THE ROLE OF HISTORICAL ENVIRONMENTAL INFORMATION IN PERCEPTIONS AND MANAGEMENT OF AN URBAN RIVER

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ABSTRACT

Environmental history can be defined as the study of past relationships between people and natural environments. Descriptions of ecosystems prior to their anthropogenic degradation (reference conditions) and their past degradation are increasingly used to set conservation goals. To a much lesser extent environmental history has been used to evaluate past environmental management.

This thesis evaluates the potential of historical information to describe an ecosystem's reference conditions, degradation and recovery and the interrelated social, economic, technological and legislative factors which drove these changes. It also assesses the potential for the dissemination of historical information to influence public perceptions of an ecosystem's present conditions and their predictions for its future. It uses the River Don as a case study of a system that has been both highly valued and severely degraded by local people over centuries and has seen substantial restoration over recent decades.

The key findings are: 1) historical biological records are of limited value in describing historical community composition due to recording biases; 2) historical newspaper articles provide much information on past relationships between people and the river but neglect some important environmental degradation issues; 3) local people's historical knowledge of the river influence their perceptions in ways which may foster support for its restoration; 4) reading historical rather than current information on the River Don under experimental conditions leads participants to hold more negative views about the river's current environmental state but does not affect their expectations regarding the river's future or their intentions to visit it.

This research provides further evidence that historical information is valuable for planning environmental restoration but is often limited by sparsity and bias. It indicates that historical knowledge has the potential to foster support for conservation but further research is needed to better understand the relationship between historical knowledge and support for conservation.

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Declaration

I wrote all chapters of this thesis, but the work has been developed following discussions with Phil Warren, Lorraine Maltby and Susan Molyneux-Hodgson. Together we identified the research questions, planned the data collection and analysis and discussed the structure and content of each chapter. I collected all primary data myself through the analysis of newspaper articles, interviews and an online experiment. The sources of the biological records data is acknowledged in Chapter two.

CONTENTS

1 INTRODUCTION

1.1 AN INTRODUCTION TO ENVIRONMENTAL HISTORY

1.1.1 What is Environmental History?

Environmental history can be defined as "*the history of the mutual relations between humankind and the rest of nature*" (McNeill, 2003). The Oxford English Dictionary (OED) defines nature as "*The phenomena of the physical world collectively; esp. plants, animals, and other features and products of the earth itself, as opposed to humans and human creations"* (OED, 2016). Interactions between people and nature include: direct exploitation; indirect adverse effects of human activities on wildlife for example through habitat degradation; human efforts to actively conserve and restore wildlife; and the adverse effects of nature on people such as natural hazards (Nash, 1967, LeRoy Ladurie, 1974 and Henk van Zon, 2002 all cited in McNeill, 2003; Clapp, 1994; Simmons, 2001; McNeill, 2003; Mauch, 2009). They are mutual because frequently the natural environment shapes human actions which aim to maximise the extent to which society benefits from and minimise the extent to which society is adversely affected by the natural environment; and these actions often modify the natural environment which in turn modifies the effects of the natural environment on society both in intended and unintended ways.

The documentation of historical relationships between people and nature and their long term effects on nature is by no means new, with written sources dating back at least as far as the early 19th century. Famously, William Blake lamented Britain's pastoral past in contrast with its industrial present with clear reference to pollution, using the phrase "*dark satanic mills*" in his poem, And Did Those Feet In Ancient Time (Simmons, 2001). In his book "*Man and Nature; or, Physical Geography as Modified by Human Action*" Marsh (1864) used examples from across the world to describe national and regional changes in the abundances and distribution of species together with physical and chemical changes in the natural environment since Roman times, most of which he attributed to the actions of people. Topics covered in his book included: the effects of changes in land use on the hydrological cycle and the fertility of soils; the extirpation, extinction and introduction of species; and the preservation and restoration of the natural world. On a more local scale Holland (1843) wrote "*The wood-crowned hills surrounding Sheffield, once abounded in objects of interest to the Ornithologist; but the destructive axe, and the more destructive strolling grinder, have caused the rarer birds to disappear, whilst the formerly common are now equally scarce*".

However, the increasing demand for informed conservation over recent decades has fuelled a rapid expansion of the field of environmental history and a desire for increasingly accurate and detailed information in order to set restoration goals which reflect an ecosystem's previous degraded state and describe environmental degradation with the aim of reversing it (Nash, 1972; McNeill, 2003). The use of historical data to describe environmental degradation may be particularly important to identify environmental degradation which is not obvious from current observations (Harding *et al.*, 1999). For example, a river which has been historically affected by agriculture may have a higher level of biodiversity than one which has not which could indicate that it has not been degraded to a great extent. However, a comparison between the composition of its current community and its community prior to changes in land use may reveal the extent to which it has been degraded.

1.1.2 Applications of Environmental History

Given the current severe threats to wildlife and ecosystem service provisioning globally there is high demand for effective environmental management (Millenium Ecosystem Assessment, 2005a; Wilson *et al*., 2007; Meyer *et al*., 2015). For the purpose of this thesis I will use the term ecosystem services as it is defined in the Millenium Ecosystem Assessment (2005b): as "*the benefits people obtain from ecosystems*". With regards to this definition of ecosystem services, an ecosystem is defined as "*a dynamic complex of plant, animal and microorganism communities and the non-living environment interacting as a functional unit"*. Well informed decisions are essential for environmental management as poor decisions have the potential to: prevent limited resources being allocated where they can make the most difference (Ferraro and Pattanayak, 2006); have adverse social and economic impacts which are not justified by environmental benefits (Kareiva and Marvier, 2007); reduce broad public support for conservation (Jepson, 2005); and even directly or indirectly cause environmental harm (Ausden *et al*., 2001; Xu and Melick, 2007). By describing an ecosystem in a previous less degraded state, conservation practitioners can make more informed decisions regarding its restoration and monitor their progress against a benchmark (Swetnam *et al.*, 1999; Jackson and Hobbs, 2009; Meyer *et al*., 2015). Historical evidence has been used to contrast the current conditions and reference conditions of many degraded ecosystems including: coastal seas and estuaries (Lotze *et al*., 2006), islands (Fritts and Rodda, 1998) and rivers (Gillette *et al*., 2012). Reference conditions can be defined as an ecosystem's "*non-degraded natural baseline"* (Bennion *et al*., 2011). However, although these papers call for action to help restore these conditions very few river restoration evaluations have used historical records to compare pre-degradation and post-restoration community composition. A rare example of this type of study undertaken by Winter *et al*. (2009) proved that such studies could be highly illuminating. They used the reference conditions of the River Vecht in the Netherlands and Germany based on historical records from the river itself, two other ecologically similar rivers and the current community composition of an ecologically similar but much less degraded river, to evaluate the effectiveness of restoration attempts to re-establish historical community composition. They found very little evidence of success and even evidence that restoration had increased the differences between current and reference community composition.

Once an ecosystem's reference conditions have been described restoring them may involve reversing or otherwise minimising the impacts of anthropocentric changes in the abiotic environment such as pollution (Brenner *et al.*, 1993) and physical degradation (Eden and Tunstall, 2006), reintroducing or replacing extirpated species (Seddon and Soorae, 1999; Seddon, 2010; Jørgensen, 2013) and identifying and/or controlling non indigenous invasive species (Reichard and Hamilton, 1997; Meyer *et al.*, 2015). Once a difference between current and historical community composition has been identified in terms of the extirpation of a native species or the introduction of an invasive species management actions have been taken with varying success. For example, Short *et al*. (1992) documented both successful and unsuccessful reintroductions of marsupials to ecosystems within Australia. Similarly, Zavaleta *et al*. (2001) reviewed several examples of the successful eradication or control of invasive species whilst Bomford and O'Brien (1995) recognised that no attempts to eradicate well-established vertebrate pests have been successful. In addition to historical information regarding community composition, historical information on land use can also inform restoration - particularly when land uses which incidentally increased biodiversity have declined due to the decreased social and economic benefits which they bring in technologically advanced societies (Krahulec *et al.*, 2001; Metera *et al*., 2010). Such projects can be very successful. For example, Krahulec *et al.* (2001) reported that the use of sheep grazing as a conservation measure on land which had been previously grazed in order to produce meat in the Kronoše mountains in the Czech Republic helped increase cover of upland meadow relative to grassland vegetation and thus provide more suitable habitat for several rare species, some of which increased in abundance.

Analysis of historical data can also facilitate conservation practitioners to evaluate the likely consequences of future human activities. For example, Reichard and Hamilton (1997) used historical data on the invasiveness of plant species following their introduction to the United States together with their functional traits to predict the invasiveness of other species which could potentially be introduced to this environment. Furthermore, historical data enable the long term impacts of human activities to be described and thus further facilitate conservation practitioners to make informed decisions (Quinn and Kwak, 2003). For example, Quinn and Kwak (2003) demonstrated that the short term (up to four year) impacts of river impoundment on fish communities in the upper White River in the Ozark Mountains in Arkansas in the United States were very different from the long term, (approximately thirty year) impacts. Similarly, describing historical changes in restored ecosystems enables conservation practitioners to evaluate the effectiveness of their methods in the long term and thus better manage similar problems in the future (Miller *et al*., 2010). For example, Massey *et al.* (2014) evaluated the long term conservation benefits of fences around protected areas in the Aberdare Conservation Area in Kenya. They concluded that fences were ineffective conservation measures unless they were combined with strict enforcement of restrictions to human activities within the fenced areas. Whilst conservation practitioners often use historical data to inform decisions which must be taken at a local scale, international non-governmental organisations and policy makers often use historical data which is collected on a regional or even global scale to make decisions regarding the sustainable management of ecosystem services and the allocation of limited resources.

By describing changes in ecosystems and populations through time a better understanding of the effects of different drivers of such changes can be developed (Smith *et al*., 2007). Such data can facilitate the identification of the most vulnerable species and ecosystems. The IUCN (International Union for the Conservation of Nature) Red List uses historical data to describe the extent to which the size of a population and the area and quality of its habitat have changed to assess the extent to which a species is endangered relative to other species (IUCN, 2001). Similarly the IUCN Red List of Ecosystems classifies the vulnerability of ecosystem types using data on changes in their geographical distribution and biotic and abiotic components from 1750 onwards where possible (Rodríguez *et al*., 2015). Similarly, proportionate habitat loss is often used to prioritise conservation action on an international scale (Brooks *et al*., 2006).

However, documenting the history of ecosystems in an accurate and detailed manner is unfortunately rarely possible. Instead academics and conservation practitioners must rely on records which are often opportunistic, highly sporadic, taxonomically, temporally and spatially biased and include errors due to misidentifications and incorrectly recorded geographical locations (Boshoff and Kerley, 2010; Newbold, 2010). Biological records databases are the best known example of efforts to bring these records together to form systematic data resources from which trends can be identified and inferences drawn (Graham *et al*., 2004). However, their value is limited by the nature of the records held within them as described within this section above. This means that caution must be taken when interpreting historical data and using it to inform future environmental management.

1.1.3 Applications of Cultural Environmental History

Section 1.1.2 focused on the direct impacts of human activities on biological, chemical and physical ecosystem components, but the human element in environmental history means it is also important to contextualise these changes in a broader cultural framework. The most important cultural developments with regards to the natural environment are arguably industrialisation, which has been described as the most pollution-intensive phase of economic development (Perkins, 2003) and the development of societal attitudes and associated legislation and practices focussed on the minimisation and reversal of environmental degradation. Countries which are currently passing through the industrialisation phase are attempting to learn from the mistakes which today's developed countries made when they passed through it around two centuries ago (Perkins, 2003). Their approach is to encourage the development of green industry through incentives and legislation. This trajectory is facilitated by key global cultural changes which have occurred since the industrialisation of the developed countries, particularly the development of global trade, green technologies and foreign direct investment. Despite this, developing countries often follow highly environmentally destructive industrialisation trajectories (Perkins, 2001 cited in Perkins, 2003). Comparisons between the first tier of newly industrialised countries when they were at the beginning of the industrialisation phase and those which are at the beginning of this phase now have enabled the identification of key differences which if not managed will lead to severe environmental degradation in the latter countries. These include the lack of infrastructure, an educated workforce and foreign direct investment. Perkins (2003) uses these historical comparisons to highlight the need for these key factors to be addressed.

Historical studies of the development of the conservation ethics that are reflected in legislation and industrial practices in post-industrial societies have identified the importance of: scientific research to identify the causes and consequences of environmental degradation (including those relating to public health); communication of research findings to the public often via interest groups and the mass media; and public pressure on governments and businesses to minimise negative anthropogenic impacts on the natural environment (including increased demand for greener products as societies become more affluent) (Parlour and Schatzow, 1978; Lowe and Morrison, 1984; Clapp, 1994; Sandhu, 2010).

Historical studies of the development of conservation ethics and practices in pre-industrial societies have facilitated the development of two models: the depletion crisis model (Berkes and Turner, 2006) which recognises the importance of learning from the severe effects of overharvesting on the availability of valued biological resources; and the ecological understanding model (Turner and Berkes, 2006) which recognises the accumulation of knowledge and beliefs which facilitate the sustainable management of biological resources within a society as these are passed down from generation to generation and are modified through time in light of new experiences.

In addition to the management of ecological resources, intergenerational cultural learning through the accumulation of experience has been evidenced in the history of attitudes towards and management of ecosystem disservices. Ecosystem disservices can be defined as ecosystem functions which adversely affect people, communities and/or economies including natural hazards (Lyytimäki and Sipilä, 2009). White (1973) and Correia *et al*. (1998) recognised that as a society's economy develops from pre-industrial to industrial and ultimately post-industrial attitudes change from: a fearful phase during which natural hazards are viewed as acts of deities, and management approaches are focused around prayer and ritual; a controlling phase in which natural hazards are viewed as phenomena which can be controlled by man and management approaches are focused around heavy engineering; and finally a phase of harmony during which people realise the limitations of heavy engineering and the need to take a more balanced approach towards minimising ecosystem disservices as well as minimising impacts of management strategies on nature.

On a more local scale recognising the ecosystem services which have been valued in the past and the extent to which these values have been passed down to the current generation can play an important role in predicting and influencing attitudes towards restoration projects. Greater awareness of ecosystem services which have been valued in the past but have since been provided to a much lesser extent as a result of environmental degradation can foster support for restoration. For example, the Songhees community whose ancestors had lived in Tl'chés, a small archipelago near Canada were primarily motivated to ecologically restore the area due to their beliefs regarding the spiritual healing services which their ancestors had benefited from. Similarly, Petts (2006) found that those who remembered paddling in a stream in the West Midlands of the UK which had since been culverted wanted this opportunity to be restored which would require it to be de-culverted and thus would be likely to bring associated ecological benefits (Wild *et al*., 2011).

1.2 AN INTRODUCTION TO THE ENVIRONMENTAL HISTORY OF RIVERS

According to Naiman *et al.* (1993) "*Natural riparian corridors are the most diverse, dynamic, and complex biophysical habitats on the terrestrial portion of the Earth*". Furthermore, they are used in some way by nearly 70% of the vertebrate species present within a region (Raedeke, 1989 cited in Naiman *et al*., 1993) and several studies have reported unusually high levels of plant biodiversity along riparian corridors (reviewed in Naiman *et al*., 1993). Rivers have also been highly valued by people throughout history for a wide range of uses including: drinking water (Brechner *et al*., 2000), food (Boischio and Henshel, 2000), hydropower (Lebner *et al*., 2005) and recreational activities (Haslam, 1997).

However, throughout recorded history the utilisation of rivers and their surrounding land has increasingly severely physically, chemically and biologically degraded them physically, chemically and biologically (Langford and Shaw, 2014). Since medieval times European rivers have been managed to power water mills and provide drinking water and food such as fish (Hoffmann, 1996). As the development of technology facilitated agricultural intensification, the growth of manufacturing industries and urbanisation, rivers were used to remove increasingly large quantities of waste. This resulted in them becoming grossly polluted (Bednarek, 2001; Verdonschot *et al*., 2013; Haidvogl *et al*., 2015). They were also physically degraded as a consequence of actions to improve drainage, reduce the risk of flooding, power industry, transport raw materials and goods, irrigate fields and hide grossly polluted channels from view. By the start of the 20th century, many rivers and streams in the UK, mainland Europe and the United States had become so polluted and physically degraded that they were fishless and virtually devoid of invertebrates for many kilometres (Langford and Shaw, 2014). By the late 20th century the majority of the world's rivers and 94% of UK rivers had been modified (Brookes and Shields, 1996; Langford and Shaw, 2014). In Europe and North America more than 80% of the riparian corridor area has been lost (Naiman *et al*., 1993). Recent extinction rates of freshwater fauna in continental North America are estimated at 0.5 species per decade (Ricciardi and Rasmussen, 1999). This is five times greater than that of terrestrial and marine vertebrates excluding fish. The predicted rate of extinction for freshwater fauna in continental North America, assuming that the number of species which are made extinct over the next century is the same as the number which are currently threatened is 3.7% of species per decade. In comparison, that of terrestrial and marine vertebrates excluding fish is only 0.8%.

