land e.g. meadows, moors
5. Historic Buildings



CHAPTER FIVE:
EXAMINING THE DRIVERS OF ATTITUDES TO RIVERS, FRESHWATER PEARL MUSSELS AND EROSION MITIGATION OPTIONS[1]

Many conservation campaigns are spearheaded by charismatic species, such as the polar bear, but numerous less charismatic species are also under threat whose loss would have a profound effect on the ecosystems in which they are found. Already introduced in Chapter four, the FPM is an excellent example of a native British river species under threat whose presence is all but invisible to the general public. However, the ways that the lay public assess the acceptability of conservation work to support an unfamiliar species, in this case the FPM which is found in rivers, a highly valued landscape feature has not been identified. Chapter five investigates relative contribution of values and knowledge in determining attitudes towards unfamiliar species, identifies linkages between global and local environmental attitudes, and explores how the framing of conservation messages can affect the acceptability of the proposed actions. The results indicate that both knowledge and values contribute to lay-persons assessment of species importance in the case of the FPM and that the acceptability of conservation work is determined by general environmental attitude and not message framing. A ink between global and local environmental concern is confirmed, indicating the possibility of a spill-over effect. These results will help to better communicate the local effect of global issues attitudes and to increase levels of support in cases where necessary mitigation measures could be in conflict with aesthetic values.

5.1 Background

How does general environmental concern relate to attitudes towards rivers?

Whilst most people claim to be concerned about changes to the environment and biodiversity loss (DEFRA 2011), there is a paucity of research as to whether concern for the

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[1] A modified version of this chapter will be submitted as:
Walker-Springett, K., Whitmarsh, L. & Ormerod, S. The roles of knowledge and values in the conservation of uncharismatic species

environment globally in general is linked to concern for local environments. What constitutes the 'environment' is often that which is local to the individual (Catton and Dunlap 1978) and research has shown that people show higher levels of concern and place greater importance on their *local* environment (Brody *et al.* 2004). Factors that connect people with specific spatial settings such as place identity, place dependence, and experiential contact with the natural environment particularly at a young age, are all thought to play a role in a person's affective connection with the natural environment and thus their levels of concern with ecological issues (Pyle 1978); indeed both emotions and beliefs have been shown to be key in changing environmental attitudes (Pooley and O'Connor 2000).

Research by Halpenny (2006) shows that localised environmental concern as a result of place attachment can spill over into general environmental concern; an understanding of how global and local environmental concerns are connected, will allow similarities and differences in the drivers behind global and local concerns to be identified. Knowledge and values will be used as mediators linking the global with the local, using rivers as a specific environmental example. This is particularly relevant in understanding perceptions of risks from climate change, a global issue. Rivers elicit much aesthetic appeal as well as having both functional and cultural values associated with them. In general, public attitudes towards river conservation are positive (Buijs 2009), but fundamental changes in the perceived aesthetic, cultural or functional values of the river as a result of ill-informed management choices can disengage the public with the area and reduce the 'value' of the river (Buijs, 2009; Wester-Herber, 2004). Understanding how globally concerned individuals think about specific types of environments and vice versa will help focus conservation communication messages in the future as well as helping to appreciate whether a local issue has more resonance than a global one.

What impacts are perceived to be facing UK rivers and what impact is climate change thought to have on rivers?

River ecosystems are amongst the most vulnerable to changes in climate (Ormerod 2009); understanding lay-persons' perceptions of the risk to freshwater environments has never been more pertinent than today with the impacts of climate change already being observed both globally (IPCC 2002, 2007) and within UK rivers (Durance and Ormerod 2007, 2010). However, this is complex and necessitates understanding how climate change impacts, often perceived as being both geographically and psychologically distant (Spence *et al.* 2011) can cause such changes in UK rivers. Little work has been done to examine perceived threats to freshwater ecosystems but in the marine context, public opinion is dominated by oil and sewerage pollution (Jefferson 2010). Issues such as pollution are tangible and have a clear cause and effect, that is easy for the non-expert to interpret; more complex issues such as biodiversity loss, or habitat fragmentation are more challenging to comprehend and thus often appear to be invisible to the public (Nassauer 1992). In addition, there is not necessarily a linear relationship between environmental awareness (i.e. being aware of the impact of humans on the environment) and knowledge about potential impacts (Kollmuss and Agyeman 2002). Increasing awareness does not automatically leads to a greater knowledge about how risks might impact the environment, particularly with issues such as climate change that have complex societal as well as ecological impacts. If action by the public is dependent on knowing the risk, then it is vital that we understand what risks the lay-persons attributes to rivers.

What factors contribute to laypersons' attitudes towards aquatic species and habitats?

Attitude formation is influenced by both knowledge and values, obtained through a combination of direct experience and related information. Perceptions of species are strongly determined by aesthetic values and those species that elicit fear, irrational or otherwise (e.g. spiders) are often perceived negatively (Knight 2008) whereas higher order species, for example mammals and fish confer greater levels of preference compared to invertebrates

(Czech and Krausman 1999). However, knowledge can be a key factor in lay-persons' attitudes towards species (Martín-López *et al.* 2007), it has been shown that well-informed persons make choices based on ecological reasons. In contrast, affective factors play a more significant role in the choices of less well-informed individuals, who tend to assess importance in terms of the familiar, the useful or the charismatic, mediated by experience (Martín-López *et al*. 2007 2004, Factors influencing human attitudes to animals and their welfare)}. In addition, factors such as whether or not the species is native also contributes towards perceptions of the species and attitudes towards it removal (Bremner and Park 2007). At the habitat level, values have also been shown to be key in understanding choices lay-persons make with regards to conservation management (Fischer and van der Wal 2007) and the influence of values in determining ecological behavioural intentions is well recognised (Kaiser *et al.* 1999). The aesthetic value of water in the landscape has long been appreciated (Kaplan 1977; Kaltenborn and Bjerke 2002) and the connection of place attachment and environmental value (Vorkinn and Riese 2001) has been extended to geographical proximity, with increased familiarity and concern connected to decreased driving distance to waterbody (Brody *et al*. 2004). If it can be assumed that place attachment and familiarity are a type of 'knowledge' then this also indicates the role of knowledge in mediating attitudes towards habitats

The relative importance of values and knowledge has been shown to vary in accordance with what is being measured. For example, in the prioritisation of species conservation, values have been shown to be the dominant factor (Hunter and Rinner 2004) whereas when there is a choice to be made about a particular behaviour based on the understanding of the consequences of different action, such as car choice, knowledge has been shown to play an important role in this process (Kaiser *et al*. 1999). Understanding whether values or knowledge underpins perceptions of natural environments, or a combination of both factors, is fundamental to allowing conservation authorities to effectively garner public support (Fischer and van der Wal 2007) and produce effective communication strategies.

Little prior research has demonstrated the influence of socio-demographic factors, on the perception of specific habitats and species; however, there is much work that shows that socio-demographic factors such as gender, education and voting intention can all influence perceptions of the environment and climate change. Women have been shown to be more ecocentric and less sceptical about climate change than men (Bord and O'Connor 1997; Gustafsod 1998; O'Connor *et al.* 1999); a higher level of education has also been linked to lower scepticism and a more ecocentric environmental attitude (Whitmarsh 2011) and Conservative voters are more sceptical about climate change and have anthropocentric environmental views (Whitmarsh 2011). Given that the species used in this research, the freshwater pearl mussel, is predominantly found in upland catchments in rural areas, yet rivers themselves are found in both urban and rural location, of particular interest is the research that suggests a rural-urban difference in environmental concern. Environmental concern and climate scepticism have been shown to be higher in urban samples (Berenguer *et al.* 2005; Whitmarsh 2011), whereas rural residents exhibit a greater level of environmental responsibility and have stronger utilitarian views of nature (Tremblay and Dunlap 1977), perhaps due to an economic dependence on the environment (Berenguer *et al*. 2005)

What factors influence the acceptability of mitigation measures for the freshwater pearl mussel?

An important question, thus far unanswered in the literature, is whether the publics' support for conservation is dependent on the type of species being targeted. This presents a difficult situation for conservation bodies that equally have a duty to protect unfamiliar and un-charismatic species, often fundamental to the goods and services provided by an ecosystem. One such example is the freshwater pearl mussel, currently experiencing a decline in numbers across the UK and Europe. Potentially climate change could have deleterious impacts on the freshwater pearl mussels due to its strict habitat requirements (Hastie *et al.* 2003); climate change is widely accepted but certain action to reduce the impacts are less acceptable because of the impacts on society and the level of uncertainty as to the causes of climate change. Thus, mitigation measures specifically designed to protect an uncharismatic species from the consequences of contentious maybe less acceptable from the public's perspective.

Conservation management not only prioritises which species or habitats to protect, but also how this will be achieved, with possible consequences to the aesthetic, functional and cultural values of the area. Naturalness is known to be an important aspect of landscape preference (Anderson 1981; Purcell *et al.* 1994; Purcell and Lamb 1998; Tveit *et al.* 2006) and management options that are seen as 'balanced' or 'natural' are generally preferred (Fischer and van der Wal 2007). Visual attractiveness, water quality improvements and habitats for wildlife have all been shown to be important to communities in the midst of river management projects (Wagner 2008). Public support for species-specific conservation is most often associated with aesthetics, human-like characteristics or high levels of familiarity (Kellert 1996); however, the framing of the message, such as the reason behind the need for conservation, can also contribute to the resonance of the message and the subsequent choices an individual makes (Chong and Druckman 2007). Value matching information with a person's intrinsic values or cognitive/affective orientation has been shown to be more persuasive and increase the efficacy of the message (Petty and Wegener 1998; Mayer and Tormala 2010) because it leads to a more personally relevant message (Debono and Packer 1991).

5.1.1 Chapter Aims

Given the value placed on riverscapes by the public and the critical need for workable conservation solutions to prevent the continued decline of the freshwater pearl mussel it is vital to understand the values, knowledge and attitudes that the public have in relation to both river environments and the freshwater pearl mussel. Only by better understanding the drivers behind current levels of public support for this species and its habitats can we construct management plans that enhance this support, by encompassing both ecological aims and social values.

Due to the paucity of existing evidence relating to the public perception of rivers, aquatic species, risks from climate change and preferences for conservation methods, the approach used here within is exploratory. A quantitative approach in the form of a survey was adopted, guided by the results from Chapter four and the exiting literature on wider environmental concern and preference in order to formulate and test the following hypothesis:

1. *How does general environmental concern relate to attitudes towards rivers?*

H1: Based on work by Halpenny (2006) which indicated that concern for one's local environment could spill-over into a general concern for the environment, it is expected that positive attitudes towards local rivers will positively correlate with positive attitudes for rivers generally and general environmental concern.

H2: Emotions and beliefs have been shown to affect attitudes towards the environment (Pooley and O'Connor 2000) and opinions about the environment have been shown to be a negative determinant of climate change scepticism (Whitmarsh 2011). Therefore it is expected that increased river affect and ecocentric environmental attitudes will relate to a positive attitude towards rivers whilst climate change scepticism will contribute to negative river attitudes

2. What impacts are perceived to be facing UK rivers and what effect is climate change perceived to have on rivers?

H3 Work by Kaplan (1977) indicates the variety of aesthetic qualities that combine to explain a person's enjoyments of rivers whilst Whitmarsh (2011) shows that water pollution is a key environmental concern for the public. It is expected that the themes of changing aesthetic appeal and pollution will be the major threats to rivers as perceived by the lay-person.

H4: Based on the concept of environmental awareness described in Kollmuss and Agyeman (2002), it is expected that the perception of the magnitude of the threat to UK rivers from climate change will be greater in those who are less sceptical about climate change, who have an ecocentric environmental attitude and those who have a more positive attitude towards rivers.

3. *What factors contribute to lay-persons' attitudes towards aquatic species and habitats?*

H5: Based on the high value placed on water in the landscape shown by Kaplan (1979) and Kaltenborn (2002) and the lay-persons' preference of high-order species shown by Czeck *et al*. (1998; 1999) it is expected that both aquatic habitats and birds and mammals will be ranked as more important than other habitats and species.

H6: Work by Brody (2004) showed that with decreasing distance to water body, levels of knowledge and levels of environmental concern about the water body increased. Combined with research by Vorkinn and Reise (2001) that explained environmental attitudes using place attachment, it is expected that there will be a relationship between river attitude, affect and frequency of river visits with measures of geographical proximity to rivers.

H7: Work by Martin-Lopez *et al*. (2007) and Serpell (2004) highlights the importance of species familiarity in explaining a person's willingness to support conservation measures. Hunter and Rinner (2004) found that ecocentric attitudes lead to a higher concern for species diversity than anthropocentric attitudes. Based on this, it is expected that the factors affecting perceptions of species importance to conservation will be species familiarity and environmental attitude and that ecocentric environmental attitude will lead to an increased perception of the conservation importance of unfamiliar species.

H8: Proximity to waterbody has been shown to be a significant predictor of familiarity and environmental knowledge about rivers (Brody *et al*. 2004; Brody *et al.* 2005). Therefore it is expected that those who live closest to rivers will be most familiar with aquatic species and will be able to correctly identify those that are native to the UK.

H9: Women have been shown to be more ecocentric and less sceptical about climate change than men (Bord and O'Connor 1997; Gustafsod 1998; O'Connor *et al*. 1999). A higher level of education has also been linked to lower scepticism and a more ecocentric environmental attitude, shown by Whitmarsh (2011). Conservative voters are more sceptical about climate change and have anthropocentric environmental views, again shown by Whitmarsh (2011). It is expected that the measures of environmental views and climate change scepticism in this study will show similar relationships and that river attitudes (both general and local) will be more positive in those with a higher level of education, women and those who are not Conservative voters.

H10: Pro-ecological viewpoints will be higher and climate change scepticism lower in urban residents, as shown by Berenguer *et al*. (2005) and Whitmarsh (2011) and this will follow through to river attitude with urban residents having a more positive attitude to rivers than rural residents, both at a general and local scale. Higher river affect will be shown in urban residents as rural residents view nature in a more utilitarian manner (Tremblay and Dunlap 1977).

H11: Attitudes towards FPMs will have a positive relationship with environmental attitude and positive river attitude based on the findings from Hunter and Rinner (2004) which showed that an ecocentric attitude led to greater support for the conservation of unfamiliar species. Based on the work by Brody (2004) who indicated that a closer proximity to water body increases knowledge about the condition of the water body, it is hypothesised that this could expand to knowledge about species present. Tisdell and Wilson (2006) show that knowledge can lead to a more positive attitude towards unfamiliar species, thus those in closer proximity to FPM populations will show a more positive attitude to FPMs .

4. *What factors influence the acceptability of mitigation measures for the freshwater pearl mussel?*

H12: A greater preference for rivers that are perceived to be natural has been shown in studies by Piegay *et al*. (2005) and Wyzga (2009); Purcell *et al*. (1994) and Anderson (1981) both show that the perception of naturalness is linked with landscape preference. Therefore images that appear to be less natural are expected to be less acceptable.

H13: Based on findings by Gagnon Thompson and Barton (1994) which showed that anthropocentric attitudes were linked to apathy towards the environment and findings by Bremner and Park (2007) that knowledge of the need for conservation increases support, it is expected that acceptability for mitigation measures will increase with knowledge about the need, an ecocentric environmental attitude and a positive attitude toward rivers.

H14: Using framing and value matching (Chong and Druckman 2007), it is expected that preference for mitigation measures will be higher in ecocentric individuals who read the text advocating the benefits to FPMs and other species when compared to anthropocentric individuals who read the text regarding benefits solely for the FPM.

5.2 Methodology

5.2.1 Participants

In order to assess the effect of species knowledge, specifically familiarity of the freshwater pearl mussel (*Margaritifera margaritifera*), on attitudes, participants were selected from two locations: Scotland, which hosts the UK's most viable freshwater pearl mussels populations; and Wales, which historically had large freshwater populations that have subsequently declined and no longer exist in most rivers. The locations were further subdivided to ensure both urban and rural residents were sampled (Table 5.1).

	Urban	Rural	FWPM Current	FWPM Historic	Participants (%)
Group 1	x			x	**20.6**
Group 2	x		x		**23.0**
Group 3		x		x	**19.2**
Group 4		x	x		**24.8**

Table 5.1: Breakdown of participants in the four sampling locations.

The questionnaire was administered to 553 individuals, 53.5% of whom were female and 46.4% were male. Participants were asked to self-classify their home location as either rural or urban. Participants from urban areas comprised slightly more of the sample (57.8%) than those from rural areas; likewise numbers of participants from areas with current populations of *M. margaritifera* were slightly higher (54.5%) that those with historic populations (45.5%). The majority of participants (83.8%) had never been a member of or had volunteered with a conservation organisation or charity, with 5.6% claiming to be current members or volunteers and 10.6% purporting to have been members or volunteers with a conservation body.

The age profile of the sample shows that proportionally more replies came from the 55-64 year old age group (24.0%). In comparison with UK census data, the age range of the participants is broadly nationally representative (Table 5.2); however deviations from the at-age proportion shown for the UK census data are most pronounced at both ends of the age range i.e. 18-24 yrs and 75+ yrs.

At-Age Categories	UK Census Data 2012 (%)		Questionnaire Respondents (%)	
	Male	Female	Male	Female
18-24	6.2	5.7	0.7	2.6
25-34	8.8	8.4	5.7	15.6
35-44	8.4	8.5	9.4	10.1
45-54	8.8	9.0	11.2	10.5
55-64	7.1	7.4	13.4	10.6
65-74	5.5	6.0	5.1	4.2
75+	4.2	6.0	0.6	0.4

Table 5.2: Comparison of gender and age split of questionnaire participants and UK census data, 2012.

In terms of education level, most respondents had some type of formal qualifications (92%) with the most frequent being Bachelor's degree or equivalent (30.1%). However looking at science qualifications, a far greater proportion had no formal scientific qualification (24.6%) and the most frequent science qualification was GCSE or equivalent (36.3%).

Support for the top three UK political parties (namely Conservatives, Labour and Liberal Democrat) represented just over half of the responses for voting preference (51.1%), with Labour leading. The Scottish National Party represented 18.5% and the Green Party 3.9%. Voting preference in the sample is reflective of the geographical area that respondents were chosen from, likely why voting intention in the sample differs from recorded UK polling reports from the same time (Wells 2012).

5.2.2 Materials

The questionnaire was divided into six sections to ensure a logical order for participants.

Section 1 contained items relating to general attitudes towards rivers, measures to assess proximity and connection to local rivers, and the relative importance of rivers in conservation compared to other sectors.

- Research Question 1: *How does general environmental concern relate to attitudes towards rivers?*
- Research Question 3: *What factors contribute to lay-persons' attitudes towards aquatic species and habitats?*

Section 2 contained questions relating to the impact of climate change on rivers as well as general climate change attitudes.

- Research Question 2: *What risks are perceived to be facing UK rivers and what effect is climate change perceived to have on rivers?*

Section 3 contained a selection of UK river species to elucidate familiarity and provenance of these species.

- Research Question 3: *What factors contribute to lay-persons' attitudes towards aquatic species and habitats?*

Section 4 contained four versions of text to be read prior to completing the task of assessing acceptability of various river conservation methods. The text describes who and what would benefit from the proposed conservation options to assess the role of knowledge on participant attitudes towards conservation methods. This section also had a question designed to assess whether awareness about the role of freshwater pearl mussels in the aquatic environment influences respondents' willingness to conserve it.

- Research Question 4: *What influences the visual acceptability of mitigation measures for the freshwater pearl mussel?*

Section 5 contained the revised 15-item NEP scale (Dunlap *et al.* 2000) which is designed to assess general environmental values.

- Research Question 1: *How does general environmental concern relate to attitudes towards rivers?*

Section 6 measured demographic characteristics such as gender, voting intention and age.

- Research Question 3: *What factors contribute to lay-persons' attitudes towards aquatic species and habitats?*

5.2.2.1 Section 1

The first section began by asking participants about the name and distance of the river closest to their home, in metres, from a choice of six options: less than 1 mile; 1-2 miles, 3-5 miles; 6-10 miles, more than 10 miles and don't know. Subsequent analysis required re-classification into three categories: less than 1 mile, 1-2 miles and greater than 2 miles. The importance of freshwater systems relative to other sectors was evaluated using a ranking exercise with five options: *Beaches & seas; Forest and woodland; Grassland and moorland; Rivers and lakes; Historic building and castles* where participants were asked to arrange the five sectors in order of importance, from high to low.

The importance of local rivers was assessed using four statements, e.g. '*I would not mind if I couldn't regularly visit a river'*, and participants were asked to indicate how much they agreed or disagreed with them, using a five point numerical rating scale of 1 (strongly disagree) to 5 (strongly agree). The statements were based on the outcomes of workshops held with members of the public prior to the development of the questionnaire.

A principal components analysis (PCA) was conducted on the four items with orthogonal rotation (varimax). The Kaiser-Mayer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = 0.72 ('superb' according to Field, 2009), and all KMO values for individual items were > .71, which is above the acceptable limit of 0.5 (Field 2009). Bartlett's test of sphericity χ^2 (6) = 520.45, $p < 0.001$, indicated that the correlations between items were sufficiently large for PCA. PCA revealed only 1 component with an eigenvalue over 1 (Kaiser's criterion for retaining factors) which represented 57.41% of the variance. Table 5.3 shows the factor loadings (rotation is not possible with only 1 factor) and the single factor is representative of the value of local rivers. Reverse phrased questions were reverse scored and the scale, taken to indicate local river value, was shown to have high internal reliability (Table 5.3). The local river value scale, where high scores indicate a high value attributed to local rivers had a mean score for local river value from the total sample of 3.69, SD = 0.76 and the range was 4; based on these, almost three-quarters (74.9%) of participants placed high importance on the presence of local rivers.

Participants' general views on rivers were assessed using an author constructed scale of 19 statements based on the outcomes of workshops held with members of the public. Examples of these statements are '*Rivers are a positive feature in the natural environment*' and

'*River conservation only benefits plants and animals*'. Again, participants were asked to indicate how much they agreed or disagreed with the items, using the five-point numerical scale of 1 (strongly disagree) to 5 (strongly agree). A preliminary PCA conducted on all 19 items from this question was run which, based on Kaisers criterion for retaining factors with eigenvalues greater than one, showed three factors. Subsequent reliability analysis on the three subscales produced by each factor lead to the removal of four items from the original 19.

	Factor Loadings	Descriptive Statistics		
	Local River Value	Agreement (%)	Neither Agree nor Disagree (%)	Disagreement (%)
*I would not mind if I couldn't regularly visit a river**	.82	28.5	29.0	42.5
For me, rivers are an intrinsic part of my local landscape	-.79	73.8	20.3	5.9
In an ideal world, I would choose to live near a river	-.71	47.5	46.4	6.1
*I would not really mind if local river species were lost because of climate change**	.70	5.7	14.3	80.0
Eigenvalues	2.296			
% of variance	57.4			
Cronbach's α	.75			

Table 5.3: Component Matrix for principle components analysis on the four local river attitude statements.
Reverse phased question (*) were reverse scored and mean values for the four statements were calculated. The resulting scale indicates the value placed on local rivers by participants, from 1 (low value) to 5 (high value). The percentage of respondents who either agreed or strongly agreed with each statement is given alongside the percentage of respondents who disagreed or strongly disagreed with each statement.

A second principal components analysis (PCA) was conducted on the remaining 15 items with orthogonal rotation (varimax). The Kaiser-Mayer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = 0.94 (Field 2009), and all KMO values for individual items were > .79, which is above the acceptable limit of 0.5 (Field 2009)(Field, 2009). Bartlett's test of sphericity χ^2 (105) = 4122.21, $p < 0.001$, indicated that the correlations between items were sufficiently large for PCA. The scree plot for the final PCA indicated inflexions that that would justify retaining two or three factors, despite only two factors with eigenvalues above Kaiser's criterion of 1. Given the large sample size and the presence of communalities <0.6, three factors were retained (Stevens 2002). Table 5.4 shows the factor loading after rotation. The items that cluster on the same components suggest that component 1 represents positive attitudes towards rivers, component 2 negative attitudes towards rivers and component 3 positive affect of rivers. All three subscales had high reliabilities, as shown in Table 5.4.

Thereafter each subscale was treated as a scale in its own right and ratings were averaged across each item within the scale. The positive river attitude scale, where high scores indicate a positive attitude to rivers, had a mean of 4.16 ± 0.63 and a range of 4; based on this, the majority of participants had a positive attitude towards rivers (92.8%). The negative river attitude items were reverse scored, so a low score on this scale is indicative of a negative attitude towards rivers. This scale had a mean of 2.3 ± 0.68 and a range of 4; based on this, less than 10% (9.8%) of the sample showed negative attitudes toward river and their conservation. The positive river affect scale, where high scores indicate a positive emotive response to river, had a mean of 3.46 ± 0.86 and a range of 4; based on this, just over half of participants (58.3%) showed a positive affect towards rivers.

	Rotated Factor Loadings			Descriptive Statistics		
	Positive River Attitude	Negative River Attitude	River Affect	Agreement (%)	Neither Agree nor Disagree (%)	Disagreement (%)
It is important that rivers are protected all over the country	**.80**	-.21	.20	84.6	13.0	2.4
Rivers are a valuable national resource	**.79**	-.15	.29	82.8	15.4	1.8
Rivers are a positive feature in the natural landscape	**.79**	-.26	.17	88.5	9.7	1.8
Rivers are places where there are a wide variety of plants and animals	**.77**	-.17	.19	85.8	12.4	1.8
As humans, we have a moral obligation to conserve rivers	**.77**	-.23	.17	80.4	16.3	3.3
Conservation of rivers is important even if you cannot visit the river	**.75**	-.21	.10	82.8	14.1	3.1
Rivers are a valuable local resource	**.70**	-.14	.33	79.2	18.2	2.6
Rivers are places where there are rare plants and animals	**.66**	-.08	.40	77.9	19.9	2.2
Rivers are not important for nature conservation	-.53	**.50**	.06	9.1	11.3	79.6
River conservation may lead to loss of agricultural land	.06	**.77**	-.08	14.6	49.6	35.8
River conservation increases the risk of flooding	-.23	**.76**	-.04	12.6	42.8	44.6
River conservation only benefits plants and animals	-.25	**.67**	-.06	7.5	28.5	64.0
Rivers make me feel fearful and uneasy	-.41	**.57**	-.05	7.5	17.8	74.7
Rivers evoke strong personal memories	.21	-.08	**.86**	51.2	31.2	17.6
Rivers give me a sense of mystery and excitement	.34	-.03	**.77**	11.7	75.0	13.3
Eigenvalues	5.28	2.48	1.84			
% of variance	35.21	16.55	12.28			
Cronbach's α	.93	.76	.71			

Table 5.4: Rotated factor loadings for the second principle components analysis on 15 of the original 19 river attitude statements (author constructed).
Mean values for all statements which loaded onto the same factors were calculated and the resulting scales indicates the participants' degree of positive and negative river attitudes and a measure of the emotive response to rivers (affect). The percentage of respondents who either agreed or strongly agreed with each statement is given alongside the percentage of respondents who disagreed or strongly disagreed with each statement.

Correlations between the two river attitude types (local and general) with the knowledge, familiarity and proximity measures allowed an assessment of whether this sample shows that residents place a higher value on local environments, as has been found elsewhere in the literature. This division of river attitude also enables a measurement of the contribution of knowledge and proximity to both local and general river values.

5.2.2.2 Section 2

This section began with the open question '*What do you consider to be the biggest threat to river areas and habitats*'. The responses were thematically coded as described by Braun and Clark (2006) which allowed a hierarchy of themes and sub-themes to be identified (Table 5.5).

The following question consisted of six statements designed to assess participants' views on climate change (as a possible threat to rivers) based on attitude statements from Whitmarsh (2008)(2008) for example '*I regularly take action out of concern for climate change*'. Participants were asked to indicate their views with respect to these statements by scoring each statement on a scale of 1 (strongly disagree) to 5 (strongly agree).

Main Themes	Sub-themes
Agriculture	• Use of chemical • Development • Use of pesticides • Run off • Irrigation
Industry/Development	• Development (incl. houses, roads and land) • On floodplains • On Greenbelts • Urban Areas • Industry • Diverting rivers/culverts • Tree felling • Fishing • Hard flood defences • Water wastage
Pollution	• Chemical • Human • Rubbish dumping • Industrial/Farming • Litter
Climate Change	• Flooding • Drought • Increase in rainfall • Natural disasters
River Management	• Human activities • Intervention • Lack of conservation • Lack of understanding • Lack of drainage • Non-native Species • Erosion
Nothing	
Don't Know	

Table 5.5: Themes and sub-themes resulting from responses to the open question 'What do you consider to be the biggest threat to river areas and habitats'.

A principal components analysis, with orthogonal rotation (varimax) was run on the six climate change statements from question 16. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO = .86 ('great' according to Field, 2009) and all KMO values for individual items were >.80, above the acceptable limit of 0.5 (Field 2009). Bartlett's test of sphericity χ^2 (15) = 1502.35, p<.001 demonstrating that correlations between items were large enough for PCA to be conducted. PCA revealed only one component with an eigenvalue over 1 (Kaiser's criterion for retaining factors) which represented 60.59% of the variance. Using Jolliffe's (1972; 1986) suggestion of retaining all factors with eigenvalues greater than 0.7, two components met this criteria. However, given the scree plot convergence and the large sample size, Kaiser's criterion was deemed the most appropriate and so one component was retained in the final analysis. Table 6 shows the factor loadings (rotation is not possible with only 1 factor) and the single factor is representative of the degree of climate change scepticism.

Items 1, 3 and 5 were reverse scored (*) and reliability analysis showed a high reliability (Table 5.6). Rating were then averaged across all six items and the resulting scale of 1 to 5 measuring the degree of climate change scepticism, with high scores indicating high levels of scepticism. The mean for the total sample was 2.8 ± 0.84 with a range of 4; based on this, almost one-third of participants (30.8) exhibited high level of climate change scepticism. Climate change scepticism is a possible driver of conservation measure preference and attitudes towards impacts on rivers in the future given that the need for mitigation can be as a result of climate driven environmental change. Therefore this measure was used as an explanatory factor in participants' choice of conservation measure and perception of risk factors to rivers of climate change.

A binary variable reflecting climate change scepticism was created to allow comparisons between 'sceptics' and 'believers' levels of agreement with the river impacts statements and choices of preferred conservation measures. The median value from the mean climate change scepticism scores was calculated (Mdn = 2.67). Responses larger than this value were assumed to reflect a sceptical viewpoint (N = 275), mean scores equal to or lower than the median value were assumed to reflect a climate change 'believer' (N = 267).

Following on, participants were asked to use a sliding scale bar to indicate the magnitude (0 being no effect, 10 being maximum effect) and direction (minus being a negative effect, plus being a positive effect) of any effect they believed climate change might have on UK rivers.

Finally, participants were asked to indicate their views with respect to eight statements about effects climate change might have on river ecosystems, for example '*River biodiversity will be reduced as a result of climate change'* derived from workshops held with members of the public, using a 1 (strongly disagree) to 5 (strongly agree) scale.

	Rotated Factor Loadings	Descriptive Statistics		
	Climate Change Scepticism	Agreement (%)	Neither Agree nor Disagree (%)	Disagreement (%)
I do not believe that climate change is a real problem	**.85**	16.5	25.9	57.6
Claims that human activities are changing the climate are exaggerated	**.83**	27.1	25.4	47.5
*Climate change is something that frightens me**	**-.81**	46.4	32.9	20.7
The media is often too alarmist about issues like climate change	**.78**	42.9	31.2	25.9
*Recent floods in this country are due to climate change**	**-.73**	43.0	39.0	18.0
*I regularly take action out of concern for climate change**	**-.66**	34.2	42.6	23.2
Eigenvalues	3.64			
% of variance	60.59			
Cronbach's α	0.869			

Table 5.6: Rotated factor loadings for principle components analysis on the six climate change scepticism statements.
Reverse phased question (*) were reverse scored and mean values for the six statements were calculated. The resulting scale indicates the participant's scepticism towards climate change. The percentage of respondents who either agreed or strongly agreed with each statement is given alongside the percentage of respondents who disagreed or strongly disagreed with each statement.

A principal components analysis (PCA) was conducted on the eight items with orthogonal rotation (varimax). The Kaiser-Mayer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = 0.79 (Field 2009), and all KMO values for individual items were > .73, which is above the acceptable limit of 0.5 (Field 2009). Bartlett's test of sphericity χ^2 (28) = 1301.98, $p < 0.001$, indicated that the correlations between items were sufficiently large for PCA. The scree plot for the final PCA indicated inflexions that that justified retaining two factors, and only two factors had eigenvalues above Kaiser's criterion of 1; therefore two factors were retained. Table 5.7 shows the factor loading after rotation. The items that cluster on the same components suggest that component one represents negative impacts of climate change on rivers and component two represent positive impacts of climate change on rivers.

	Rotated Factor Loadings		Descriptive Statistics		
	Negative Impacts	Positive Impacts	Agreement (%)	Neither Agree nor Disagree (%)	Disagreement (%)
In the future climate change is likely to cause more flooding	**.79**	-0.8	63.8	30.2	6.0
River biodiversity will be reduced as a result of climate change	**.78**	.15	39.3	50.5	10.2
Climate change will alter the amount of soil that gets washed from land into rivers	**.78**	.13	50.7	41.4	7.9
New rivers will appear because of climate change	**.71**	.26	26.9	59.8	13.3
More drinking water will be available in the future because of climate change	.25	**.77**	9.3	48.8	41.9
Fewer droughts will occur as a result of climate change	.17	**.76**	12.5	42.2	45.3
Climate change will have no effect on rivers	-.20	**.73**	7.3	34.2	58.5
River biodiversity will increase as a result of climate change	.43	**.59**	14.0	62.0	24.0
Eigenvalues	2.67	2.19			
% of variance	33.33	27.39			
Cronbach's α	.76	.72			

Table 5.7: Rotated factor loadings for principle components analysis on the eight climate change impact statements.
This resulted in two scales and the mean values for the statements within each scale were calculated. The two scales represent the negative impacts and positive impacts of the affects climate change will have on rivers. Descriptive statistics are includes to show levels of agreement and disagreement for each statement.

5.2.2.3 Section 3

Six UK freshwater species were chosen to assess participants' familiarity and knowledge of freshwater organisms in the UK. The species chosen reflected the range and diversity associated with UK freshwater environments; therefore the species chosen incorporated several variables, such as physiology and conservation status but also considered economics and emotive appeal (Table 5.8).

Participants were given an image of each species along with both the common and Latin names and asked to indicate how familiar each of these species were, using an author-developed scale (Table 5.9). A ranking exercise followed with participants asked to '*Please rank the species in order of importance for conservation, in your opinion*', this approach was used to ensure participants prioritised the six choices rather than simply making a selection. Finally, participants were asked to choose whether each of the six species were native to the UK or non-native.

	Type	Physiology	Conservation Status	Commercially Important	Taxonomic Preference	Legal Protection
Common Otter (*Lutra lutra*)	Mammal	Vertebrate	Recovering	N	H	Y
Brown Trout (*Salmo trutta*)	Fish	Vertebrate	Recovering	Y	M	Y
FPM (*Margaritifera margaritifera*)	Mollusc	Invertebrate	Rare	N	L	Y
Japanese Knotweed (*Fallopia japonica*)	Plant	Plant	Invasive	Y	H	N
Ruddy Duck (*Oxyura jamaicensis*)	Bird	Vertebrate	Invasive	N	H	N
Great Diving Beetle (*Dytiscus marginalis*)	Insect	Invertebrate	Common	N	L	N

Table 5.8: Variables considered when choosing aquatic species to include in section 3 of the questionnaire.

An additional reason to support the choice of the common otter was the large amount of conservation effort that has been put into restoring habitat of this species over the last 10 years. The Japanese Knotweed and Ruddy Duck were specifically chosen to represent non-native species to highlight those participants who base decisions on provenance, particularly those species whose common name identifies them as not being native to the UK. Commercially important was defined as species with a direct commercial value, with the trout fishery in England and Wales reported to be worth a total of £622 million in 2001 (Environment Agency 2004). Taxonomic Preference is defined using the results from work by Czech and Kaussman(1999) such that mammals, plants and birds are most preferred (H = high); invertebrates and micro-organisms are least preferred (L = low) and fish are a distinct set between the two (M = medium).

		
Common Otter (*Lutra lutra*) (source: www.123rf.com)	Brown Trout (*Salmo trutta*) (source: www.bbc.co.uk)	Freshwater Pearl Mussel (Margaritifera margaritifera) (source: www.arkive.org)
		
Japanese Knotweed (*Fallopia japonica*) (source: www.wiseknotweed.com)	Ruddy Duck (*Oxyura jamaicensis*) (source: www.fws.gov)	Great Diving Beetle (*Dysticus marginalis*) (source: www.dreamstime.com)

Table 5.9: Image details for UK freshwater species used in familiarity and provenance questions. Scale participants used to indicate their level of familiarity with these species was: Know the name and have seen in the wild; Know the name and have seen in captivity of on TV; Recognise the name and the picture but have never seen; Recognise the name but not the picture, Recognise the picture but not the name, Never seen or heard of before.

5.2.2.4 Section 4

This section was the experimental section, and began by asking participants to read a short paragraph of text upon which the next section of question would be based. There were four versions of the text in order to identify difference in mitigation measure preference related to perceived beneficiaries of the work. Participants were randomly allocated a version of the text to read.

All versions began with a brief description about how rivers might be affected by soil erosion in the future as a result of climate change, as well as informing participants that the following questions relate to conservation actions that might be employed to reduce the quantity of soil entering watercourses. The next portion of the paragraph explained who or what might benefit from these conservation measures, with each of the four versions describing benefits for different groups (Table 5.10).

The first question in this section asked participants to rank images of seven sediment control options in terms of how acceptable the participants found them. All of the options used were industry recognised methods of reducing or preventing diffuse pollution of watercourses and details were obtained from DEFRA's Catchment Sensitive Farming advice, conversation with conservation managers and construction industry best practice guidelines. They include 'soft' options, for example bank re-vegetation, where there is no obvious human involvement and 'hard' options, for example livestock fencing, which are much more obvious visually[2]. In addition, some options have added benefits to biodiversity or an impact (either positive or negative) on aesthetic appeal. Participants ranked each option using a five-point scale, from 1 (completely unacceptable) to 5 (completely acceptable). Each image was accompanied by a short description of how each option reduced sediment input (Table 5.11).

Participants were next asked how well a series of 11 statements reflected their opinions of the conservation methods that they had ranked in the previous question, using a scale of 1 (strongly disagree) to 5 (strongly agree). These statements were distilled from comments made by members of the public in a series of workshops held in early 2012 in Cardiff, UK (see Chapter Four).

[2] The terms 'hard' and 'soft' engineering are typically used to describe coastal engineering. Hard engineering methods, for example groynes or sea walls, are temporary and typically unsustainable naturally. In comparison, soft engineering options, for example managed retreat, use ecological principles to achieve objectives.

		Of benefit to:		
Text read by all participants	Research suggests that in the future, levels of soil in rivers will become an issue, in part due to the predicted changes in our climate. The source of the soil can be from nearby land as well as the river banks themselves, both of which will be increasingly worn away with higher amounts of rain. The following questions relate to possible conservation measures that could be used to reduce the amount of soil reaching rivers.	**Freshwater Pearl Mussel**	**Other River Species**	**Humans**
Text 1	These options would improve the habitat quality for the freshwater pearl mussel (a native endangered species) which is particularly badly affected by excessive amounts of soil in the water.	x		
Text 2	These options would improve the habitat quality for the freshwater pearl mussel (a native endangered species) which is particularly badly affected by excessive amounts of soil in the water. Freshwater Pearl Mussels are an important part of the river ecosystem because they clean the water and are a food source for many other larger species. Other aquatic species like salmon are also negatively affected by high concentrations of soil in the water – so many other species will benefit from these options as well, either directly or indirectly.	x	x	
Text 3	These options would improve the habitat quality for the freshwater pearl mussel (a native endangered species) which is particularly badly affected by excessive amounts of soil in the water. As a consequence, the river will become healthier which benefits the people that use the river recreationally and who get their drinking water from the river network	x		x
Text 4	These options would improve the habitat quality for the freshwater pearl mussel (a native endangered species) which is particularly badly affected by excessive amounts of soil in the water. Freshwater Pearl Mussels are an important part of the river ecosystem because they clean the water and are a food source for many other larger species. Other aquatic species like salmon are also negatively affected by high concentrations of soil in the water – so many other species will benefit from these options as well, either directly or indirectly. As a consequence of the river becoming healthier, humans that use the river recreationally and who get their drinking water from the river network will also benefit	x	x	x

Table 5.10: All four versions of text read by participants prior to answering the questions about acceptability of mitigation options in section 4.

Arable Drainage Ditches To allow soil to settle before water is returned to the river  source: anon	**In-Field Margins** To trap soil before it reaches the river  source: www.ag.iastate.edu	**River Bank Tree Buffer Strips** To trap soil before it enters the river  source: www.buffer.forestry.iastate.edu
Sediment Fencing To trap soil before it reaches the river  source: www.thebeatnews.org/	**Re-planting River Banks** Reduces soil input by trapping it and by reducing bank erosion  source: River Restoration Centre	**Reduced Field Sizes** Reduces soil input by trapping in in hedges and promotes use of smaller machinery  source: anon
Livestock Drinking Bays Limiting livestock access to the river reduces bank poaching (erosion) caused by high livestock numbers  source: www. everysite.co.uk	**Livestock Fencing** Limiting livestock access to the river reduces erosion caused by high numbers of livestock walking along the banks  source: Author's Image, Courtesy of Shrophire AONB	

Table 5.11: Images and accompanying text for the question 'Please rank the following sediment control measures in terms of how acceptable you find these images'
Participants scored each photo from 1 (completely unacceptable) to 5 (completely acceptable). Images also used for follow-up questions 'Which option did you feel was the most acceptable?' and 'Which option did you feel was the least acceptable?'.

A principal components analysis (PCA) was conducted on the 11 items from this question with orthogonal rotation (Varimax). The Kaiser-Mayer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = 0.80 (Field 2009), and all KMO values for individual items were > .68, which is above the acceptable limit of 0.5 (Field, 2009). Bartlett's test of sphericity χ^2 (55) = 1090.727, $p < 0.001$, indicated that the correlations between items were sufficiently large for PCA. The scree plot for the PCA indicated inflexions that justified retaining two factors, and only two factors had eigenvalues above Kaiser's criterion of 1, therefore two factors were retained. Table 5.12 shows the factor loading after rotation. The items that cluster on the same components suggest that component one represents positive attitudes towards sediment mitigation and component two reflects negative attitudes towards sediment mitigation. However the Cronbach's alpha values indicate that only the scale representing positive attitudes to sediment mitigation was reliable and thus only these items were used in further analysis. The sample mean for the positive sediment attitude scale was 3.90 ± 0.56 with a range of 3.

The scores from the five items that formed the positive sediment attitude were averaged to give a single value which was used to represent the degree of positive attitude associated with the sediment mitigation options, with positive attitude increasing with increasing score (1 = least positive, 5 = most positive). The mean for the positive attitude scale was 3.90 ± 0.56 with a range of 3. Over two-fifths of respondents (88.2%) exhibited a positive sediment attitude.

	Rotated Factor Loadings		Descriptive Statistics		
	Positive Sediment Attitude	Negative Sediment Attitude	Agreement (%)	Neither Agree nor Disagree (%)	Disagreement (%)
Re-vegetation looks like it would provide good habitat for other species	**.79**	-.04	81.0	16.8	2.2
The benefits of these measures should be balanced across both humans and the environment	**.71**	.15	76.1	22.4	1.5
These ideas would encourage farming and conservation to work together	**.74**	-.05	76.5	21.5	2.0
Those ideas that make it look like nature has taken over are the best	**.69**	.05	69.8	25.8	4.4
*The larger scale projects would have to be managed centrally, for example by a government department**	**.43**	.29	53.3	32.2	14.5
Food production will suffer if land has to be used for conservation	-.28	**.70**	22.9	41.8	35.3
Re-vegetating the river banks will mean it is less accessible and more difficult to walk alongside the water	.08	**.65**	44.3	38.7	17
Livestock have the right to access the water, they shouldn't be fenced in	-.05	**.64**	36	40.6	23.4
I think these ideas would require a lot of on-going maintenance to ensure they continue to work	.34	**.53**	64.9	28.3	6.8
*These ideas will need a lot of government subsidies for farmers to put them in place**	.48	**.48**	61	30.7	8.3

The presence of barbed wire makes me think that the river is dangerous	.23	**.43**	55.3	24.8	19.9
Eigenvalues	2.83	2.13			
% of variance	25.59	19.33			
Cronbach's α	.72	.63			

Table 5.12: Rotated factor loadings for principle components analysis on the 11 sediment mitigation statements obtained from earlier focus group work, Cardiff 2012 (Chapter four).

Only the positive sediment attitude had a Cronbach's alpha larger than .7 to allow use in further analysis. Statements 3 and 6 (*), though similar, reflect different streams of thoughts from focus groups. Government departments were believed to be the most appropriate way of managing river conservation actions whereas an increase in taxation to pay for river conservation (for example through increased subsidies for farmers) was not thought to be good way of financing such schemes.

The sediment control measures were also grouped into 'soft' and 'hard' options with respect to the level of visible engineering required (Table 5.13). The respective acceptability scores were averaged, to give a single acceptability score for each option.

'Soft' Options	'Hard' options
• Arable drainage ditches	• Sediment fencing
• In-field margins	• Livestock drinking bays
• Re-planting river banks	• Livestock fencing
• River bank tree buffer strips	• Reduced field sizes

Table 5.13: The eight mitigation measures used in the survey, split into soft and hard options. 'Soft' refers to options that require less engineering and are visually less obtrusive; 'Hard' refers to measures which need some sort of engineering and/or those which would be immediately visible or out of place.

Participants were asked to choose the mitigation measure that they found most and least acceptable, and there were free text questions that asked why the participant had chosen the option that they had. The responses were thematically coded as described by Braun and Clark (2006) which allowed a hierarchy of themes and sub-themes to identified (Table 5.14 and 5.15).

Main Themes	Sub-themes
Low Impact	• Farm Animals • Environment (general) • Farmers • Land Use
Benefits	• Farm animals • Environment • Rivers • Farming • Soil erosion • Wildlife • Land and drainage
Ease of Use	• Implementation • Maintenance
Secondary Benefits	• Irrigation • Water for livestock • Water during shortages • Protects crops
Familiarity	• Already in use • Replacing what has been lost
Accessibility	• Animals • Humans • Limits access
Aesthetics	• Visually appealing • Looks natural • Unobtrusive
Rivers	• Low Impact • Flood Prevention • Improve water flow • Stops pollution • Prevents erosion (strengthens banks, stops sediment entering water
Project Attributes	• Effective • Cheap • Feasible • Appropriate • Immediate results • Sustainable • Safe
Reduces conflict between farming and conservation	
Don't Know	

Table 5.14: Themes and sub-themes resulting from responses to the open question 'Why do you think this' in relation to the previous question which asked 'Which option did you feel was the most acceptable'

Main Themes	Sub-themes
Farming Impacts	• General • Economic • Reduction of available land • Reduction of food production • Limitation to land use choices
Perception of Outcomes	• Not viable • Benefits not obvious • Efficacy • Not necessary
Perception of Implementation	• Increased food cost • More planning • More maintenance • Difficulty in getting approval from farmers • Expensive • Not a novel idea • Difficult
Livestock Welfare	• Restricts movement and space • Limits water availability • Usage (e.g. danger to livestock)
Aesthetics	• Visually unappealing • Dirty • Intrusive • Appears cheap • Unnatural • Looks dangerous
Reduced river access (humans)	
Lack of understanding	
Environmental Impacts	• Landscape Change • Reduced space for wildlife • Damage to river banks • Damage or disruption to wildlife • Rick of plants being washed away • Increase in river pollution
Danger	• Humans • Livestock

Table 5.15: Themes and sub-themes resulting from responses to the open question 'Why do you think this' in relation to the previous question which asked 'Which option did you feel was the least acceptable'

Finally, all participants read a short description about freshwater pearl mussels which explained their role as an indicator species for river health as well as their ideal habitat characteristics. This ensured that all participants received the same amount of information about this species. There followed six statements about perceptions of conservation measures to support freshwater pearl mussels distilled from focus groups responses, for example '*I have never heard of this species before, how important can it be?*'. Participants were each asked to score in terms of how well the statements reflected their own opinions on a scale from 1 (strongly disagree) to 5 (strongly agree).

A principal components analysis (PCA) was conducted on the six items from this question with orthogonal rotation (Varimax). The Kaiser-Mayer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = 0.79 ('great' according to Field, 2009), and all KMO values for individual items were > .77, which is above the acceptable limit of 0.5 (Field, 2009). Bartlett's test of sphericity χ^2 (15) = 1199.23, $p < 0.001$, indicated that the correlations between items were sufficiently large for PCA. The scree plot for the PCA indicated inflexions that justified retaining two factors, and only two factors had eigenvalues above Kaiser's criterion of 1, therefore two factors were retained. Table 5.16 shows the factor loading after rotation. The items that cluster on each component indicate that component one represents the importance of water and the multiple beneficiaries as a result of FPM conservation and component two represents the negative associations with the conservation of FPMs.

	Rotated Factor Loadings		Descriptive Statistics		
	Multiple beneficiaries	Negative Attitude to conservation	Agreement (%)	Neither Agree nor Disagree (%)	Disagreement (%)
Water is a valuable resource and must protected, if other species benefit indirectly from this then that is an added advantage	**.85**	-.09	84.1	15.2	0.7
Conservation measures to protect FPMs are a good idea because many other species will benefit	**.84**	.30	78.1	20.5	1.4
Both humans and the wider natural environment will benefit from conserving FPMs	**.79**	-.35	70.4	25.6	4.0
I have never heard of this species, how important can it really be?	-.21	**.81**	14.1	34.6	51.3
We should focus on protecting beautiful and iconic species rather than ugly species like the FPM that we might never see.	-.24	**.76**	10.7	22.0	67.3
There are more important things to spend taxpayers' money on than conserving just one species	-.17	**.75**	22.3	48.0	29.7
Eigenvalues	2.18	2.02			
% of variance	36.39	33.62			
Cronbach's α	.83	.72			

Table 5.16: Rotated factor loadings for principle components analysis on the six FPM attitude statements.
This resulted in two scales and the mean values for the statements within each scale were calculated. The two scales represent the contribution of aesthetics to conservation targets and the multiple Beneficiaries conservation of FPMs has. Descriptive statistics are includes to show levels of agreement and disagreement for each statement.

The scores from the three items that formed the multiple beneficiaries' attitude were averaged to give a single value which was used to represent the degree of agreement with the attitude that water is a valuable resource and there would be multiple benefits to FPM conservation, with agreement increasing with increasing score. The mean for this scale was 4.1 ± 0.70 with a range of 4; based on this over three-quarters of respondents (86.9%) agreed with this attitude.

The scores from the three items that formed the negative attitude to conservation attitude were averaged to give a single value which was used to represent the degree of agreement with the attitude that the low aesthetic appeal of FPM is a reason not to conserve them, with agreement increasing with increasing score. The mean for this scale was 2.5 ± 0.82 with a range of 4; based on this, less than one-fifth of respondents (18.2%) agreed with this attitude.

5.2.2.5 Section 5

The 15-point NEP scale was used to assess environmental viewpoint and was assumed to be uni-dimensional (Dunlap *et al*. 2000) with ecocentric viewpoints indicated by agreement with the eight odd-numbered items, e.g. *When humans interfere with nature, it often produces disastrous consequences* and disagreement with the seven even numbered items, e.g. *Humans have the right to modify the natural environment to suit their needs* and *vice-versa* indicating an anthropocentric viewpoint. Participants were asked to show the extent they agreed or disagreed with the statements using a scale from 1 (strongly disagree) to 5 (strongly agree). The seven even numbered items were reverse scored (1 = strongly agree; 5 = strongly disagree) and the ratings were averaged across the 15 items. This resulted in a scale where a low mean score indicates an anthropocentric viewpoint and a high mean score suggests an ecocentric viewpoint. Reliability analysis was conducted which showed high reliability; Cronbach's alpha = .86.

To create a binary variable reflecting environmental viewpoint, the median value from the mean NEP scores was calculated (Mdn = 3.53) and responses larger than this value were assumed to reflect an ecocentric viewpoint (N = 262), mean scores equal to or lower than the median value were assumed to reflect an anthropocentric viewpoint (N = 264). This binary measure was then used to identify differences in question responses as a result of an anthropocentric or ecocentric viewpoint, particularly where MANOVA analysis was used.

5.2.2.6 Section 6

Participants were invited to fill in a series of questions at the end of the survey designed to capture demographic data, some of which have been shown in previous research to help explain environmental attitudes (Dietz *et al.* 1998; Dalrymple 2006; Swanwick 2009).

- Age (18-24; 25-34; 35-44; 45-54; 55-64; 65-74; 75-84 & 85+)
- Gender (Male/Female)
- Highest Qualification (No formal qualifications; GCSE/O-level; Vocational/NVQ1 or 2; A-level or equivalent; Bachelor or equivalent and Master/PhD or equivalent)
- Highest Science Qualification (No formal qualifications; GCSE/O-level; Vocational/NVQ1 or 2; A-level or equivalent; Bachelor or equivalent and Master/PhD or equivalent)
- Voting Preference (Conservative; Labour; Liberal Democrats; Green Party; UK Independence Party; Scottish National Party; Plaid Cymru; British National Party; Other)

In addition, these sections also asked participants to designate themselves as living in an urban or rural area as well as asking whether they were or ever had been a member of or volunteer with a conservation organisation or charity. This measure was used as an indicator of environmental concern, as demonstrated in work by Bremner and Park (2007) and Fischer and van Wal (2007). The questionnaire concluded with questions about how frequently participants visited rivers, on a scale of 1 (never) to 5 (very frequently) and finally what activities they use rivers for, e.g. walking, fishing, irrigating land in order to identify recreational and economic uses.

5.2.3 Procedure

The survey was administered online, in part due to the associated costs in comparison to other methods given the large geographical distribution of respondents. Other factors that influenced the choice of an online survey were ease of subsequent analysis and speed of data collection (Evans and Mathur 2005). The survey content was approved by the Ethics Committee of Cardiff University prior to being conducted and was evaluated through piloting prior to use. This helped overcome common issues of online surveys such as variations in internet browser and unclear instructions (Evans and Mathur 2005)(Evans & Mather, 2005).

The survey began with a consent page which required participants to give consent before proceeding further, after which the questions moved sequentially through the sections described previously. The questionnaire settings ensured that participants could not go back and change their initial answers to particular questions but they could decide not to answer certain questions. After completion of the survey, the final screen debriefed participants and thanked participants for completing the questionnaire.

Participants were randomly assigned a version of the text they would read in section four, with no mention made of the conservation status of freshwater pearl mussels prior to this point in the questionnaire.

5.2.4 Design

The experimental design of this questionnaire encompassed a framing (or informed choice) component which then allowed a value matching comparison to be conducted. Both of these approaches are recognised within the field of environmental psychology as methods to elicit the role of knowledge in decision-making.

In brief, framing theory is based upon the premise that the way something is presented (i.e. the frame) can exert an influence over the opinions and choices individuals make (Chong and Druckman 2007). In this case, the frame was the different beneficiaries of conservation management in an attempt to identify whether variation in expected beneficiaries (FPMs only, FPMs and other species, FPMs and humans and FPMs, humans and other species) altered perceptions about the acceptability of the conservation approaches. Two of the four 'frames' (benefits to FPMs and other species; and benefits to FPMs and humans) were then matched to environmental values (ecocentric and anthropocentric) to identify any differences between the two groups.

Both general and local river attitudes have been assessed in this research in order to identify any relationships between the two. Chapter four touched upon the different perceptions the lay-public have of urban and rural rivers, and participant-defined urban or rural residence has been used as an independent variable in some of the analysis to ascertain its relevance alongside two other potential measures of knowledge and familiarity: geographical distance and residence in an area with FPMs. Urban or rural location has also been used alongside residence in an area with FPMs since in the UK, FPMs are most often found in rural locations.

What threats are perceived to be facing UK rivers and what effect is climate change perceived to have on rivers?

H4: It is expected that the perception of the magnitude of the threat to UK rivers from climate change will be greater in those who are less sceptical about climate change, who have an ecocentric environmental attitude and those who have a more positive attitude towards rivers. This hypothesis will be test using ANOVA.

Independent Variables	Dependent Variables
• Climate Change Scepticism (binary variable)	• Change Impact on Rivers statements

What factors contribute to lay-persons' attitudes towards aquatic species and habitats?

H6: It is expected that there will be a relationship between river attitude, affect and frequency of rivers visits with measures of geographical proximity to rivers. This hypothesis will be tested using ANOVA

Independent Variables	Dependant Variables
• Distance to nearest river	• Frequency of river visits • Positive river attitude • Negative river attitude • River Affect • Local River Value

H7: It is expected that the factors affecting perceptions of FPM importance to conservation will be species knowledge, familiarity and environmental attitude and that ecocentric environmental attitude will lead to an increased perception of the conservation importance of unfamiliar species. This hypothesis will be tested using MANOVA.

Independent Variables	Dependant Variables
• Distance to nearest river • Environmental attitude scale • FPM presence/absence • Urban/Rural location	• Species Importance ranking

H8: It is expected that those who closest to rivers will be most familiar with aquatic species and will be able to correctly identify those that are native to the UK. This hypothesis will be tested using ANOVA[1] and chi-squared[2] tests.

Independent Variables	Dependant Variables
• Distance to nearest river [1] • FPM presence/absence[2] • Urban/Rural location[2]	• Species Familiarity • Species Provenance

H9: It is expected that the measures of environmental views and climate change scepticism in this study will show similar associations and that river attitudes (both general and local) will be most positive in those with a higher level of education, women or those who are not Conservative voters. This hypothesis is tested using Kruskall-Wallis and Man Whitney U tests.

Independent Variables	Dependant Variables
• Gender • Highest Qualification • Highest Science Qualification • Voting Intention	• Positive river attitude • Negative river attitude • River Affect • Local River Value • Environmental Attitude • Climate Change Scepticism

H10: There will be a relationship between distance to nearest river and urban/rural location, with rural residents living closer to rivers than their urban counterparts. This hypothesis will be tested using Mann Whitney U tests.

Independent Variables	Dependant Variables
• Urban/Rural Location	• Distance to nearest river

H11: It is expected that urban residents will have a more positive attitude to rivers and the environment than rural residents, both at a general and local scale. This hypothesis will be tested using ANOVA and MANOVA.