As discussed in section 1.1.2 historical information has the potential to facilitate restoration by describing the historical environmental degradation which environmental managers aim to reverse. Several studies have documented historical changes in the community composition of fish caused by anthropogenic environmental degradation (Anderson *et al*., 1995; Winter *et al*., 2009; Gillette *et al*., 2012; Haidvogl *et al*., 2014). The two studies which provided the most information on the effects of environmental degradation on fish community composition were undertaken by Anderson *et al*. (1995) and Gillette *et al*. (2012) in America. They surmised that a combination of physical degradation including impoundments, chemical pollution and the introduction of invasive fish species led to declines in the abundances of habitat specialists and increased abundances of habitat generalists. This resulted in the extinction of several endemic species and several others becoming

endangered. Gillette *et al*. (2012) explicitly asserted that knowledge of the historical impacts of human activities on fish community composition could facilitate the prediction of the effects of future activities. These studies will be discussed in more detail in Chapter Two.
Given their high potential value and severely degraded states due to the adverse direct and indirect ecological effects of the human activities described within this section above much effort has been put into their restoration in recent decades (Langford and Shaw, 2014). By 2000 the Environment Agency (EA) were spending £10 million per year on river restoration (Walker *et al*., 2002). According to Langford and Shaw (2014), "*most definitions of river restoration or recovery include some reference to restoring to or toward the natural state*" so understanding their historical trajectories is essential to their restoration. Such projects have included reducing pollution levels by reducing discharges (Turnpenny and Williams, 1981), reducing acidification through liming (Raddum and Fjellheim, 2003), removing dams (Doyle *et al*., 2005), restoring the connectivity between rivers and their previously drained floodplains (Pedersen *et al*., 2007), eradicating non-indigenous species (Marks *et al*., 2010) and reintroducing extirpated species (Raesly, 2001). Some projects have been ecologically successful in terms of increased biodiversity of native species and increased abundances of some threatened species. However, other projects have not brought the ecological benefits which were anticipated (reviewed in Palmer *et al*., 2010). Increased habitat heterogeneity may not have increased biodiversity as: habitat heterogeneity may not have been increased over a large enough geographical area; in-stream structures designed to increase habitat heterogeneity may have been quickly degraded; high pollution levels and unnatural hydrological regimes may prevent ecological recovery despite increased habitat heterogeneity; and even if the restored environment is ideal, depletion of the regional species pool may prevent natural recolonisation.

Despite high levels of effort and resources being invested into river management, relatively little work has been done to compare the community composition of restored ecosystems with their community composition prior to their environmental degradation. Where enough reliable data is available such comparisons would be a useful evaluation tool to establish the extent to which reference conditions had been restored. A rare example of such work is Winter's *et al.* (2009) study which compared the current fish community composition of the river Vecht in Germany and the Netherlands following nearly four decades of restoration with that of its reference conditions which were based on both historical information and similar less degraded current ecosystems. Unfortunately they found very little evidence that restoration had increased the similarity between current and reference community composition and in some cases had even increased the differences between them. They concluded that reduced chemical pollution and the installation of fish ways were not sufficient to restore historical fish community composition, increasing habitat heterogeneity and connectivity with backwaters were also necessary.

In addition to informing restoration targets historical data may be used for the long-term evaluation of the ecological effects of restoration actions. For example, Vaughan and Ormerod (2012) studied data on the composition of macroinvertebrate communities of UK rivers from the last 20 years. They demonstrated that pollution-sensitive species had become more dominant through time but the relationship between improved water quality and increased prevalence of pollution-sensitive species was relatively weak. They reasoned that sustained efforts to minimise pollution will benefit macroinvertebrate communities as whilst recovery of macroinvertebrate assemblages was slow given time they recovered without further intervention when low pollution levels were maintained. Similarly, Langford *et al*. (2009) used biological records of macroinvertebrates from three streams in the Midlands and North East of England to describe how macroinvertebrate community composition had been affected by reduced pollution since the 1940s and 1950s. They found that recovery was highly dependent on the presence of source populations upstream from which the previously severely polluted area could be colonised and warned that reducing pollution would not necessarily result in ecological recovery at least in the near future, particularly in rivers which had previously been severely polluted from their source. However, whilst the potential benefits of monitoring the long-term ecological effects of restoration projects is widely recognised, this is rarely done (Muotka *et al*., 2002).

Historical data can also increase the sample size for meta-analyses performed to evaluate the effectiveness of restoration techniques. For example, Stanley and Doyle (2003) aggregated empirical evidence from dam removal projects in the United States dating back at least as far as 1967 to demonstrate that some restoration efforts do cause a substantial amount of ecological damage through the initial mass mortalities caused by dewatering and suffocation of fauna downstream due to the deposition of fine sediment which was previously held behind the dam. Meta-analyses also show the social drivers behind both environmental degradation and restoration. For example, Langford and Shaw (2014) took a broad overview of the history of rivers in the developed world to identify relationships between attitudes and the states of rivers. They recognised the negative roles of concerns over the effects of the loss of manufacturing industries in allowing continued pollution. They also recognised the positive roles of increased demand for effective flood alleviation and of public health concerns in fostering support for environmental management. They also recognised that many riverine environmental problems historically associated with heavy manufacturing industries were translocated to newly industrialising countries together with the industries.

Despite the high value of historical information to inform and evaluate restoration projects, a lack of historical data to describe changes in ecological communities as a result of restoration projects is frequently highlighted by those aiming to draw conclusions from multiple projects to evaluate current practice. For example, Langford and Shaw (2014) expressed concern that although chemical and ecological improvements in rivers have been monitored for over 100 years, not monitoring the ecological effects of environmental restoration projects means that they could be causing much undetected damage through dredging or channel re-alignment using heavy machinery. Bernhardt *et al*. (2005) stated that of 37,000 river restoration projects in the United States, only 10% included some form of monitoring and even when some information was available it was often inadequate to evaluate the overall successes and failures of such projects. However, according to Verdonschot *et al*. (2013) substantially more monitoring data are available for rivers and lakes than estuaries and coastal waters.

In summary rivers have the potential to support diverse aquatic and terrestrial wildlife and provide a broad range of ecosystem services on which people have depended throughout history and on which they continue to depend. However, many have been severely degraded both chemically and physically by human activities for centuries and have been adversely affected by invasive species. It has thus been widely recognised that they must be restored for the benefit of wildlife and society particularly in post-industrial societies. This will require the substantial investment of limited resources and it is thus important to maximise return on this investment. Historical information may help to achieve this by increasing our understanding of rivers' reference conditions which inform conservation goals; describing environmental degradation which environmental mangers may then aim to reverse; and evaluating historical restoration attempts so that best practice can be identified and implemented and ineffective management practices can be discontinued.

1.3 AN INTRODUCTION TO THE ENVIRONMENTAL HISTORY OF THE RIVER DON

A case study is defined by Green and Thorogood (2009 cited in Crowe *et al*., 2011) as an "*in-depth study of one particular "case" which could be a site, individual or policy*". Case studies are a useful tool for developing theory through inductive reasoning (Siggelkow, 2007). Developing theory from inductive rather than deductive reasoning decreases the likelihood that important explanatory variables will be overlooked by the researcher due to their prior assumptions (George and Bennett, 2005). They are also often more effective than quantitative studies using large databases at explaining rather than simply identifying relationships between variables (Crowe *et al*., 2011; George and Bennett, 2005).

It is clear from the studies cited in sections 1.1 and 1.2 that case studies have contributed greatly to our understanding of environmental history and its applications both from an ecological and a social perspective. For example, Winter *et al*. (2009) used a comparison of the River Vecht in its current conditions with its reference conditions inferred from both historical ecological data and current ecological data from ecologically similar but less degraded rivers to evaluate the effectiveness of recent restoration actions and advocated that this evaluation approach be used more widely. Furthermore, Parlour and Schatzow (1978) and Lowe and Morrison (1984) evidenced how elites and special interest groups increased public concern for the environment through the media in Canada and the UK respectively by analysing these national case studies using a wide range of quantitative and qualitative methods.

Case studies should be selected to maximise their contribution to theory development (Scapens, 2004). Currently there are many gaps in our current knowledge of the effectiveness of environmental history as a tool to inform future management, particularly with regards to its potential to be used as an environmental education tool in urban communities. These communities have great influence over the success or failure of urban conservation projects (Wohl *et al*., 2005). It is therefore important that they are convinced that the aims pursued by the conservation practitioners are worthwhile and that the potential social and economic risks are well thought out and appropriately managed (Lyytimäki *et al*., 2008; Lyytmäki and Sipilä 2009). Previous studies have found that knowledge of environmental history has the potential both to foster support for and opposition against conservation so it is important that we improve our understanding of the relationship between historical knowledge and attitudes towards urban ecosystems before using historical information as an environmental education tool (Stoll-Kleemann, 2001; Gooch, 2003; Ostergen *et al*., 2008; Drenthen, 2009; Cuerrier *et al*., 2015).

The River Don was selected as a case study for this thesis as in many ways its history is similar to that of other post-industrial urban rivers (Bothmann *et al*., 2006; Firth, 1997). It has been degraded through pollution, physical degradation and the introduction of invasive species largely as a result of the growth and technological advancement of its heavy manufacturing industries and associated urbanisation. It has then been restored to a large extent particularly with regards to reduced pollution and to some extent the reversal of physical habitat degradation. These similarities are likely to increase the transferability of the key research findings (Yin, 2012 cited in Wickfeldt, 2016; Wickfeldt, 2016). Whilst the types of degradation which the River Don experienced were similar to that of many other rivers, the extent of the degradation meant that it was an extreme case. Extreme cases are recognised by Pettigrew (1988 cited in Eisenhardt, 1989) to be particularly valuable to researchers as the relationships between variables are usually more readily observable. When selecting case studies it is also important to consider the practicality with which they can be researched (Scapens, 2004). I expected that as the River Don is in an urban environment in the UK and has been highly valued by people throughout history albeit for very different reasons more historical sources would be available to describe its environmental history particularly with regards to biological fish records and newspaper articles and local people would be somewhat knowedgable about its history (Firth, 1997).

The name of the River Don is derived from its previous name, the River Dun, meaning deep or low channel in ancient British (Firth, 1997). The source of the River Don is in the Pennine moors in the Peak District National Park (Sheffield Local Biodiversity Action Partnership, n.d.). The upper section of the river is shallow and fast flowing. The river flows through Penistone, Sheffield, Rotherham and Doncaster before flowing in its entirety into the River Ouse at Goole, a river it was never naturally connected to (Firth, 1997; Figure 1). Naturally water from the River Don passed very slowly through marshland and ultimately drained into the rivers Aire and Trent (Holland, 1837a; Firth, 1997). The reasons for this substantial change are outlined in section 1.3.5. The lower section of the River Don is tidal up to Doncaster (Firth, 1997). Its major tributaries are the Rivers Loxley, Rivelin, Porter and Sheaf. The geology of the headwaters of the catchment is dominated by millstone grit (NRA, 1994 in Amisah, 1998). The remainder of the catchment provided great coal reserves which were heavily exploited until the late 20th century with the earliest records of coal mining dating back to the 13th century (Firth, 1997; Hey, 2015). Overlying the coal measures is highly porous magnesium limestone through which the catchment's waters flow before entering the River Don (Firth, 1997). Water from the abandoned mines continued to pollute the River Don well into the 1990s (Amisah, 1998). Naturally the Don catchment downstream of the Peak District was dominated by forest and bogs (Phillips and Danby, 1921; Walton, 1952). The following sections will describe the contributions of the river to the development of the settlements along it and the effects of such development on the river in downstream order.

Figure 1. Map of the River Don Catchment showing the River Don and its tributaries and the largest settlements along them.

1.3.1 Penistone

There is archaeological evidence of ancient settlement in the Penistone area so it is likely that the use of the River Don in this area dates back to ancient times (Addy, 1965). However, until the mid-19th century human impacts on the local natural environment including the River Don were limited by the lack of manufacturing and the hilly and wet nature of the land which prevented it from being used for more intensive agriculture (Hey, 2002). Only half the land in the vicinity of the town was ploughed (Rennie *et al*. cited in Hey, 2002). Sheep grazing was extensive due to the lack of food available for them at the relatively high altitudes of the area (Hey, 2002). In 1793 Rennie *et al* (cited in Hey, 2002) reported that the land in the Penistone District was "*very variable, but mostly wet and spongy and a great deal of moor carrying little but heath*". According to Firth (1997) the natural vegetation type of these moorland areas was woodland but they had been deforested centuries previously. This would have greatly affected the hydrology of the Don Catchment and is thus likely to have considerably altered the River Don's community composition. This deforestation could have substantially influenced the river's ecology by: reducing physical habitat heterogeneity through sedimentation, reduced bank stability and reduced input of woody debris such as logs; increasing the scale and frequency of flooding which may have reduced invertebrate abundances and injured and displaced fish; reducing the input of allochthonous detritus; reducing shading and thus increasing primary production and water temperatures (Brown, 1969 cited in Chen *et al*., 1999; Mayson, 1976, Graynoth, 1979, Murphy *et al*., 1981, Silsbee and Larson, 1983 and Glova *et al*., 1985 all cited in Hanchet, 1990; Johnson *et al*., 1995; Owens *et al*., 2005).

From 1801 to 1901 the population of the Parish of Penistone grew from 3,681 to 11,160. This growth was facilitated by the growth of the textiles and heavy metal manufacturing industries both of which depended on the river for hydropower despite the natural shallowness and narrowness of the stream in this area (Hey, 2002; Reeve, 2015). The construction of weirs to harness the river's hydropower would have greatly altered the river's ecology. Firth (1997) recognised that they blocked the migratory pathways of many fish species. The presence of weirs would have also substantially altered the river's flow regime and thus increased sedimentation upstream and scouring downstream, favouring lotic and lentic species downstream and upstream of weirs respectively (Fraser, 1972; Hayes *et al*., 1998).

Coal mining also provided substantial employment in the area in the 19th century. This caused the river to be polluted with iron ochre (Firth, 1997). Between the early 1860s and 1930 it had a steel and iron works which employed up to 1500 men and youths (Addy, 1965). Steel and bronze casting was still being manufactured at the site in the mid-1960s (Addy, 1965). Although not explicitly recognised it is probable that heavy manufacturing industries polluted the River Don in the Penistone area but given the smaller scale of the industry to a lesser extent than it did in Sheffield and Rotherham. By the turn of the 20th century Bentley (n.d. cited in Dransfield 1906) recognised that fresh water was an increasingly limited resource in Penistone. Dransfield (1906) attributed this to over abstraction together with changes in land use which increased the impervious land area and thus greatly altered the hydrological cycle by favouring quick flow processes. Both Dransfield (1906) and Hey (2002) recognised that sewage works in Penistone first opened in 1906 but neither provide any further information about them. However, according to Firth (1997) by the 1970s Penistone's sewage works all produced poor quality effluent and one still provided little more than primary treatment. In 1977 all five of Penistone's sewage works were replaced by a sewage works which provided more effective treatment (Firth, 1997).

1.3.2 Sheffield

In the Bronze Age the Sheffield area was sparsely populated (Winkler, 2007). It was not inviting to early settlers as its forest was perceived as dangerous and its marsh as damp and disease ridden. It did not provide good opportunities for agriculture and its rivers including the River Don did not provide good opportunities for navigation. However, Sheffield was founded as a small settlement around the 7th century. From the 6th to the 8th century AD Angles and Saxons drained marshland for agricultural usage (Walton, 1952). This resulted in the extensive loss of valuable wetland habitat (Firth, 1997). In both ancient and medieval times the Sheffield section of the River Don was highly valued for the defence which it provided. The Brigantes used it to defend their land against the Romans (Walton, 1952) and Sheffield castle was built at the confluence between the Rivers Don and Sheaf in the 12th century AD.