Independent Variables	Dependant Variables
• Urban/Rural Location	• Positive river attitude • Negative river attitude • River Affect • Local River Value • Environmental Attitude • Climate Change Scepticism

The experimental section of this research focuses on two hypotheses: 13 and 14:

H13: It is expected that acceptability for mitigation measures will increase with knowledge about the need, an ecocentric environmental attitude and a positive attitude toward rivers. This hypothesis will be tested using ANOVA and MANOVA.

H14: It is expected that preference for mitigation measures will be higher in ecocentric individuals who read the text advocating the benefits to FPMs and other species when compared to anthropocentric individuals who read the text advocating the benefits to the FPM and humans.

Independent Variables	Dependant Variables
• Environmental Attitude (Binary NEP	• Mitigation measure ranks

value) • Text Read	• Most preferred mitigation measure • Least preferred mitigation measure

5.3 Results

A summary table showing the outcomes for each hypothesis is provided for clarity (Table 5.17).

Hypothesis Number	Results			
	Supported	Partially Supported	Rejected	Page No.
H1	x			
H2	x			
H3		x		
H4	x			
H5	x			
H6		x		
H7		x		
H8		x		
H9		x		
H10			x	
H11	x			
H12	x			
H13		x		
H14		x		

Table 5.17: Summary list of results indicating whether the hypothesis are supported, partially support or rejected alongside the page number where the results are documented.

5.3.1 How does general environmental concern relate to attitudes towards rivers and river species?

H1: It is expected that positive attitudes towards local rivers will positively correlate with positive attitudes for rivers generally, and general environmental concern.

The response to the individual local river attitude statements shows that the majority of respondents agreed or strongly agreed with the statement '*For me, rivers are an intrinsic part of my local landscape*' (73.8%); this statement showed the highest level of agreement. Almost half of participants (47.5%) agreed with the statement '*In an ideal world, I would choose to live near a river'.* The levels of disagreement with both of these statements was approximately equal (5.9% and 6.1% respectively), indicative of more participants choosing the neither agree nor disagree option for the second statement. There was high level of disagreement for the statement '*I would not really mind if local river species were lost because of climate change*' (80.0%); in contrast there was less of a gap between levels of agreement

(28.5%) and levels of disagreement (42.5%) for the statement '*I would not mind if I couldn't regularly visit a river*'.

Local river value correlated with the three general river attitude scales as well as with environmental attitude. As river attitude become more positive or river affect increased, or environmental attitude become more ecocentric, the value placed on local rivers increased. The opposite is true with negative river attitude: as negative river attitude increased, the value of local rivers decreased (Table 5.18).

	Correlation Coefficients			
	Positive River Attitude	Negative River Attitude	River Affect	Environmental Attitude
Local River Value	.603***	-.464***	.576***	.375***

Table 5.18: Pearson correlation coefficients between local river value, the three general river attitude scales and general environmental attitude.
***p<0.001
Climate Scepticism scale: low values = believers, high values = sceptics
Environmental Attitude (NEP scale): low values = anthropocentric viewpoints, high values = ecocentric attitudes; Positive River Attitude: positive river attitude increase from low to high scores.
Negative River Attitude: negative river attitude increases from low to high scores.

A multiple regression using positive river attitude, negative river attitude, river affect and environmental attitude investigated the relative contribution of these attitude scales to local river value and showed that river affect has the greatest influence (Table 5.19). Together, all four factors accounted for 50% of the variance of local river value within this model.

			Standardised Coefficients - *β*			
	R value	**F value**	River Affect	Positive River Attitude	Environmental Attitude	Negative River Attitude
Local River Value	0.70	122.93***	.39***	.23***	.12***	-.20***

Table 5.19: Results from multiple regression analyses to predict local river value (DV) from river affect, positive river attitude, negative river attitude and environmental attitude (IV's).
R^2 = .496 ***p<0.001

These results support the hypothesis, H1.

H2: It is expected that increased river affect and ecocentric environmental attitudes will predict positive rivers attitudes whilst climate change scepticism will predict negative river attitudes

The author constructed scale of general river attitudes showed that an over three-quarters of all participants agreed or strongly agreed with all eight statements that made up the positive river attitude scale. The statement that had the highest level of agreement was '*Rivers are places where there are a wide variety of plants and animals*' (85.8%); the statement that had the lowest agreement was '*Rivers are places where there are rare plants and animals*' (77.9%). The corresponding percentages of participants who disagreed or strongly disagreed with these statements (2.2% and 1.8% respectively) did not show a large increase to compensate for the drop in agreement. Rather, the drop in agreement was as a result of participants choosing the 'neither agree nor disagree option.

The negative river attitude scale is characterised by lower values of agreement, with the highest level of agreement being shown for the statement '*River conservation may lead to loss of agricultural land'* (14.6%) and the lowest level of agreement for the statement '*River conservation only benefits plants and animals*' and '*Rivers make me feel fearful and uneasy*' (both 7.5%). The levels of 'neither agree nor disagree' were much higher for the statements that comprised the negative river attitude scale; for example 49.6% of participants chose the 'neither agree nor disagree' response for the statement '*River conservation may lead to loss of agricultural land*' and 42.8% for the statement 'River *conservation increases the risk of flooding*'.

The river affect scale showed that just over half of participants (51.2%) agreed or strongly agreed with the statement '*Rivers evoke strong personal memories*', with 17.6% disagreeing or strongly disagreeing with the same statement. Responses to the statement '*Rivers give me a sense of mystery and excitement*' were almost identical between those who agreed and those who disagreed (11.7% and 13.3% respectively), with the majority of participants neither agreeing nor disagreeing with the statement (85%).

The statements that made up the climate scepticism scale were based on statements previously used in surveys of the British public in 2003 and 2008 (Whitmarsh 2008, 2011), shown in Table 5.20. Levels of agreement with the statement '*Climate change is something that frightens me*' have almost doubled since 2003; both the statements '*I do not believe that climate change is a real problem'* and *'Recent floods in this country are due to climate change'* have both increased in a linear fashion with the latter statement rising much less. The two statements *'The media is often too alarmist about issues like climate change'* and *'Claims that human activities are changing the climate are exaggerated'* also showed an increase from 2003 to 2012, however there is an associated drop in agreement levels from 2008 to 2012.

Climate Change Statements	Total Agreement (%) 2003[a]	2008[b]	2012[c]
Climate change is something that frightens me	26.3		46.4
The media is often too alarmist about issues like climate change	49.0	51.2	42.9
Claims that human activities are changing the climate are exaggerated	15.0	29.1	27.1
I do not believe that climate change is a real problem	9.6	12.0	16.5
Recent floods in this country are due to climate change	40.4		43.0

Table 5.20: Longitudinal comparison of responses to climate change statements.
[a](Whitmarsh 2008); [b](Whitmarsh 2011) and [c] this survey.

Both positive river attitude and negative river attitude were strongly correlated with climate change scepticism, environmental attitude (NEP score) and river affect (Table 5.21). The direction of the correlation showed that as environmental attitude became more ecocentric and river affect increased, positive river attitude also increased. Conversely, results indicate that as climate change scepticism decreased, attitude towards river became more positive. Equally, as environmental attitude became more anthropocentric and river affect decreased, negative river attitude became increasingly negative. As climate change scepticism increased, river attitude also became increasingly negative.

	Correlation Coefficients River Affect	Climate Change Scepticism	Environmental Attitude
Positive River Attitude	.547***	-.246***	.474***
Negative River Attitude	-.241***	.134**	-.435***

Table 5.171: Pearson correlation coefficients between positive/negative river attitude and river affect; climate change scepticism and general environmental attitude.
**p<.01; ***p<0.001

A linear regression was conducted, using environmental attitude, climate change scepticism and river affect to predict both positive and negative river attitude. The results reveal that proportionally more influence is exerted by environmental attitude and river affect than by climate change scepticism, which is not a significant predictor of river attitude (Table 5.22). The results also showed that in combination, these three factors explain 46.0% of the variance in positive river attitude and 22.0% of the variance in negative river attitude.

	R^2 value	F value	Standardised Coefficients - *β* River Affect	Climate Change Scepticism	Environmental Attitude
Positive River Attitude	0.46	146.61***	.37***	.001	.48***
Negative River Attitude	0.22	48.77***	-.15***	.06	-.54***

Table 5.182: Results from simultaneous multiple regression analyses to predict positive or negative river attitude (DV) from river affect, climate change attitude and environmental attitude (IV's).
R^2 = .46 (positive river attitude) and .22 (negative river attitude).
*p<.05; ***p<0.001

Therefore, these results support hypotheses H2.

5.3.2 What threats are facing UK rivers and what affect is climate change perceived to have on rivers?

H3: It is expected that the themes of changing aesthetic appeal and pollution will be the major threats to rivers as perceived by the lay-person.

In answer to the open question '*What do you consider as the biggest threat to river areas and habitats?*' over half (54%) of responses were related to pollution, which included chemical pollution, rubbish and industrial sources. The next most common response was related to human development of rivers (24%), this section included the expansion of urban areas, building on floodplains and the general increase in houses and land development. Such impacts would undoubtedly alter the aesthetic value of the river landscape and potentially threaten a person's enjoyment of this feature as well as threatening place attachment values. The threat that received the smallest proportion was agriculture, and suggestions here included pesticide use, irrigation and runoff (Figure 5.1).

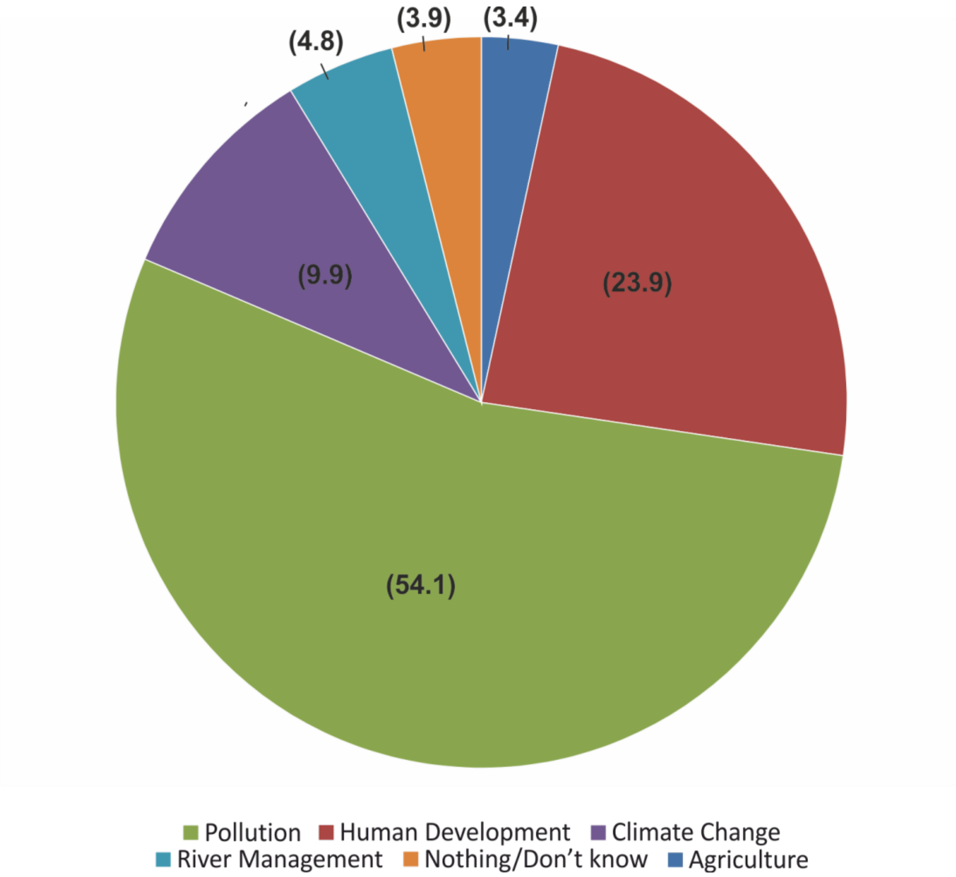

Figure 5.1: Pie chart showing results from the free text question 'What do you consider to be the biggest threat to river areas and habitats'

These results partially support the hypothesis, H3. Further work would be needed to confirm the link between human development of rivers and a lowering of the aesthetic value of riverscapes.

H4: It is expected that the perception of the magnitude of the threat to UK rivers from climate change will be greater in those who are less sceptical about climate change, who have an ecocentric environmental attitude and those who have a more positive attitude towards rivers.

Participants were asked to quantify the magnitude of the effect they believed climate change would have on rivers. There was a significant relationship between the magnitude of the effect climate change is perceived to have on UK rivers and climate change scepticism, environmental values and attitudes towards rivers. Respondents who were less sceptical about climate change, who had an ecocentric viewpoint or who tended towards a positive attitude about rivers believed that climate change would have a greater effect on UK rivers. Those with a negative attitude towards rivers also showed this trend (i.e. with increasing negative attitude towards rivers, climate change is seen having less of an effect) but this was observed at lower significance levels (Table 5.23).

	Correlation Coefficients			
	Climate Change Scepticism	Environmental Attitude	Positive River Attitude	Negative River Attitude
Magnitude of climate change effect on UK rivers	-.471***	.317***	.297***	-.100*

Table 5.193: Pearson two-tailed correlation coefficients between the perceived magnitude of climate change impacts on UK rivers and measures of climate change scepticism; general environmental attitude and general river attitude scales.
*p<0.05, ***p<0.001
Climate Scepticism scale: low values = believers, high values = sceptics
Environmental Attitude (NEP scale): low values = anthropocentric viewpoints, high values = ecocentric attitudes
Positive River Attitude: positive river attitude increase from low to high scores.
Negative River Attitude: negative river attitude increases from low to high scores.

Analysis of the eight statements designed to elicit opinions surrounding the type of effects that climate change might cause rivers confirm that climate change 'sceptics' perceived less of a causal link between climate change and flood events and between climate change and soil erosion, are less convinced that river biodiversity will reduce as a result of climate change and felt that climate change would have less of an effect on rivers in comparison to climate change 'believers' (Table 5.24). As well as the connection that climate change 'believers' made between climate change and increases in flood frequency, they also made a connection between climate change and drought occurrence and followed this through by disagreeing more with the statement '*More drinking water will be available in the future because of climate change*'.

	Mean Score		Welch's F	Degrees of freedom	
	sceptic	believer		df1	df2
In the future climate change is likely to cause more flooding	3.58	4.25	69.970***	1	432.034
River biodiversity will be reduced as a result of climate change	3.48	4.15	44.042***	1	529.646
More drinking water will be available in the future because of climate change	3.08	2.81	5.185*	1	531.970
Fewer droughts will occur as a result of climate change	2.64	3.09	16.475***	1	537.791
River biodiversity will increase as a result of climate change	3.35	3.40	.172	1	526.340
Climate change will alter the amount of soil that gets washed from land to rivers	3.98	3.58	19.064***	1	518.884
New rivers will appear because of climate change	3.84	3.43	14.222	1	537.906
Climate change will have no effect on rivers	2.90	2.07	54.5***	1	539.998

Table 5.204: ANOVA results for statements concerned with potential climate change effect on rivers.
Independent variable is a binary variable based on respondents mean score from 6 climate change attitude statements. Welch's F used to confirm ANOVA results because homogeneity of variance assumption was violated. Mean score column reflects Likert scale scoring system: 1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree
'sceptic' = scores > = median value for the mean climate change attitude scores; 'believer' = scores < median value for the mean climate change attitude scores
*p< 0.05; ***p< 0.001

Likewise a similar pattern of results was revealed when environmental attitude was used instead of climate change attitude as the independent variable with the same eight statements. In general those respondents with an ecocentric attitude agree more with statements highlighting potential climate change impacts on river habitats (Table 5.25).

	Mean Score		Welch's F	Degrees of freedom	
	Ecocentric	Anthropocentric		df1	df2
In the future climate change is likely to cause more flooding	4.21	3.64	47.841***	1	502.853
River biodiversity will be reduced as a result of climate change	4.05	3.61	18.148***	1	522.262
More drinking water will be available in the future because of climate change	2.77	3.14	9.393**	1	506.295
Fewer droughts will occur as a result of climate change	2.65	3.11	18.174***	1	519.164
River biodiversity will increase as a result of climate change	3.26	3.52	3.912*	1	499.432
Climate change will alter the amount of soil that gets washed from land to rivers	4.02	3.54	26.864***	1	528.910
New rivers will appear because of climate change	3.89	3.42	17.776***	1	516.751
Climate change will have no effect on rivers	2.07	2.86	47.542***	1	519.405

Table 5.25:ANOVA results for statements concerned with potential climate change effect on rivers.
Independent variable is a binary variable based on respondents mean score from NEP statements. Welch's F used to confirm ANOVA results because homogeneity of variance assumption was violated.
Mean score column reflects Likert scale scoring system: 1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree
'anthropocentric' = scores <= median value for the mean NEP scores; 'ecocentric' = scores > median value for the mean NEP scores
*p< 0.05; ***p< 0.001

The two scales derived from the climate change impact statements show that the highest levels of agreement for all eight statements were found within the negative impact scale '*In the future climate change is likely to cause more flooding*' (63.8%) '*Climate change will alter the amount of soil that gets washed from land into rivers*' (50.7%). The levels of disagreement with these statements were low (6.0% and 7.9% respectively). The highest levels of disagreement were found within the positive impact scale, namely the statements '*Climate change will have no effect on rivers*' (58.5%) and '*Fewer droughts will occur as a result of climate change*' (45.3%). In a similar pattern, the levels of agreement were low (7.3% and 12.5% respectively). These statement were characterised by relatively high levels of neither agree nor disagree responses, with 59.8% of participants neither agreeing nor disagreeing with the statement ' *New rivers will appear because of climate change*' and 62% neither agreeing nor disagreeing with the statement '*River biodiversity will increase as a result of climate change*'.

There was a significant relationship between the two scales derived from the climate change impacts statements (positive impacts and negative impacts) and the climate change scepticism scale (see Table 5.26). This indicated that as climate change scepticism increased, the more likely an individual is to perceive climate change impacts as positive, for example *'River biodiversity will increase as a result of climate change'.* In contrast, as climate change scepticism decreased, there was increased agreement with statements indicating more negative impacts of climate change on rivers, for example *'In the future, climate change will cause more flooding'.*

Additionally there was a significant relationship between the two climate change impact scales and the magnitude of the perceived threat of climate change on rivers. As the perceived magnitude of impact increased, the level of agreement with the negative statements also increased, whereas agreement with the positive statements decreased.

These results support the hypothesis, H4.

	Correlation Coefficients	
	Negative Climate Change Impacts	Positive Climate Change Impacts
Climate Change Scepticism	-.411**	.154**
Magnitude of climate change effect on UK rivers	.205**	-.178**

Table 5.216: Pearson two-tailed correlation coefficients between climate change impacts scales, climate change scepticism and the perceived magnitude of climate change impacts to UK rivers.
**p<0.01
Climate Scepticism scale: low values = believers, high values = sceptics
Negative Impacts: Levels of agreement with statements on a Likert scale, 1 – strongly disagree – 5 = strongly agree
Positive Impacts: Levels of agreement with statements on a Likert scale, 1 – strongly disagree – 5 = strongly agree

5.3.3 What factors contribute to lay-persons' attitudes towards aquatic species and habitats?

H5: It is expected that both aquatic habitats and birds and mammals will be ranked as more importance than other habitats and species.

The most frequent rank of rivers and lakes was as the second most important conservation sector when compared to beaches & seas; forests & woodlands; grassland & moorland and historic buildings & castles. Figure 5.2 shows the relative proportion of each sector at each importance ranking, clearly indicating that the *most* important rank (importance rank = 1) was attributed to both beaches & seas (33.6%) and forest & woodland (37.0%), this was more frequent than rivers & lakes (14.2%). Figure 5.2 also shows that rivers & lakes were infrequently ranked as least important (5.3%), which appears to be dominated by historic buildings and castles (51.5%) indicating that overall, respondents believe the conservation of the natural environment to be relatively more important than the built environment.

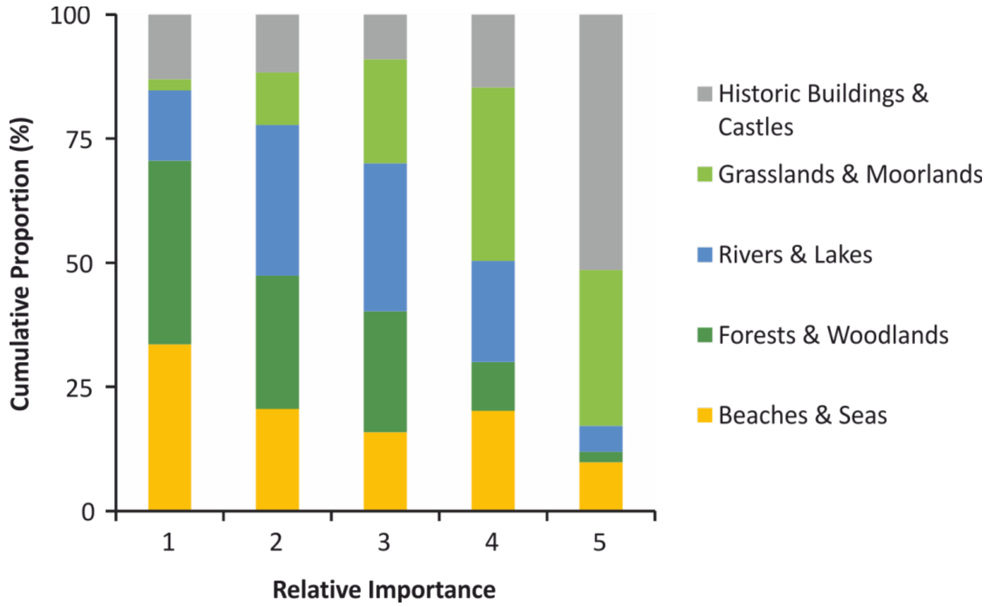

Figure 5.2: Bar graph showing the cumulative proportion of the conservation impoatnace attrivuted to each of the five conservation sectors.
Importance scale: most important = 1; least important = 5.

Importance to conservation of six aquatic species was assessed by asking respondents to rank the species from 1 (most important) to 6 (least important). Table 5.27 shows that the mean rank attributed to the FPM was between 3 and 4, indicating that this species was perceived to be of medium importance. In comparison, the otter was ranked as the most important species for conservation.

Residential Locale	**Mean Conservation Importance**					
	Common Otter	Brown Trout	Ruddy Duck	Freshwater Pearl Mussel	Great Diving Beetle	Japanese Knotweed
Urban	2.26	2.38	3.10	3.82	4.20	5.23
Rural	2.25	2.45	3.28	3.63	4.11	5.28
Historic	2.08	2.38	3.16	3.98	4.11	5.29
Current	2.40	2.35	3.06	3.69	4.30	5.20

Table 5.227: Mean values for the six species that participants were asked rank in order of conservation importance.
Results are groups by residential location (urban or rural) and FPM population (current or historic).

Charismatic and well-known species such as the common otter and the brown trout were ranked as the most important. These, alongside the non-native species that could be deemed 'attractive' such as the ruddy duck, were also rated higher than invertebrates such as the FPM and great diving beetle.

These results support the hypothesis, H5.

H6: It is expected that there will be a relationship between river attitude, affect and frequency of rivers visits with measures of geographical proximity to rivers.

The majority of respondents believed they knew the name of their local river (88.7%); moreover more than two-thirds of respondents lived less than two miles from a river (65.8%). Very few respondents lived more than 10 miles from a river (5.3%) with more respondents living less than one mile from a river than any other category (40.9%).

There was a significant relationship between the frequency of river visits and the distance between respondent's home and nearest river. As distance to nearest river decreased, frequency of visits increased, r_s = .27, p (one-tailed) <0.001. Distances were then re-classified into three groups (<1 mile; 1-2 miles and >2 miles) to spread the data across the groups more evenly. Mann –Whitney U tests show that frequency of river visits differed significantly between distances of <1miles (*Mdn* = 'frequently') and 1-2 miles (*Mdn* = 'occasionally') showing that visits to rivers were more frequent with decreasing distance to home, U = 11039.5, z = -4.58, p<0.001, r = -0.23. This is repeated between distance of < 1mile (*Mdn* = 'frequently') and >2 miles (*Mdn* = 'occasionally'), U = 11604.5, z = -5.812, p<0.001, r = -0.30.

There appears to be a threshold above which this trend does not hold true. There is not a significant difference in frequency of river visits from distances of 1-2 miles (*Mdn* = 'occasionally') and > 2 miles (*Mdn* = 'occasionally'), U = 9860.5, z = -1.11, *ns*, r = -0.07. This indicates that difference in visit frequency is constrained to those that live very close (i.e. < 1 mile) to a river.

There was a significant relationship between river attitudes and self-reported distance to local river positive river attitude (Table 5.28) but post-hoc testing revealed that these were only significant between the don't know category and < 1 mile category.

	Mean Distance to Local River				**Welch's F**	**Degrees of freedom**	
	<1 mile	1-2 miles	>2 miles	Don't know		df1	df2
Positive River Attitude	4.28	4.15	4.13	3.43	10.109***	3	123.456
Negative River Attitude	2.23	2.33	2.32	2.63	4.696**	3	135.692
River Affect	3.55	3.47	3.43	2.94	4.496**	3	129.255
Local River Value	3.83	3.72	3.58	3.05	10.084***	3	128.542

Table 5.238: ANOVA comparisons between self-reported distance to local river and the four river attitude scales
Welch's F used to confirm ANOVA results because homogeneity of variance assumption was violated.
Positive River Attitude: positive river attitude increase from low to high scores.
Negative River Attitude: negative river attitude increases from low to high scores
River Affect: positive river affect increase from low to high scores.
Local River Attitude: positive local river attitude increase from low to high scores.

The results partially support H6: distance to nearest river and frequency of river visits did show a relationship. However, a less clear relationship is observed between river attitudes and distance.

H7: It is expected that the factors affecting perceptions of species importance to conservation will be species familiarity and environmental attitude and that ecocentric environmental attitude will lead to an increased perception of the conservation importance of unfamiliar species.

When participants ranked the six aquatic species in terms of conservation importance (where a rank of 1 is the most important and a rank of 6 is the least important), the median rank of the FPM was 4. However, 13.4% of respondents who live in areas with current FPM population ranked the FPM species as *the* most important for conservation. In comparison only 7.4% of respondents from areas with historic freshwater pearl mussel populations ranked the FPM as the most important species for conservation (Table 5.29).

	Percentage At Rank					
	Common Otter	Brown Trout	Great Diving Beetle	Japanese Knotweed	Ruddy Duck	Freshwater Pearl Mussel
1	41.5	28.2	5.5	4.7	9.4	10.8
6	2.4	1.2	11.9	67.3	4.7	12.3
Median rank	1	3	5	6	2	4

Table 5.249: Results showing the proportion (%) of each species ranked 1 (most important) and 6 (least important) in terms of conservation importance.
The median rank for each species is also reported.

Species importance was only correlated with positive river attitude for the FPM and the ruddy duck, such that as positive river attitude increases, relative importance of the FPM also increase; conversely as positive river attitude increases, importance of the Ruddy Duck decreases (Table 5.30).

	Correlation Coefficients – Species Conservation Importance					
	Common Otter	Brown Trout	Ruddy Duck	FPM	Great Diving Beetle	Japanese Knotweed
Positive River Attitude	.001	-.055	.178**	-.125**	-.086	.091*

Table 5.30: Spearman's Rank two-tailed correlation coefficients between positive river attitude scale and species conservation importance.
*p<0.05; **p<0.01
Positive River Attitude: positive river attitude increase from low to high scores.
Importance: Species rank from most important (1) to least important (6)

A multivariate analysis showed that there was a significant effect of presence/absence of FPM populations in respondents' residential locale with respect to species importance, Pillai's trace V = 0.11, $F(5, 445) = 1.031$, $p<0.05$, $\eta^2 = .011$. Additionally there was a non-significant effect of urban/rural location on species importance, V = .026, $F(5,445) = 2.375$, ns, $\eta^2 = .026$ and a non-significant interaction effect between the two independent variables, V = .014, $F(5, 445) = 1.304$, ns, $\eta^2 =.014$ on mean conservation importance.

Individual comparisons highlight that the FPM was the only species whose relative importance ranking showed a significant relationship with presence/absence of FPM populations in respondents' residential locale, $F(1) = 5.112$, $p<0.05$.

Using Pillai's trace, a significant relationship was found between environmental viewpoint (V = .025, $F(5, 456) = 2.367$, $p<0.05$, $\eta^2 =.025$) with regards to conservation importance for the six aquatic species. No relationship was found between proximity to local river (V = .021, $F(10, 914) = .988$, ns, $\eta^2 =.011$) and conservation importance for the six aquatic species, and there was not a significant interaction effect (V = .035, $F(10, 914) = 1.649$, ns, $\eta^2 =.018$). This indicates that species importance increases with increasing ecocentric value, but further analysis reveals that the relationship between environment viewpoint and conservation importance was only significant for the ruddy duck ($F(1) = 6.091$, $p<0.05$).

Whilst not significant, respondents with an ecocentric viewpoint tended to rank the freshwater pearl mussel as more important as proximity to local river decreased. For those with an anthropocentric viewpoint, the importance rank for freshwater pearl mussel remained constant irrespective of local river proximity.

Looking specifically at factors affecting FPM importance and its relationship with the importance of other species, it can be seen that as the relative importance of FPM increased, the importance of the common otter, Japanese knotweed and ruddy duck decreased. There was no relationship with FPM importance and the importance of the brown trout or the great diving beetle (Table 5.31).

	Correlation Coefficients				
	Common Otter	Japanese Knotweed	Ruddy Duck	Brown Trout	Great Diving Beetle
FPM Importance	-.377***	-271***	-470***	-.010	.038

Table 5.31: Spearman's Rank two-tailed correlation coefficients between the conservation importance of the FPM and the other five specie used in this questionnaire.
***p<0.001
Participants were asked to place the six species in order of importance, with 1 being the most importance and 6 the least.

These results support partially support H7 with respect to FPMs only.

H8: It is expected that those who closest to rivers will be most familiar with aquatic species and will be able to correctly identify those that are native to the UK**.**

Overall, freshwater pearl mussels were shown to be less familiar than the common otter, the brown trout, the Japanese knotweed and the ruddy duck. Only the great diving beetle was less familiar than the freshwater pearl mussel. Figure 5.3 highlights the cumulative level of familiarity for the six species. The horizontal black line indicates the 50% response level and it can be seen that there is a marked difference in familiarity at this level between the species, with otters, brown trout and Japanese Knotweed all being more familiar than the remaining three species.

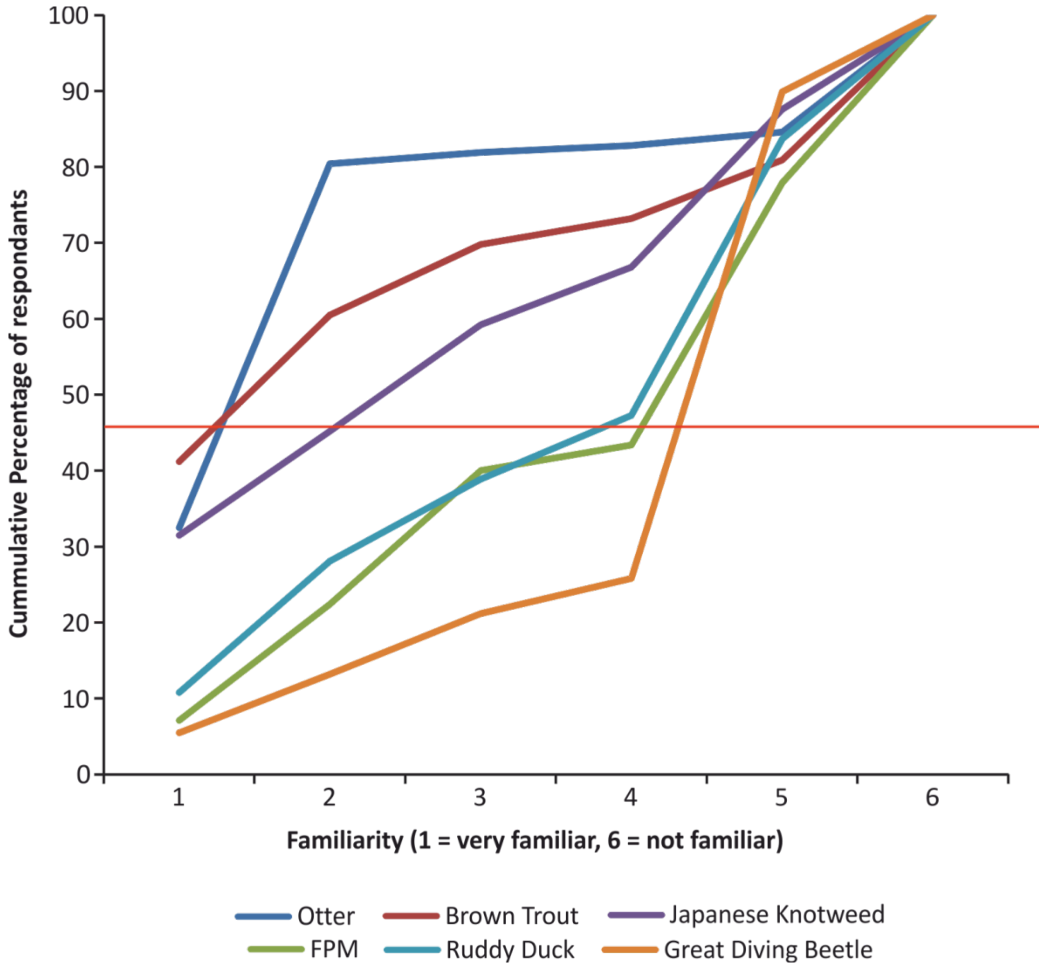

Figure 5.3: Line graph showing how familiar each of the six species were, by percentage of respondents.

Of the six aquatic species, only Japanese knotweed showed a significant association between respondents' location (urban or rural) and the degree of familiarity with the species, (χ^2 = 17.712, $p<0.01$). Cramer's V = 0.18 showed the effect size of urban/rural location on familiarity to be small (Cohen, 1986); however based on the odds ratio between the categories 'know the name and have seen in the wild' and 'never seen or heard of before', the odds of rural residents 'knowing the name and have seen in the wild' for Japanese knotweed are 2.65 times that for urban residents.

Examining levels of familiarity with respect to regions with current or historic freshwater pearl mussel populations showed that differences in familiarity exist across the two regions for freshwater pearl mussels (χ^2 = 40.375, $p<0.001$), brown trout (χ^2 = 16.090, $p<0.01$)

and Japanese knotweed ($\chi2 = 35.411$, $p<0.001$). The values for Cramer's V (.289, .183 & .270 respectively) show that the effects sizes underpinning these relationship were small (Cohen, 1986). The odds of respondents from regions with current FPM areas 'knowing the name and have seen in the wild' were 1.59 times and 1.95 times that for respondents from regions with historical freshwater pearl mussel populations, for the freshwater pearl mussel and brown trout respectively.

Conversely, the odds ratio showed that respondents from regions with historic FPM populations were 4.33 times more likely to choose 'know the name and have seen on the wild' for Japanese knotweed, than respondents from areas with current FPM populations. Japanese knotweed was ranked as less important in areas with historic FWPM populations – this may correspond to areas where Japanese knotweed is more of a problem, or its presence had been more widely publicised. Swansea (grouped into the historic FWPM region) is said to have the largest infestation of Japanese Knotweed in the UK (Japanese Knotweed Solutions Limited n.d).

The effect of distance on familiarity was examined, both including and excluding the 'don't know' category from the distance options of <1 mile, 1-2 miles and >2 miles (Table 5.32). With respect to distance from local river, no relationship was found with familiarity with the exception of the Japanese knotweed, (which was less familiar as distance to local river increased) when the 'don't know' option was excluded. Including the don't know option, both Japanese knotweed and FPM showed an effect of distance on familiarity, with those participants who did not know the distance to their local river being less familiar with both species.

	Mean Distance to Local River						
	<1 mile	1-2 miles	>2miles	don't know	**Welch's F**	**df1**	**df2**
Common Otter	2.32	2.45	2.25	3.06	1.945 .476	3 2	127.576 305.700
Brown Trout	2.69	2.65	2.77	3.39	1.449 .160	3 2	131.309 316.923
FPM	4.05	3.90	4.19	4.71	3.794* 1.085	3 2	140.019 311.585
Japanese Knotweed	2.77	3.23	3.21	4.26	8.048*** 3.862*	3 2	131.307 306.895
Ruddy Duck	3.89	4.02	3.76	4.32	1.477 .926	3 2	133.139 312.156
Great Diving Beetle	4.39	4.45	4.48	4.58	.297 .211	3 2	133.376 313.195

Table 5.252: ANOVA results for species familiarity, comparing between self-reported distances to nearest river.
Independent variable is the condensed distance to nearest river categories of <1 mile; 1-2 miles, >2 miles and 'don't know' Welch's F used to confirm ANOVA results because homogeneity of variance assumption was violated. Test results with 'don't know' values included have a df1 = 3, where 'don't know' is not included, the df1 = 2.
Mean score columns reflects familiarity scoring system: 1 = Know the name and have seen in the wild; 2 = Know the name and have seen in captivity or on TV; 3 = Recognise the name and the picture but have never seen; 4 = Recognise the name but not the picture; 5 = Recognise the picture but not the name; 6 = Never seen or heard of before. *p<0.05, ***p< 0.001

Overall results showed that 71.2% of urban and 72% of rural participants thought freshwater pearl mussels were native compared to 90.8% and 92.1% respectively for the common otter and 46.6% and 51.6% for the great diving beetle.

Only the provenance of Japanese knotweed showed a significant difference between urban and rural participants (χ^2 = 4.349, p< 0.05, V = .09). This result was driven by fewer urban participants rating Japanese knotweed as non-native than expected and more rural participants rating Japanese knotweed as non-native than expected, indicating that rural residents are more aware of this species' invasive nature than their urban counterparts . The odds ratio indicated that the odds of urban residents thinking that Japanese knotweed was native to the UK are 1.75 times greater than for rural residents. However, the effect size of this relationship was small.

Analysis of distance to nearest river and species provenance only showed a significant relationship between distance and perceived provenance of the ruddy duck (χ^2 = 13.712, p<0.01). This result is likely driven by the distance category of <1 mile, where numbers of participants thinking the ruddy duck was native were less than expected and those deciding that the ruddy duck was non-native were over represented. The odds ratio shows that respondents living 1-2 miles from a river had 1.28 times higher odds of perceiving the ruddy duck as native than respondents living <1 mile from a river. The same was true of respondents living >2miles from a river, who had 2.14 higher odds of classing the ruddy duck as native than those living < 1 mile from a river. However, the effect size of this relationship was small (Cramer's V = 0.164).

When species provenance was examined with respect to the presence of current or historic FPM populations, the only species to show a relationship with residence in areas with current/historic FPM populations was the FPM (χ^2 = 7.081, df =1, p<0.01, Cramer's V = .122). If a respondent lived in current FPM areas, the odds of their thinking that the FPM is native were 1.72 times greater than if they live in an area with historic FPM population.

These results show that H8 is partially supported: lower geographical distance does not indicate increased species knowledge but living in an area where specific species are found seems to increase knowledge related to that species.

H9: It is expected that the measures of environmental views and climate change scepticism in this study will show similar trends and that river attitudes (both general and local) will be most positive in those with a higher level of education, women or those who are not Conservative voters.

Mann-Whitney tests showed no significant difference in environmental attitude (U = 33540, z = -.209, *ns*) or river attitude according to gender (positive river attitude: U = 34246, z = -0.64, *ns*, r = -0.03; negative river attitude: U = 34149, z = -0.855, *ns*, r = -0.04; river affect: U

= 32986.5,, z = -1.901, *ns*, r = -0.08; local river value: U = 33340.5, z = -1.465, *ns*, r = -0.06), but there was a significant difference by gender for climate change scepticism score (U = 32058.5, z=-2.186, $p<0.05$, r = -0.09). The results of individual climate change statements show proportionally more women agreed or strongly agreedwith *climate change is something that frightens me* and *recent floods in this country are due to climate change* and again more women disagreed with the statement *claims that human activities are changing the climate are exaggerated* than men.

Kruskall-Wallis tests revealed no significant relationship between highest qualification and climate change scepticism (H(5) = 7.353, *ns*, η^2 = 0.01); positive river attitude (H(5) = 4.457, *ns*, η^2 = 0.008), river affect (H(5) =2.443, *ns*, η^2 = 0.005), local river value (H(5) = 1.004, *ns*, η^2 = 0.002) or environmental attitude (H(5) = 9.614, *ns*, η^2 = 0.02). A relationship between negative river attitude and highest qualification was found (H(5) = 11.596, $p<0.05$, η^2 = 0.02). Mann-Whitney tests revealed that the difference lies between those with Bachelor degree (*Mdn* = 3.8) and GCSE/'O'-level (*Mdn* = 3.6) qualifications (U = 7248.5, z = -2.079, $p<0.05$, r = -0.13), indicating that those participants whose highest qualifications were 'O'-levels had a more negative attitude towards rivers than those with a Bachelor's degree.

No significant relationship was found between highest science qualification and climate change scepticism (H(5) = 3.184, *ns*, η^2 = 0.006), positive river attitude (H(5) = 3.258, *ns*, η^2 = 0.006), negative river attitude (H(5) = 7.669, *ns*, η^2 = 0.01), river affect (H(5) = 1.453, *ns*, η^2 = 0.003), local river value (H(5) = 3.921, *ns*, η^2 = 0.007) or environmental attitude (H(5) = 4.553, *ns*, η^2 = 0.009). Chi-squared tests used to analyse the individual climate change statements revealed that only statement showed a significant relationship with highest science qualification (*I regularly take action out of concern for climate change*: χ^2 = 32.746, df = 20, $p<0.05$, Cramer's V = .123), mainly driven by fewer participants with a science degree or equivalent disagreeing with this statement (z = -2.1) and strongly disagreeing (z = -2.0).

No significant relationship was found between voting preference and environmental attitude (H(8) = 9.538, *ns,* η^2 = 0.02); positive river attitude (H(8) = 5.975, *ns*, η^2 = 0.01), negative river attitude (H(8) = 6.889, *ns*, η^2 0.01), river affect (H(5) = 13.514, *ns*, η^2 = 0.025) or local river value (H(5) = 8.145, *ns*, η^2 = 0.015).

However, climate change scepticism was significantly affected by voting preference, H(8) = 23.637, p<0.01, η^2 = 0.04. Mann-Whitney tests were used to follow up this finding and a Bonferroni correction was applied so all effects are reported at a .0167 level of significance. Climate change scepticism was significantly different between Conservative (*Mdn* = 3.0) and Labour (*Mdn* = 2.7) voters (U = 5136, z = -3.155 r = -.20) and between Conservatives and Green Party (*Mdn* = 2.0) voters (U = 394.5, z = -3.997, p<0.01, r = -.39) but no difference was observed between Conservative voters and Liberal Democrat voters (*Mdn* = 2.4) (U = 886, z=-1.602, *ns*, r = -.15). In general, climate change scepticism increased from Green Party > Liberal Democrats > Labour > Conservative voters.

These results indicate that H9 is partially supported: gender differences exist in climate change scepticism only; no relationship was found with education, and no relationship between river attitudes and voting intention was shown. However, climate change scepticism did show a relationship with voting intention.

H10: It is expected that urban residents will have a more positive attitude to rivers than rural residents, both at a general and local scale.

Mann-Whitney tests showed no significant relationship between urban (*Mdn* = 2.8) and rural (*Mdn* = 2.7) residence and climate change attitude (U = 33728, z = -1.03, *ns,* r = -0.04). Only one of the eight climate change impact statements showed a significant effect of location (i.e. urban or rural). Urban respondents showed a high level of agreement with the statement *'New rivers will appear because of climate change'* than rural respondents, F(1, 545) = 6.588, p<.05.

However, Mann-Whitney tests did reveal a significant relationship between urban and rural residence with respect to environmental value (U = 29379.5, z = -2.213, p<0.05, r = -0.1). Rural residents appeared to have a slightly stronger pro-ecological viewpoint than their urban counterparts (urban *Mdn* = 3.5, rural *Mdn* = 3.7). No difference in river attitude was seen when urban and rural residents were compared (positive river attitude: U = 32715.5, z = -1.313, ns, r = 0.06); negative river attitude: 34324.5, z = -.501, ns, r = 0.02); river affect: U = 33516.5, z = -1.324, ns, r = 0.06).

Using the local river value scale, based on participants' average scores for the four local river statements, a significant effect of location between urban and rural residents was observed,(U = 29318, z = -3.486, p<0.001, r = 0.15), with urban participants (*Mdn* = 3.5) placing less value on local rivers than rural participants (*Mdn* = 3.75). Investigating the results for each statement revealed a significant effect of location within three of the four statements (Table 5.33). In terms of local rivers and when compared to rural residents, urban inhabitants tended to place less value on regularly visiting rivers, were less concerned about losing local river species due to climate change and didn't consider rivers part of their local landscape.

The statement that did not show a significant relationship to location, '*In an ideal world, I would choose to live near a river'* is indicative of a ceiling effect, given that almost three-quarters of participants agreed or strongly agreed with that statement.

	Median Score		U	Df
	Urban	Rural		
I would not mind if I couldn't regularly visit a river	3	2	29893.0***	1
In an ideal world, I would choose to live near a river	3	3	34559.5	1
For me, rivers are an intrinsic part of my local landscape	4	4	31079.5**	1
I would not really mind if local river species were lost because of climate change	2	1	31591.5**	1

Table 5.263: Mann Whitney U test results for local river value statements, comparing urban and rural residence.
Mean score reflect Likert scale scoring system: 1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree
**p< 0.01; ***p< 0.001

Therefore, H10 is not supported by these results.

H11: It is expected that those in closer proximity to FPM populations will show a more positive attitude to FPMs.

Of the six attitude statements about attitudes towards the conservation of FPMs, '*Water is a valuable resource and must protected, if other species benefit indirectly from this then that is an added advantage*' and '*Conservation measures to protect FPMs are a good idea because many other species will benefit*' showed the lowest level of disagreement (0.7% and 1.4% respectively). The statement ' *There are more important things to spend taxpayers' money on than conserving just one species*' had almost equal proportions of agreement and disagreement (22.3% and 29.7 respectively) and also had the highest level of neither agree nor disagree (48.0%) of all the FPM attitude statements. The two statements that referred to the aesthetics and familiarity of the FPM, '*We should focus on protecting beautiful and iconic species rather than ugly species like the FPM that we might never see*' and '*I have never heard of this species, how important can it really be?*' received the highest levels of disagreement, at 67.3% and 51.3% respectively: these statements also received agreement levels of 10.7% and 14.1% respectively.

The results from the six FPM attitude statements showed a significant relationship between residents' environmental attitude and attitudes to FPMs. In general it can be seen from Table 5.34 that those with a more ecocentric outlook tended to agree with statements advocating the conservation of this species and the value of water as a resource. In comparison, those with an anthropocentric view tended to agree more with statements which undermine the value of this species, due to their less charismatic nature or the fact that it is relatively unknown amongst large proportions of the public.

	Mean Score			**Degrees of freedom**	
	Ecocentric	Anthro-pocentric	**Welch's F**	df1	df2
Conservation measures to protect freshwater pearl mussels are a good idea because many other species will benefit	4.44	3.84	92.227***	1	505.833
We should focus on protecting beautiful and iconic species rather than ugly species like the freshwater pearl mussel that we might never see	1.63	2.58	134.980***	1	491.727
Both humans and the wider natural environment will benefit from conserving freshwater pearl mussels	4.27	3.67	72.302***	1	522.992
Water is a valuable resource and must be protected, if other species benefit indirectly from this then that is an added advantage	4.58	3.97	102.104***	1	495.449
There are more important things to spend taxpayers money on than conserving just one species	2.55	3.25	80.500***	1	523.995
I have never heard of this species before, how important can it really be?	2.03	2.86	96.284***	1	523.480

Table 5.27: ANOVA results for statements concerned with FWPM attitudes, comparing ecocentric and anthropocentric viewpoints.
Independent variable is a binary variable based on respondents mean Likert score from NEP statements.
Welch's F used to confirm ANOVA results because homogeneity of variance assumption was violated.
Mean score column reflects Likert scale scoring system: 1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree
'ecocentric' = scores < =median value for the mean NEP scores; 'anthropocentric' = scores > median value for the mean NEP scores
***p< 0.001

A multivariate analysis was used to examine the role of urban and rural location and residence in an area with current or historic FPM populations, on attitudes to FPMs. Using Pillai's trace, there was a significant main effect of living in an area with current or historic FPM populations on the agreement/disagreement of the FPM attitude statements, V = 0.027, F(6. 466) = 2.178, P<0.05, η^2 = 0.027. It appears that respondents from current FPM areas were more likely to agree with statements that promote the conservation of FPMs and advocate the wider benefits of its conservation. In contrast, those from historic FPM areas showed a higher level of agreement with the concepts that conservation should focus on more charismatic or multiple species conservation strategies.

There was a non-significant main effect of urban/rural location on the agreement/disagreement of the FPM attitude statements, V = 0.017, F(6, 466) = 1.363, *ns*, η^2 = 0.017 and a non-significant interaction effect between living in an urban or rural area and living in an area with a current FPM or an historical FPM population, V = 0.012 F(6, 466) = 0.943, p = 0.464, η^2 = 0.012.

Separate univariate ANOVAs on the outcome variables revealed non-significant effects of living in an area with current of historic FPM populations for all statements with the exception of "*I have never heard of this species before, how important can it be*", F(6, 466) = 5.428, p<0.05, η^2 = 0.01. The mean scores for this statement showed that those living in current FPM areas disagree more strongly with this statement than those living in historic FPM areas. Additionally, distance to nearest river did not show a significant main effect on attitudes to FPM, using Pillai's trace, V = .034, F(12,1006) = 1.450, p = .137, η^2 = 0.034.

Using the two FPM attitude scales identified through the PCA, a significant relationship was found between attitudes towards FPMs and the perception of FPM importance to conservation (Table 5.35). As agreement with the multiple benefits scale increased so did FPM importance. This indicates that perceive importance of the FPM was increased in those participants who believe that there will be many beneficiaries to the conservation of FPMs. Conversely, as agreement with Negative Attitude to conservation increased, conservation importance of FPMs decreased. In other words, participants who felt aesthetics was important in conservation tended to rank the FPM as being of lower importance to conservation.

	Correlation Coefficients	
	Multiple Beneficiaries	Negative Attitude to conservation
FPM Importance	-.136*	.161**

Table 5.35: Spearman's Rank two tailed correlation coefficients between FPM conservation importance and FPM attitude scales.
* p<0.05 **p<0.01
FPM Importance scale: 1 = Most Importance – 6 = Least Important
Multiple Beneficiaries scale based on Likert scoring system, 1 = strongly disagree – 5 = strongly agree
Conservation Aesthetics scale based on Likert scoring system, 1 = strongly disagree – 5 = strongly agree

In order to assess the relative contribution of values and knowledge towards perceptions of the importance to conservation of FPMs a Spearman's Rank correlation analysis was performed was performed using the river attitude scales (general and local), environmental attitude scale, FPM attitude scales, FPM familiarity, FPM provenance, distance to nearest river and residence in an FPM area (Table 5.36). Of these, only residence in an FPM area did not show a significant relationship with FMP importance.

	Correlation Coefficients							
	Environmental Attitude[1]	Local River Value[1]	Positive River Attitude[1]	Multiple Beneficiaries[1]	Negative Attitude to Conservation[1]	FPM Provenance[2]	FPM Familiarity[2]	Distance to Local River[2]
FPM Importance	*p*(489) = -.094*	*p*(502) = -.146**	*p*(499) = -.125**	*p*(502) = -.502**	*p*(509) = .161**	*p*(499) = .216**	*p*(507) = .142**	*p*(509) = .094*

Table 5.36: Spearman's Rank two-tailed correlation coefficients for FPM importance and value-based[1] and knowledge-based[2] variables
*p<0.05; **p<0.01

To identify which of the knowledge and value-based variables could explain the variation in FPM importance between participants, a stepwise multiple regression[3] was conducted on the variables that had been shown to have a significant relationship with FPM importance in the correlation analysis (Table 5.37).

The only factors that were found to increase the predictive capacity of the model were local river value, FPM provenance and FPM familiarity, giving the regression equation:

FPM Importance = 0.645 (FPM Provenance) + 0.120 (FPM Familiarity) – 0.230 (Local River Value) + 3.285

		B	SE B	*β*
Step 1	Constant	2.797	.213	
	FPM Provenance	.715	.158	.209***
Step 2	Constant	2.343	.256	
	FPM Provenance	.645	.158	.189***
	FPM Familiarity	.135	.043	.149***
Step 3	Constant	3.285	.455	
	FPM Provenance	.621	.157	.182***
	FPM Familiarity	.120	.043	.129***
	Local River Value	-.230	.092	.115*

Note: Adjusted R^2 = .045*** for Step 1; Adjusted R^2 = .060* Adjusted R^2 = .071* for Step 4

Table 5.37: Results for stepwise multiple regression comparing knowledge and values factors in the conservation importance of the FPM.
Significant predictors of FPM importance were found to be FPM Provenance (native or non-native); FPM Familiarity (1 = most familiar – 6 least familiar) and Local River Value (the value placed on local rivers by participants, from 1 (low value) to 5 (high value)).
*** = p<0.001, * = p<0.05

This model explains 7% of the variance associated with the independant variable indicating that other unmeasured variables contribute the the public assessment of FPM importance; furthermore, FPM Provenance plays the greatest role in the publics assessment of importance when compared to the other three predictor variables.

Whilst the results support H11, in that general knowledge and values both contribute towards determining FPM importance assessed by the lay-person, there is much variance not explained by these factors.

[3] Whilst the FPM importance variable was obtained from the species ranking exercise, the issue of non-independence of the dependant variable is overcome by using only the ranks attributed to the FPM; none of the ranks assigned to the other five species feature in this analysis. Furthermore, work by Pasta (2013) indicated that ordinal data can be used within a linear regression analysis under certain circumstances.

5.3.4 Can knowledge influence the visual acceptability of mitigation measures for the freshwater pearl mussel?

H12: It is expected that images which appear to be less natural are expected to be less acceptable.

Overall, the most acceptable mitigation measure was re-planting river banks, which was the most acceptable choice for 50.3% of respondents. Almost half of participants' comments (47%) related to this mitigation measure cited aesthetics as the reason behind their choice. Arable drainage ditches were the next most acceptable mitigation measure, with 29% of participants choosing this option. However the reason behind this choice was the ease of implementation and subsequent management.

The highest proportion of reasons for least and most acceptable mitigation measure concerned aesthetics. Comments such as "*visually appealing*" and "*looks natural*" were justifications for respondents' choice of most acceptable mitigation measure whilst comments like "*unsightly*" and "*intrusive*" were used to describe participants' choice of least acceptable mitigation measure.

The mitigation measures of livestock fencing and reduced field sizes were the least acceptable, each receiving 24% of the votes. The reasons behind these choices were distinct. Respondents were concerned about the impacts on livestock welfare (39%) if fencing was used, with concerns raised over the provision of water for the animals and the opinion that livestock have the right to roam and not be "*penned in*". The reduced field size option elicited concerns over detrimental impacts to farming industry and consequences to food production (60%).

These results support H12.

H13: It is expected that acceptability for mitigation measures will increase with knowledge about the need, an ecocentric environmental attitude and a positive attitude toward rivers.

H14: It is expected that preference for mitigation measures will be higher in ecocentric individuals who read the text advocating the benefits to FPMs and other species when compared to anthropocentric individuals who read the text regarding benefits solely for the FPM.

Levels of agreement with the statements concerned with opinions of the mitigation measures showed that the highest agreement was achieved with the statement '*Re-vegetation looks like it would provide good habitat for other species*' (81.0%), '*These ideas would encourage farming and conservation to work together*' (76.5%) and '*The benefits of these measures should be balanced across both humans and the environment*' (76.1%). These three statements also received the lowest levels of disagreement. Statements with the highest level of disagreement were '*Food production will suffer if land has to be used for conservation*' (35.3%) and '*Livestock have the right to access the water, they shouldn't be fenced in*' (23.4%): these statements also had the highest levels of neither agree nor disagree responses, of 41.8% and 40.6% respectively.

In order to assess the influence of environmental attitude and sample text read on the acceptability of sediment control measures, a multivariate approach (Pillai's trace) was utilised. There was a significant main effect of environmental attitude on acceptability of sediment control measure, $V = 0.079$, $F(8, 476) = 5.100$, $p<0.001$, $\eta^2 = .079$. There was a non-significant main effect of text read on acceptability of sediment control measure, $V = 0.029$, $F(24, 1434) = 0.587$, *ns,* $\eta^2 = 0.01$. There was also a non-significant interaction effect between text read and environmental attitude on acceptability of sediment control measure, $V = 0.021$, $F(24, 1434) = 0.412$, *ns*, $\eta^2 = .07$

Those respondents with an ecocentric viewpoint tended to find the mitigation measures more acceptable, across all texts, than those with an anthropocentric viewpoint. Further analysis using separate univariate ANOVA's on the outcome variables revealed that environmental attitude had a significant effect on attitudes towards all sediment control measures, except for sediment fencing, which was universally less acceptable across both anthropocentric and ecocentric environmental attitudes (Table 5.38).

Mitigation Measure	Mean Score	
	Ecocentric	Anthropocentric
Arable drainage ditches	4.52	4.17
In-field margins	4.38	4.14
Sediment fences	3.85	3.76
Riverbank re-vegetation	4.57	4.19
Livestock drinking bays	4.06	3.80
Livestock fencing	4.03	3.86
Riverbank tree buffer strips	4.13	3.88
Reduced field sizes	3.88	3.68

Table 5.38: ANOVA result comparing the acceptability of mitigation measures between ecocentric and anthropocentric participants.
Mean score column reflects Likert scale scoring system: 1 = very unacceptable; 2 = unacceptable; 3 = neither acceptable nor unacceptable; 4 = acceptable; 5 = very acceptable

There was a non-significant main effect of both text read and environmental attitude on participants' choice of *most* acceptable sediment control measure, $F(3, 515) = 0.752$, *ns*, $\eta^2 = .004$ & $F(1, 515) = 3.395$, *ns*, $\eta^2 = .007$. There was also a non-significant interaction effect between the text read and environmental attitude on participants' choice of acceptable sediment control measure, $F(3,515) = 0.591$, *ns*, $\eta^2 = .003$.

Likewise, there was a non-significant main effect of both text read and environmental attitude on participants' choice of least acceptable sediment control measure, $F(3, 506) = 0.211$, ns, $\eta^2 = .001$ & $F(1, 506) = 3.144$, *ns*, $\eta^2 = .006$ There was also a non-significant interaction effect between the text read and environmental attitude and participants' choice of least acceptable sediment control measure, $F(3,506) = 0.656$, *ns*, $\eta^2 = .004$.