In Medieval times (approximately 500AD-1500AD (Hoffmann, 2014)) industry greatly benefited from the River Don particularly with regards to hydropower but the growth of industry and associated urbanisation led to it becoming severely polluted. The river's hydropower was harnessed in the Sheffield area from at least the 12th century (Hey, 1979). From the 15th century the harnessing of hydropower enabled Sheffield's cutlery industry to drive out all its competition from other places within the UK with the exception of London (Walton, 1952). From this time Sheffield was large enough to be classified as a town rather than as a village. The River Don has a more gentle fall than its tributaries which increases the necessary minimum distance between weirs for the generation of hydropower (Ball *et al*., 2006). No new weirs were constructed for the purposes of generating power between Sheffield and Brightside, now part of East Sheffield, since 1600. By 1615 Sheffield had a population of approximately 2,200 people. Even in the Medieval period for its drinking water, Sheffield relied on wells rather than the River Don because it was so polluted (Walton, 1952). However, in the mid-17th century salmon were so abundant in the river that they were too cheap to be deemed worth selling at market and employers were prohibited from feeding their apprentices salmon more than three times a week (Firth, 1997)!

The Industrial Revolution took place in the UK roughly from the mid-18th to the mid-19th century and although these dates are much disputed they will suffice for the purpose of this thesis as they receive the most agreement from historians who study this time period and coincide with the rapid industrial development of South Yorkshire (Hey, 1979; Deane, 1979). During this time period Sheffield was one of Britain's leading industrial cities (Winkler, 2007). Between 1736 and 1801 the industrialisation of Sheffield enabled its population to grow from 9,696 to 31,314 people (Walton, 1952). At this time its dominant manufacturing industries produced steel, cutlery and silver-plated goods (Walton, 1952). In 1911 the heavy trades dominated by steel making employed nearly 40,000 people, whilst the lighter trades which produced products such as cutlery and tools employed a further 35,000 (Watts, 2004). From the mid-18th century steam power generated using water abstracted from the River Don gradually replaced hydropower in Sheffield's heavy metal manufacturing industries (Walton, 1952). Large volumes of water were also abstracted from the River Don for other industrial processes (Firth, 1997). Sheffield's heavy metal industries needed to transport large quantities of heavy resources and products but Sheffield was not connected to the River Don navigation until Sheffield canal opened in 1819 (Walton 1952; Winkler 2007).

Increased demand for water for both industrial and domestic purposes necessitated that from the mid-18th century Sheffield's drinking water was supplied from reservoirs (Firth, 1997). In the mid1-19th century sewage from Sheffield's 150,000 residents was simply flushed into the streams and gullies and ultimately into the rivers (Firth, 1997). In 1886 Sheffield's first sewage treatment facility was opened at Blackburn Meadows. It used the lime precipitation process, aeration over weirs and coke filtration. These methods were so advanced for the time that the facility was viewed as a model and visited by groups from across the country who were potentially interested in adopting similar practices. Despite this in 1891 a medical officer's report stated "*It would be hard to find in any town poorer conditions than are to be found in the centre of Sheffield. Nuisance and unsanitary conditions of every description abound. Diseases such as cholera and typhoid spread from privy middens and filthy unpaved courts into rubble sewers and contaminated water and waste flows down steep hill slopes into the river and streams"* (cited in Firth, 1997). Fevers were endemic and between 1850 and 1880 the average death rate was 27 per thousand people, whilst the national death rate was 21.8 deaths per thousand people (Walton, 1952). Despite the high death rate by 1901 Sheffield's population had reached 451,195 (GB Historical GIS n.d. cited in Sheffield City Council, n.d.). In 1932 the extent to which effluent from Blackburn Meadows reduced biological demand was substantially reduced through the introduction of the Sheffield aeration system (Firth, 1997). Shortly afterwards it was introduced to other sewage works across Sheffield. However, as the population grew it became increasingly common for untreated sewage to enter the river through the storm overflows even when rainfall was relatively low. Furthermore, treatment had little impact on ammonia concentrations. The former problem was abated to a great extent by improvements to Sheffield's sewer system from the 1970s to the 1990s. Improvements to address the latter issue were implemented from the first half of the 1990s onwards.

Sheffield’s population peaked at 577,050 in 1951 then declined each decade until it reached 513,234 in 2001 (GB Historical GIS n.d. cited in Sheffield City Council, n.d.). Between 2001 and 2011 its population recovered to a large extent and in 2011 Sheffield had a population of 552,700 making it the fourth largest city in England (Sheffield First Partnership, 2014). The population decline was probably due to the loss of its manufacturing industries. In 1971 136,000 people were employed in Sheffield’s manufacturing industries and in the mid-1970s Sheffield was still a prosperous manufacturing centre with unemployment levels below the national average (Watts, 2004). However, the scale of Sheffield’s manufacturing industry declined from the late 1970s onwards. From 1971 to 2001 the number of people employed in Sheffield’s manufacturing industries fell by approximately one third each decade and by 2001 only 16% of Sheffield’s workforce were employed in the manufacturing sector. Concurrently the proportion of Sheffield’s workforce employed in the service sector increased from 51% in 1971 to 84% in 2001. The lack of current significance of the River Don to Sheffield’s industries is expressed well by the Sheffield First Partnership (2014) in this statement: *“However, the continued manufacture of metal products on inland sites owes little to natural resources and much more to the high levels of technical innovation by steel producers and their willingness to adopt new technologies.”* In 1988 41% of the land in the Sheffield section of the Lower Don Valley was vacant, derelict or underused. However, despite this decline Sheffield is still a major European centre for the production of stainless steel (Sheffield First Partnership, 2014).

1.3.3 Rotherham

According to Munford (2000) Rotherham owes its existence at least partly to a ford across the River Don which improved Rotherham’s strategic position in the regional transport network. A Roman camp at Templeborough in the Rotherham area benefited from the defence afforded by the river (Walton, 1952). Rotherham’s manufacturing industry dates back at least this far as there is archaeological evidence that the Romans manufactured glass and iron products there (Munford, 2000). Munford (2000) used Rotherham’s entry in The Domesday Book which was published in 1086 to estimate that it had a population of 70 people excluding free tenants and tradesmen who did not work the land. A corn mill which may have been powered by the River Don was included in the town’s entry. The oldest remaining bridge on the Rotherham section of the River Don dates back to the 15th century and is of high heritage value as it supports one of the only four surviving medieval bridge chapels in the UK (Reeve, 2015; The Church of England, 2016). Travellers used the chapel to pray for safe journeys on which they were about to embark and thank the Christian God for safe journeys upon completion.

The River Don’s power was harnessed in Rotherham from at least the 17th century onwards but at the turn of the 18th century Rotherham was still primarily a market town with some manufacturing on the outskirts (Munford, 2000). Improvements to the River Don navigation enabled cargo to be transported as far as Rotherham by 1740 (Willan, 1965). By 1769 thirty thousand tons of coal were being transported along the navigation from the collieries around Rotherham each year (Munford, 2000). However, these improvements would have been ecologically degrading. Modification of the river channel for navigation is likely to have: fragmented habitats and blocked migratory pathways; decreased habitat heterogeneity; and destroyed spawning and nursery habitats for fish (reviewed in Wolter and Arlinghaus, 2003). The use of the river by boats is likely to have caused fish mortalities through: direct collisions between vessels and fish; and the generation of waves and currents which cause collisions with substrate and force fish out of the water causing them to suffocate (reviewed in Wolter and Arlinghaus, 2003). Furthermore, behavioural changes in response to vessels such as reduced feeding and nest-guarding behaviour may also be detrimental to fish survival and reproduction. These factors have been demonstrated to reduce fish species richness and abundances. Like Sheffield, Rotherham had a relatively large heavy metals manufacturing industry. In 1850 it was estimated that 970 people were employed in the production of iron and steel production or manufacturing metal products. A further 30 were employed in glassworks, 35 in potteries, 47 in chemical works and 82 in breweries. The development of industry enabled Rotherham's parish population to have reached 24,098 by 1851 but life was generally unpleasant with endemic levels of diseases indicative of poor water quality such as fever, diarrhoea and dysentery and a mortality rate as high as Sheffield's at 27 deaths per thousand people per year (Munford, 2000). Despite the high death rate by 1901 Rotherham's population was 61,541.

Rotherham's manufacturing industries continued to thrive in the first half of the 20th century but declined rapidly in the second half. Steel, Peach and Tozer's steelworks employed ten thousand people in the mid-20th century (Reeve, 2015). In 1983 improvements were made to the River Don navigation including deepening and widening the channels and enlarging the locks to enable 700 ton barges to reach Rotherham with the expectation that Rotherham would become an inland port trading with mainland Europe (Reeve, 2015). However, this did not revitalise the navigation and today only one tanker uses the waterway to transport cargo. Since 1945 the future of local industries, particularly coal mining and steel production was uncertain, the late 1980s was a period of industrial decline and in 1993 steelmaking ceased at Steel, Peach and Tozer's steelworks (Munford 2000; Rotherham Metropolitan Borough Council 2015). Despite deindustrialisation Rotherham's population grew rapidly over the 20th century and now exceeds 250,000 (Rotherham Metropolitan Borough Council, 2015). Engineering tools are still produced in Rotherham and its growing Advanced Manufacturing Park is "*world renowned*" (Watts, 2004; Rotherham Metropolitan Borough Council, 2015).

1.3.4 Doncaster

Doncaster is described by Phillips and Danby (1921) as being "*one of the very oldest towns in England"*. The name Doncaster is derived from Danum Castra which translates as Danish camp and thus evidences Viking settlement. In Saxon times Doncaster was one of the most influential towns in Yorkshire and probably the most important in South Yorkshire as Sheffield was not yet in existence. Ancient civilisations in the Doncaster area benefited from the River Don largely as a source of water and a defence mechanism. The river provided a natural defence for a Roman military station and following the Norman invasion the town was not walled as it was believed that the River Don provided adequate protection. Hydropower has been harnessed from the River Don in Doncaster since Saxon times. From the Roman times when the Great North Road was constructed further northwards Doncaster was a communications hub. The furthest downstream section of the River Don which could be bridged or forded and the furthest upstream section of the River Don which could be navigated by coastal traffic was in Doncaster (Phillips and Danby, 1921; Hey, 1979). However, the navigation was always challenging, and although villages on the section of the River Don downstream of Doncaster were important ports from the 12th century, it was difficult for even relatively small craft to reach Doncaster so merchants preferred to transport goods by road to Bawtry on the River Idle and from there to the Humber Estuary (Firth, 1997). In Medieval times Doncaster was the most prosperous town in South Yorkshire due to its market trade (Hey, 1979).

Unlike Sheffield and Rotherham, Doncaster never had a particularly large manufacturing sector. According to Phillips and Danby (1921) "*The example of Sheffield, its murky gloom, its belching furnaces, the roar and rattle of mill and forge, made no appeal to Doncaster"*. However, Doncaster had a range of small manufactories including: breweries, saddlers, tanners and the "*usual trades of a country town*" which are highly probable to have contributed to the pollution of the river. Doncaster's strategic position with regards to transport enabled its population to reach 10,030 by 1831 (Wormald, 1973). In the mid-19th century a substantial proportion of Doncaster's population were still sourcing their drinking water from the River Don though the health implications of the pollution were widely recognised amongst public health professionals. Around this time there were cholera and typhoid endemics (Firth, 1997). Doncaster's largest company within the heavy manufacturing sector produced and maintained trains at the Plant Works (Bagwell, 1991). These opened in 1853 and employed 2,107 people by 1870 and were still employing 2,634 people in 1970. By 1921 Doncaster had a population of 60,000 (Phillips and Danby, 1921).

Today one of Doncaster's greatest economic advantages is still its "*unparalleled connectivity*" though this is due to its position on the road and rail networks rather than the River Don Navigation (Doncaster Together, 2013). Doncaster's logistics sector employs 6,500 people. Despite the town never having large scale manufacturing, its manufacturing and engineering sector employs over 10,000 people. This includes engineers in the rail and aviation industries and manufacturers of tools.

1.3.5 Goole

As stated at the start of section 1.3 the River Don naturally flowed through a vast wetland/marsh complex between Doncaster and Goole and ultimately into the Rivers Aire and Trent. These wetlands are now known as the Humberhead Levels (Van de Noort and O'Sullivan, 2007). The ecosystem services which were provided by these wetlands had long been valued by local people. The land was used for arable and pastoral agriculture and the peat was used as a fuel and as a building material at least from the 13th and 14th centuries onwards. Since the Middle Ages fish and other animals had been harvested as food and reeds had been harvested to be used as a construction material and in basket making. However, Charles I did not value these ecosystem services highly and commissioned a Dutch engineer, Vermuyden, to drain a large part of this area known as Hatfield Chase between 1626 and 1630 to enable the land which was previously used for grazing to be used to grow crops (Thirsk, 1953; Firth, 1997; Munford, 2000). His work included blocking the channel which connected the River Don with the River Trent, forcing all of the River Don's output into the River Aire (Firth, 1997). This caused widespread flooding on land which had not previously been frequently flooded and strong local opposition which described as "*considerable litigation and riots almost leading to civil war*" and necessitated the construction of a flood relief channel which connected the River Don with the River Ouse at Goole (Firth, 1997). When the flood gates on this channel had been washed away by a particularly severe flood it provided a route of less resistance for the water from the River Don to take and the channel between the River Don and the River Aire quickly silted up (Firth, 1997). As a result the River Don flowed and continues to flow into the River Ouse in its entirety, a river which it was never naturally connected to. Further drainage over a large area in the Lower Don Valley was undertaken for agricultural land use from 1650. According to Firth (1997) "*The loss of meandering channels, saltmarshes, freshwater ponds and reedbeds, which provided habitats to an almost unimaginable range of birds, animals and fish, could be argued as equal in proportion to the present day destruction of rainforests"*. Disconnection between rivers and wetlands can: reduce input of allochthonous nutrients; and prevent migration between the channel and wetland habitats thus potentially preventing wetland habitats from being used by fish which spend their adult stages in the main channel for spawning and preventing the channel from being colonised from wetland habitats which serve as refugia following perturbations (Sedell *et al*., 1990; Ward and Stanford, 1995).

As a town Goole does not have a long history. In 1820 the Hamlet in the Old Goole area comprised of just a few farmhouses and labourers' cottages (Goole Library, n.d.). Goole developed from the early 1820s when the Aire and Calder Navigation company began to construct a canal which connected the River Ouse with the River Aire and followed the course of the straightened lower section of the River Don called the Dutch River. Housing was built for workers associated with the port including watermen, dockers and mariners. Goole Town was constituted a Local Government District in 1875 (Goole Library, n.d.). By 1913 the port of Goole was trading 3.6 million tons of cargo per year. In 2011 Goole had a population of 17,500 people (East Riding of Yorkshire Council, 2011).

International trade through Goole's port is still valuable to its economy and the East Riding of Yorkshire Council (2011) recognised an opportunity for further intensification. Despite Goole having a history primarily as a port rather than as a manufacturing town in 2008 19.4% of jobs in the Goole and Selby Functional Economic Area were in the manufacturing sector, nearly double the proportion of England as a whole, 10% (NOMIS 2008 cited in East Riding of Yorkshire Council, 2011). Today the Port of Goole is the UK's most inland port and handles two million tonnes of cargo each year (Humber Local Enterprise Partnership 2014). However, the proportion of people employed in transport and logistics is only slightly higher than that of England as a whole (7.2% and 6% respectively) (NOMIS 2008 cited in East Riding of Yorkshire Council, 2011).

1.3.6 Overview of the Environmental History of the River Don

As discussed in section 1.3.1 to 1.3.4 industry and associated urbanisation severely polluted the River Don. According to Firth (1997) chemical pollution began to have serious effects on the River Don by the mid 19th century, and by the turn of the 20th century "*the river had been reduced to little more than a foul smelling, lifeless sewer.*" The River Don was one of the most polluted in Europe. As stated in section 1.3.2 sewage works did not open in the Sheffield area until the late 19th century and in the Penistone area the early 20th century and until the late 20th century provided little more than primary treatment. As discussed in sections 1.3.1 to 1.3.5 industry also severely physically degraded the river particularly through the construction of weirs, the drainage of wetlands and the modification of the channel for the benefit of navigation. Furthermore, reservoirs in the headwaters of the Don catchment heavily reduce flow, sometimes almost to nothing (NRA, 1994 cited in Amisah, 1998). Reduced flow directly affected the biota for example by trapping salmon in small puddles causing them to suffocate (Firth, 1997). It probably also altered its ecology more broadly by altering flow speeds, sedimentation patterns, wetted channel area and water temperatures (Dewson *et al*., 2007).