These results partially support H13.

Value matching environmental viewpoint and text read did reveal significant differences in preference for so-called 'soft' mitigation options (namely arable drainage ditches, in-field margins; re-planting river banks and river bank tree buffer strips). Participants who read the text highlighting the benefits for FPMs and other species *and* who held an ecocentric viewpoint showed higher levels of acceptability for all four soft mitigation options than those participants who tend towards an anthropocentric viewpoint and who read the text advocating the benefits solely for FPMs (V = 0.118, F(4,130) = 4.361, p<0.01, η^2 = 0.118, Figure 5.4). This relationship was not observed for the 'hard' engineering options (V = 0.054, F(4, 132) = 1.880, *ns*, η^2 = 0.054). In the subsequent ANOVA results for each mitigation measure individually, both sediment fencing (F(1) = 5.346, p<0.05, η^2 = 0.038) and livestock drinking bays (F(1) = 4.084), p<0.05, η^2 = 0.034) showed a relationship with respect to preference; again participants with an ecocentric viewpoint showed a higher level of acceptability of these two measures.

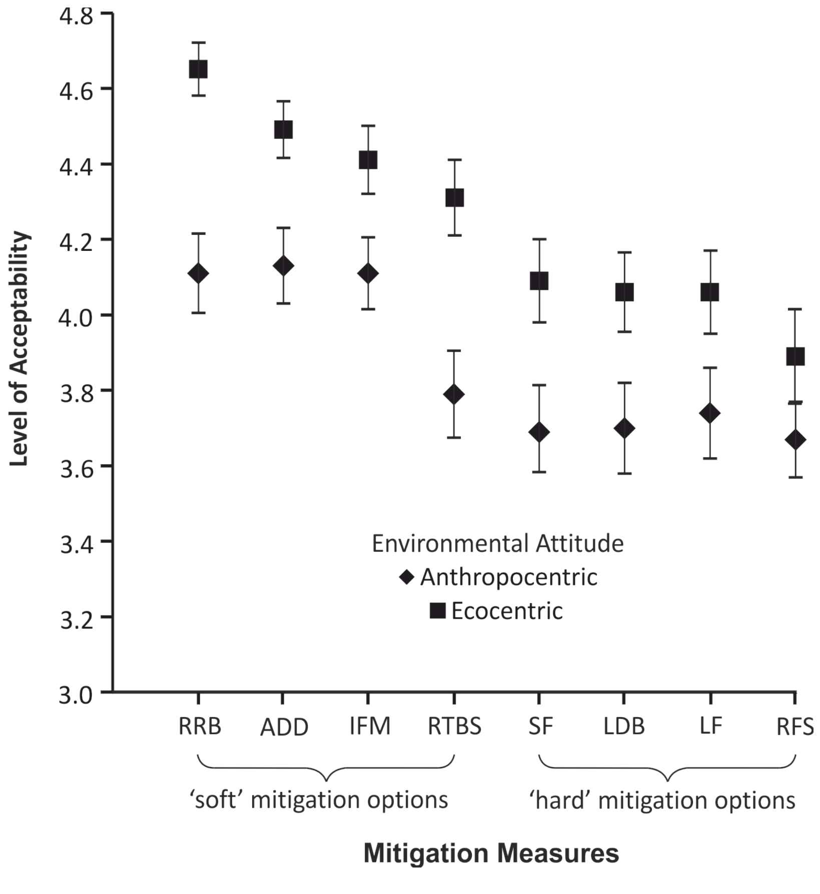

Figure 5.4: Scatter graph showing the effect on the acceptability of sediment control measures of value matching the text read to the environmental viewpoint of the participant. Eror bars show the stndard error.

'Ecocentric' are respondents who hold an ecocentric viewpoint and read the text which promoted the benefits from sediment control measures for both freshwater pearl mussels and other species.
'Anthropocentric' are respondents who hold an anthropocentric viewpoint and who read the text which advocated sediment control measures as beneficial to only freshwater pearl mussels.
Level of acceptability scale: 1 = very unacceptable – 5 = very acceptable
Mitigation Options: ADD = Arable Drainage Ditches; IFM = Iny field Margins; RRB = Rey planting river banks; RTBS = River bank Tree Buffer Strips; SF = Sediment Fencing; LDB = Livestock Drinking Bays; LF = Livestock Fencing; RFS = Reduced Field Sizes.

Positive sediment mitigation attitude showed a significant relationship with all three attitude scales derived from the general rivers statements as well as environmental attitude (Table 5.39). This result indicates that as participants tended towards a ecocentric viewpoint, alongside a more positive river attitude (and consequently a lesser negative river attitude), their attitude towards mitigation measures to control sediment became more positive, reflecting in the higher levels of agreement with the statements that formed part of the positive sediment mitigation attitudinal scale, for example '*These ideas would encourage farming and conservation to work together'.* Additionally, there were positive correlations observed with the mean acceptability scores for both the 'soft' and 'hard' mitigation measures with the measure of positive sediment mitigation attitude. This indicates that acceptability of both types of mitigation measure increased with a more positive attitude towards sediment mitigation.

	Correlation Coefficients						
	Environmental Attitude	Positive River Attitude	Negative River Attitude	Positive River Affect	Local River Value	'Soft' mitigation options	'Hard' mitigation options
Positive Sediment Mitigation Attitude	.434***	.529***	-.268***	.230***	.310***	.492***	.356***

Table 5.39: Pearson two-tailed correlation coefficients between the positive sediment mitigation attitude scale and local river attitude, general river attitude scales; general environmental attitude scale and the acceptability of the mitigation option, split into hard and soft categories..
***p<.0001;
Positive sediment mitigation attitude scale derived from statements such as '*These ideas would encourage farming and conservation to work together',* which were scored using a 5 point Likert scale, 1 = strongly disagree – 5 = strongly agree.
Environmental Attitude (NEP scale): low values = ecocentric viewpoints, high values = anthropocentric attitudes
Positive River Attitude: positive river attitude increase from low to high scores.
Negative River Attitude: negative river attitude increases from low to high scores.
River Affect: River affect increase from low to high scores
Local River Value: Value of local rivers increases from low to high scores.
Soft mitigation options: mean acceptability scores of the 'soft' mitigation options (arable drainage ditches; in-field margins; re-planting river banks and river bank tree buffer strips), low scores = unacceptable, high scores = acceptable
Hard mitigation options: mean acceptability scores of the 'hard' mitigation options (sediment fencing; livestock drinking bays; livestock fencing; reduced field sizes), low scores = unacceptable, high scores = acceptable.

Isolating individual mitigation statements and correlating these with specific mitigation measures showed some significant relationships. Using the statement '*Livestock have the right to access the water, they shouldn't be fenced in*' and the acceptability of both livestock fencing and livestock drinking bays, a negative correlation was observed such that as the level of agreement with the statement increased, the acceptability of the measure decreased, r = -.29 and r = -.19, both *p's* (two-tailed) <0.01. Additionally, the statement '*Re-vegetation looks like it would provide good habitat for other species*' showed a significant relationship with the re-planting river banks mitigation measure, r = .44, p (two-tailed) <0.01, indicating that as acceptability for the mitigation measure increased so too did agreement with the related statement. Finally, using the same mitigation measure but the statement '*Re-vegetating the river banks will mean it is less accessible and more difficult to walk alongside the water'* showed a non-significant relationship between the two, highlighting that concern for reduced accessibility resulting from replanting river banks did not lead to less acceptability of this mitigation measure, r = -.02, *ns*.

No significant relationship was found between the text read and respondents' positive sediment mitigation score, F(3) = .766, *ns*, indicating that the text read did not influence the level of agreement with the positive sediment mitigation statements.

These results partially support H14.

5.4 Discussion

Throughout this research and that from the qualitative work in Chapter four, it can be seen that rivers are almost universally valued as a place to relax and enjoy and the majority of participant displayed a positive attitude towards rivers. Rivers appear to interact with many human senses, for example the sights and sounds of rivers were often used by focus group participants describe what came to mind when thinking about rivers. Concern for rivers in the future focuses on pollution and development whereas aesthetics dominates the reasons for preference of certain river scenes, with a clear desire for natural looking rivers coming from the qualitative work. Charismatic river species, such as the otter, are very familiar whereas others such as the freshwater pearl mussel (FPM) are not as widely recognised. This is reflected in the lower levels of conservation importance attributed to the FPM; however results from the focus groups did show that, once understood, the concept of the FPM being an indicator species is sufficient to elevate its importance ranking.

1. *How does general environmental concern relate to attitudes towards rivers?*

The results of this study indicate that general environmental attitude does play a role in determining attitudes towards rivers. The results show that an ecocentric viewpoint is indicative of a positive river attitude; whereas anthropocentric attitudes inferred stronger negative river attitudes. The statements that made up the positive river attitude scale were primarily concerned with non-use values of water, such as the presence of wildlife but did also include two statements focussed on water as a resource. In contrast, the negative river attitude statements were predominantly concerned with impacts on humans, for example loss of agricultural land. As such, ecocentric viewpoints, that nature is valued for intrinsic qualities, are more closely aligned to the positive river statements. The negative river attitude statements, which include items that propose a conflict between river conservation and resource availability for human use, would most closely be aligned with anthropocentric viewpoints, namely valuing nature as a resource for human use.

Factors influencing both positive and negative river attitude were shown to be environmental viewpoint and local river attitude, suggesting a role for local river attitude in determining both positive and negative river attitude. Positive river attitude was additionally influenced by river affect; affect has previously been shown to be important in modulating attitudes and behaviours toward the environment (Kals *et al.* 1999; Pooley and O'Connor 2000; Fischer and van der Wal 2007) and this result suggests that positive emotions appear to increase positive river attitude but having no discernible effect on negative river attitude. This has consequences for environmental education programmes, particularly in urban areas since exposure to nature at an early age stimulates increased positive connections with nature which can lead to more positive attitudes as adults (Kals *et al*. 1999).

There is much evidence to suggest that there is a disparity between local and global environmental attitudes with evidence to suggest that global issues are too psychologically distant to evoke concern (Catton and Dunlap 1978) or that it is challenging to understand how global issues might be downscaled to affect the local environment (Uzzell 2000). However, local residents appear to be more concerned about their geographically local environments (Brody *et al*. 2004; Brody *et al*. 2005) and issues relating to these, for example water pollution. The results reported in this study suggest that in terms of local river attitudes, there is a synergy with these and general river and environmental attitude. Halpenny (2006) suggests that place-specific pro-environmental intentions could carry over into general pro-environmental intentions. It is also likely that because rivers are tangible components of our landscape, not an abstract concept such as climate change, concern for one's local river can be more easily projected onto rivers in general.

2. What impacts are perceived to be facing UK rivers and what affect is climate change perceived to have on rivers?

The climate change statements indicate that whilst climate change elicits relatively high levels of concern, the degree to which humans are responsible for this continues to be contested. Whitmarsh (2011) reported that levels of climate scepticism had remained largely unchanged in a comparison of statements used in surveys in 2003 and 2008, with the exception of the influence of humans on climate, which indicated that public belief in an anthropogenic cause of climate change is decreasing. Using the statement as those in Whitmarsh (2011) this study found conflicting evidence in connection with the publics' perception of climate change risk. Despite a large increase in fear of climate change, there was a corresponding increase in those who do not believe that climate change poses a real problem indicating that the publics' view of climate change has become increasingly polarised; belief in an anthropogenic cause of climate change has remained virtually unchanged from 2008 levels.

The perceptions of the magnitude of climate change impacts on UK rivers show that climate believers rate the impacts as larger than sceptics. These results show that sceptics not only doubt the anthropogenic cause of climate change but also downplay the size of the impact that climate change might have on rivers. This corroborates a large body of evidence that suggests risk levels are increased in persons who have a clear understanding of the influences and impact of pathways of a particular risk (McDaniels *et al.* 1995, 1996; McDaniels *et al.* 1997). It is impossible to generalise these findings and conclude that climate change sceptics will perceive the impacts from climate change to be reduced across all environments in comparison to climate change believers, but this is an avenue that should be further investigated. This difference in understanding of cause and effect between sceptics and believers is again apparent when specific impacts to rivers are assessed. Sceptics perceive climate change impacts to be beneficial to humans or at least not detrimental, or simply perceive there to be no impact at all. This is suggestive of some mechanism of motivated reasoning and possibly biased assimilation whereby information is discredited if is not congruent with the person's beliefs (Corner *et al.* 2012). In this case, evidence to suggest that the effects of climate change on humans would be detrimental would be discredited in favour of evidence that there would be no effect or possibly even a positive impact. Given that scepticism is a psychological defence mechanism, this result could be interpreted as the positive impact not being perceived as threatening. This also corresponds to the increased in levels of agreement with the climate change statement regarding impacts to humans, disused previously. The levels of agreement with some of the impact statements bear similarities to previous research; flooding has previously been shown to be one of the greatest effects of climate change (Whitmarsh 2008) and in this study the attribution of flooding to climate change garnered agreement from almost two-thirds of the respondents. In general the key impacts of climate change were seen as erosion and flooding: it is difficult to ascertain whether concern over these two is related to impacts on rivers or humans, or both.

Despite that lack of human responsibility attributed to climate change by over one-quarter of participants, the major risks to rivers as perceived by lay persons are all the result of human activities. Pollution was the greatest perceived impact of climate change on rivers, corroborating previous research that showed water pollution to be the second most concerning environmental impact of climate change (Whitmarsh 2008). This also corresponds to work by Patel *et al.* (1999) which found water quality to be among the main concerns in forest health. Human activities were also perceived as being detrimental to rivers, a theme that is consistent with result from the focus groups. That pollution is perceived as the biggest risk to rivers correlates with the high importance placed on aesthetics when preferences for mitigation measures were investigated. The sight of objects in a river that do not conform to a person's mental construct of what a river ought to look like will lessen the aesthetic value of the river. This is analogous to the work by Mary Douglas (1966) on pollution and the idea that dirt is out of place and puts at risk the perceived order of a person's environment.

3. *What factors contribute to lay-persons' attitudes towards aquatic species and habitats?*

Considering aquatic environments (beaches and seas, and rivers and lakes) as one, it can be seen that water plays a key role in the types of environments that the public considered to be the most important. Considered individually, rivers and lakes were consistently ranked as the second most important environment for conservation. The work by Kaplan and Kaplan focussed on visual aesthetics and showed the value placed on water in the landscape by lay-persons (Kaplan 1977; Kaplan 1979, 1982; Kaplan *et al.* 1989). However, no visual aids were given with this question and likely there were other aspects that played a role in the ranking. From a similar exercise conducted with participants in focus groups (Chapter four), there were a variety of reasons given for participants' choice, such as the sheer size of the coastline meaning that it would need relatively more money to conserve it. It is clear from the responses to the river attitude statements that there is strong appreciation for the range of species that rivers support, although less so for rare species, coupled with a high value of water both as a national and local resource. Correspondingly, there was also strong negative feeling associated with the loss of local river species; so overall, despite rivers and lakes not being the most often ranked as the most important for conservation, there appears to be a strong support for river conservation in the public's consciousness. This research also indicated a high level of value placed upon local rivers which supports previous research that indicates an attachment to local environment can predict the level of protection of that environment (Hunter and Rinner 2004), particularly in terms of resources (Brehm *et al.* 2006).

The majority of participants in this survey believed that they knew the name of their local river and most live relatively close to a river of some sort. Based on work by Brody *et al*. (2004; 2005), this would indicate an increased likelihood of at least some level of familiarity with rivers based on the premise that there is a relationship between distance and familiarity. Indeed, the relationship between river attitude and distance to closest river examined in this study does show a more positive attitude towards rivers the closer participants live to a river. However, this relationship was only significant between those who lived very close to the river (less than 1 mile) and those that didn't know the distance and not the linear relationship observed by Brody *et al*. (2004). Additionally, these results show that those people who live very close to a river will visit it much more often than any other distance category. This is likely because many everyday activities, such as walking the dog or their journey to work involve 'visiting' the river given its proximity to their home. Another consideration is that it is simply easier for individuals who do live very close to a river to be able to visit it.

Connections between familiarity and experience were further investigated using specific freshwater species. Relative species importance initially follows the model suggested by Czech and Kraussman (1999), with the mammal (the common otter) having the highest (i.e. most important) mean ranking. This is likely a combination of the high level of previous conservation work done to protect this species and its use as a flagship alongside its humanistic features and ability to evoke positive emotions (Knight 2008; Serpell 2004). However, the brown trout was the second most important, above the ruddy duck. In the model postulated by Czech and Kraussman (1999), it is mammals, bird and plants which are ranked as most important and these results represent a clear divergence from their results. However, it is possible that the economic value of the brown trout in the regions surveyed (particularly Scotland) have influenced its importance ranking. As predicted, both invertebrates were ranked as less important than the mammal, bird and fish species.

The inclusion of two non-native species (the ruddy duck and the Japanese knotweed) was done in order to distinguish whether the perception of importance was dependant on perceived provenance. Initially it appears that the names of the two non-native species may be at least in part the reason behind their importance ranking; the Japanese knotweed having a lowest mean rank of all six species, especially when previous findings show that plants are often ranked as more important than invertebrates that these result clearly show findings to the contrary. However, there has been a large amount of negative publicity of the Japanese knotweed, highlighted in press articles, with headlines such as 'Hertfordshire couple has to demolish 300 million home after it was invaded by Japanese knotweed' (Elliot 2011). This, alongside the numerous removal programs due to the environmental consequences of this invasive species, is also a contributing factor that meant that not only was the Japanese knotweed ranked as the least important it was also one of the more familiar species. In contrast, the ruddy duck, whilst being ranked as more important to conservation was less familiar. It is possible that the morphology of the ruddy duck drove perceptions of conservation importance as opposed to ecological knowledge or familiarity (Serpell 2004; Martín-López *et al*. 2007; Knight 2008).

In the six species used in this study, general environmental attitude alone played a lesser role in affecting conservation importance than posited by Hunter and Rinner (2004), who found that those with an ecocentric values felt species preservation was more important than those with anthropocentric values. In this study, only the importance of one species, the ruddy duck, showed a relationship with an ecocentric attitude. Neither measure of proximity to rivers (geographic distance or urban/rural location) showed a significant relationship with species importance either, which is likely to indicate that general distance to habitat is not necessarily a good indicator of the perceived conservation importance of specific species. In work done by Brody *et al*. (2004) distance was shown to be an indicator of conservation importance; however it was the importance of river habitats in general and not individual species.

Whilst general environmental attitude was not shown to be related to perceptions of importance of the FPM, living in an area with known populations of FPM was shown to increase the importance ranking of this species. It appears that whilst simply living near a river doesn't generally increase the perception of importance of species, living in an area known for a specific endangered species does. This indicate that there is role for alternative factors, such as specific species knowledge, perhaps as a result of active conservation management in the area, in influencing the perception of importance (Martín-López *et al*. 2007). For example, in the Balinderry catchment in Northern Ireland, and the Clun catchment in Shropshire, much work has been undertaken to engage the community in efforts conserve the FPM through hands-on projects, community meetings and work with local schools. This type of approach means that local residents will have a greater opportunity to learn about this species than those who do not live in the area. Additionally, the relative importance of other species was shown to play a role in determining perceptions of FPM importance: in this research, the relative importance of FPM is related to the importance of the common otter, Japanese knotweed and ruddy duck. This indicates that when laypersons are considering the conservation of multiple species, they were actively prioritising some species over others. A possible explanation is that one group based decisions on physical characteristics similar to those described in work by Serpell (2004) and Knight (2008); thus the common otter and ruddy duck were perceived as being more important to this group than the other group, who ranked the FPM as more important and consequently the importance of the common otter and ruddy duck were reduced. This change may be as a result of knowledge about the FPM through being resident in an area that holds populations of FPM, as discussed previously. Whilst these are only speculations as to the reasons behind this finding, this would corroborate work conducted by McFarland and Witson (2008), which found that knowledge and residency were the most consistent predictors of perceptions of risk from the invasive mountain pine beetle on national park ecosystems.

The results for species familiarity are similar to those related to species conservation importance: the mammal and fish species were perceived as more familiar and the invertebrates as less familiar. Little research has been undertaken to elicit differences in species familiarity between urban and rural residents, and of the six species used in this study, the Japanese knotweed is perhaps the one most likely to be found in a variety of habitats but was the only species whose levels of familiarity showed a relationship to urban/rural location. Therefore, the fact that rural residents are more likely to be aware of this species than urban residents, despite its prevalence in both locations is perhaps indicative of rural residents having a higher level of environmental knowledge and thus an ability to distinguish particular plant types.

Levels of familiarity of the FPM did differ with respect to residents in regions with current or historic population of FPMs. This indicates that the FPM is more familiar to those who live in an area where it is currently found: further confirming that the FPM is not as ubiquitously familiar as the common otter. Differences also existed in familiarity levels between the brown trout and the Japanese knotweed. In regions with FPM population, the brown trout was more familiar and the Japanese knotweed less familiar. This can be partially explained by the parasitic relationship between brown trout and FPMs that is necessary for the FPMs survival coupled with the economic importance of the brown trout in Scotland, the region which has current FPM populations in this study. The difference in familiarity for the Japanese knotweed showed that its familiarity increased in regions where FPMs are not found; in this study this was Wales. This correlates with UK regions where Japanese knotweed is a particular problem, for example Swansea. These result also showed that there was a greater familiarity of the FPM in respondents that know the distance to their local river compared to those that not, further indicating that distance to local river plays a role in the familiarity of less well known species, like the FPM. However, the effect size of these findings is small.

Urban and rural residents showed similar views on whether the species were native or not native to the UK, across all species except for the Japanese knotweed which was perceived as native almost twice as often by urban residents than by rural residents. This corroborates previous results discussed previously that showed urban residents to be less familiar with the Japanese knotweed than rural residents and supports the finding that familiarity is connected with species knowledge. The majority of respondents felt that the common otter was native, this proportion dropped to approximately half for the great diving beetle, a common freshwater invetebrate. This pattern mimics the trend in importance, with invertebrates not only being ranked as less important to conservation, but also more likely to be perceived as being non-native. Whether the importance ranking is affected by the perceived provenance is unclear in this study but is an avenue to further research given the implications on the support and consequently the conservation success of rare and endangered species such as the FPM.

Alongside previous results, it appears that distance to the nearest river does not explain differences in respondents' levels of knowledge about specific species. There is not a relationship between distance and species provenance for less familiar species. However, those respondents who lived in an area with FPM populations were almost twice as likely to think that the FPM was native than those who live in areas with historic FPM populations. As with the previous result for the familiarity of FPM, it appears that the local environment plays a role in what is familiar and what is native. What this result is unable to clarify is the source of this understanding: do people believe the FPM to be native, for example, as a result of oral histories of pearl fishing, or current localised conservation work to support the species?

The attitude statements concerned with the conservation of FPMs reveal a preference for conservation plans with multiple beneficiaries and further reinforce the importance of water a resource. Both values and knowledge (or more generally awareness) play a role in respondents' views about FPM conservation: anthropocentric individuals, viewing nature as utilitarian and resource focused, are more likely to believe that conservation should focus on aesthetically pleasing or familiar species, whereas respondents from current FPM areas are more likely to have heard of the FPM, value it more highly and thus elevate its conservation importance. The two scales that were derived from these statements also showed a relationship with participants' ranking of the importance of FPM, namely that individuals who ranked the FPM as higher in conservation importance also agreed with the statements relating to the benefits of conserving this species. The statements from which the scale was constructed were read after information was given to participants about why the conservation of FPM is important and who and what would benefit whereas the important ranking was done prior to this information being read. The results indicate that the knowledge given to participants did not create a universal opinion about the importance of FPMs, suggesting that the values held by respondents also play a role in their perception of importance.

When measures of knowledge about FPMs, familiarity of FPMs, general environmental values, river values and FPM attitudes were used to explain the relative importance attributed to FPMs it was the knowledge and familiarity measures alongside the local river attitude scale that explained the variance in importance ranks and not the general environmental or river value metrics. This indicates that species-specific knowledge plays an important role in the publics' perceptions of the conservation importance. This result show similarities with work done by Tisdell and Wilson (2006) who showed that after receiving species-specific information, participants gave more financial aid to those species who need it as opposed to the charismatic species who were more familiar. However this research does not show that it is solely knowledge that determines perceptions of conservation importance since local river attitude was also a significant variable within the regression analysis. Whilst this initially appears to show that general environmental attitudes and general river attitudes play no role in determining the importance of the FPM, it must be remembered that half the variance in local river attitude can be explained by these variables. It seems that in the case of rare species whose morphology make them less charismatic, knowledge plays a role that is as important as values when lay persons assess conservation importance. This has serious implications for organisations involved in the conservation of such species. In order to generate support it is vital to inform the public not only about the species in question but its relationship with other species within the same habitat and link the work to wider issues surrounding resource use or general habitat degradation.

Despite much research to the contrary (Bord and O'Connor 1997; Gustafsod 1998; O'Connor *et al*. 1999), this study did not show consistent effects of gender, voting intention or education on general environmental attitude, or attitude specifically towards rivers. The only values metric to show a relationship with highest qualification was negative river attitude; this indicated that those with a Bachelor's degree had a less negative river attitude that those with 'O' levels. With no further information as to what degrees were held by participants it is difficult to ascertain the reason behind this difference. Further, the effect size is small. However, levels of climate change scepticism were different, with women exhibiting higher concern than men, which has been reported in other studies (Whitmarsh 2011). Additionally climate change scepticism was shown to be greatest in Conservative voters, which is in line with previous studies (Whitmarsh 2011). This appears to indicate that the ideological biases that are behind the socio-demographic divisions in climate change attitude are not present in attitudes towards rivers. Particularly in the UK whose topography is criss-crossed with rivers and streams, rivers are almost ubiquitous within everyday life, irrespective of gender, voting intention or qualifications. Valuing rivers is not at odds with other social values and can be from both an ecocentric and utilitarian perspective. Nor does one have to have a level of formal education in order to appreciate rivers. Rivers are tangible entities through multiple senses, are unanimously valued (see Chapter four) and can be enjoyed as part of one's leisure activities, thus facilitating an emotional connection dependent only upon being able to be in close proximity to a river.

Differences between urban and rural residents with respect to environmental values, river attitudes and climate change scepticism were also examined. Given that there was no difference in distance to nearest river between urban and rural participants, it follows that these results also show no difference in general river attitude either. However, there was a difference in environmental values between the two urban residents exhibiting a slightly lower pro-ecological viewpoint than urban residents. With respect to local rivers, urban residents placed less value on local rivers than rural residents. This ties in with the higher pro-ecological viewpoint of rural residents also found in this study but is not in line with other research, which suggest that rural residents view nature through a more utilitarian lens (Tremblay and Dunlap 1977). Some studies have suggested a higher level of moral obligation to be responsible for the environment exhibited by rural residents; unrelated to rural residence or economic dependence on nature (Berenguer *et al*. 2005). Alternative views state that urban residents are more likely to have seen environmental degradation which may explain the lower value urban residents place on local rivers (Nassauer *et al.* 2001). However, this is normally used to explain urban residents' higher ecological values in comparison to rural residents, which has not been found in this study. These results reflect the concern for environmental change found in the DEFRA survey of environmental attitudes in 2007, where slightly fewer urban residents purported to be worried about changes to the countryside in the UK and to the loss of native species (DEFRA 2011). Additionally, research has also shown that views on restoration schemes differ between urban and rural residents: whilst urban residents assume the restoration measures are for their benefit, rural residents assume they were for the benefit of the environment, which adds support to findings of this study (Tunstall *et al.* 2000).

4. *Can knowledge influence the visual acceptability of mitigation measures for the freshwater pearl mussel?*

Aesthetics dominate the reasons behind the acceptability of mitigation measures to support the FPM. This is not surprising given the large volume of work conducted on landscape aesthetics and the factors which impact laypersons perceptions of landscape scenes. The most preferred choice, the re-planting river banks, included elements described in Kaplan and Kaplan's work (1979, 1982), for example nature, mystery and legibility and is similar to the types of scenes preferred by lay-person as documented by Piegay *et al*.(2005) and Wyzga *et al*.(2009). In contrast, respondents' choice of least acceptable measure was related to the economic and welfare implications of the measure and not the appearance (for example animal welfare and consequences to farming). This is particularly important when considering that popular methods to control sediment influx into rivers are to prevent livestock accessing the river by way of fencing. This method was amongst the least preferred under the misconception that it would be detrimental to the welfare of the livestock. This method is often cheaper and easier to implement than replanting river banks but indicates that this would not automatically garner public support. Alternative methods such as re-planting river banks, whilst more costly and time-consuming would create an environment which encourage the public to use, to engage with, thereby increasing a person's experiential contact with this environment, increasing levels of attachment and fostering more positive attitudes towards rivers (Kals *et al*. 1999; Pooley and O'Connor 2000).

Whilst there was a significant relationship between environmental viewpoint and mitigation measure acceptability, with ecocentric respondents rating each measure as more acceptable than anthropocentric respondent, two points emerge. The first is that the four most acceptable measures (the 'soft' mitigation options) remain in the same order of acceptability irrespective of environmental attitude; the second is that sediment fencing was universally unacceptable. These results further demonstrate the overriding influence of aesthetics in determining lay-persons' preference for mitigation measures, especially when considered in conjunction with the results showing a lack of relationship between environmental values and most and less acceptable mitigation measure. There appears to be an overwhelming consensus about what constitutes an attractive river scene. In essence, there is a preference for the soft mitigation options, those that do not appear to have been influenced by humans and retain a 'natural' appearance. Practically, these results mean that river restoration and conservation plans that are ecologically effective can also be socially acceptable. Measures such as livestock fencing or drinking bays that meet conservation priorities and agricultural needs will undoubtedly still be used, however these result highlight the need to raise public awareness about these to dispel the idea that animal welfare or agricultural productivity is being compromised.

The experimental component of this study showed that mitigation measure acceptability was not influenced by the sample text read. The range of other species and/or humans that might benefit from these measures did not influence participants' choice of most or least acceptable mitigation measure, or the acceptability of these measures in general. It is proposed, based on these results, that the aesthetic appeal of each photo dominated participants' decision-making process. However, the value-matching component did show that when the text read was 'matched' to the participants' environmental viewpoint: the acceptability of the four 'soft' mitigation measures was increased for those with ecocentric values. This indicates that the acceptability of preferred measure can be enhanced when the reasons behind them match the readers' environmental values; meanwhile the less acceptable measures do not change in terms of acceptability. This could be related to the reasons given for the lack of acceptability of these measures. The text read did not cover livestock welfare or agricultural production, two of the key reasons which participants used to explain their choices. These reasons contribute to both ecocentric values of the intangible importance of nature and to anthropocentric utilitarian values of nature and could explain the lack of effect of environmental viewpoint on acceptability, even when text read was matched to environmental values.

The positive sediment scale, which described attitudes towards the positive aspect of these sediment mitigation measure, for example, conservation and farming working together, showed that ecocentric individuals who had a positive attitude towards rivers in general and who had higher levels of river affect agreed more with the items that made up the positive sediment scale. This further demonstrates the role of values in lay person perceptions as regards conservation measures. The positive sediment scale is also correlated with both soft and hard mitigation measures: acceptability of even the least acceptable mitigation measure is greater in participants who agree with statements that extol the positive aspects of these sediment control measures.

5.5 Conclusions

Climate change is undoubtedly going to put pressure on freshwater systems, which are highly valued landscape features by the lay-person; some species may be more vulnerable than others as is the case with the FPM, a less familiar and un-charismatic native British species. Where it is possible to mitigate for any detrimental changes, care must be taken that the underlying social values are not disrupted. This research set out, firstly, to investigate lay-persons' attitudes toward rivers and how this connects to attitudes toward the environment in general and to specific risks for climate change; and secondly, to identify whether values or knowledge (or both) drive lay-person assessment of the importance of aquatic species and thirdly to ascertain whether perceptions of mitigation measures are dependent on the reason behind the need.

Concerning the contribution of values in shaping attitudes towards rivers, this research has shown that general environmental value and emotional affect to be significant predictors of both positive and negative attitudes towards rivers. Consequently the continued use of the information deficit model within the conservation sector in order to broadly engage the public with specific habitats that are under threat is not the most appropriate tool, particularly given that studies have shown that participants pick out messages that confirm opinions and discard those that do the opposite (Taber and Lodge 2006). Instead as has been seen in more recent times, a continued move towards encouraging people to have experiential contact with nature is likely to be more beneficial, since it can facilitate an affective connection with nature. This could be in the form of river clean up days, guided walks and open days, especially given the relationship identified within this study between environmental values, river attitudes and membership of conservation organisations. When focussing on specific species, then knowledge (alongside familiarity) was been shown to be important in lay-persons' assessment of species importance in the case of less charismatic species. In this case, targeted information which helps the lay-person to understand why this species is important, specifically explaining its role within the ecosystems and any contribution towards the health of other well-known species that would resonate with the reader.

A strong relationship was found between local river attitudes and general river attitudes, showing that concern for rivers at the local and general scale is strong. It is postulated that this relationship is in part due to the general importance of water in the landscape but that the commonality of rivers allows a carry-over affect as demonstrated by Halpenny (2006). Detrimental impacts on rivers are often highly sensory (for example unpleasant odours as a result of discharges into a river) and thus more tangible than the impacts of climate change which often show a disparity between local and global perceptions (Spence *et al*. 2011).

Climate change impacts on rivers appear to be poorly understood by lay-persons and in some case, climate sceptics are more likely to believe that climate change could have a positive impact on rivers than those who are less sceptical. It appears that climate sceptics, when forced to give a response, disagree with items that are attitudinally incongruent to their prior held beliefs about climate change (Taber and Lodge 2006). The agreement with those statements that propose positive effects of climate change indicates that perhaps the public divide over climate change is not only based on whether climate change is a reality and its anthropogenic cause, but also on the magnitude and directionality of perceived impacts. The impacts of climate change on rivers are focussed on those that have a potentially detrimental impact on humans, for example flooding; concern for erosion as a result of climate change was also high but it is unclear what underlying factors that drive this concern. However, given findings in the field of risk research (e.g. Slovic *et al*.(1984)), it is likely that this concern stems from the implications to human wellbeing and not environmental harm that underlies this. The consequence of climate scepticism on attitudes towards river conservation measures specifically to combat climate change related degradation indicates that climate scepticism leads to lower acceptability of such mitigation measures.

Both familiarity and importance are generally highest with mammal, bird and fish species likely as a result of their morphological characteristics and higher emotive appeal when compared to invertebrates and insect examples. This study also indicates that for the freshwater pearl mussel, a rare species, familiarity and relative importance are correlated, emphasising the role of experience in determining lay-persons' perceptions of species importance. Perceptions of the conservation importance of rare or unknown species, in this case the freshwater pearl mussel, have been shown within this research to be a combination of knowledge/awareness both of this species and other species within the same habitat and environmental values. This has implications for the management of species such as the freshwater pearl mussel, which shares space with more well-known and charismatic species such as the common otter.

Lay-persons' views of mitigation measures are dominated by aesthetic appeal, indicating a preference for a 'natural' look and one that is in keeping with the landscape. Mitigation measures that are perceived as natural are those which blend in and any human influence is effectively invisible, such as replanting river bank or riparian buffer strips. This preference is universal, irrespective of environmental values and demographic differences, unlike riverscapes preference work carried out previously (Piegay *et al*. 2005), although it must be noted that the work by Piegay *et al*.(2005) focussed on woody debris in rivers, a specific and contentious aspect of river habitats The soft options used in this study are therefore likely to reflect lay-persons' perceptions of how a river should look, which is a useful starting point from which river conservation work can proceed, especially in cases where what is natural and what is believed to be natural is not identical, as found by Wyzca *et al*. (2009) In contrast, reasons given for least acceptable mitigation measure focus on the implications that such measure may have on the agriculture sector, including animal welfare issues. Both livestock fencing and livestock drinks fall under this less acceptable category and both are measures routinely used in the control of river bank erosion. Given the prevalence of these and their lower acceptability, conservation organisations would be wise to highlight the reason behind their usage and dispel misconceptions about the detrimental effects on livestock where such measures are needed, especially in areas that are accessed by the public. The value-matching exercise in this study showed an effect of matching the message to individuals' underlying environmental views to preference of mitigation options (when mitigation measures were grouped as 'hard' versus 'soft'); but this only polarised the difference in preference between ecocentric and anthropocentric individuals. This is an approach that conservation organisation advertising rare or uny�charismatic species could utilise in order to more effectively increase positive opinions from those already engaged but would do little to bring in new supporters.

Little difference in environmental values or attitude towards rivers as a result of demographic differences was identified in this research. As with previous studies, women continue to be more concerned about climate change than men but this was the only attitudinal scale to show a difference based on gender or age. Urban and rural residents did show differences in environmental viewpoint and local river attitude but not in the direction anticipated. Instead of rural residents viewing the environment in a utilitarian manner as concluded by Tremblay and Dunlap (1977), these results show that rural resident have a more pro-ecological environmental value than urban residents and tend to value local rivers and local river species higher than urban residents. There was no difference in general river attitude between the two; however neither was there a difference in mean distance to river, indicating that urban residents are no more or less removed geographically than rural residents. Therefore, work to improve the condition of urban rivers would increase urban dwellers' experiential contact with nature, increasing emotional ties with a view to creating a more pro-ecological view alongside increased knowledge about riverine habitats. This would necessitate the creation or improvement of dedicated green spaces, for example Natural England's Free to Explore initiative, as a way to connect urban dwellers with nature. This would be of benefit to both river habitats and to the large proportion of the public that inhabit cities in the UK whilst also increasing resilience to flooding in urban areas which can affect large numbers of people.

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CHAPTER SIX:
A CONSERVATION STRATEGY FOR THE FRESHWATER PEARL MUSSEL: A CASE STUDY ON THE DEE CATCHMENT, SCOTLAND, UK[1]

The inclusion of human aspects in conservation planning is necessary because the success or failure of conservation policy is often determined by human behaviours; however, an integrated approach to catchment management has yet to be tested when the need is driven by population declines of an unfamiliar or un-charismatic species. With this in mind, this final chapter seeks to offer an approach to the conservation of the freshwater pearl mussel, taking into account both social and biological aspect of management. Building on work presented in Chapter 3 on erosion predictions for the period 2010-2039, a quantitative risk assessment is performed on FPM population in the river Dee, E. Scotland. Thereafter, using future scenarios of land management, the findings from Chapters 4 and 5 are used to choose the most suitable habitat management choices taking into account the socially acceptability of such methods within the context of different futures, thereby integrating both the natural science and the environmental psychology aspects of the three Chapters. The results indicate that future scenarios with greater proportions of forested land reduce the risk to FPM from excess sediment mobilization. Attitudes toward sediment control measures were found to be consistent across the UK and under all future scenarios; the public favoured natural scenes without obvious man-made structures. Mitigation options exist that allowed socially acceptable conservation priorities to be implemented in areas shown to be at-risk from the natural science findings. These results indicate that healthy river ecosystems from a biological standpoint are also aesthetically pleasing riverscapes from a lay-persons perspective.

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6.1 Background

River networks deliver a range of goods and services, such as the provision of fresh water, natural resources (such as food) and flood management (de Groot *et al.* 2002; Opperman *et al.* 2009; Arthington *et al.* 2010). Rivers are vital for health, while the continued economic prosperity of a region or country can be attributed to the presence of good quality freshwater in sufficient quantity (Chou *et al.* 1997). These same resources, and the organisms that provide them, are at risk from a wide range of pressures in their channels, catchments and flood plains. For example land drainage and agricultural intensification (i.e. the removal of hedgerows, increasing field sizes and channelling of rivers) have had devastating effects on river biodiversity but can also heighten flood risk from increased runoff rates and reduced permeability of the soil (Wheater and Evans 2009). Rivers are particularly vulnerable to climate change, and to the effects of altered temperature and discharge that will have ecological effects both directly and through interactions with existing stressors (Ormerod 2009).

In an attempt to conserve rivers, some of the most important aquatic habitats and species are the subject of legislation under the EC Habitats Directive which stipulates the conservation of both species and habitats of European importance (Council Directive 92/43/EEC). More generally, the concept of managing rivers holistically at the catchment scale has been gaining momentum and this change in approach to managing waterways that is now formalised through the EU Water Framework Directive (WFD) (Directive 2000/60/EC). The WFD became part of UK law in 2003 and aims to deliver a better aquatic environment with a focus on ecological status. Moreover, the WFD explicitly requires the inclusion of public consultation in order to guide and achieve the ecological objectives.

The consultative requirement in the WFD links to the broader need for civic scrutiny and stakeholder involvement in publically funded projects or state initiatives. This is particularly relevant since people have a great affinity for water in the landscape, not only for its functional values, but for more complex aesthetic and cultural values (Kaplan 1977; Shafer Jr and Brush 1977; Kaplan *et al.* 1989; Buijs 2009; Birckhead *et al.* 2011). Adapting conservation strategies to take into account the values attributed to rivers by a person or community can help to ensure the public support the proposed work and can improve project outcomes by the inclusion of local knowledge (Nassauer *et al.* 2001; Spink *et al.* 2010). In this sense, river restoration schemes have the potential to engage the local community with the natural environment, to increase levels of well-being and to foster an understanding of the importance of the goods and services that rivers provide. However, a positive outcome depends on obtaining agreement between expert and public opinion which can be challenging. Key reason behind the breakdown of the consultative process have been identified as trust in the facilitator and the process itself, and differing opinions as to the need and relevance of the proposed works (Wester-Herber 2004; Hovik *et al.* 2010).

In the UK, there are several examples where the combination of natural science and public consultation has been successful in managing rivers. In April 2006, the catchment sensitive farming programme, jointly run by DEFRA and Natural England was rolled out across England which aimed to reduce diffuse pollution of waterways from agricultural input and at the same time making farm business savings (Natural England 2014). In 2011, the Environment Agency launched a Catchment Based Approach in England the aim of which is to encourage great local participation in order to achieve benefits for both the waterways and their communities (Environment Agency 2014a). In Scotland, stakeholder engagement has long been seen as critical in managing the countries natural resources; Scottish Natural Heritage (SNH) and the Scottish Government use the ecosystem approach to encourage collaborative partnerships at local and national scales to better manage the environment (Mudge and Christie 2009; Aspinall *et al.* 2010). The catchment management plans for Scottish rivers for example the Dee in Aberdeenshire, are seen as a good example of this process (Aspinall *et al.* 2011). The common thread through all these examples is a recognition that successful schemes should create benefits for all concerned, be they ecosystem enhancement, savings of time or money for commercial enterprises or community benefits, such as recreational space. Across the UK, involving the local community in this way is seen as critical to sustainable solutions that meet societal needs as well as those that improve the physical habitat of the river (UK National Ecosystem Assessment 2011).

In conservation biology, the use of indicator species and umbrella species are used firstly to identify the need for remediation efforts and secondly to justify work to maintain the strict habitat requirement of such species as this indirectly protects the other species within the ecosystem. The freshwater pearl mussel (*Margaritifera margaritifera*) is a native British bivalve mollusc which is endangered throughout the whole of its Holarctic range. The FPM has been described as an indicator, umbrella, flagship and keystone species; where conditions are good for both adult and juvenile freshwater pearl mussels, many other river species benefit (Geist 2010). However, continued decline in rural water quality has placed more FPM populations under threat leading to reduced juveniles survival and reduced adult viability. FPMs are particularly vulnerable to the diffuse pollution of rivers by fine sediments, often as a result of catchment land management (Moorkens *et al.* 2007; Killeen 2009, 2013; Degerman n.d); the FPM has a life cycle comprising of four distinct stages, with increasing vulnerability to fine sediments from the adult to the glochidial life stage (Figure 6.1).

Freshwater pearl mussel juveniles are prone to suffocation as fine sediments block the interstitial pore spaces through which nutrients and oxygen diffuse(Skinner *et al.* 2003; Degerman n.d). Additionally, the FPM has a parasitic life stage, where it matures on the gills of salmonid fish for the first nine months of its life. Thus, salmon and trout populations are fundamental to the survival of the pearl mussel; such fish are also vulnerable to excess sedimentation which impairs oxygen availability to the developing salmon embryos (Greig *et al.* 2005).

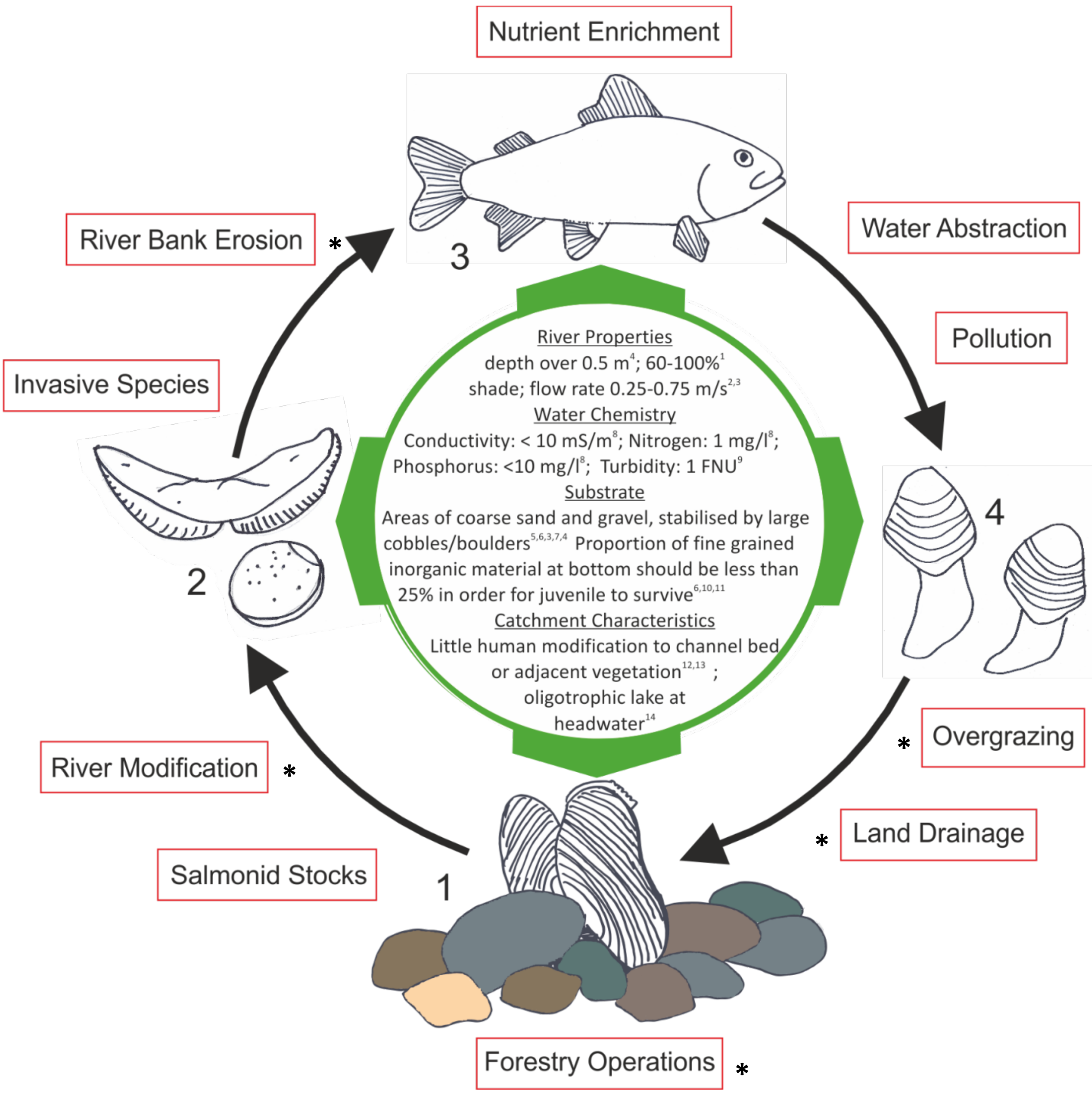

Figure 6.1: Life cycle of the freshwater pearl mussel, including habitat requirements and environmental impacts.
Female mussels (1) release larvae (glochidia) (2) which then need to attach to a salmonid host fish (3). After almost a year the glochidia drop off the host fish and burrow into the substrate (4). Juvenile mussels reach sexual maturity at approximately 10-15 years old. Items in central green circle are ideal freshwater pearl mussel habitat characteristic. Items in red boxes are detrimental impacts to freshwater pearl mussels (Moorkens 1999); those with * indicate impacts which are likely to directly increase fine sediment into the water.
[1](Hendelberg 1960)[2](Moog *et al.* 1993) [3](Björk 1962) [4](Hastie *et al.* 2000) [5](Degerman n.d) [6] (Söderberg 2008)[7] (Hastie and Boon 2001)[8](Geist and Auerswald 2007) [9](Hastie *et al.* 2003a) [10](Österling 2006) [11](Arbuckle and Downing 2002) [12](Brainwood *et al.* 2006) [13](Moorkens 1999)

At the catchment-scale, changes in land use are a significant cause of increased influx of fine sediments into rivers. Such changes include: cropping changes allowing soil to be exposed to the effects of precipitation for longer periods; the increasing mechanisation of agriculture which allow previously unsuitable land to be ploughed for arable use; hedgerows removed; land drained (Cebecauer and Hofierka 2008) and increasing stocking densities (McHugh 2007). At a local scale, the use of rivers to water livestock is often a source of serious bank erosion which can lead to local sedimentation (AONB Shropshire Hills 2011). At both the local and the catchment-scale, the consequences of increased sedimentation of rivers are detrimental to a range of aquatic organisms, including the FPM (Richards and Bacon 1994). Unlike point-source pollution which has an identifiable source, diffuse pollution is challenging to control, often necessitating changes to land use planning on a large-scale (Environment Agency 2014b). However there are societal impacts to altering and use, for example implication to food security. How willing the public is to support measures that curb sediment mobilisation for the benefit of a single species whose contribution to river health is unknown to many, has not been investigated

Current practical approaches to the conservation of the FPM focus on diffuse water pollution and ways that this can be prevented (Environment Agency 2014c; JNCC n.d.). For example, riparian buffer strips, in-field margins and sediment traps all prevent sediment reaching the river, along with any associated chemicals that have adsorbed onto the soil particles (DEFRA 2005, 2009). Using livestock fencing or cattle drinks to prevent or limit the accessibility of livestock to the river banks also prevents poaching and bank erosion (DEFRA 2005, 2009). However, such measures are reliant on funding sources and the permission from the landowner; in some cases, applications for funding have to be made by the landowner taking both time and effort. Re-wetting degrading upland regions by blocking drains can also prevent the movement of sediment into river channels and encourage wetland plants to recolonize the area (The Rivers Trust n.d.).

Whilst much of these measures provide benefits for river ecosystems as a whole, there are consequences for the landowner. Loss of agricultural land; increased water costs and the time and effort to implement these measures are some of the side effects that might foster resentment and lack of co-operation if the landowner is not fully supportive of the end results, particularly for the preservation of an uncharismatic and often unfamiliar species (AONB Shropshire Hills 2011). When such works are done on recreational land (i.e. not privately owned) or if there are public rights of access across privately owned land, then the perceptions of the public also play a role. Indeed, given the importance of green spaces to public health and well-being (UK National Ecosystem Assessment 2011), ensuring that conservation work meets the public values attached to riverscapes (Kaplan 1977; Buijs 2009) and that they continue to be of significance from the public perspective. Thus far, little research has demonstrated how this could be achieved, in practice.

When conservation objectives are focussed on the support of a specific species, local knowledge and values attributed to the species contribute to how important the project is deemed (Tisdell and Wilson 2006). Research suggests that humans place higher value on species that have human-like morphological characteristics, or those that are more familiar (Martín-López *et al.* 2007; Knight 2008). This has led to charismatic species spearheading conservation campaigns; the limited efforts of conservation authorities are often best focussed on umbrella species, such as the FPM, whose habitat requirements are shared with a range of other organisms. Yet, little research has shown how acceptable conservation work would be to the public, to support unfamiliar species, such as the FPM. This is particularly pertinent given the high values placed on rivers by the public; it is unclear if societal values can be maintained whilst improving the biodiversity within UK rivers.

6.1.1 Perceptions of rivers: A UK perspective

In keeping with previous literature about landscape preference, UK residents attribute high levels of value towards rivers; based on the results from Chapter four it was shown that the majority of participants had a positive attitude towards rivers (92.8%) and over half also had a positive emotive attitude towards rivers (58.3%). However, despite the overwhelmingly positive association with rivers, differences between stakeholder and lay-persons perceptions of rivers did exist (see Chapter 2), with the potential to cause conflict during any consultative process. However, these differences focus on the need for conservation and the risks to rivers. In general terms, across public and stakeholder groups, natural rivers scenes, for example those with vegetated banks were preferred, and such scenes were connected with pleasant images of the countryside and a positive association with wildlife accompanied a desire for rivers to return to a more pristine state. In contrast, river scenes with man-made elements, such as concrete banks, were perceived as less attractive places to visit.

Localness as a driver of river knowledge can explain differences in perceptions between lay-persons (who have limited understanding of rivers) and stakeholders (for example those who volunteer with their local rivers trust) who have a greater understanding of the societal needs fulfilled by rivers, such as the provision of potable water, "that river flows into Lough Neagh . . .40% of Northern Ireland get their drinking water from it, so 40% of Northern Ireland are dependent on that river and it being clean" (Chapter 2: FG5). Such differences have been documented in work by Tapsel *et al*. (1997) who found that the perceived beneficiary of river restoration projects to be different based on rural or urban residence. However, localness is not the only driver to impact river familiarity, many individuals have a level of familiarity with river which was independent of residential location, for example from childhood memories " I used to go and play down there [the river}" (Chapter 2: FG1), and this further explains the high level of importance generally placed on rivers in the landscape.

Pollution is often cited as one of the most concerning environmental threats and the questionnaire study in Chapter five showed that pollution was the most concerning threat to UK rivers, cited by 54% of respondents. Based on work by Douglas (1982), it is likely that the concern for pollution is based the negative impact the idea of pollution has on the mental construct more people have of an idyllic river scene, also highlighted by the perception of urban river being more polluted than rural ones. However, it was also recognised that rural rivers suffer from agricultural pollution; however, only 3% of respondents cited agriculture as a major impact on UK rivers (Chapter five).

Risks associated with a changing climate are not well understood and are focussed on increased flooding risk. Changes to habitat suitability or loss of biodiversity were not immediately associated with climate change; however, the prospect of reduction to wildlife numbers, when suggested as a consequence of climate change, was met with concern. Whilst the connection between biodiversity loss and climate change is not necessarily well defined within the public construct of climate change risk, high levels of concern for wildlife loss indicated a level of support for measures to prevent further declines. The role of experiential contact in determining attitudes was revealed; stakeholders (including those who regularly use rivers for recreational use e.g. fisherman) had a higher level of concern for the impact of climate change on rivers, based on their increased knowledge stemming for experience. Thus the importance of the public engagement process in determining levels of public support for conservation projects was revealed, particularly in the case of unfamiliar species such as the FPM.

6.1.2 Chapter Aims

This paper presents a novel methodological approach for the future planning of catchment-wide habitat management strategies to answer the question: *can river conservation meet both ecological and societal needs?* Figure 2.4 (Chapter 2) illustrates how integration across each of the respective disciplines in order to combine the distinct components into a cohesive strategy for FPM conservation.

The drivers behind the predicted changes to land use and underlying social pressures are derived from the UK National Ecosystem Assessment future scenarios and this novel approach to integrate catchment management has been trialled on the Dee catchment, Scotland using the example species of the freshwater pearl mussel, an endangered British bivalve mollusc which has very specific habitat requirements. The use of a less familiar species to drive the need for conservation action allows an evaluation of how species familiarity can impact the acceptability of management options.

This research attempts to i) identify any differences between Scottish perceptions of river habitats and those from the rest of the UK and then combines this data with future predictions of land use change and potential environmental consequences to FPM habitat to ii) provide recommendation of publically acceptable mitigation strategies that combat the predicted environmental changes.

6.2 Methodology

6.2.1 Study Site

The 140-km long River Dee drains 2100 km^2 of eastern Scotland into the North Sea at the Dee Estuary (Cooksley 2007; Baggaley *et al.* 2009) and supports 1.3 million freshwater pearl mussels. The river Dee is protected under the EU Habitats Directive as a Special Area of Conservation due its populations of freshwater pearl mussels (FPM), Atlantic salmon and otters. FPMs have been recorded along the entire length of the Dee, beginning 30km from the river's source in the Cairngorm National Park and extending to 6-7 km upstream of the river mouth in Aberdeen. Juvenile FPMs make up approximately 30% of the population, amongst the highest proportion recorded Scotland, indicating strong recruitment is taking place in the river Dee (Figure 6.2).

Most of the human population within this catchment, a total of approximately 220,000 people, live in Aberdeen at the mouth of the River Dee. The dominant land use within the Dee catchment is forest and moorland class (71.2%). Arable land makes up 7.9% of the catchment, and pasture and grassland comprise the remaining 17.5%, with sheep and dairy farming concentrated in the flatter lowlands (Fuller *et al.* 2002). The uplands of the Dee catchment have been identified as being particularly susceptible to erosion due to the prevalence of peaty soils (Towers *et al.* 2006). Erosion hotspots under baseline conditions have been identified in the upland areas of the Dee catchment, due to vulnerable soil typology, and in the NE quadrant of the catchment, as a result of arable land use in this area (see Chapter three).