Despite the River Don's severe degradation, sections of it have always been appreciated for their beauty. In 1864 Harrison described the few miles downstream of its confluence with the River Loxley in North West Sheffield as "*exceedingly picturesque and lovely*" and states "*On the banks of the stream and on the hill sides groves and woods add a charm to scenes which an artist or poet might delight to pourtray*". Today local people welcome the opportunity to see charismatic species such as kingfishers (*Alcedo atthis*) and herons (*Ardea cinerea*) which have recently returned following environmental improvements (Sheffield Local Biodiversity Action Partnership, n.d.). It also has a long history of being used for of recreational use. In the 14th century the River Don afforded such good angling opportunities that even the ex-King of Scotland participated (Firth, 1997). Having acquired fishing rights on a section of the River Don above Penistone in the mid-1970s, the Salmon and Trout Association were the first to make efforts to restore the river beyond reducing the amount of pollution which was discharged into it. Today it supports brown trout fisheries (NRA, 1994 cited in Amisah, 1998). Since the transport of cargo on the River Don Navigation declined to the extent that it nearly ceased completely it has been increasingly used by recreational boats and several marinas have been developed along it for such purposes including at least one on the River Don itself downstream of Doncaster (Firth, 1997). The Five Weirs Walk trust has constructed a path to greatly increase access for walkers and cyclists. Information boards provide visitors with the opportunity to learn about the river's wildlife and heritage (Sheffield Local Biodiversity Action Partnership, n.d.).

In recent decades anthropogenic threats to the river's environment, particularly pollution have been greatly reduced in large part due to greater awareness and cleaner manufacturing processes facilitated by technological advances (Sheffield Local Biodiversity Action Partnership, n.d.). This has greatly improved the river's water quality. Today the River Don and its tributaries are collectively "*of crucial importance to biodiversity conservation*" (Sheffield Local Biodiversity Action Partnership, n.d.). They act as wildlife refuges and migratory corridors connecting fragments of habitat in a predominately urban landscape. Along the upper section of the River Don above Sheffield there are several UK Local BAP (Biodiversity Action Plan) habitats including grassland, broad-leaved woodland and wet woodland. The section of the River Don from Sheffield to Rotherham also includes many UK BAP habitats on brownfield sites and rare and threatened open vegetation communities which collectively support a high diversity of species including nationally rare invertebrates and plants. Populations of brown trout, grayling and barbel are recovering on the river. Kingfishers and herons are increasingly seen there and otters, a priority LBAP (Local Biodiversity Action Plan) species, have recently begun to return though recovery of their populations is hindered by the weirs which block their migration, and a lack of bankside vegetation. The whole area covered by the Don Catchment Flood Management Plan includes the Peak District National Park, two Special Areas of Conservation (SACs) and two Special Protection Areas (SPAs) (EA, 2010). Although the trajectory of the River Don can largely be surmised as degradation followed by recovery, anthropogenic threats towards some of the species which live on it have increased in recent years. For example, water vole (*Arvicola amphibius*) populations have declined substantially due to predation by the non-native invasive American mink (*Neovision vision*) and domestic cats (*Felis catus*) (Sheffield Local Biodiversity Action Partnership, n.d.).

In addition to the River Don benefiting people it has always posed a threat to them. There is a long history of flooding within the Don Catchment and today the risk of flooding within the Don Catchment Flood Management Plan area is described as "significant" despite the existence of over 530 separate flood defence structures within the catchment (EA, 2010). The most severe floods occurred in 2007 and 1864. In June 2007 over 6,750 properties were flooded with Sheffield, Rotherham and Doncaster all severely affected. The 1864 flood was caused by a damn burst at Dale Dyke Reservoir on the Loxley, a tributary of the River Don but this event also caused the River Don to flood. It killed at least 240 people, destroyed 15 bridges and approximately 4,000 domestic properties (Teasdale, 2008) and is described by Sheffield City Council (2015) as "*the greatest civilian disaster of Victorian Britain"*. Efforts to manage the flood risk have contributed to the degradation of the River Don and even as recently as 2007 such efforts did not prioritise the needs of wildlife highly enough according to the Sheffield Local Biodiversity Action Partnership (n.d.). However, these efforts also included the creation of Centenary Washlands on the Rotherham section of the River Don which is now a nature reserve (Reeve, 2015).

Today there are still very few fragments of wetland within the Don Catchment (Firth, 1997). The majority of weirs which were constructed along the river to harness its power still remain and block wildlife migratory pathways (Ball *et al*., 2006); Sheffield Local Biodiversity Action Partnership, n.d.). They also slow water flow, causing sedimentation and favouring plant, invertebrate and fish assemblages more characteristic of lentic ecosystems (Firth, 1997). Raising weirs for the benefit of navigation increased the extent to which they blocked fish migration and according to Firth (1997) the construction of a lock downstream of Doncaster in 1729 was a "*decisive blow"* for salmonid migratory runs. During times of low flow a substantial proportion of the water in the River Don continues to be diverted to the canals which connect with it. From the 19^{th} century the River Don was diverted in a number of places for the benefit of industry.

1.4 Aims of this Thesis

Broadly this thesis aims to answer the question "*Can Environmental History inform future management?*" It aims to answer this question by evaluating the extent to which the environmental and cultural history of an ecosystem can be described and by exploring the ways in which historical knowledge of an ecosystem can influence people's perceptions of it as it is today and their predictions for its future using the River Don as a case study. The aims of this thesis and the methodology which will be used to meet these aims are defined and explained broadly below and in more detail in the subsequent chapters:

1) Biological records are frequently used in environmental history to describe the composition of reference communties and changes in community composition caused by environmental degradation and restoration (Fritts and Rodda, 1998; Langford *et al.*, 2009; Gillette *et al.*, 2012). However, their utilitarian value is often reduced due to their sporadic nature and recording biases (Bernard and Parker, 2006; Boshoff and Kerley, 2010). This thesis therefore aims to assess the extent to which historical changes in community composition can be described and inferences can be drawn concerning the factors which drove these changes despite these biases particularly with regards to environmental degradation and restoration. The River Don's fish communities were chosen for this purpose because I expected that more comprehensive historical records would exist for fish than other species as they have always been valued by local people, increasing the extent to which they could be used to describe historical community composition (Firth, 1997). Furthermore, strong consistent relationships between the abiotic environment and the phylogenetically conserved functional traits of the fish species which live in it increased the likelihood that useful inferences concerning changes in the abiotic environment could be drawn from descriptions of changes in community composition (Angermeir and Winston, 1999; Jackson *et al.*, 2001; Douglas and Matthews, 1992; Reynolds *et al.*, 2005). To meet this aim I will collect biological records from local biological records centres and libraries and use this information to produce a table describing when each species was recorded. I will then collect information on the functional traits, habitat preferences and utilitarian values of all the fish species which appear in the River Don's historical records. I will use this information to describe how the number of coarse fish and salmonids; pollution tolerant and pollution sensitive; species of different levels of interest to anglers; and species which were eaten to different extents changed historically. As recording effort is likely to have changed greatly through time I will not analyse these relationships statistically. Instead I will categorise the fish species according to their presence trajectories into the following categories: extinct, NISs, recently reappeared, resident and restocked. I will then statistically compare these categories in terms of their functional traits, habitat preferences and utilitarian values to establish how these variables influenced the likelihood of them appearing in the historical records at different times due to true changes in presence status and abundances resulting from changes in the abiotic environment; the likelihood of them being introduced or restocked; and the likelihood of them being recorded when present.

2) Newspaper articles are frequently used as a tool to describe historical relationships between people and nature in terms of ecosystem services, ecosystem disservices and efforts to conserve nature (Jensen, 2000; Vuorisalo *et al.*, 2001; Lahtinen and Vuorisalo, 2004a; Pohja-Mykrä *et al.*, 2005). They are particularly useful because in addition to providing information on a broad range of social and economic harm and benefits derived from specific ecosystems they refect societal attitudes at the time of publishing (Kellert, 1985; Vuorisalo *et al.*, 2001). However, the studies which have used them to date have all been limited in terms of their focus on particular relationships. For example, the consequences of pollution in terms of human health and recreational opportunities have received much attention (Jensen, 2000; Lahtinen and Vuorisalo, 2004b) whilst I was unable to find any studies which used historical newspaper articles to consider navigation or hydropower from an environmental perspective. This study aims to take a much more holistic approach to describe the history of the River Don as conveyed through newspaper articles in terms of the social and economic benefts derived from the river, the social and economic damage caused by or facilitated by the river and the environmental management of the river; and consider

how this information may contribute towards the effective future environmental management of the river.

3) Although the importance of public perceptions in determining the outcomes of conservation projects is widely recognised and particularly important in urban areas due to high population densities, relatively little research has been done on the influence of historical knowledge on these perceptions (Antrop, 2004; Wohl *et al*., 2005). The existing limited research suggests that historical knowledge has the potential to both foster support for and opposition against conservation (Stoll-Kleemann, 2001; Gooch, 2003; Ostergen *et al*., 2008; Drenthen, 2009; Cuerrier *et al*., 2015). It is therefore vital that its influences are better understood if historical information is to be used effectively as an environmental education tool. Therefore this thesis aims to assess the extent to which local people are knowledgeable about the history of the River Don and describe how their perceptions of its current state and predictions about its future state are influenced by their historical knowledge and consider how these findings may inform communications to foster support for and minimise opposition against the river's conservation. A grounded theory approach using semi-structured interviews will be taken to enable participants to fully express themselves and minimise the impact of my own preconceptions on the results of the study as far as possible (Price, 1999 cited in Stoll-Kleemann, 2001; Stoll-Kleemann, 2001; Bryman 2008). Members of local walking groups will be interviewed as walkers are key stakeholders for whom the River Don is currently managed, have in common an interest in the outdoor environment but are likely to have sufficiently heterogenous interests with regards to different aspects of the landscape such as heritage and nature. This will increase the likelihood of identifying a broad range of ways in which the relationships between historical knowledge and public perceptions affect support for and opposition against conservation (Bryman, 2008).

4) This thesis also aims to experimentally assess the effects of the provisioning of historical information about the River Don on people's perceptions of how it is now and how they expect it to be in the future and use the findings to consider how historical information may be used as a tool to raise public awareness and foster support for the river's conservation. Cause and effect relationships can only be distinguished from spurious relationships through experiments and quantitative research enables particular aspects of several participants' perceptions to be measured in a short space of time (Arceneaux, 2010; Newman, 2010). However, I was only able to find one other experiment which assessed the relationship between processing historical information on a particular ecosystem and forming oppinions regarding its current and/or future state. Whilst the experiment which was conducted by Hanley *et al*. (2009) proved that an experimental approach could be used to identify relationships between processing historical information about an ecosystem and forming desires for its future state, it had a narrow scope focused on support for afforestation or deforestation. Conversely, the experiment in Chapter Four will take a much more holistic approach which considers partcipants' perceptions of the river from broad social, economic and environmental perspectives.

2 TO WHAT EXTENT DO HISTORICAL FISH RECORDS PROVIDE INFORMATION WHICH IS USEFUL FOR PLANNING FUTURE ENVIRONMENTAL MANAGEMENT?

2.1 INTRODUCTION

2.1.1 Use of Historical Biological Records to Describe Changes in Community Composition

As discussed in Chapter One, historical biological records which collectively describe changes in community composition are commonly used to describe how community composition has changed from that of an ecosystem's reference community to those of an ecosystem's current community composition (Fritts and Rodda, 1998; Lotze *et al*., 2006; Gillette *et al*., 2012). Here I use the term reference conditions to describe an ecosystem's "*non-degraded natural baseline"* (Bennion *et al*., 2011). This includes identifying the species which have decreased in abundance, including those which have been extirpated, and identifying the species which have been introduced or become more abundant. Once these trends have been identified it may then be possible to infer the chemical, physical or biological changes within the ecosystem and ultimately the human activities which drove them. Historical studies are particularly well suited to this purpose because the factors which affect community composition often act over long time periods (Mather, 1992; Pandolfi *et al.*, 2003; Lotze *et al*., 2006).

The main ecological theory underpinning the relationship between changes in the chemical, physical and biological environment and resulting changes in the prevalence of species with particular functional traits within a community is the habitat filter framework (Poff, 1997; Statzner *et al*., 2004). This theory recognises that the functional traits of a species affect its ability to survive under specific ecological conditions so as these ecological conditions change, their abundances change. In extreme cases this includes extirpations and introductions. Knowledge of the relationship between habitat filters and community composition in degraded ecosystems can thus facilitate the restoration of habitats and communities (Craig *et al*., 2012). However, it is also important to realise that species with traits which are well suited to an ecosystem's current ecological conditions but not its previous ecological conditions may be absent for a long time due to slow colonisation rates even if they are regionally present. Statzner *et al*. (2004) define historical filters as habitat filters which "*acted historically on communities producing trait patterns that have persisted till today"*. Bond and Lake (2003) explained that dispersal and colonisation are often slow in restored rivers even when species are regionally present due to ecological disconnection between rivers which are geographically close to each other. This leads to community composition being substantially affected by historical filters.

However, despite their high value, historical biological records often have many limitations and this has contributed to their underutilisation and thus untapped potential (Newbold, 2010). Historical records, especially older records, are often sparse and biased (Bernard and Parker, 2006; Boshoff and Kerley, 2010). The sparsity of earlier records together with a lack of information on surveying methodologies makes it particularly difficult to determine whether a species was not recorded in a particular location at a particular time because it was absent or because survey efforts were lower (Igl and Johnson, 2005). The lack of methodological data has even greater consequences if one wishes to describe changes in abundances rather than coarse presence-absence trajectories. Historical recording efforts are often biased towards more charismatic species (Newbold, 2010) or species of greater social or economic importance (Karr *et al*., 1985). Less conspicuous species, such as nocturnal species are generally recorded to a lesser extent in the historical records (Boshoff and Kerley, 2001). They are often spatially biased in terms of the ease with which a site can be accessed, for example with regards to proximity to major roads (Sobéron *et al*., 2000) and the number of species which have been observed there previously (Sastre and Jorge, 2009). Although recording biases have generally decreased through time, Boakes *et al*. (2010) reported that threatened species of galliformes, an order of birds, have been reported more frequently in the scientific literature since the 1960s, which they attribute to changes in the priorities of scientific research. In addition to recording biases historical records often include mistakes both in terms of species misidentifications and incorrect geographical locations (Graham *et al*., 2004; Newbold, 2010). The precision of place names varies hugely from the grounds of an individual building of historical social importance through to the name of a large country.

Given the value of environmental records in informing environmental management and the limited extent of such records for many ecosystems, the aims of this study are to evaluate the utility of historical records to environmental managers in terms of informing future decisions. The specific objectives are to: 1) describe the composition of the river's reference fish community 2) evaluate the degree to which changes in community composition reflect changes in the extent to which the functional traits and habitat preferences of different fish species are suited to the temporally changing environment of the River Don in terms of both degradation and improvements; 3) evaluate the extent to which differences in life history traits determine the response of different species to these changes through time; 4) evaluate the extent to which historical fish records are affected by recording bias.

2.1.2 Review of Previous Studies which Have Described Historical Changes in the Composition of Riverine Fish Communities

As rivers are highly valuable to both people and wildlife yet are often severely degraded and threatened they are often in desperate need for well-informed management (Naiman *et al*., 1993; Brookes and Shields, 1996; Haslam, 1997; Everard and Moggridge, 2012; Langford and Shaw, 2014). Historical biological records have the potential to contribute greatly towards making informed decisions with regards to the environmental management of rivers (Winter *et al*., 2009; Gillette *et al*., 2012). Evidencing the widely recognised need for their management, it has been estimated that the US population value their freshwater ecosystems highly enough to pay an extra $58 billion US of tax per year to improve their water quality (Mitchell and Carson, 1989 cited in Wilson and Carpenter, 1999; Wilson and Carpenter, 1999). Similarly it has been estimated that UK households are willing to pay on average between £50.50 and £128.90 to improve the quality of the nation's water bodies to the extent that 95% achieve high quality status under the Water Framework Directive depending on survey methodology (Metcalfe *et al*., 2011). Unfortunately I was unable to find any national or continental willingness to pay studies specific to rivers for the UK or Europe. However, (Hanley *et al*., 2006) estimated that local households were willing to pay on average between £12.19 and £12.54 to improve the ecological status of the section of the River Wear in Durham in North East England from fair to good under the Water Framework directive whilst households local to the River Clyde in Scotland were willing to pay on average between £38.70 and £60.08 depending on the model which was used to make the estimations. These values fit well within the range of values estimated for willingness to pay for the conservation of terrestrial landscapes reviewed by (Moran, 2005). Of the UK studies of willingness to pay for the conservation of specific landscapes included in this review the lowest average value was reported by Willis and Garrod (1993) and pertained to the willingness of local residents to pay for the conservation of the Yorkshire Dales National Park in the North West of England. The highest average value of £98 was reported by Hanley *et al*. (1998) and reflected the willingness of visitors to an Environmentally Sensitive Area (ESA) in Perthshire in the South of Scotland to pay to conserve and enhance the quality of an agricultural landscape.