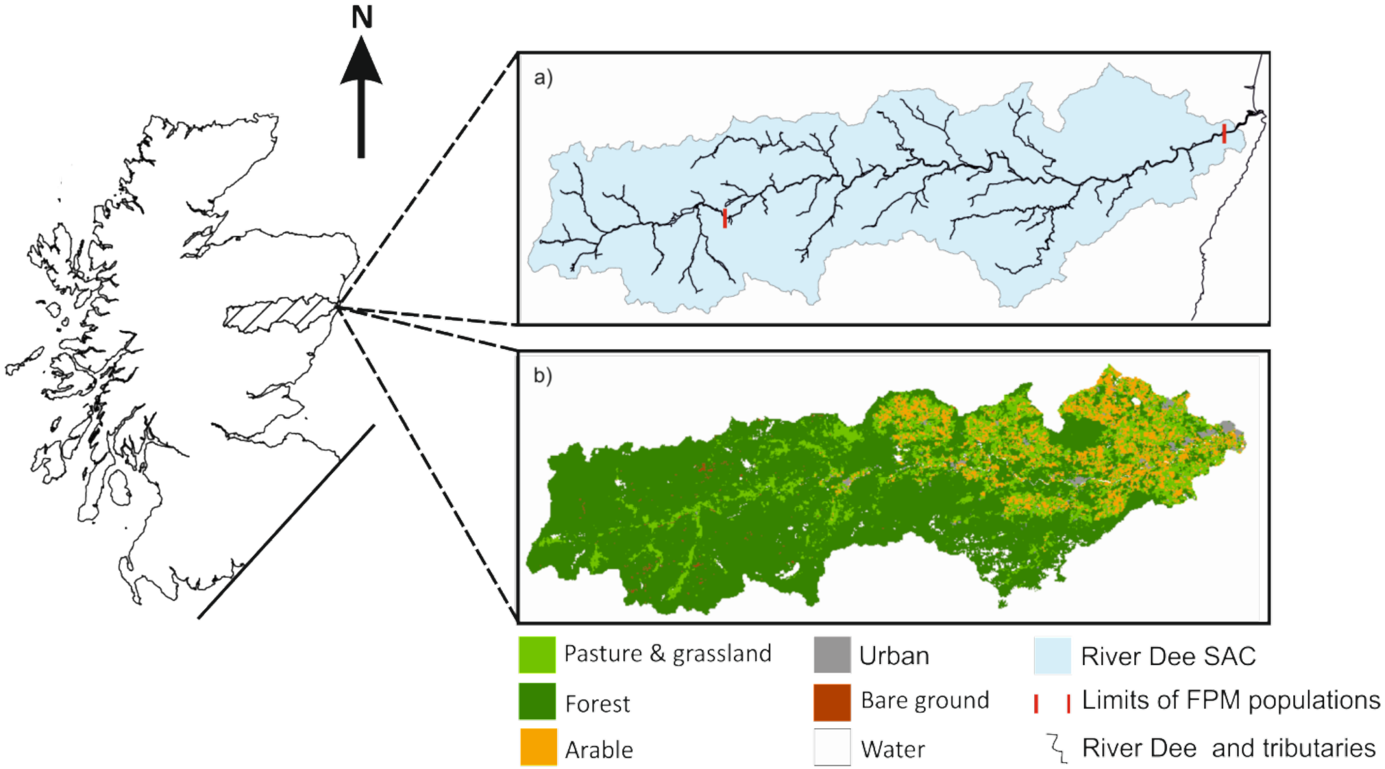

Figure 6.2: Map of the study area
Insert a) shows the Dee catchment and river system, with the extent of the FPM range shown. Insert b) shows the land use within the catchment.

6.2.2 Future Scenarios

The predictions for current and future erosion rates in the Dee catchment were produced using the erosion risk assessment model PESERA (Kirkby *et al.* 2008), developed to provide erosion risk assessments at the 1 km^2 European scale and adapted here for use at the 100 m^2 catchment-scale (see Chapter 3 for further details). Both the implication for erosion risk from land use change and climate change were modelled using the PESERA model. The economic and societal drivers of change to land management were provided by the UK National Ecosystem Assessment (UK National Ecosystem Assessment 2011).

Modelling limitations meant that only large scale land use change were modelled and as a result, two of the three erosion scenarios are aligned with more than one NEA scenario (Table 6.1). Land use data and soil characteristics were supplied by the James Hutton Research Institute, Aberdeen and baseline rainfall and temperature estimates were obtained from the British Atmospheric Data Centre, averaged across the period 1961 - 1990. Climate change predictions over the 2010 – 2039 time period were based on the UKCP09 predictions for the UK, under the medium emission scenario. For a full description of the model and data inputs, see Chapter 3: Determining changes to soil erosion by sheet wash in response to climate change across Great Britain.

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6.2.2.1 NEA Scenario 1: Go with the flow

Under the 'Go with the flow' NEA scenario (GWTF), current trends are continued with more awareness generally about environmental issues, which aligns well with the climate change only modelling scenario. GWTF leads to changes to land management to provide greater protection to freshwater systems and increase erosion control (i.e. cropping changes on agricultural land), incentivised by both the government and the agricultural industry. Land use change is limited to increased afforestation on floodplains and higher levels of afforestation on moorland and heathland. From a social perspective, there is a decline in connectivity with the countryside; whilst outdoor recreation still exists it is somewhat confined to National Parks since access is limited to private land.

6.2.2.2 NEA Scenario 2: Nature@Work and Green and Pleasant Land

Drivers behind the conversion of arable land to woodland share many similarities with two NEA scenarios: Green and Pleasant Land (G&PL) (i.e. reduction of arable land in favour of recreational space); and Nature@Work (N@W) (i.e. provision of services such as flood alleviation). Whilst both these scenarios are environmentally focussed the reasons behind such approaches are fundamentally different. G&PL stems from a preservationist approach, where the countryside is managed as a cultural space with a focus on aesthetic appeal. Consequently, there are boosts to the tourism and leisure sectors at the expense of the farming sector. N@W has a pragmatic approach and moves towards a multifunctional landscape with a utilitarian outlook to nature. Both schemes recognise the importance of erosion control albeit with differing *modus operandi*. G&PL uses agri-environment schemes to facilitate change whereas the changes to land management seen under N@W are as a result of farmers being remunerated for service provision as well as food production. In a social sense, G&PL has a greater sense of place and associated pride in the landscape than N@W although both scenarios lead to increased use of the countryside, for example through the promotion of walking as a healthy activity.

6.2.2.3 NEA Scenario 3: World Markets, National Security & Local Stewardship

Both the World Markets (WM) scenario and the National Security (NS) scenario envisage a UK where agriculture intensifies, albeit for differing reasons. Under NS, the UK becomes more self-sufficient in terms of fuel, food and fibre leading to a conversion from woodland to arable and grassland. The WM scenario sees a UK with fewer barriers to international trade; consequently upland areas are converted for use in agriculture and a decline in trees, standing vegetation and peat occurs as wood fuel is needed to counter burgeoning energy costs. In contrast, the Local Stewardship (LS) scenario is focused on localism leading to a greater heterogeneity in the landscape. As a result, farms diversify as the population becomes more dependent on local resources. Both the NS and LS scenarios see good erosion control because soil is seen as an important agricultural resource. However, under the WM scenario with increasing trade, erosion control is lax because increasing control means that UK-based food production is not as important as it is in the LS and NS scenarios. Despite such differences, the three scenarios have been combined because all three posit reason aligned to a change in land use, from woodland to grassland. Connection with the countryside declines under both the WM and NS scenarios; increasing private ownership of land under the WM scenario leads to decreasing opportunities for leisure activities and a loss of aesthetic appeal whereas under the NS scenario, in regions where the environment has been maintained, people continue to visit and enjoy them. The LS scenario has the greatest opportunity for recreation and leisure use of the countryside and these are localised with a high sense of pride in the local area.

6.2.3 Public Perceptions

Between July and August 2012, a nationally representative online survey was administered to 542 participants across Wales, as a country with few viable freshwater pearl mussel (FPM) populations, and Scotland, as the last stronghold of the FPM in the UK. The survey aimed to assess the values attributed to river ecosystems by the public and to identify reasons behind preferences of mitigation measures which might be needed to conserve the FPM. Within the survey, participants were asked to rank mitigation measures according to acceptability, and to give reasons as to their choice of most or least acceptable mitigation measure (Figure 6.3).

6.2.4 Data Analysis

Comparison of Welsh and Scottish sub samples were achieved using univariate statistical approaches within SPSS v16. Analysis of Variance (ANOVA) was used to detect statistically significant difference between sample populations. Homogeneity of variance was tested for using the Levene's statistics and in the case of violations, Welch's F statistic was used in place of the ANOVA statistic.

6.2.5 Freshwater Pearl Mussel Risk Assessment

FPM population data for the Dee catchment, Scotland from 2002 was obtained under license from Scottish Natural Heritage (SNH). Due to licensing restrictions, spatially locating the exact locations of the populations was not permitted. Therefore a risk analysis approach was undertaken, using six populations which numbered greater than 50 individuals (classed as 'A' and 'B' in SNH survey records). The PESERA erosion maps used were aggregated to 1 km^2 grid resolution and the distance between each population and the centre of each 1 km^2 grid square upstream of the population was calculated using ArcMap v10. The risk value for each grid square was calculated as:

$$\text{Erosion rate} * (1 / \text{distance}) \quad (1)$$

For each population, the sum of all the upstream grid square risk values was averaged, to give a single risk value for each population.

Arable Drainage Ditches
To allow soil to settle before water is returned to the river

source: anon

In-Field Margins
To trap soil before it reaches the river

source: www.ag.iastate.edu

River Bank Tree Buffer Strips
To trap soil before it enters the river

source: www.buffer.forestry.iastate.edu

Sediment Fencing
To trap soil before it reaches the river

source: www.thebeatnews.org

Re-planting River Banks
Reduces soil input by trapping it and by reducing bank erosion

source: River Restoration Centre

Reduced Field Sizes
Reduces soil input by trapping in in hedges and promotes use of smaller machinery

source: anon

Livestock Drinking Bays
Limiting livestock access to the river reduces bank erosion (poaching) caused by high livestock numbers

source: http://adlib.everysite.co.uk

Livestock Fencing
Limiting livestock access to the river reduces erosion caused by high numbers of livestock walking along the banks

source: Author's Image, Courtesy of Shrophire AONB

Figure 6.3: Images of mitigation measures for sediment control used in the online survey.
Images and accompanying text for the question 'Please rank the following sediment control measures in terms of how acceptable you find these images' scored from 1 (completely unacceptable) to 5 (completely acceptable). Images also used for follow up questions 'Which option did you feel was the most acceptable?' and 'Which option did you feel was the least acceptable?'

6.3 Results

6.3.1 Perceptions of Scottish residents

When compared to the rest of the sample, Scottish residents showed similar opinions about the value of local rivers, the acceptability of specific mitigation measures and the perceived advantages and disadvantages of these approaches. Across the UK, rivers were valued highly, both as a general landscape feature and as a more localised element, with no difference observed between Scottish residents and the rest of the sample population in terms of the value placed on local rivers ($F(1, 477) = 1.181$, *ns*) or in the attitudes measured by the positive river attitude scale ($F(1, 471) = 1.259$, *ns*). Almost three-quarters (74.9%) of participants placed high importance on the presence of local rivers and the majority of participants had a positive attitude towards rivers (92.8%).

Scottish residents showed the same level of climate scepticism as the rest of the sample population ($F (1, 476) = .030$, *ns*), almost one-third of participants (30.8%) exhibited high levels of climate change scepticism. When questioned about possible climate change risk to rivers, Scottish resident shared similar concerns to the rest of the sample population (negative impacts $F (1, 479) = .015$, *ns* and positive impacts $F (1, 479) = .076$, *ns*). The result indicated that flooding was the most concerning risk, with 63.8% of participants purporting concern about increased flooding; in comparison to the risk of reduction in river biodiversity to which only 39% of participants were concerned with.

When levels of familiarity of the freshwater pearl mussel were examined, Scottish residents were more familiar with the FPM than the rest of the sample (Welch's F (1, 480.985 = 5.024, $p = 0.028$), likely a result of the fact that Scotland holds the last remaining healthy populations of FPMs in the UK. Furthermore, during qualitative discussions, residents local to a FPM river showed a higher level of familiarity with the species when compared to people from an area without FPM. However, when general attitude towards the conservation of the

FPM were examined, Scottish residents were not any more supportive of the conservation of this species than the other participants (multiple beneficiaries scale F (1, 475) = .141, *ns* and negative attitude to FPM conservation scale F (1, 482) = .593) *ns*).

The acceptability of mitigation measures that could be used to support the conservation of the FPM did not differ between Scottish residents and the rest of the sample (Figure 6.4). Mitigation measures that encompassed natural looking scenes, such as re-planting river banks were greatly preferred over options which include man-made elements such as fencing; the most preferred options were arable drainage ditches; re-planting river banks and in-field margins whereas the least favourite options were reduced field sizes, sediment fencing and livestock fencing. Comments regarding the re-planting river bank option included “would encourage wildlife” and “seems the most natural”, compared with comments such as “looks awful, spoils the landscape” in response to livestock drinking bays. In addition, familiar measures, such as arable drainage ditches were preferred over options which were perceived having a detrimental impact on farming and food production. Comment such as “ seems the easiest and least maintenance needed” and “they are not new to us anyway” explained participants choice of arable drainage ditches, whereas comments regarding reduced field sizes indicated the high level of concern participants had about the consequences of this option, for example “negative effect on food production” and “this will impact farming”.

6.3.2 Future Scenarios for Soil Erosion

Table 6.1 provides a summary of the climatic and land use impacts on erosion rates in the Dee catchment, under the three land use scenarios modelled, and provides a comparison of the different scenario characteristics and how these have been manipulated.

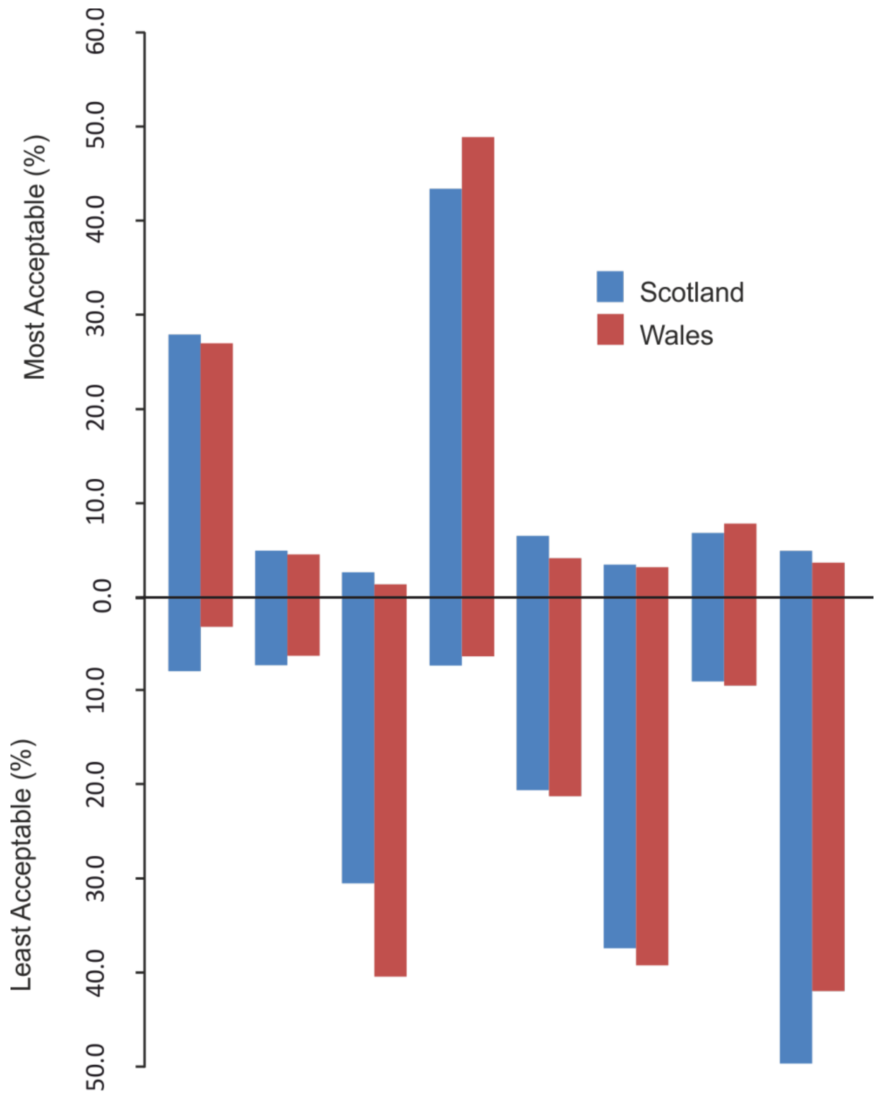

Figure 6.4: Comparison between Scottish and Welsh attitudes to eight sediment control measures
Participants were asked how acceptable the eight sediment control measures were, using a Likert scale of 1 (least acceptable) to 5 (most acceptable). Independent t-tests showed there to be no significant difference between Welsh and Scottish respondent's in terms of the acceptability of the eight sediment control measures[2]. Participants were then asked to choose which measure was the least and most acceptable (shown by the bar graph)
ADD = Arable Drainage Ditches; IFM = In-field Margins; SF = Sediment Fencing; RRB = re-planting river banks; LDB = Livestock Drinking Bay; LF = Livestock Fencing; TBS = Tree Buffer Strips; RFS = Reduced Field Sizes

[2] Independent t-tests - ADD: $F(1,478) = 2.348$, ns; IFM: $F(1,481) = .544$, ns; SF: $F(1,477) = 1.183$, ns; RRB: $F(1,475) = .970$, ns; LDB: $F(1,476) = 1.117$, ns; LF: $F(1,480) = .283$, ns; TBS: $F(1,478) = 3.281$, ns; RFS: $F(1,478) =$
1.536, ns

	NEA Scenario	Land Use Change	Major Land Use Proportion	Median Catchment Erosion Rate	Hotspot Erosion Rates
Baseline	n/a	n/a	71% Woodland 8% Arable 17% Grassland/Pasture	0.20 ± 0.1 t $ha^{-1}a^{-1}$	D1: up to 10 t $ha^{-1}a^{1}$ D2: up to 20 t $ha^{-1}a^{-1}$
Scenario 1	Go With the Flow (GWTF)	No change	71% Woodland 8% Arable 17% Grassland/Pasture	0.19 ± 0.13 t $ha^{-1}a^{-1}$	D1: 2-5 t $ha^{-1}a^{-1}$ D2: 10-20 t $ha^{-1}a^{-1}$
Scenario 2	Green and Pleasant Land (GPL) & Nature@Work (N@W)	Arable land converted to woodland	79% Woodland 17% Pasture/Grassland	0.18 ± 0.11 t $ha^{-1}a^{-1}$	D1: 0.05 – 1 t $ha^{-1}a^{1}$ D2: 10-20 t $ha^{-1}a^{-1}$
Scenario 3	World Markets (WM); National Security (NS) & Local Stewardship (LS)	Woodland converted to grassland/pastures	8% Arable 88% Pasture/Grassland	0.20 ± 0.11 t $ha^{-1}a^{-1}$	D1: 2-5 t $ha^{-1}a^{-1}$ D2: 10-20 t $ha^{-1}a^{-1}$

Table 6.1: Comparison of the three future scenarios used to model erosion change for the Dee catchment, Scotland

Catchment erosion rates are taken from the PESERA modelling predictions with climate data taken from UKCP09 predictions from the medium emission scenario. Baseline conditions were modelled using 1961-1990 climate conditions (see Chapter 3). Hotspot D1 is located at the mouth of the Dee in an area of arable land on flatter topography. In comparison, hotspot D2 in the upland portion of the catchment, in woodland, with steep topography.

6.3.2.1 Scenario 1: Go with the flow (GWTF)

The increase in erosion rate from the baseline to the medium climate change scenario in the Dee catchment was statistically significant (Wilcoxen Matched Pairs test: z = -13.28, p<0.05) (Figure 6.5, insert a.). For Hotspot D1, situated at the mouth of the catchment, where the dominant land use is arable, erosion rates were predicted to be 2-5 t $ha^{-1}a^{-1}$ under the medium climate change scenario. In comparison, in the upland portion of the catchment with steeper topography, the majority of hotspot D2 was predicted to erode at a rate of 10-20 t $ha^{-1}a^{-1}$, under the same scenario.

6.3.2.2 Scenario 2: Nature@work (N@W) and Green and Pleasant Land (GPL)

Conversion of the arable land within the Dee catchment to woodland resulted in an 8% increase of woodland land type. Again, the erosion rates predicted under this scenario were significantly different to the baseline (Wilcoxen Matched Pairs test: -129.40, p<0.05). Hotspot D1, originally on arable land, showed a marked decrease which drove a drop in total catchment erosion rate (Figure 6.5, insert b.). Hotspot D2 showed little change because the land use in this region remains unaltered under this scenario.

6.3.2.3 Scenario 3: National Security (NS); World Markets (WM) and Local Stewardship (LS)

The conversion of woodland area to grassland had little impact on median erosion rates, either at the catchment level or at individual hotspots (Figure 6.5, insert c.). However, as with the previous scenarios, there was a significant difference between the erosion rates predicted in this scenario when compared to the baseline (Wilcoxen Matched Pairs test: Dee z = -74.43, p<0.05). The lack of change in median erosion rates reflected the continued year-round cover achieved under both woodland and grassland land use types; however, changes to how the land is used as a result of this scenario could still increase the catchment vulnerability to erosion.

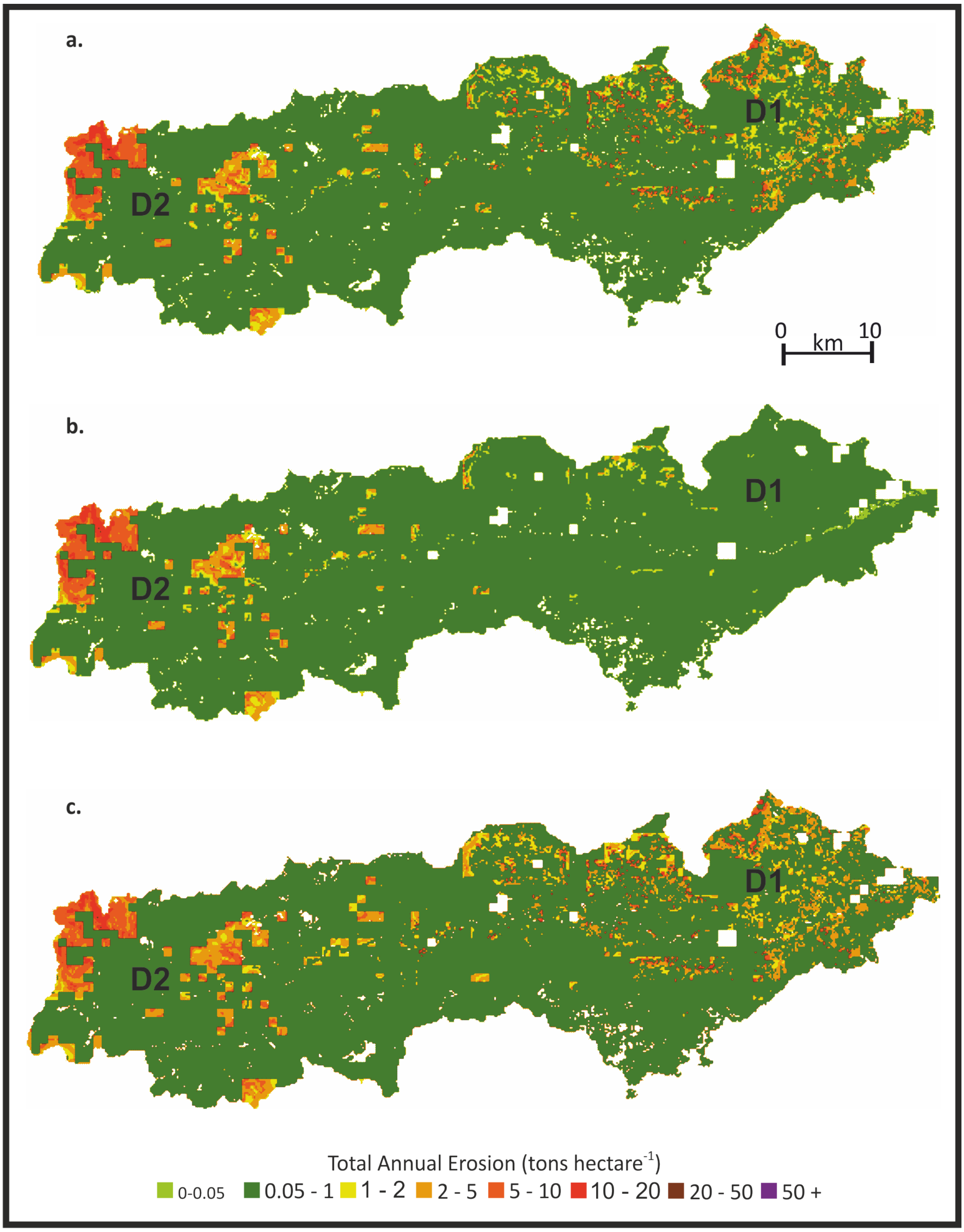

Figure 6.5: Erosion predictions of the Dee catchment, Scotland, under three future scenarios
a) Climate change only (NEA Go With the Flow); b) Climate Change and all arable land converted to woodland (NEA Nature@Work and Green and Pleasant Land), and c) Climate Change and all woodland converted to grassland (NEA World Markets; Local Sustainability and National Security)

6.3.3 Erosion Risks to Freshwater Pearl Mussels

An assessment of the risk to freshwater pearl mussels (FPM) within the Dee catchment from terrestrial erosion showed that all populations had a trend of increasing risk from the mouth to the headwaters of the Dee river (Figure 6.6), as a result of increasing proximity to the largest erosion hotspots found at the western part of the catchment (Figure 6.5).

In scenario 2, where all arable land was converted to woodland, the risk to all FPM population was much reduced in comparison to all other scenarios. The populations nearest the mouth of the Dee showed a slightly lowered risk under baseline conditions in comparison to both the climate change only (scenario 1) and the land use conversion of woodland to grassland (scenario 3). This is reflects the small increase to precipitation levels predicted under the UKCP09 climate prediction used in this research. The greatest risk to FPM population was shown under scenario 3, where all forest was converted to pasture; despite grass providing year-round cover it is likely that this land cover does not provide as much protection as forest, particularly in the regions of extremely steep topography found in the headwaters of the catchment.

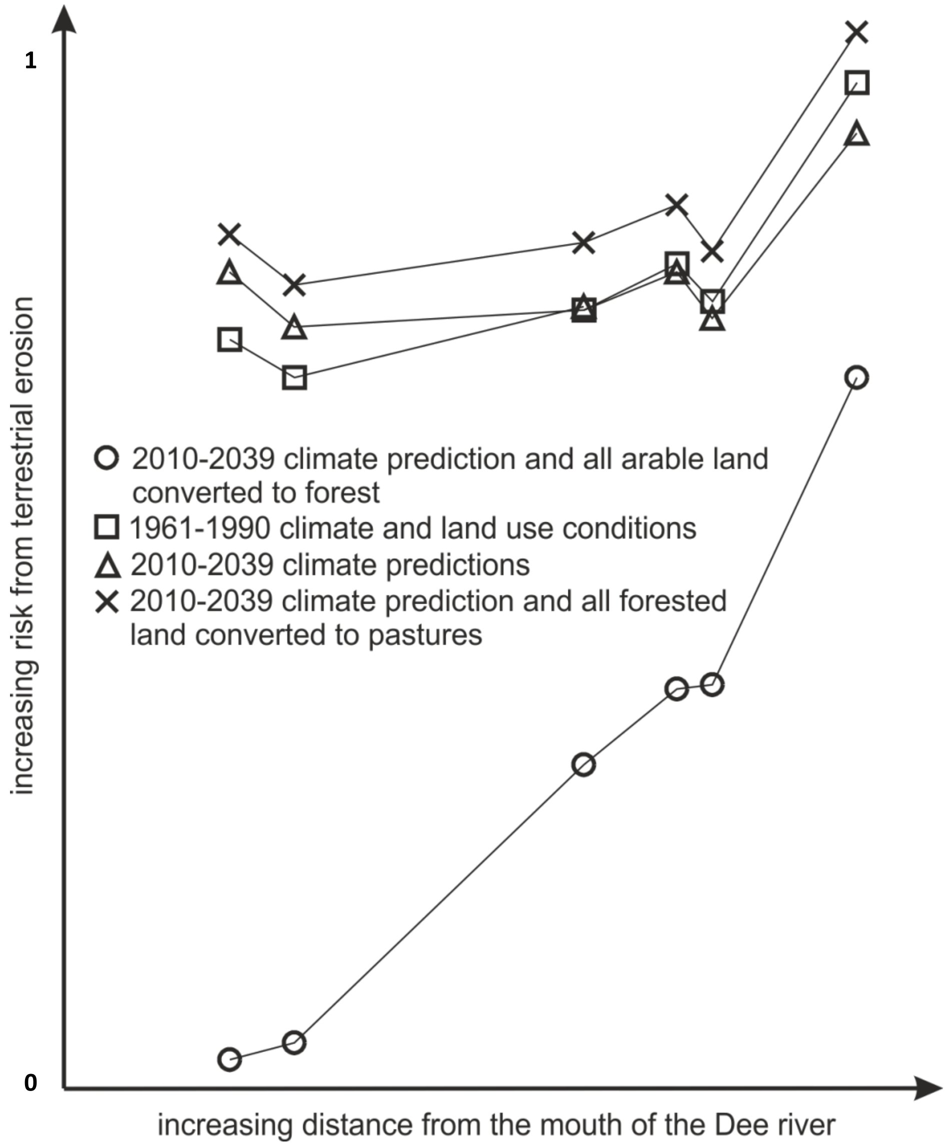

Figure 6.6: Assessment of risks to FPM populations in the Dee catchment, Scotland as a result of terrestrial erosion rates

Populations of FPM in the Dee catchment show increasing risk from terrestrial erosion rates in direct proportion to how close they are found to the river's headwaters. Baseline erosion rates are based on 1961-1990 climate data.

Due to the license restrictions imposed by SNH on data relating to the locations of FPM populations in the Dee catchment, distances from the mouth of the Dee river are shown without units, but are correct relative to the each of the six population depicted.