Of all the biological communities within rivers, historical biological fish records are likely to be particularly useful as it is likely that more complete records exist for fish than do for other taxa and they are good indicator species (Welcomme *et al*., 2006; Lasne *et al*., 2007; Haidvogl *et al*., 2014). I expect that whilst still far from complete, more comprehensive and accurate records will be available for fish than for other taxa as they have been highly valued by society for more than 10,000 years (Davies *et al*., 2004) and are relatively easy to identify (Leidy and Moyle, 1998). According to Giller and Malmqvist (1998) fish are the "*best known inhabitants in freshwater systems*". Fish were first valued as a source of subsistence and later became more valued by commercial and recreational fisheries (Davies *et al*., 2004) and many historical records of fish have been produced by those who benefited from these ecosystem services (Haidvogl *et al*., 2014). In addition to relatively complete records the historical trajectories of fish are likely to be found informative by environmental managers as much can be inferred about the ecological status of rivers from the composition of their fish communities. Fish are commonly used as indicator species (Welcomme *et al*., 2006; Lasne *et al*., 2007) because we have good knowledge of their functional traits and habitat preferences (Brazner *et al*., 2004; Davies *et al*., 2004; Olden, *et al*., 2006). Because biological interactions play a relatively minor role in shaping freshwater fish communities relative to abiotic factors, particularly in species depleted areas such as Europe, fish community composition can be expected to closely reflect changes in the abiotic environment (Taylor, 1996; Giller and Malmqvist, 1998; Angermeier and Winston, 1999; Jackson *et al*., 2001). Further advantages for drawing inferences from historical records are that fish functional traits are often phylogenetically constrained and thus conserved through time (Douglas and Matthews, 1992; Reynolds *et al*., 2005) and although some species have relatively high degrees of phenotypic plasticity this degree is also often conserved through time (Robinson and Wilson, 1994; Smith and Skulason, 1996; Daverat *et al*., 2006).

Previous studies of historical fish records have helped to identify the contexts in which species with particular functional traits are most vulnerable. For example, Anderson *et al*. (1995) found that the relative abundances of habitat generalists with opportunistic life histories had increased in Texan freshwater streams from the 1950s to the 1980s, whilst those of habitat specialists had decreased. They surmised that increased pollution and physical habitat degradation including impoundment and abstraction favoured the habitat generalists, many of which were non-indigenous and destroyed much of the habitat on which the habitat specialists depended, and that these effects were exacerbated by increased competition between habitat generalists and habitat specialists. Similarly, Gillette *et al*. (2012) attributed declines in the species richness and abundances of darters in stream communities in north-eastern Oklahoma since the 1940s to physical degradation including the construction of impoundments. They explained that darters were particularly vulnerable to such changes due to their low tolerance of physical degradation and highly specific habitat requirements. They reasoned that it is important to describe how assemblages have responded to anthropogenic activities in the past in order to predict how they are likely to respond in the future and thus make informed decisions regarding environmental management. Although Haidvogl *et al*. (2014) described and attributed potential causes of changes in community composition on the rivers Danube and Salzach in Austria from the 14th century and the 18th century onwards respectively they did not consider how the functional traits of species affected their response to anthropogenic threats which limited the wider utility of their results in informing environmental management.

Historical studies of freshwater fish communities have also occasionally been used to evaluate the effectiveness of restoration measures. For example, Amisah and Cowx (2000) compared fish communities in the River Don in South Yorkshire from the early and late 1990s. They found that despite marked improvements in water quality due to efforts to reduce the amount of domestic and industrial pollutants which are discharged into the river, no marked changes in the status of the fish communities had been recorded. They attributed this lack of success to diffuse pollution from abandoned mines, episodic pollution incidents, pollutants which are trapped in the sediments and pollution from the river's tributaries. Winter *et al*. (2009) evaluated the effectiveness of the restoration of the River Vecht in Germany and the Netherlands using reference conditions which were based on historical fish records from the River Vecht and two other degraded local rivers together with current records from a naturally similar but less degraded river. They concluded that to date restoration efforts since the 1970s had effected only small changes in the composition of the fish communities and in some cases these changes had moved the community further away from the reference conditions. They recommended further actions to remeander the river and enable macrophytes to grow along the banks. They called for environmental managers to use similar methods to evaluate the effectiveness of restoration programmes. These studies prove that historical studies covering periods through which rivers have been restored have the potential to evaluate the successes and limitations of work to date and recommend further action. This study therefore aims to build on previous research regarding historical changes in lotic fish communities by considering the ways in which the functional traits of species which are present and absent has changed over a long time period. Whilst previous studies have either focused on the degradation or the restoration of fish communities, this study will describe both the demise and recovery of fish communities.

A wide range of sources has proven useful in enabling other environmental historians to describe changes in community composition and species distributions through time. These include biological records and a wide range of other books, documents and photographs. Burnett *et al*., (1995) state that "*Biological records describe the presence, abundance, associations and changes, both in time and space, of wildlife. They range from the simplest record of presence or absence of an organism at a particular time in a specific place to extensive monitoring of many species over long periods*." Clearly knowing the identity, time and location of species sightings is essential for describing changes in community composition. Hickling *et al*. (2006) used biological records dating back to the 1960s and held by the Biological Records Centre to describe changes in the distribution of freshwater fish and other taxa. Around the turn of the 20th century large numbers of people who were members of natural history societies produced biological records which are well respected for their quality; (Withers and Finnegan, 2003; Pocock *et al*., 2015). Fortibuoni *et al*. (2010) used books which had been produced by naturalists between 1818 and 1956 to describe changes in the composition of the fish communities in the Adriatic Sea. For this reason I contacted the Sorby natural history society as well as looking at the biological records through the National Biodiversity Network Gateway. In addition to naturalists, before the commencement of formal monitoring for management purposes, anglers were the key recorders of fish. A wide range of books, documents and photographs have proven to be useful in describing changes in the community composition of fish over recent centuries (Last *et al*., 2011). Amisah and Cowx (2000) used EA records to describe changes in the community composition of freshwater fish in the River Don in South Yorkshire between 1990 and 1993.

2.1.3 Aims of this Chapter

This chapter aims to establish the extent to which biological records can be used to describe the environmental history of an ecosystem using the River Don as a case study in order to evaluate their utilitarian value to environmental historians and the factors which affect this particularly with regards to recording biases. Firstly I will use historical records to describe changes in fish community composition since the earliest records were made. I will then use knowledge of the ways in which changes in the abiotic environment affect species with different habitat preferences and functional traits differently to draw inferences regarding the likely causes of historical changes in the composition of the River Don's fish community. I hope these inferences will enable me to describe the environmental history of the River Don more holistically. I will also evaluate the likelihood that absences in the records are due to recording biases rather than true absences with regards to the utilitarian values of the fish which were and were not recorded at different times and other factors which are likely to reduce the likelihood of them being recorded when present such as small size, nocturnal activity, low levels of gregariousness and hiding behaviour.

2.1.4 Reasons for Using the River Don as a Case Study and an Overview of its History

An urban river was used as a case study for this investigation as their proximity to densely populated areas means that they are potentially of particularly high potential social and economic value but also often have long legacies of severe environmental degradation (Hoffmann, 1996; EA (Environment Agency), 2006; Lundy and Wade, 2011). Furthermore, present species may be more likely to have been recorded historically due to the ease with which urban rivers could be accessed (Sobéron *et al*., 2000). According to the EA the restoration of Britain's urban rivers has the potential to "*make a huge contribution to improving the quality of city life for people and wildlife"* (EA, 2006). Historically rivers have played an important role in determining the initial position of cities and enabling them to grow (Grimm *et al.*, 2008). Today urban rivers continue to provide a broad range of ecosystem services including: the provisioning of water; drainage; and opportunities to connect with nature which bring many health benefits and facilitate community cohesion (EA, 2006; Lundy and Wade, 2011). They also attract businesses which bring both social and economic benefits (EA, 2006). Urban rivers also play an important role as migratory corridors for wildlife which are not suited to the surrounding urban habitat (Findlay and Taylor, 2006; Douglas and Sadler, 2011). However, many urban rivers have been severely polluted and physically degraded through culverting and channelisation with the resultant depletion of their wildlife communities (EA, 2006). This combination of high potential social and environmental value together with high levels of degradation makes the need for their informed restoration high. This has resulted in great improvement in the ecological quality of many urban rivers, particularly those in the USA and Europe over recent decades described by Gobster and Westphal (2004).

The River Don in particular was chosen as its historical trajectory is similar to that of many post-industrial urban rivers in terms of having a long legacy of domestic and industrial pollution and physical degradation such as channelisation and impoundment but having been recently restored to a large extent, particularly with regards to reduced pollution (Firth, 1997; Bothmann *et al*., 2006; Yin, 2012 cited in Wickfeldt, 2016; Wickfeldt, 2016). However, both its chemical and physical degradation were extreme relative to that of other rivers (Firth, 1997). For example, it was widely recognised to be one of the most polluted rivers in Europe and the ecological consequences of its channelisation have been equated in severity to rainforest deforestation. Due to its social and economic importance the environmental history of the River Don is also well recorded, increasing the likelihood that biological records will enable the historical changes in community composition to be accurately described and thus increase its utility in informing environmental management decision making processes (Firth, 1997; Scapens, 2004).

Very little has been written on the ways in which people benefited from the River Don before medieval times. However, given the ecosystem services provided by other rivers at this time it was probably used as a source of drinking water and food (Hoffmann, 1996) and to a much lesser extent navigation and defence (Walton, 1952; Sherratt, 1996; Firth, 1997). In Medieval times water power was harnessed from many rivers across Europe (Hoffmann, 1996) and the River Don provided better opportunities for this than most European rivers (Firth, 1997). By the 13th century there were at least two mills on the River Don and by the 18th century there were 13 major impoundments between Sheffield and Doncaster (Palmer 1722 cited in Firth, 1997). These impoundments blocked fish migrations and greatly altered flow speeds and thus biological communities (Firth, 1997). During the industrial revolution (roughly from the mid-18th to the mid-19th century though these dates are much disputed (Deane, 1979) towns and cities along the River Don benefited from it greatly in terms of: water power, abstraction, navigation and waste removal, meaning that it became grossly polluted. The River Don was frequently described as "*an open sewer*" and notoriously one of the most polluted Rivers in Europe (Firth, 1997). Greater use of water power together with abstraction meant that sections of the river up to several hundred metres long frequently dried up.

Drainage of wetlands for agriculture is extensive across Europe and often involves channelisation of the rivers which previously meandered through them (Abbot and Leeds-Harrison, 1998 cited in Blan *et al*., 2009; Blann *et al*., 2009). Its history in Britain dates back to the Roman times (Darby, 1956, cited in Holden *et al*., 2004) but accelerated greatly in the 17th century (Holden *et al*., 2004). The course of the River Don was altered to reduce flooding following land drainage in the 17th century to the extent that it now flows in its entirety into the River Ouse, a river it was never naturally connected to (Thirsk, 1953). Other land use changes including urbanisation and mining also increased the risk of the River Don flooding (Firth, 1997) as it has many other European rivers (Bell *et al*., 2007; Feyen *et al*., 2009). Attempts to manage the risk of rivers flooding have a long history in Europe. For example, Pinter *et al*. (2006) state that there is evidence of river engineering activities on the River Rhine dating back to the Roman era and that the majority of such projects prior to the 19th century were undertaken to reduce the risk of flooding. By the start of the industrial revolution the risk of flooding in major cities had been reduced greatly (Mitchell 2003). Unfortunately such approaches to flood management cause much environmental degradation including the destruction of aquatic and bankside vegetation, reduced habitat heterogeneity and ultimately reduced biodiversity (Congdon, 1971, cited in Brooker 1985; Brooker, 1985) The use of flood banks to reduce the risk of flooding in the River Don began long before the 19th century when it was greatly intensified (Firth 1997).

In recent decades concerted efforts have been made to restore rivers throughout Europe primarily for the benefit of wildlife and recreation with great success (Haslam, 1997; Gobster and Westphal, 2004). The River Don has been improved to the extent that the section below Rotherham is recognised by Firth (1997) as *"one of the most popular locations for anglers"* and otters are starting to return (Sheffield Local Biodiversity Action Partnership n.d.). These improvements include greatly reduced pollution and the installation of fish passes.

2.1.5 Selection of Functional Traits, Habitat Preferences and Utilisation Values for Use in this Study

Fish functional traits determine their habitat preferences. In accordance with the habitat templet theory it can be expected that habitat preferences play an important role in determining the responses of different fish species to the extensive habitat changes which have occurred in many rivers throughout Europe (Southwood, 1977; Southwood, 1988; Scarsbrook and Townsend, 1993; Townsend *et al*., 1997). Furthermore, empirical evidence has found that many fish invasions and extirpations can be explained with regard to habitat preferences (Miller *et al*., 1989; Baltz and Moyle, 1993; Marchetti and Moyle, 2001; Light and Marchetti, 2007). Variables regarding migratory behaviour, sediment and flow preferences including habitat heterogeneity, use of vegetation and pollution tolerance are particularly likely to influence the ways in which fish respond to impoundment as there is extensive evidence to demonstrate that impoundments block migration and alter flow speeds, sediment types, the availability of vegetation and the concentration of pollutants (Stanford and Ward, 1991; Gilvear *et al*., 2002; Pretty *et al*., 2003). Several studies have found that habitat specialists are more vulnerable to a wide range of anthropogenic threats than habitat generalists (Böet *et al*., 1999; Walters, 2002; Walters *et al*., 2003).

Similarly, trophic specialisation has been found to be an important predictor of extinction risk in freshwater fish (Olden *et al*., 2008). Dietary preferences are also likely to be important in determining the historical trajectories of fish species as those at higher trophic levels are theoretically more vulnerable to disturbances due to lower absolute population sizes and dependence on species at lower trophic levels (Schoener, 1989; Holt, 1996). Karr *et al*. (1985) found that populations of invertivores, herbivores and top carnivores in the Maumee River in the US had declined more than other trophic groups, in some cases to the point of extirpation. Furthermore, a disproportionately large proportion of introduced species were planktivorous.

Life history traits are also likely to play an important role in determining the historical trajectories of different fish species because they have been found to influence the resilience exhibited by freshwater fish species when they are impacted by anthropogenic disturbances (Schlosser, 1990; Detenbeck, *et al*., 1992). Furthermore, life history strategies have been shown to influence the introduction and extirpation of freshwater fish to and from lotic ecosystems (Olden et al. 2006).

Whilst the above traits are likely to determine actual changes in community composition, biases in recording are likely to be caused by functional traits which affect the likelihood of them being observed when present and utilitarian values which affect the likelihood of them being recorded when observed. Empirical studies have found that trout are more visible when shoaling than when hiding to evade predation (Hayes and Baird, 1994) and that those with bold personalities are more likely to be caught using gillnets (Biro and Post, 2008). I expect that because the majority of recreational angling and freshwater fish surveying occurs during the day, diurnal activity is likely to have a greater impact on the likelihood of them being recorded than nocturnal activity though I was unable to find a reference to support this. Karr *et al*. (1985) stated that there were few records of freshwater fish which were not of high commercial or recreational interest predating the 20th century in the US.

2.2 METHODS

2.2.1 Objectives

1) Decribe how the list of species recorded in the River Don has changed through time since records began by creating tables which show which species were present and absent from the records each centurty. Describe these changes at a decadal scale for the second half of the 20th century and the first two decades of the 21st century.
2) Graphically describe how the number of species recorded in the River Don has changed through time in term of: the number of coarse fish and salmonids; the number of pollution tolerant and pollution sensitive species; the number of species which are of different levels of interest to recreational anglers; and the number of species which were eaten by people to different extents in the past. The reasons why changes in the number of coarse fish and salmonids were described through time are explained in section 2.3.2.1. Those for describing the changes in the number of pollution tolerant and pollution sensitive species and the number of species of different levels of interest to recreational anglers and which were eaten to different extents by people historically are explained in section 2.1.5.
3) Compare the fish species which show different presence trajectories in the River Don's historical records in terms of their functional traits, habitat preferences and utilitarian values (Table 1; and Table A.1 in Appendix A). The reasons for using these explanatory variables are described in section 2.1.5.

2.2.2 Data Collection

Records of fish in the River Don were aggregated from a broad range of collections including: Sheffield, Rotherham and Barnsley Biological Records Centres, Sorby Natural History Society, Sheffield local studies library, Sheffield Museum Collections, Leeds University Brotherton Library, local angling clubs, the Don Catchment Rivers Trust (DCRT) and the EA. This study included all records regardless of the time period to which they pertained in order to maximise the extent to which they could be used to describe historical changes over the maximum time period which the available records allowed.

The search of these collections yielded the following information sources which were analysed: biological records held by the Biological Records Centres listed above and accessed through the National Biodiversity Network Gateway (2013) data from surveys conducted by the EA between 1981 and 2012 (personal communications with Nia Hughes, Yorkshire Customer and Engagement Team, EA, 2013); information on the restocking work of the EA as described in a document called "*Stocking History of the River Don and its tributaries"* which was written by Trudgill in 2006 and obtained through personal communication with Nia Hughes in 2013; a report which was published by the Sorby Natural History Society, entitled "Fish of the Sheffield Region" (Mander, 1973); books which were written for anglers, namely Yorkshire Anglers Guide (Bradley, 1851) and Fish It 2! (Keeling, 2007); an account of the history of the River Don which was written by a retired Area Fisheries Officer for the Ridings Area EA; books about Sheffield, namely Vital Statistics of Sheffield (Holland, 1843) and Hunter's Hallamshire (Hunter, c. 1875) and personal communications with a local angler who published a book on his lifetime's experience of fishing in Sheffield and its surrounding area, Martin Read. Other collections were searched but yielded no fish records. These were the local archives and libraries in Penistone, Sheffield, Rotherham, Goole, Doncaster and the East Riding of Yorkshire Archives in Beverley. Personal communications with staff at Doncaster Museum and Art Gallery and Clifton Park Museum in Rotherham revealed that they had no records of fish within their collections. The time periods covered by all of these sources are shown in tables 2a and 2b.

Information on the habitat preferences, life history traits, dietary preferences, behavioural habits, and utilitarian values of the fish which had been recorded in the River Don (Appendix A: Table A.1) was collected from the FishBase (2013) website and various books on freshwater fish (Wheeler, 1978; Maitland and Campbell, 1992; Davies *et al*., 2004; Kotelat and Freyhof, 2007). Papers published in scientific journals, academic theses and political reports were used to find some of the information which was missing from these sources. These are listed in Table A.2 in Appendix A. The choice of variables which were included in the analysis is justified in section 2.1.4.

Whether or not a species is able to maintain its presence following modifications to the abiotic environment is dependent on how well the population which is present prior to the modification is able to tolerate its modified habitat (Poff, 1997; Statzner *et al*., 2004). This depends on the functional traits of the individuals present and if few individuals have the functional traits which enable survival and reproduction in their modified habitat or are able to develop them through phenotypic plasticity, the speed with which these traits are able to evolve within the population relative to the time taken for the population to decline below a viable size (Gomulkiewicz and Holt, 1995; Gomulkiewicz and Shaw, 2013; Merilä and Hendry, 2014; Carlson *et al*., 2014). Using trait values which describe individuals from other populations may therefore reduce the extent to which inferences regarding the driving forces behind the decline and recovery of the River Don's fish populations can be inferred by describing relationships between presence and absence trends shown by each fish species and their functional traits and habitat preferences, particularly when the other populations have adapted to very different habitat conditions than those afforded by the River Don in its reference conditions. For example, the size of trout varies greatly in response to a combination of genetic and environmental factors. The size which the majority of individuals reach in the River Don is likely to have the greatest effect on the way in which the population responds to habitat modifications (Davies *et al*., 2004). However, it was unfortunately necessary to use data collected from other populations because there was insufficient data available from the River Don. The effects of extreme length values on the analysis were minimised in this study by using average length as well as maximum length. These two variables were found to be strongly related (Spearman's rank correlation: $n=22$, $r_s=0.908$ and $p<0.001$).

2.2.3 Describing Changes in Community Composition through Time

The centuries in which each species was recorded was documented. These records dated back to the 14th century. From the 1960s onwards the decades in which each species was recorded was documented. This information was used to describe changes in the number of salmonids and coarse fish; the number of pollution sensitive and pollution tolerant species; the number of species which were of each level of interest to recreational anglers and the extent to which they were eaten historically (Tabe A.1 in Appendix A). It was expected that changes in the number of pollution sensitive and pollution tolerant species would be indicative of the extent to which pollution was likely to have been a key driver of changes in actual community composition through time as fish are often used as indicator species. It was also expected that changes in the number of species which were of different of interest to recreational anglers or consumed by people to different extents would indicate the extent to which utilitarian values affected recording biases.

2.2.4 Comparing the Functional Traits of Fish Species which Show Different Presence Trajectories through Time

Due to the scarcity of earlier records relative to later records the performance of statistical tests on the trends listed in section 2.2.2 was not justified. This meant that it was not possible to establish the likelihood that the observed trends were due to chance. In order to assess the likelihood that changes in the number of species with specific functional traits, habitat preferences and utilitarian values reflected factors which affected actual community composition such as pollution or physical habitat degradation; or recording biases rather than chance a second approach as described in the next paragraph was taken.

All fish species which appeared in the available records from the River Don were broadly categorised into what I called "*presence trajectory types*" (Table 1). The breadth of these categories reduced the impact of the scarcity of earlier records on the analysis. Each species was only included in one category and those species which met the criteria for both restocked or NIS (non-indigenous species) and resident categories were only included in the former. Criteria were based on the occurrence in the River Don records for all categories with the exception of NIS and restocked. Whether or not a species was indigenous was determined using information available from *The Species and Their Distribution* (Davies *et al*., 2004), *FishBase* (2013) and the *IUCN Red List* (IUCN, 2013) were used to determine which species were indigenous. Whether or not a species had been restocked was based on *Stocking History of the River Don and its tributaries* (Trudgill, 2006).

Table 1. Definitions of presence trajectory types.

Presence trajectory type	Definition
Extirpated	Do not appear in records since the 19th century
NIS	Not native to the UK
Recently appeared	Only appear in the records since the 19th century.
Resident	Recorded at least once before the 19th century and in each century from the 19th century onwards.
Restocked	Reported by the EA to have been restocked.

To test the significance of differences in the individual functional traits, habitat preferences and utilitarian values between fish species which show different presence trajectory types on the River Don Analysis of Variance (ANOVAs) and Fisher Exact Tests were performed in R version 3.0.1 (R Core Team, 2013). Such analyses were only performed on variables for which there was a total sample size of at least 10 species. Presence trajectory categories were excluded from analyses when they were only represented by one species. All models took the form response~predictor where the response was a functional trait, habitat preference or utilitarian value and the predictor was presence trajectory type.

Some of these variables were grouped together in principal component analyses (PCAs). A full PCA which included all variables for which data were not missing for more than five species and a series of subset PCAs was performed (Table 3). Those which referred to life history traits were clustered for one subset PCA. As stated in the introduction life history traits are likely to influence the ability of species to resist and recover from environmental disturbances. Those which were thought likely to influence the extent to which fish species were affected by physical habitat degradation were used in another PCA. The third subset PCA used variables which were identified in the introduction to be likely to affect the probability of it being recorded when present. PCAs were performed using correlation matrices rather than covariance matrices to allow for the different units and variances in the variables (McGarigal *et al*., 2000). ANOVAs were performed using each of the principal components (PCs) which explained at least 10% of the variation within the data set.

Table 3. Habitat preferences, functional traits and utilitarian values describing fish historically recorded in the River Don included in each PCA. Variables are described in table A.1 in Appendix A.

PCA	Habitat preferences, functional traits and utilitarian values included in model
Full	Pollution tolerance
	Habitat heterogeneity
	Require vegetation
	Maximum length
	Usual length
	Parental care
	Lifespan
	Migratory behaviour
	Hiding behaviour
	Eaten
	Angling
Life history	Maximum length
	Usual length
	Parental care
	Lifespan
Physical habitat degradation	Habitat heterogeneity
	Pollution tolerance
	Vegetation
	Migratory behaviour
	Hiding
	Angling
	Eaten
Likelihood of being recorded when present	Maximum length
	Usual length
	Hiding
	Angling
	Eaten

2.3 RESULTS

2.3.1 Reference Community Composition

The extent to which the composition of the River Don's fish community can be described using historical records is greatly limited by the scarcity of the records (Table 3a). The River Don has been anthropogenically both chemically and physically degraded for a long time and its course was greatly altered and channelised from 1626 onwards (Thirsk, 1953; Firth, 1996; Munford, 2000). However, the severity of this degradation probably increased greatly from the middle of the 18th century due to the industrial revolution and in particular the growth of the steel industry and associated growth of urban populations. The only fish species which were unambiguously recorded before or during the 18th century were: sturgeon (*Acipenser sturio)*, pike, salmon, barbel, bream, chub, dace, grayling, perch, roach and trout (Appendix A: Table 3a). The remaining non-indigenous species: burbot (*Lota lota*), ide and spined loach (*Cobitis taenia*) may well have also been recorded before or during this century as the only records of these species are that Firth (1997) stated that they were recorded before 1850.

Table 3a. Changes in the number of records of fish species recorded in the River Don each century since records began. Fish species have been categorised according to their presence type categories (Ext=Extirpated (no longer extant in UK), NIS=Non Indigenous Species (Introduced to the UK through anthropogenic activities), ReA=Recently Appeared (First observed in the 19th century or later), Res=Resident, Rsto=Restocked (Records of these species being released into the River Don with the intent of establishing self-sustaining populations are available)). The sources of the records are recorded (Fir=Firth (c. 1997), BRCs=Biological Records Centres, Sor=The Sorby Record (Mander, 1973), HH=Hunter's Hallamshire (Hunter, c. 1875), VSS=Vital Statistics of Sheffield (Holland, 1843), YAG=Yorkshire Angler's Guide (Bradley, 1851), EA=Envionment Agency survey records and stocking records (Trudgill, 2006; personal communications with Nia Hughes, Yorkshire Customers and Engagement Team, Environment Agency, August 2013), LA=Personal communications with local angler, MuB=Book published by local museums (Mander 1976), SMC=Sheffield Museum Collections, FI2=Fish It 2! (Keeling, 2007). Tan=Secondary historical sources, green=sources written primarily for those with an interest in natural history, blue=scientific surveys and official restocking records, grey= records from more than one of these categories. Numbers in brackets indicate the number of records available.

Species	**1300s**	**1400s**	**1500s**	**1600s**	**1700s**	**1800s**	**1900s**	**2000s**
Sturgeon (*Acipenser sturio*) (Ext)				Fir, Sor (4)		Sor (4)		
Carp (*Cyprinus carpio*) (NIS)						VSS (1)		BRCs, EA, FI2 (4)
Crucian Carp (*Carassius carassius*) (NIS)							BRCs, EA (5)	
Ide (*Leuciscus idus*) (NIS)								EA (6)
Rainbow Trout (*Oncorhynchus mykiss*) (NIS)							BRCs, MuB (5)	EA (18)
Brook Lamprey (*Lampetra planeri*) (ReA)							BRCs (1)	
Bullhead (*Cottus gobio*) (ReA)						BRCs, VSS (2)	BRCs, EA, MuB, Sor (28)	BRCs, EA (132)
Eel (*Anguilla anguilla*) (ReA)						BRCs, VSS, YAG (3)	EA, Fir (17)	EA, FI2 (19)
Flounder (*Platichthys flesus*) (ReA)							EA, Fir (3)	EA (20)
Gudgeon (*Gobio gobio*) (ReA)						BRCs,	BRCs,	BRCs,

						Sor, VSS (4)	EA, Fir, LA, MuB, Sor (127)	EA, LA (130)
Minnow (*Phoxinus phoxinus*) (ReA)						VSS (1)	BRCs, EA, MuB (131)	BRCs, EA (136)
River Lamprey (*Lampetra fluviatilis*) (ReA)						VSS (1)	EA (2)	
Rudd (*Scardinius erythrophthalmus*) (ReA)							EA (2)	EA (16)
Ruffe (*Gymnocephalus cernuus*) (ReA)						VSS (1)		EA (18)
Silver bream (*Abramis bjoerkna*) (ReA)							EA (10)	EA (12)
Stone Loach (*Barbatula barbatula*) (ReA)							BRCs, EA, MuB (72)	EA (85)
Ten spined stickleback (*Pungitius pungitius*) (ReA)							EA (6)	
Tench (*Tinca tinca*) (ReA)						VSS (1)	EA, MuB (3)	EA (8)
Three spined stickleback (*Gasterosteus aculeatus*) (ReA)							BRCs, EA, MuB, SMC (91)	BRCs, EA (108)
Pike (*Esox lucius*) (Res)	Fir (1)					VSS, YAG (2)	BRCs, EA, Fir (24)	BRCs, EA, FI2 (81)
Salmon (*Salmo salar*) (Res)				Fir (2)	Fir (1)	Fir, VSS, YAG, HH (4)	Fir, Sor (2)	EA (2)
Barbel (*Barbus barbus*) (Rsto)				Fir (1)		VSS (1)	BRCs, EA, Fir (13)	BRCs, EA, FI2, LA (93)
Bleak (*Alburnus alburnus*) (Rsto)						VSS (1)	EA (5)	EA (69)
Bream (*Abramis brama*) (Rsto)	Fir (1)			Fir (1)		YAG, VSS (2)	BRCs, EA, Fir, MuB (5)	BRCs, EA, FI2, LA (56)
Chub (*Leuciscus cephalus*) (Rsto)				Fir (1)		BRCs, HH, Sor,	BRCs, EA, Fir (55)	BRCs, EA, FI2 (151)

						VSS, YAG (5)		
Dace (*Leuciscus leuciscus*) (Rsto)				Fir (1)		VSS (1)	BRCs, EA, Fir (51)	BRCs, EA, FI2, LA (146)
Grayling (*Thymallus thymallus*) (Rsto)				Fir (1)		Fir, VSS (2)	EA, Fir (4)	BRCs, EA (129)
Perch (*Perca fluviatilis*) (Rsto)	Fir (1)			Fir (1)		VSS (1)	BRCs, EA, Fir, MuB (67)	BRCs, EA, FI2 (178)
Roach (*Rutilus rutilus*) (Rsto)				Fir (1)		VSS, YAG (2)	BRCs, EA, Fir, LA (103)	BRCs, EA, FI2, LA (176)
Brown/sea trout (*Salmo trutta*) (Rsto)				Fir, BRCs (2)		Fir, Sor, VSS, YAG (6)	BRCs, EA, Fir, MuB (142)	BRCs, EA (256)

Table 3b. (See Table 1a for key). Changes in the number of records of fish species recorded in the River Don over the 20th and 21st centuries.