6.3.4 Catchment Management Options

The use of future scenarios such as those produced by the NEA scenarios offers the opportunity to suggest a variety of catchment management plans for the river Dee with aim to both maintain good ecological status for the FPM (by preventing excess sediment influx from terrestrial sources) whilst at the same time choosing options that are preferred by the public which could also have secondary benefits such as flood risk reduction. The habitat requirements of the FPM appear have a high level of congruence with the public's concept of how a river should look (Table 6.2). For example, good FPM habitat includes tree-lined banks to provide temperature mediation through shading, and the public perceive vegetated river banks as natural and consequently prefer these to bare river banks. Whilst it is acknowledged that aesthetics are not the only social dimension to affect how the lay person values rivers, the results reported here indicate that much emphasis is placed on aesthetics when the public decide which mitigation option is most and least acceptable. The ecological components that provide the elements of shading, for example, create a natural looking river scene from the public's perspective. The presence of wildlife is a positive component of a river scene for the lay-person, again accentuating the perception of naturalness; whilst this does not necessarily create a good habitat for the FPM, it is a consequence of a healthy FPM given its status as an indicator species. There are, however, elements of landscape aesthetics such as mystery (i.e. seeing glimpses of the water) and legibility (being able to find a way through the landscape) as defined by Kaplan *et al*. (1989), which do not resonate with the ecological needs of the FPM. Such elements would be overlooked by restoration work focussed solely on improvements for the FPM alone, but could easily be included, incorporating societal preferences alongside conservation outcomes. The following scenarios demonstrate how this could be achieved under different futures, identifying options which meet both socio-economic and ecological needs (Figure 6.7).

Indicators of good FPM habitat	Socially Acceptable Riverscapes	Criteria
No modification of river channel or banks (Arbuckle and Downing 2002; Brainwood *et al*. 2006)	Meandering river channels (Kaplan, 1977, 1970; Chapter four)	Meandering channels invite exploration and include an air of mystery for the on-looker
River bed comprised of cobbles and boulders (Hendelberg 1960; Hastie *et al*. 2000; Hastie and Boon 2001; Hastie *et al.* 2003b; Geist and Auerswald 2007)	In-stream boulder can accentuate the noise and light associated with rivers (Chapter four).	The noise of water over rocks and the effect of sunlight on the water given as positive associations with riverscapes.
Other sediment-intolerant aquatic species (e.g. Trichoptera sp.) would indicate that conditions might be suitable for FPM	Presence of wildlife (Chapter four)	Encourages recreational use of rivers both for wildlife watching and pursuits such as fishing which depend on river species.
Vegetation to give 60-100% shading to water surface (Moog *et al*. 1993)	Vegetation that allows glimpse of water (Kaplan, 1977; Kaplan *et al*. 1989; Chapter four)	Being able to see the water is important as water in the landscape is highly valued but only being able to see part of the river encourages exploration.
Low levels of nutrient enrichment or aquatic vegetation (Bauer 1986, 1992; Valovirta 1998)	Clean, clear water; low levels of aquatic vegetation (Chapter four)	Aquatic vegetation is seen as clogging up rivers, making them appear less healthy.
Little or no fine sediment in or on river bed (Arbuckle and Downing, 2002; Buddensiek, 1995)	Clean, clear waters (Chapter four)	Clear waters indicate clean rivers, free from pollution.
Vegetation to give 60-100% shading to water surface (Moog *et al*. 1993)	Reasonable level of accessibility (Kaplan and Kaplan, 1970; Chapter four)	Reduced accessibility is a barrier to all river users.
Surrounding land not modified by humans; undisturbed vegetation (Cosgrove and Hastie, 2001; Young and Williams, 1983)	Little human-made infrastructure along river banks (Chapter four)	Desire for river to be natural, strongly associated with being free from pollution

Table 6.2: Comparison of the ecological habitat requirements for the FPM and components of riverscapes that make socially acceptable, from the public perspective.

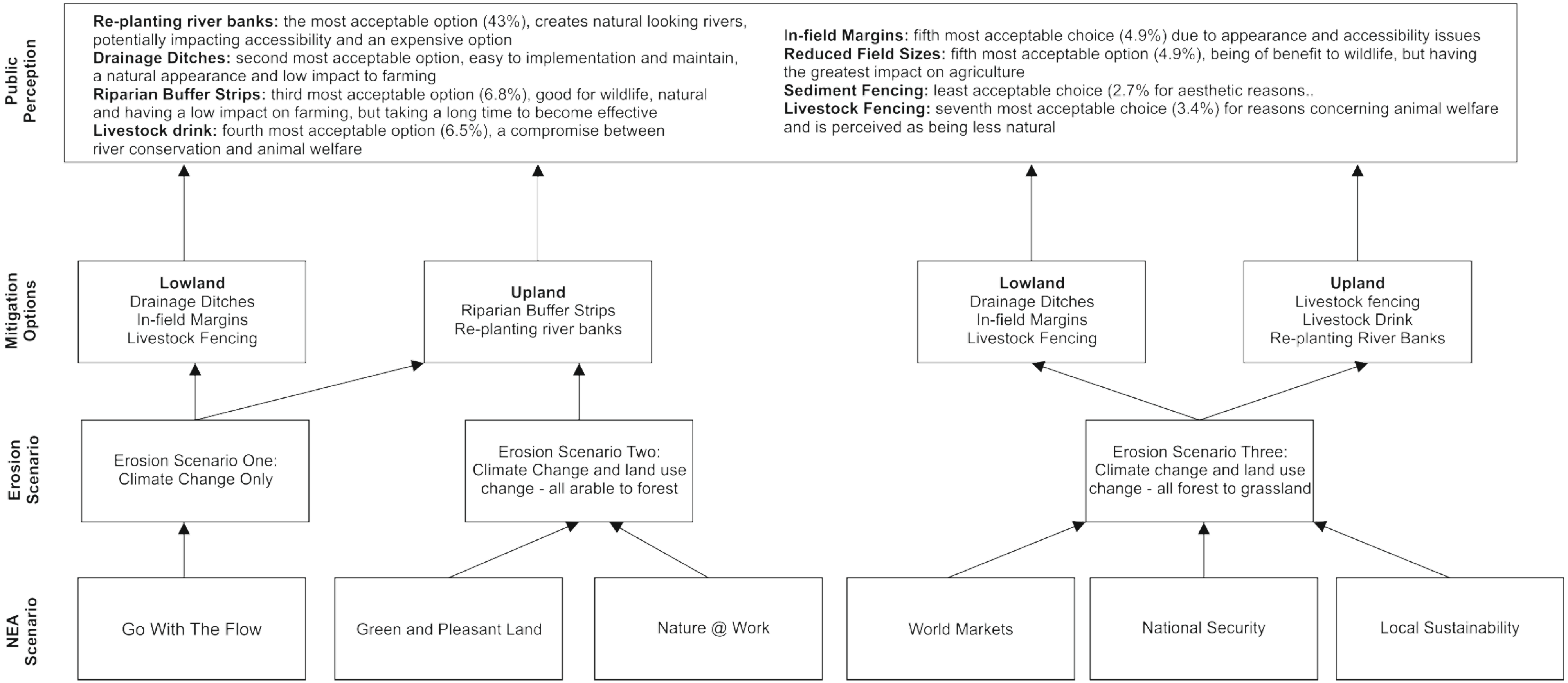

Figure 6.7: Flow chart illustrating the connectivity between impacts, mitigation options and public preference in relation to conservation options of the FPM.

6.3.4.1 Scenario 1 – Go with the flow (GWTF)

Management options on agricultural land under the GWTF scenario would be driven by the provisions from agri-environment schemes, given the emphasis on erosion control. In conjunction with the limited public access on private land, public preference is unlikely to play an important role in the choice of mitigation option. From the focus groups presented in Chapter four, factors such as cost and ease of implementation and maintenance were believed to influence the choices made by farmers given that farming is a business. Additionally, it was believed that subsidies, such as the use of agri-environment scheme to fund such work, would help to encourage uptake by the farming community.

Additional issues such as flood alleviation will also be relevant in this scenario, given the economic impact of flooded agricultural land. Example options include in-field margins or drainage ditches (on arable land) and fencing (on grazed land). Public acceptability of drainage ditches was high (drainage ditches were the second most favoured option by lay-persons; Figure 6.4) because of the perceived ease of use and familiarity. Despite not basing the choice of mitigation option on any societal preference, public acceptability could still be included in such decisions, especially given the concern voiced by many during the focus groups (Chapter four) about the consequences of losing agricultural land used for crop production. Moreover, focus group participants from agricultural areas expressed high levels of place attachment to agricultural scenes.

In areas where public access is permitted, adapting the fencing option to allow re-planting along the river bank would increase the appeal of this option as well as providing a better habitat for the FPM through the provision of shade. It was mentioned by focus group participants that fencing alone was unnatural, but that if natural vegetation were allowed to grow in between the fence the river banks, the fencing option would be more acceptable. The fencing option was amongst the least favoured (Figure 6.4), but by using it in conjunction with re-planting the river banks, thereby increasing the aesthetic appeal, the public would be encouraged to spend leisure time in the countryside by providing an aesthetically pleasing environment.

In the upland regions of this catchment, the hotpots were found in areas of high topographic relief with year-round cover which is as effective at reducing erosion as most of the proposed mitigation options. However, the proposed afforestation of moorland and heathland in this region would likely lead to the re-introduction of Caledonian forest. This type of mixed-woodland was much preferred in the public's eye, compared with coniferous plantations, which were perceived to have detrimental effects on biodiversity alongside a wider distrust of the management approaches on commercial forestry land. In addition, such a heterogeneous landscape was viewed as natural by many focus group participants and contains many components that enhance appreciation, such as mystery and legibility (Shafer and Brush 1977; Kaplan *et al*. 1989). From an ecological standpoint, mixed-woodland provides a buffer from sediment influx, nutrients and provides temperature control via shading, all of which increase habitat suitability for the FPM.

6.3.4.2 Scenario 2: Nature@work(N@W) and Green and Pleasant Land.(GPL)

Under the arable to forest scenario, the need for management options in former agricultural areas is much reduced. Such a change in land use would create greater areas of the landscape that are preferred by the public at the same time as being more suitable for the FPM. As aimed for in the GPL scenario, this would create more opportunities for the public to use the countryside as a recreational resource, whilst at the same time enhancing habitat for the FPM. The N@W scenario focusses on ecosystems services and the conservation of the FPM, an indicator species for river health, is well suited to this approach. In keeping with the N@W ideal, new woodland is likely to be a resource as well as helping to achieve ecological goals; to maintain ecosystems services and provide a sustainable source of fuel, coppiced woodland would be an appropriate choice. This would also allow the formation of vista's enabling a person traversing this landscape to glimpse at the river (Kaplan *et al*. 1989); an impeded view is a concern when riparian woodland is re-introduced and explained why re-planting riverbanks is preferred over riparian buffer strips (Figure 6.4).

Much like scenario 1, woodland areas continue to contain erosion hotspots but management options, designed to limit sediment movement, are limited since such areas are already under permanent year-round cover. Conversion to Caledonian forest (as is currently under consideration for the Scottish Highlands) would provide alternative recreational opportunities, which would also be of benefit to local communities through increased job and recreation opportunities.

However, this could be at the expense of swathes moorland and heathland which already provide some measure of flood protection and have seen dramatic declines in Scotland in recent years (UK National Ecosystem Assessment 2011). This counters both the preservationist approach of the GPL scenario and utilitarian outlook in N@W. Moorland and heathland landscapes currently provide good habitat for FPM and so a conversion to woodland would not be necessary for the conservation of this species. However, public perception of moorland or heathland landscapes were not ubiquitously positive, for example when asked to rank five different environments in order of conservation importance, forests were ranked as most important by 35% of respondents whereas grassland and moorland were only ranked as most important 2.2% of the time (see Chapter five). Factors such as order, locomotion and legibility help to explain why woodland is more highly valued by the lay-person considering themselves in both landscapes (Shafer and Brush 1977; Kaplan *et al*. 1989).

6.3.4.3 Scenario 3: National Security (NS); World Markets (WM) and Local Stewardship (LS)

Under the LS scenario upland habitats (which account for the majority of the forested areas of the Dee catchment) are increasingly used for grazing cattle and sheep. Under the NS and WM scenarios, timber is an important resource but the desire for home-grown biofuels in response to rising energy prices means that land might be converted to the production of biofuel crops such as *Miscanthus* sp. (Elephant grass). Whilst the conversion of woodland to grass shows little change in erosion risk *per se*, there are consequences for both public connectivity with the landscape and the ecology of the FPM under this scenario. Since *Miscanthus* would effectively be a crop plant, cover would not be maintained year-round and the application of chemicals (i.e. fertilisers and pesticides) would be detrimental to river habitats, including those that support the FPM. Such risks would be further intensified as the topographic relief in the former woodland areas in the Dee catchment is high, leading to greater erosion risk than that indicated in Figure 6.5. The public appreciate a grazed landscape, in part due to a perceived ease of locomotion and navigation, as documented in the focus group results. It is likely that plantations of *Miscanthus* would not only appear difficult to move through but easy to get lost within. Under the NS and WM scenarios, the transition from a natural landscape to one that is explicitly managed would likely decrease the connection between the public and the countryside, as accessible areas are further reduced.

Mitigating the effect of a grazed landscape in upland regions of the Dee catchment in order to reduce erosion risk would require a combination of approaches. Stocking densities and vehicular access would need to be limited, particularly in winter months, to prevent the grass cover becoming worn (McHugh 2007). Preventing livestock poaching of river banks would also be necessary, however fencing (a cost-effective and simple option), particularly that with barbed wire, was perceived by the focus group participants as reducing accessibility to rivers and as looking unnatural. An alternative are livestock drinks, often perceived as a compromise, but this can limit public access and often farmers prefer to prevent livestock entering rivers for safety reasons. Re-planting river banks in combination with fencing would compromise the public aesthetic values, farming needs and the need to limit sediment influx into rivers.

If the conversion of woodland to grassland was for the production for *Miscanthus sp*. more robust erosion control measures would be needed, to take into account the topography and highly erodible soil characteristics in the upland region of the Dee catchment. Drainage ditches, in which sediment is allowed to settle, are an option which would be supported by the public, for reason discussed earlier. However, these need regular maintenance and the rainfall during winter (when the crop provides the lowest level of cover) could overwhelm these and reduce efficacy. In-field margins would limit runoff from croplands but are not well-thought of by the public as they are perceived as being ugly and further limiting access to the river. Riparian buffer strips or replanting river banks, whilst expensive, would be effective all year round; concerns by the public about limiting the view and accessibility of the river would be less applicable given the impediment from *Miscanthus* itself. The limited view is a trade-off for other benefits (acknowledged by the public) such as increased biodiversity and a more natural scene. The ecological advantages of re-planting river banks or riparian buffer strips are numerous, for example the control of summer water temperatures by tree shading is vital in maintaining good FPM habitat.

6.4 Discussion

This research aimed to identify how the conservation needs of the FPM could be meet without detrimentally affecting the values placed on riverscapes by the public, in the context of the Dee river, Scotland. The results have shown that these two goals are not mutually exclusive; the conditions associated with good FPM habitat are closely aligned with public preference of rivers, which are driven predominantly by aesthetic values. Scottish preference of river habitats shows no difference to other groups within the UK and the recommendations discussed could be applicable to other river catchments across the country. This research was based around scenarios developed by the UK National Ecosystem Assessment and demonstrates that socially acceptable conservation work for the FPM can be achieved under scenarios with varying degree of ecological focus and economic pressures.

Previous research has shown that rivers are highly valued landscape features, valued for a range of reasons: cultural (Buijs 2009; Birckhead *et al*. 2011), aesthetic (Kaplan 1977; Shafer and Brush 1977) and economic (Gibbons 1986; Turner *et al.* 2004). The public have also been shown to have well-defined concepts of what constitutes a natural river scene and express a clear preference for natural riverscapes, free from obvious human influence (see Chapter 4). At times there can be a disconnect between conservation policy and environmental preference by the public. For example in Piegay *et al*.(2005) woody debris, whilst ecologically beneficial, was perceived as dangerous by the public. This discrepancy extends to future risks, despite the vulnerability of river ecosystems to climate change (Ormerod 2009) the public remain unaware of such risks (see Chapter five). This research represents a step forward in combining natural science with the consultative approach, as stipulated in the Water Framework Directive, and the results indicate that integrating public perceptions within conservation objectives would have far-reaching benefits in terms of river habitats and public connectivity with nature.

Acknowledging the importance that the public place on natural looking river scenes should encourage these values to be incorporated into river management plans, where applicable. Not only would this generate outcomes that are more robust against future perturbations in climate, but options such as re-planting river banks or recreating riparian buffer strips have greater longevity and require little future management. Despite this research focusing on the FPM, the implementation of many of the mitigation measures discussed would benefit the wider river ecosystem, and would have economic impacts. For example better habitat for salmonids species could increase the revenue from fishing rights, an important income generator in the UK, particularly in Scotland.

The results indicate that Scottish residents have similar perceptions of river habitats and species when compared to other UK groups. This is an important finding because it further reinforces the ubiquitous value ascribed to rivers, irrespective of differences in river management or public access rights. In Scotland, rivers generate fishing revenues from the estates through which they run. Whilst the fish are not owned, the rights to fish are, many of which are inherited. There is a specific term in Scotland for the person who acts as the attendant on such rivers (Ghillie); by comparison, whilst the rights to fish are still private in England or Wales, it is less formally managed. There is no equivalent of the Ghillies in England and Wales, although a rod license is needed to fish with fines levied if caught fishing without a license. The similarity in values between Scottish residents and other UK residents means that the management of cross-border river catchments should be straightforward. These findings also serve to highlight the importance for rivers to the public in general; this means that there is a need to ensure river management funded through the public purse reflects this.

The various scenarios used in this research document different possibilities for the future of the UK and in many, connectivity between the countryside and the public is reduced in comparison to what it is currently. This change is concerning from a conservation perspective because there is much evidence to suggest that place attachment and concern for the environment are linked (Pyle 1978; Hinds and Sparks 2008). Whilst the conservation measures proposed in this research cannot overrule legal restrictions to access, they can help to encourage increasing experience of the countryside by making it somewhere that the public would like to visit. By focussing on values, in this case particularly aesthetic values, conservation work can more easily generate support from the public. Reasons for work, including enhanced naturalness and appearance, resonate well with the public and can encourage the public to visit and experience river environments. Positive experiential contact with the countryside can then have multiple other benefits; for example, health and well-being also increase as people are more active outdoors (White *et al.* 2010). As the associated value of rivers increases, and attachment to place increases, concern and a desire for them to be maintained also rise alongside the value placed on them. Previous research indicates that the value placed on local rivers is an explanatory variable in predicting how important the FPM is perceived to be (see Chapter five). By creating aesthetically pleasing river environments, which also benefit species such as the FPM, the value of rivers in the local community can be increased and potentially raise the profile of the FPM.

There are wide ranging benefits of a conservation approach which includes social values and such a methodology demonstrated in this paper is generalizable to river catchment across the UK. The scenarios used in this research show highlight the environmental consequences of climate change and land use on erosion risk, in the Dee catchment. However, the results are applicable across many other catchments across the UK that are predicted to experience similar changes to precipitation patterns and temperature. Whilst this research has also focussed on the FPM, many other aquatic species would also be adversely affected by increases to erosion rates, some of which are commercially important in the Dee (and many other catchments across the UK), such as salmonids, estimated to bring in over £622 million in 2001 (Environment Agency 2004). An invisible consequence of higher erosion rates is the increased cost of providing potable water as a result of higher purification costs resulting in higher water bills for the consumer (see Chapter four). Whilst some of the methods here require more time and money in the short term along with more government support (for example as agri-environment schemes), the long-term outcomes are of benefit to society and the environment.

6.5 Policy Implications

This research promotes a methodological approach to combining societal values of the landscape with the requirements of key species within the ecosystem. The social implications of landscape change have been recognised within the UK through the UK National Ecosystem Assessment and other work concerning the goods and services the various ecosystems provide. For example, access to the countryside through Public Rights of Way (PRoW) and open access land (i.e. mountains, moorland, heath, downs and registered common land) are an intrinsic way of promoting use and enjoyment of the countryside. However, if landscapes are created that benefit species such as the FPM, at the cost of restricting public access to the countryside, links between the public and the rural environment would be put at risk. With less of a connection to the countryside, rural UK could become less important to the average person, reducing the value of the goods and services these ecosystems produce. This could lead to a situation where support for the conservation of specific species, particularly less charismatic examples such as the FPM, become ever more challenging.

The inclusion of societal values into species or habitats management plans at a policy or practitioner level has not so far been achieved. As the UK moves through the 21st century, environmental and economic pressures will play an increasing role in the functioning of rural UK. Including social needs in a formal way into species management does not necessarily mean a change in focus or priorities; merely an acceptance that riverscapes are as important to the local community as they are for the species they support. This is particularly pertinent in the case of the FPM, whose location has been deliberately hidden from the public in some catchments over concerns of illegal poaching, restricting opportunities for local engagement. Widening the remit of river management and conservation to the creation of natural and beautiful rivers would provide numerous public engagement opportunities, which would facilitate experiential contact with nature and consequently greater value being placed on such landscape features as rivers, promoting concern and care for the future management of UK rivers.

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CHAPTER SEVEN:
CONCLUSIONS

Merging natural science with a consultative approach as stipulated in the Water Framework Directive is a complex, long-winded undertaking with no guarantee of success. However, if done correctly, it provides natural scientists with an unrivalled opportunity to see habitats and wildlife from the perception of the lay-person and stakeholder, and to be better able to understand what landscape features mean to everyday users. Additionally, such an approach begins to breakdown the long-held belief that conservation is predominantly for the benefit of the natural environment. Furthermore, lay-persons involved in such proceedings can feel empowered, particularly those who have high levels of place attachment to the habitats in question. A sense of responsibility fostered through participatory decision-making can increase the likelihood that measures put in place will be successful in the long term and foster a greater understanding and sense of pleasure in the complex interactions of the natural environment.

The FPM has provided a novel opportunity to explore the interplay between potential climate-driven environmental change and the publics' preference for mitigation measures that might be needed to combat this change. By examining how habitat suitability could be affected by climate change and how the public feel about the measures needed to protect the FPM, this research has attempted to merge natural science with the consultative approach. This level of public engagement is explicitly required in the legislation that protects inland waters, the Water Framework Directive. As such, the conclusions drawn as a result of this research have wide-reaching implications that could formalise how the public are engaged with the decision making process of river management in the UK. This research provides a methodology that can be adapted for use with other publics, and be expanded to different species and habitats as needed.

One of the most useful conclusions for practitioners of river management from this research is the empirical evidence that rivers are valuable resources, from a social perspective, in the UK. The overwhelming majority of people had a positive attitude towards rivers and had clearly-defined concepts of how a river should look. Opinions about naturalness, practicality and the implications for agriculture helped particpants to prioritise river management options. What the public appear to want from riverscapes is a visually attractive and natural scene, that has accessibility without being overtly managed. Instead of needing to persuade the public of the merit of conserving individual species, more effort should be put into communicating how the proposed work will be of benefit to end users, either for aesthetic reasons, or for recreational purposes; in short to match the proposed work to the underlying values of the users. That is not to say that engagement opportunities should not be made to increase the public's intrinsic environmental values, for example by explaining why certain species are important for river health, but this will reach a far narrower audience; indeed this research clearly showed that acceptability of mitigation measures to support an un-charismatic freshwater species was not dependant on information about the beneficiaries of the proposed work.

The use of an un-charismatic and unfamiliar species within this research demonstrated how perceptions of conservation importance are not necessarily the drivers behind acceptability of conservation action. Utilitarian values and emotional connections to species have been shown to be important drivers of how the public assess species importance. However, in this research, the value of the landscape feature (i.e. the river) appeared to supersede any importance placed upon the species (i.e., the FPM). In other words, the acceptability of the mitigation measures was distinct from how important (or not) the FPM was seen as being. This has important ramifications for conservation agencies when dealing with similar species; namely, that the support of conservation work does not always depend on how much the public care about the species being protected. The results of this research suggest that values such as place attachment may be more important in determining acceptability of conservation work. Further work is needed to clarify this, and to ascertain if this finding would occur across other landscapes in order for such results to be usefully integrated into wider environmental management.

The typical upland river habitat that the FPM inhabits are vulnerable to the impacts of soil erosion processes within the terrestrial region of the catchment. Steeper topography in upland areas means that soil erosion process occur more readily; however land use plays a fundamental role in controlling erosion rates. For example, increased grazing densities or wide-spread tree felling as a result of commercial forestry operations can leave the soil bare and increasingly likely to be eroded by water. Increased erosion rates have a detrimental impact on river habitat functionality at all trophic levels. Interstitial pore spaces within the river bed substrate are easily blocked by fine sediments, limiting oxygen and nutrient exchange which is vital for those species that spend time within the interstitial zone; increased water turbidity reduces light availability for aquatic vegetation, thereby reducing photosynthesis rates and finding prey for freshwater predators becomes increasingly difficult. In contrast, re-planting trees in upland regions and excluding sheep from certain areas has been trialled within the Pont Bren catchment in north Wales, consequently increased soil infiltration rates and reduced runoff were obsred, thereby limiting the potential for soil erosion to occur.

In terms of the likely climate-driven environmental change impacts on the FPM, this research indicates that catchment erosion rates will increase, albeit slightly, in response to increases to precipitation and temperature as predicted by the UKCIP over the period 2010 – 2039. However, the results highlight that ground cover will play a bigger role in determining changes to the vulnerability of the landscape to erosion than climate change itself, over the temporal period studied, mirroring the trends documented over the recent past. Much previous work is based on plot or field scale data which often focuses on the agricultural sector because of the consequences of soil loss on farming productivity and food security.. Thus the conclusion that land cover must be maintained as far as is practicable with emphasis on agricultural land is not necessarily new advice; however, the finding that erosion rates on other land use types is significantly lower, despite steeper topography, is novel and of use to other sectors, for example forestry and upland management. As a consequence, erosion control mechanisms should focus on maintaining cover on arable land; managing forestry operations to avoid clear cutting on slopes to ensure constant cover in the wettest periods of the year and managing upland drainage schemes.

The use of multiple study sites, with differing land use characteristics, demonstrated that the consequences of land use and climatic change on erosion rates was consistent across the three sites used in this research. This provides an indication that regions in the UK expected to undergo a similar level of temperature and precipitation change in the future will be expected to see increased erosion rates in the same order of magnitude, with a corresponding control on erosion process by land cover. As climate change influences the type of crops that can be grown in the UK and the demand for higher levels of food security, maintaining year-round cover will become an increasing challenging, but all the more important as crops such as maize and vineyards have been shown to be more vulnerable to erosion events than those crops traditionally grown in the UK.

In order to manage rivers at the catchment scale, the data upon which management decisions are based needs to be at an appropriate spatial scales. The use of a model to predict changes to erosion rates at the catchment scale is not a widely-used approach; most erosion data is based on plot- or field-scale experiments. A criticism of large-scale modelling is that the underlying data used to generate the model output is often generalised as a compromise to facilitate modelling at a large spatial scale. However, the contraints of a large-scale approach also give distinct benefits; only by employing models of sufficient complexity can we predict what future conditions might be like at a scale large enough to influence policies and allow management decisions to made based on model outputs. The implementation of the coarse-scale risk based erosion model, PESERA, in this research served to highlight regions within each catchment most at-risk from increased erosion rates as a consequence of changing environmental conditions. Information at this scale is vital considering the current impetus of managing rivers at the catchment scale, for example the Catchment Based Approach currently under trial by DEFRA in England. By basing management decision on both environmental data at the appropriate scale and public acceptability, resilient ecosystems that are both ecologically productive and socially valued can be created and managed, for the present and the future.

7.1 Research Limitations

The geographical extend of this research was Wales, Scotland and northern England, following the current distribution of the freshwater pearl mussel. As such, the results, whilst generalizable within the study areas, are not representative of the south or west of England. Additionally, the focus of the research on the freshwater pearl mussel only allows an assessment of the specific values and knowledge surrounding this, or similar species. The findings from this research would not be as applicable in the case of un-charismatic species that are more visible to the public or elicit negative emotions.

The availability of high resolution climate change predictions across the UK were not available at the time of this project; as a result, manipulations of precipitation data did not include changes to rainfall intensity. Given that increase in both magnitude and intensity are expected in precipitation events across the UK, the erosion rates predicted by the PESERA and presented within Chapter Three may be conservative estimates.

Limitations as to the availability of participants for the questionnaire study in Chapter Five meant that areas outside the three study catchments were sampled. Ultimately this meant that full integration between the soil erosion predictions and the public values and attitudes work was not possible; however, it is unlikely that river management policy will be localised entirely. The broad overview from national perspective, as documented within this research, provides a starting point from which more localised approaches can begin from.

7.2 Future Research Directions

The relationship between local environmental values, general environmental values and climate change scepticism presents an opportunity to further investigate exactly how these variables interact. This would identify how attitudes towards climate change can be modulated when the risk is to the local or general environment, identifying the role of place attachment and place identity and the interactions between the two in this process. Such information would be invaluable to policy makes at a national scale when designing and communicating adaptation and mitigation strategies.

The role of both knowledge and value based variables in determining the conservation importance attributed by the lay-public to the FPM highlights the need to include both factors when developing communication strategies. Further work to identify if such factors hold true for a wide range of endangered and un-charismatic species would further compound the need for an integrated approach from conservation organisations.

Recent developments such as the JULES model by the UK Met Office mean that it is now possible to predict short duration heavy rainfall events and this information, alongside more detailed future land use changes should be used to hone the erosion risk maps produced in this research. Inclusion of finer scale data such as this would more accurately identify areas of high risk where mitigation measures and further work should be focussed.

Finally, an evaluation of the integrated approach, proposed in Chapter Six, in a small catchment in the UK in conjunction with on-the-ground practitioners, would yield invaluable information as to the practicalities of this approach and the realities associated with its implementation.