Species	**1900-1950**	**1950s**	**1960s**	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**
Sturgeon (*Acipenser sturio*) (Ext)								
Carp (*Cyprinus carpio*) (NIS)							BRCs, EA, FI2 (4)	
Crucian Carp (*Carassius carassius*) (NIS)						BRCs, EA (5)		
Ide (*Leuciscus idus*) (NIS)							EA (4)	EA (2)
Rainbow Trout (*Oncorhynchus mykiss*) (NIS)				BRCs, MuB (5)			EA (16)	EA (2)
Brook Lamprey (*Lampetra planeri*) (ReA)						BRCs (1)		
Bullhead (*Cottus gobio*) (ReA)				MuB, Sor (2)		BRCs, EA (26)	EA (71)	BRCs, EA (61)
Eel (*Anguilla anguilla*) (ReA)				Fir (1)	EA (8)	EA (8)	EA, FI2 (19)	EA (10)
Flounder (*Platichthys flesus*) (ReA)				Fir (1)		EA (2)	EA (14)	EA (6)
Gudgeon (*Gobio gobio*) (ReA)	BRCs (1)			BRCs, MuB, Sor (6)	EA, Fir (34)	BRCs, EA, Fir, LA (86)	BRCs, EA, LA (88)	EA, LA (42)
Minnow (*Phoxinus phoxinus*) (ReA)				BRCs, MuB (5)	BRCs, EA (45)	BRCs, EA (81)	BRCs, EA (90)	EA (46)
River Lamprey (*Lampetra fluviatilis*) (ReA)						EA (2)		
Rudd (*Scardinius erythrophthalmus*)					EA (2)		EA (8)	EA (8)
Ruffe (*Gymnocephalus cernuus*) (ReA)							EA (2)	EA (16)
Silver bream (*Abramis bjoerkna*) (ReA)						EA (10)	EA (10)	EA (2)
Stone Loach (*Barbatula barbatula*) (ReA)				MuB (2)	EA (22)	BRCs, EA (48)	EA (45)	EA (40)
Ten spined stickleback (*Pungitius pungitius*) (ReA)					EA (6)	EA (2)		
Tench (*Tinca tinca*) (ReA)				MuB (1)		EA (2)	EA (8)	
Three spined stickleback (*Gasterosteus aculeatus*) (ReA)				BRCs, MuB, SMC (11)	BRCs, EA (75)	BRCs, EA (74)	BRCs, EA (74)	EA (34)
Pike (*Esox lucius*) (Res)					EA, Fir	BRCs,	EA, FI2	BRCs,

					(5)	EA (19)	(56)	EA (25)
Salmon (*Salmo salar*) (Res)				Sor (1)		Fir (1)	EA (2)	
Barbel (*Barbus barbus*) (Rsto)	BRCs (1)			BRCs (1)		BRCs, EA, Fir (12)	BRCs, EA, FI2 (60)	EA, LA (31)
Bleak (*Alburnus alburnus*) (Rsto)						EA (5)	EA (47)	EA (22)
Bream (*Abramis brama*) (Rsto)				MuB (2)	Fir (5)	BRCs, EA (6)	BRCs, EA, FI2, LA (38)	EA, LA (18)
Chub (*Leuciscus cephalus*) (Rsto)				BRCs (2)	EA, Fir (5)	BRCs, EA, Fir (48)	BRCs, EA, FI2 (115)	EA (36)
Dace (*Leuciscus leuciscus*) (Rsto)					EA, Fir (5)	BRCs, EA, Fir (46)	BRCs, EA, FI2, LA (104)	EA, LA (42)
Grayling (*Thymallus thymallus*) (Rsto)					EA, Fir (4)	EA (26)	EA (96)	BRCs, EA (33)
Perch (*Perca fluviatilis*) (Rsto)	BRCs (1)			BRCs, MuB (2)	BRCs, EA, Fir (16)	BRCs, EA (48)	BRCs, EA, FI2 (122)	EA (56)
Roach (*Rutilus rutilus*) (Rsto)				BRCs (4)	BRCs, EA, Fir (24)	BRCs, EA, Fir, LA (75)	BRCs, EA, FI2, LA (124)	EA, LA (52)
Brown/sea trout (*Salmo trutta*) (Rsto)				BRCs, EA, MuB (7)	BRCs, EA, Fir (46)	BRCs, EA (89)	BRCs, EA (179)	BRCs, EA (77)

These lists are likely to differ substantially from the species which were present prior to anthropogenic degradation, particularly with regards to omissions. With the exception of spined loach these lists did not include any small species which were of low interest to recreational anglers (Table 3a, Table 4). This is most likely to be due to recording bias. They also did not include any species which require still to slow flowing water in their adult stages with the exception of spined loach. Seven out of nine of these species were of major interest to anglers so I expect that they would have been recorded if present in substantial quantities. However, I think that their populations were greatly depleted due to channelisation which isolated the River Don from its backwaters between 1626 and 1630 (Firth, 1997). Unfortunately it is not possible to determine from the historical records how many species were recorded prior to this as many of Firth's (1997) records simply state that the species was recorded before 1850. The number recorded before 1626 may have been as few as the three species which were recorded on a single fishing trip in the 14th century (Table 3a). The likely erroneous recording of spined loach as discussed in section 2.3.3.1 also highlights the need for caution to be taken when using historical records to infer reference conditions.

Table 4. Functional traits, habitat preferences and utilitarian values of all fish species ever recorded in the River Don. For a more detailed description of each variable please see Table A.1 in Appendix A.

Species	Presence trajectory type	Migratory behaviour	Pollution tolerance	Maximum temperature (°C)
Barbel	Restocked	Potamodromous or non-migratory	Sensitive	34
Bleak	Restocked	Potamodromous or non-migratory	Tolerant	34
Bream	Restocked	Potamodromous or non-migratory	Tolerant	34
Brook Lamprey	Recently appeared	Potamodromous or non-migratory	Sensitive	29
Bullhead	Recently appeared	Potamodromous or non-migratory	Sensitive	33
Burbot	Extirpated	Potamodromous or non-migratory	Sensitive	32
Carp	NIS	Potamodromous or non-migratory	Tolerant	40
Chub	Restocked	Potamodromous or non-migratory	Tolerant	NA
Crucian carp	NIS	Potamodromous or non-migratory	Tolerant	NA
Dace	Restocked	Potamodromous or non-migratory	Sensitive	34
Eel	Recently appeared	Potamodromous or non-migratory	Sensitive	38
Flounder	Recently appeared	Obligately anadromous or catadromous	Sensitive	NA
Grayling	Restocked	Potamodromous or non-migratory	Sensitive	25
Gudgeon	Recently appeared	Potamodromous or non-migratory	Sensitive	18
Ide	NIS	Potamodromous or non-migratory	Sensitive	NA
Minnow	Recently appeared	Potamodromous or non-migratory	Sensitive	31
Perch	Restocked	Obligately anadromous or catadromous	Sensitive	NA
Pike	Resident	Potamodromous or non-migratory	Tolerant	34
Rainbow trout	NIS	Facultatively anadromous or catadromous	Sensitive	26
River Lamprey	Recently appeared	Facultatively anadromous or catadromous	Sensitive	NA
Roach	Restocked	Potamodromous or non-migratory	Tolerant	34
Rudd	Recently appeared	Potamodromous or non-migratory	Sensitive	34
Ruffe	Recently appeared	Potamodromous or non-migratory	Tolerant	NA
Salmon	Resident	Facultatively anadromous or catadromous	Sensitive	23
Silver Bream	Recently appeared	Potamodromous or non-migratory	Sensitive	NA
Smelt	Extirpated	Facultatively anadromous or catadromous	Sensitive	20
Spined Loach	Extirpated	Potamodromous or non-migratory	Tolerant	31
Stone Loach	Recently appeared	Potamodromous or non-migratory	Sensitive	NA
Sturgeon	Extirpated	Obligately anadromous or catadromous	Sensitive	NA
Ten spined stickleback	Recently appeared	Facultatively anadromous or catadromous	Tolerant	NA
Tench	Recently appeared	Potamodromous or non-migratory	Tolerant	34
Three spined stickleback	Recently appeared	Facultatively anadromous or catadromous	Tolerant	NA
Trout	Restocked	Facultatively anadromous or catadromous	Sensitive	30

Table 4 continued

Species	Spawning temperature (°C)	Physical degradation tolerance	Spawning sediment	Spawning flow
Barbel	29	Sensitive	Coarse	Moderate to fast
Bleak	15	Tolerant	Coarse	Moderate to fast
Bream	20	Tolerant	Either	Still to slow
Brook Lamprey	9	Sensitive	Coarse	Moderate to fast
Bullhead	12	Sensitive	Coarse	NA
Burbot	6	Sensitive	Coarse	NA
Carp	26	Sensitive	Coarse	Still to slow
Chub	14	NA	Coarse	Moderate to fast
Crucian carp	30	Sensitive	NA	Still to slow
Dace	15	Tolerant	Coarse	Moderate to fast
Eel	NA	Sensitive	NA	NA

Flounder	NA	Sensitive	NA	NA
Grayling	9	Tolerant	Coarse	Moderate to fast
Gudgeon	17	Tolerant	Either	NA
Ide	10	NA	Either	Moderate to fast
Minnow	16	Sensitive	Coarse	Moderate to fast
Perch	15	NA	NA	Still to slow
Pike	18	NA	NA	Still to slow
Rainbow trout	15	NA	Coarse	Moderate to fast
River Lamprey	9	Sensitive	Coarse	Moderate to fast
Roach	14	Tolerant	Coarse	Either
Rudd	20	Tolerant	NA	NA
Ruffe	10	Tolerant	Either	NA
Salmon	NA	Sensitive	Coarse	Still to slow
Silver Bream	15	NA	Coarse	Still to slow
Smelt	12	Sensitive	Either	Moderate to fast
Spined Loach	18	NA	Either	Moderate to fast
Stone Loach	NA	Tolerant	Either	NA
Sturgeon	20	Sensitive	Coarse	Moderate to fast
Ten spined stickleback	NA	NA	NA	NA
Tench	24	Sensitive	NA	Still to slow
Three spined stickleback	12	Tolerant	NA	NA
Trout	NA	Sensitive	Coarse	Moderate to fast

Table 4 continued

Species	Spawning river section	Spawning main channel	Spawning Depth	Juvenile flow
Barbel	Upstream	Yes	Shallow	Either
Bleak	NA	Yes	Shallow	Either
Bream	Upstream	No	Shallow	Either
Brook Lamprey	Upstream	NA	NA	NA
Bullhead	NA	NA	NA	Moderate to fast
Burbot	NA	NA	Shallow	Either
Carp	NA	No	Shallow	Either
Chub	NA	Sometimes	Shallow	Either
Crucian carp	NA	NA	NA	Still to slow
Dace	NA	Sometimes	Shallow	Still to slow
Eel	NA	NA	NA	Still to slow
Flounder	NA	NA	NA	Still to slow
Grayling	Upstream	NA	Shallow	Either
Gudgeon	NA	NA	Shallow	Either
Ide	Upstream	Sometimes	Shallow	Still to slow
Minnow	Upstream	NA	NA	Either
Perch	NA	NA	Shallow or deep	NA
Pike	Downstream	No	NA	Moderate to fast
Rainbow trout	NA	NA	NA	NA
River Lamprey	Upstream	NA	Shallow	Still to slow
Roach	NA	Sometimes	Shallow	Either
Rudd	NA	NA	Shallow	Still to slow
Ruffe	NA	NA	Shallow	Still to slow
Salmon	Upstream	NA	NA	Moderate to fast
Silver Bream	NA	No	Shallow	Still to slow
Smelt	Downstream	No	Shallow	NA
Spined Loach	NA	NA	Shallow	Still to slow
Stone Loach	NA	NA	NA	Moderate to fast
Sturgeon	Downstream	Yes	Deep	NA
Ten spined stickleback	NA	NA	Shallow	Still to slow
Tench	NA	NA	Shallow	Still to slow
Three spined stickleback	NA	Sometimes	Shallow	NA
Trout	Either	Sometimes	NA	Still to slow

Table 4 continued

Species	Adult sediment	Adult flow	Adult river section	Adult main channel
Barbel	Coarse	Either	Upstream	Yes
Bleak	Coarse	Either	Downstream	Yes
Bream	Either	Either	Either	Sometimes
Brook Lamprey	NA	NA	Either	Sometimes
Bullhead	Coarse	Moderate to fast	NA	Sometimes
Burbot	Coarse	Either	Either	Sometimes
Carp	Either	Either	Either	NA
Chub	NA	Either	Either	Sometimes
Crucian carp	Fine	Still to slow	Either	Sometimes
Dace	Coarse	Moderate to fast	Either	Sometimes
Eel	Either	Still to slow	Either	No
Flounder	Fine	Still to slow	Downstream	NA
Grayling	Either	Moderate to fast	Downstream	NA
Gudgeon	Either	Either	Either	NA
Ide	NA	Still to slow	Downstream	NA
Minnow	Either	Either	Either	NA
Perch	NA	Either	Downstream	NA
Pike	NA	Moderate to fast	Downstream	Yes
Rainbow trout	NA	NA	Either	Sometimes
River Lamprey	NA	NA	NA	NA
Roach	NA	Either	Either	Sometimes
Rudd	NA	Still to slow	Downstream	Sometimes
Ruffe	Either	Still to slow	Downstream	NA
Salmon	NA	Moderate to fast	NA	NA
Silver Bream	Either	Still to slow	Downstream	No
Smelt	NA	NA	Downstream	NA
Spined Loach	Fine	Still to slow	Either	Sometimes
Stone Loach	Either	Moderate to fast	Either	NA
Sturgeon	NA	NA	NA	NA
Ten spined stickleback	Either	Still to slow	NA	Sometimes
Tench	Fine	Still to slow	Downstream	Sometimes
Three spined stickleback	Fine	NA	NA	Sometimes
Trout	NA	NA	Upstream	Sometimes

Table 4 continued

Species	Adult depth	Habitat heterogenity	Require vegetation	Spawning sediment width
Barbel	Shallow	Required	Required	Require particular sediment type (fine or coarse) but not vegetation
Bleak	NA	Required	Required	Require particular sediment type (fine or coarse) but not vegetation
Bream	Shallow	Required	Not required	Can use either fine or coarse sediment but require vegetation
Brook Lamprey	NA	Required	Not required	Require particular sediment type (fine or coarse) but not vegetation
Bullhead	Shallow	Not required	Required	Require particular sediment type (fine or coarse) but not vegetation
Burbot	NA	Required	Required	Require particular sediment type (fine or coarse) but not vegetation
Carp	Deep	Required	Beneficial	Can use either fine or coarse sediment and do not require vegetation
Chub	NA	Required	Required	Can use either fine or coarse sediment and do not require vegetation
Crucian carp	NA	Required	Not required	NA
Dace	NA	Required	Required	Require particular sediment type (fine or coarse) but not vegetation
Eel	NA	Not required	Required	NA

Flounder	Shallow	Not required	Required	NA
Grayling	NA	Required	Not required	Require particular sediment type (fine or coarse) but not vegetation
Gudgeon	Shallow or deep	Beneficial	Required	Can use either fine or coarse sediment and do not require vegetation
Ide	NA	NA	Required	Can use either fine or coarse sediment and do not require vegetation
Minnow	Shallow or deep	Beneficial	Required	Require particular sediment type (fine or coarse) but not vegetation
Perch	NA	Not required	Beneficial	NA
Pike	Deep	Required	Not required	NA
Rainbow trout	NA	Not required	Required	Require particular sediment type (fine or coarse) but not vegetation
River Lamprey	NA	Required	Required	Require particular sediment type (fine or coarse) but not vegetation
Roach	NA	Beneficial	Beneficial	Require particular sediment type (fine or coarse) but not vegetation
Rudd	NA	Not required	Not required	NA
Ruffe	NA	Not required	Required	Can use either fine or coarse sediment and do not require vegetation
Salmon	NA	Required	Required	Require particular sediment type (fine or coarse) but not vegetation
Silver Bream	NA	Required	Beneficial	Require particular sediment type (fine or coarse) but not vegetation
Smelt	NA	Not required	Required	Can use either fine or coarse sediment and do not require vegetation
Spined Loach	NA	Required	Beneficial	Can use either fine or coarse sediment and do not require vegetation
Stone Loach	NA	Required	Required	Can use either fine or coarse sediment and do not require vegetation
Sturgeon	NA	Required	Required	Require particular sediment type (fine or coarse) but not vegetation
Ten spined stickleback	Shallow	Not required	Not required	NA
Tench	Shallow	Beneficial	Not required	NA
Three spined stickleback	Deep	Required	Not required	NA
Trout	Shallow or deep	Beneficial	Required	Require particular sediment type (fine or coarse) but not vegetation

Table 4 continued

Species	Adult sediment width	Spawning flow width	Juvenile flow width	Adult flow width
Barbel	Require particular sediment type (fine or coarse) but not vegetation	NA	NA	Can use either still to slow or moderate to fast
Bleak	Require particular sediment type (fine or coarse) but not vegetation	Requires still to slow or moderate to fast	NA	NA
Bream	Require particular sediment type (fine or coarse) but not vegetation	Requires still to slow or moderate to fast	NA	Requires still to slow or moderate to fast
Brook Lamprey	NA	Requires still to slow or moderate to fast	NA	NA
Bullhead	Require particular sediment type (fine or coarse) but not vegetation	Requires still to slow or moderate to fast	NA	Requires still to slow or moderate to fast
Burbot	Require particular sediment type (fine or coarse) but not vegetation	Requires still to slow or moderate to fast	NA	Requires still to slow or moderate to fast
Carp	Require particular sediment type (fine or coarse) but not vegetation	Can use either still to slow or moderate to fast	NA	Requires still to slow or moderate to fast
Chub	NA	Can use either still to slow or moderate to fast	NA	NA
Crucian carp	Require particular sediment type (fine or coarse) but not vegetation	NA	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast
Dace	Require particular sediment type (fine or coarse) but not vegetation	NA	NA	Requires still to slow or moderate to fast
Eel	Do not require particular sediment type (fine or coarse) or vegetation	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast
Flounder	Require particular sediment type (fine or coarse) but not vegetation	Requires still to slow or moderate to fast	NA	NA
Grayling	Do not require particular sediment type (fine or coarse) or vegetation	NA	Requires still to slow or moderate to fast	Can use either still to slow or moderate to fast

Gudgeon	Do not require particular sediment type (fine or coarse) or vegetation	Requires still to slow or moderate to fast	NA	Can use either still to slow or moderate to fast
Ide	NA	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast	NA
Minnow	Require particular sediment type (fine or coarse) but not vegetation	NA	NA	Requires still to slow or moderate to fast
Perch	NA	NA	NA	Requires still to slow or moderate to fast
Pike	NA	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast	Can use either still to slow or moderate to fast
Rainbow trout	NA	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast
River Lamprey	NA	NA	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast
Roach	NA	NA	NA	Requires still to slow or moderate to fast
Rudd	NA	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast
Ruffe	Do not require particular sediment type (fine or coarse) or vegetation	NA	NA	NA
Salmon	NA	NA	NA	Requires still to slow or moderate to fast
Silver Bream	Require particular sediment type (fine or coarse) but not vegetation	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast
Smelt	NA	Requires still to slow or moderate to fast	Can use either still to slow or moderate to fast	Can use either still to slow or moderate to fast
Spined Loach	Require particular sediment type (fine or coarse) but not vegetation	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast
Stone Loach	Do not require particular sediment type (fine or coarse) but require vegetation	Requires still to slow or moderate to fast	NA	Requires still to slow or moderate to fast
Sturgeon	NA	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast
Ten spined stickleback	Require particular sediment type (fine or coarse) but not vegetation	Requires still to slow or moderate to fast	Can use either still to slow or moderate to fast	Can use either still to slow or moderate to fast
Tench	Require particular sediment type (fine or coarse) and vegetation	Requires still to slow or moderate to fast	NA	Can use either still to slow or moderate to fast
Three spined stickleback	Require particular sediment type (fine or coarse) and vegetation	Can use either still to slow or moderate to fast	Requires still to slow or moderate to fast	Can use either still to slow or moderate to fast
Trout	NA	Requires still to slow or moderate to fast	Requires still to slow or moderate to fast	NA

Table 4 continued

Species	Juvenile diet width (number of categories)	Adult diet width (number of categories)	Lowest trophic level	Hatching period (days)
Barbel	2	3	Plants including algae	15
Bleak	3	2	Plankton and detritus	NA
Bream	NA	4	Plankton and detritus	12
Brook Lamprey	1	NA	NA	NA
Bullhead	3	2	Macroinvertebrates	NA
Burbot	1	2	Macroinvertebrates	70
Carp	2	2	Plankton and detritus	8
Chub	NA	4	Plankton and detritus	10
Crucian carp	NA	3	Plankton and detritus	NA
Dace	2	3	Plankton and detritus	25
Eel	3	2	Plankton and detritus	NA
Flounder	1	2	Macroinvertebrates	7
Grayling	1	3	Plankton and detritus	40

Gudgeon	NA	1	Macroinvertebrates	30
Ide	1	4	Plankton and detritus	20
Minnow	2	3	Plankton and detritus	10
Perch	NA	3	Plankton and detritus	18
Pike	2	3	Macroinvertebrates	NA
Rainbow trout	1	2	Macroinvertebrates	NA
River Lamprey	NA	1	Fish	NA
Roach	NA	2	Plankton and detritus	12
Rudd	3	3	Plankton and detritus	NA
Ruffe	NA	3	Plankton and detritus	10
Salmon	NA	NA	NA	183
Silver Bream	NA	2	Plankton and detritus	6
Smelt	2	2	Macroinvertebrates	35
Spined Loach	1	1	Plankton and detritus	NA
Stone Loach	3	1	Macroinvertebrates	16
Sturgeon	1	NA	NA	7
Ten spined stickleback	1	3	Plankton and detritus	10
Tench	3	3	Plankton and detritus	8
Three spined stickleback	2	3	Plankton and detritus	10
Trout	2	2	Macroinvertebrates	56

Table 4 continued

Species	Parental care	Usual length (cm)	Maximum length (cm)	Lifespan (years)
Barbel	Adhesive or strings	45	120	25
Bleak	No nest or adhesive eggs	14	25	6
Bream	Adhesive or strings	45	82	20
Brook Lamprey	Make nest	25	20	20
Bullhead	Guard eggs	10	18	5
Burbot	No nest or adhesive eggs	41	152	NA
Carp	Adhesive or strings	56	110	50
Chub	Adhesive or strings	40	60	12
Crucian carp	Adhesive or strings	20	64	10
Dace	Bury or shelter eggs	20	40	10
Eel	NA	65	100	12
Flounder	NA	36	60	NA
Grayling	Make nest	40	60	6
Gudgeon	No nest or adhesive eggs	22	20	8
Ide	Adhesive or strings	37	100	15
Minnow	Bury or shelter eggs	8	14	11
Perch	Adhesive or strings	30	60	21
Pike	No nest or adhesive eggs	85	137	24
Rainbow trout	Make nest	100	120	4
River Lamprey	Make nest	38	50	NA
Roach	Adhesive or strings	30	53	18
Rudd	Adhesive or strings	20	51	19
Ruffe	Adhesive or strings	17	30	10
Salmon	Make nest	58	150	7

Silver Bream	Adhesive or strings	23	36	10
Smelt	Adhesive or strings	14	45	10
Spined Loach	Adhesive or strings	8	13.5	5
Stone Loach	Adhesive or strings	8	21	7
Sturgeon	Adhesive or strings	250	600	40
Ten spined stickleback	Provide nursery	6	9	3
Tench	Adhesive or strings	NA	70	20
Three spined stickleback	Provide nursery	6	11	2
Trout	Make nest	72.5	140	24

Table 4 continued

Species	Circadian rhythm	Hiding	Gregarious transience
Barbel	Not active nocturnally	Usually	Seasonally
Bleak	Not active nocturnally	None	Seasonally
Bream	Not active nocturnally	Seasonally	Seasonally
Brook Lamprey	Seasonally active nocturnally	Seasonally	Seasonally
Bullhead	Not active nocturnally	Usually	Not gregarious at all
Burbot	Not active nocturnally	Usually	Throughout year
Carp	Not active nocturnally	Circumstantially	Throughout year
Chub	NA	Usually	Seasonally
Crucian carp	Somewhat active nocturnally	Usually	NA
Dace	NA	Seasonally	Throughout year
Eel	Not active nocturnally	Seasonally	Not gregarious at all
Flounder	Somewhat active nocturnally	Circumstantially	NA
Grayling	NA	Usually	Seasonally
Gudgeon	Somewhat active nocturnally	Usually	NA
Ide	NA	NA	Seasonally
Minnow	Somewhat active nocturnally	Seasonally	Throughout year
Perch	Most active nocturnally	Seasonally	Seasonally
Pike	Seasonally active nocturnally	Seasonally	Not gregarious at all
Rainbow trout	Somewhat active nocturnally	Usually	NA
River Lamprey	Seasonally active nocturnally	Seasonally	Seasonally
Roach	Somewhat active nocturnally	Circumstantially	Throughout year
Rudd	NA	Usually	Seasonally
Ruffe	Somewhat active nocturnally	Usually	Throughout year
Salmon	Not active nocturnally	Seasonally	Seasonally
Silver Bream	Not active nocturnally	NA	Throughout year
Smelt	NA	NA	Seasonally
Spined Loach	Somewhat active nocturnally	Usually	Not gregarious at all
Stone Loach	Not active nocturnally	Usually	Throughout year
Sturgeon	Not active nocturnally	NA	Not gregarious at all
Ten spined stickleback	Seasonally active nocturnally	Usually	Not gregarious at all
Tench	Not active nocturnally	Seasonally	NA
Three spined stickleback	Most active nocturnally	Usually	Seasonally
Trout	Somewhat active nocturnally	Seasonally	NA

Table 4 continued

Species	Group size	Eaten historically	Angling
Barbel	Large	Minor	Major
Bleak	Large	Major	Minor
Bream	Large	Major	Major
Brook Lamprey	Large	Not eaten	None
Bullhead	Usually solitary	Major	Bait
Burbot	Large	Unspecified extent	Angled outside UK
Carp	Small	Major	Major
Chub	NA	Not eaten	Major
Crucian carp	NA	Major	Major
Dace	Large	Unspecified extent	Minor
Eel	Usually solitary	Major	Major
Flounder	NA	Not eaten	Major
Grayling	NA	Major	Major
Gudgeon	NA	Major	Minor
Ide	NA	Minor	Major
Minnow	NA	Eaten outside UK	None
Perch	Small	Unspecified extent	Minor
Pike	Usually solitary	Major	Major
Rainbow trout	NA	Minor	Major
River Lamprey	Large	Eaten outside UK	Bait
Roach	Large	Major	Major
Rudd	NA	Eaten outside UK	Major
Ruffe	Small	Major	Bait
Salmon	NA	Major	Major
Silver Bream	NA	Major	Major
Smelt	NA	Major	Minor
Spined Loach	Usually solitary	Major	None
Stone Loach	Small	Major	Bait
Sturgeon	Usually solitary	Major	NA
Ten spined stickleback	Usually solitary	Major	NA
Tench	NA	Minor	Major
Three spined stickleback	NA	Eaten outside UK	Bait
Trout	NA	Major	Major

2.3.2 Records through Time

Overall the total number of species increased greatly through time though there were fluctuations (Table 3a). Only three species were recorded in the 14^{th} century and no species were recorded in the 15^{th} or 16^{th}. Until the 19^{th} century the number of species recorded each century did not exceed ten but from the 20^{th} century onwards at least 20 species were recorded each century. The substantial increase from the 18^{th} to the 19^{th} century is strongly indicative of increased recording efforts as the River Don's ability to support fish populations did not begin to increase until the mid-1970s (Firth, 1997). In the 20^{th} century only three species were recorded prior to the 1970s (Table 3b). The number of species recorded per decade reached 16 in the 1970s and has not fallen below 15 since then. From the 1990s to the 2010s it remained between 22 and 25. The increased number of species can be attributed to: environmental improvements, particularly in terms of decreased pollution (Firth, 1997); and increased reporting with the publication of *Freshwater fishes of the Sheffield area* (Mander, 1976).

2.3.2.1 Coarse fish and salmonids

Prediction one: The number of salmonid species recorded in the River Don was affected by chemical and physical environmental degradation to a greater extent than the number of coarse fish species.

The presence of salmonids is generally believed to indicate good ecological quality so I expected that salmonids would only be recorded on the River Don before it had been severely degraded and when it had recovered to a great extent. I expected salmonids to have been affected by pollution to a greater extent than coarse fish as all four species which have ever been observed on the River Don are sensitive to pollution: salmon, trout, grayling and rainbow trout. Furthermore, other papers have reported that as a group salmonids are highly sensitive to hypoxia, acidification and a wide range of pollutants including: nitrites, nitrates and ammonia (Kemp *et al.,* 2011). I expected salmonids to have been affected by physical degradation, particularly impoundment to a greater extent as weirs block the migratory pathways of salmonids to the extent that they have caused the extirpation of several salmon populations (de Leaniz, 2008). Increased turbulence can also reduce their ability to find food as they are mostly visual predators (DeYoung, 2007).

However, trends in the number of salmonid and coarse fish species recorded each century did not support this prediction (Appendix A: Figure A.1a). In the 17th century and from the 19th century onwards salmon, trout and grayling were all present and the only species which was recorded in the 18th century was salmon (Table 3a). Rainbow trout was only present in the most recent two centuries as it is a non-indigenous species which was not introduced to the UK until the 1880s (Davies *et al*., 2004). Conversely, only 7 and 17 coarse fish species were recorded in the River Don in the 17th and 19th centuries respectively (Appendix A: Figure A.1a). . These accounted for 24% and 55% of the indigenous coarse fish species which were ever recorded there.

However, in support of the prediction it was found that no salmonids were reported in the first half of the 20th century (Appendix A: Figure A.1a) and no salmonids were mentioned in personal communications with Martin Read, a local angler who described changes in the composition of fish assemblages on the River Don and whilst one book on coarse fishing was found in Sheffield Library (Keeling, 2007) no information on recent angling for salmonids was found in any local library. The low level of attention given to salmonids by anglers on the River Don is likely to reflect low abundances as salmonids are nationally of great interest to recreational anglers. Salmon was not recorded in the 1980s or 2010s. The maximum number of salmon records from any decade since the 1950s was two which suggests that whilst they were present their abundances were very low. These low abundances are also recognised by the National Rivers Authority (1996 cited in Firth, 1997) who described the sighting of a single salmon as "*Perhaps the most vivid demonstration of the river improvement"*. There were also only three coarse fish species recorded in the first half of the 20th century: gudgeon, barbel and perch (Table 3b; Appendix A: Figure A.1b).

Prediction two: Prior to more systematic scientific sampling recording biases increased the likelihood of salmonid species relative to coarse fish species being recorded when present in the River Don due to their popularity with anglers and large size.

All four of the salmonids which were ever recorded on the River Don were of major interest to anglers (Table 4). Furthermore, three of the seven species with the largest maximum lengths which were ever recorded on the River Don were salmonids. As predicted changes in the numbers of coarse fish and salmonids recorded through time indicated that in earlier centuries a much greater proportion of the salmonids which were present were recorded (Appendix A: Figure A.1a). A similar pattern was observed within the 20th century (Appendix A: Figure A.1b). By the 17th century all salmonids which were ever recorded on the River Don with the exception of the non-indigenous species rainbow trout which was not introduced to the UK until the 1880s had been recorded there (Table 3a). Conversely, only seven of the 25 native coarse fish species which were ever recorded in the River Don had been recorded there by the 17th century and six were not recorded there until the 1970s or later (Tables 2a and 2b). It is likely that both recording biases and environmental changes are partially responsible for these species first appearing in the records so late. This will be explored further in section 2.3.3.3.

2.3.2.2 Pollution tolerance

Prediction one: The number of pollution sensitive species recorded in the River Don decreased to a greater extent in response to increased pollution than the number of pollution tolerant species and took longer to recover as pollution decreased.

Before the 19th century pollution tolerant and pollution sensitive species were both recorded (Appendix A: Figure A.2a). Unfortunately, due to the scarcity of records it was not possible to identify meaningful trends in the number of species in each of these categories through time until the 19th century onwards. Similarly a century in which the River Don was clearly unable to support pollution sensitive fish species cannot be identified from these records.

From the 19th century to the 20th century the number of pollution tolerant species recorded increased by only 12.5% from 8 to 9 whilst the number of pollution sensitive species recorded increased by 41.7% from 12 species to 17 species (Appendix A: Figure A.2a). The number of pollution tolerant species did not change from the 20th to the 21st century, whilst the number of pollution sensitive species fell by one. This suggests that pollution tolerant species have always been present on the River Don in high enough abundances to have been recorded whilst pollution severely suppressed the abundances of many pollution sensitive species in the 19th century perhaps to the point of temporary extirpation but reduced pollution levels in the 20th century enabled these populations to recover.

However, a closer investigation of the species concerned makes it more difficult to unambiguously attribute these changes to a reduced severity of pollution between the 19th and 20th centuries. The pollution sensitive species which were present in the 20th century but not the 19th century were: rainbow trout, brook lamprey, flounder, rudd, silver bream and stone loach (Tables 2a and 3). There were six pollution sensitive species which were present in the 20th century but not the 19th century despite the fact that the number of pollution sensitive species only increased by five as sturgeon was present in the 19th century but not the 20th. Alternative explanations for the absences of all six pollution sensitive species in the 19th century are provided in section 2.3.3 below and include: actual population changes in response to the slow colonisation of impounded sections by lentic species; the introduction of rainbow trout; and recording biases such as low interest to anglers and differences in recording effort which mean that species which have never been common on the River Don were more likely to be recorded in the 20th century.

Despite great improvements in water quality from the 1970s to the 1990s (Firth, 1997) the number of pollution sensitive and pollution tolerant species increased to a proportionately similar extent (36.4% and 34.4% respectively; Appendix A: Figure A.2b). Both groups showing such similar increases may suggest that the perceived recovery was driven at least in part by additional factors. The pollution sensitive species which were present in the 1990s but not the 1970s were: brook lamprey, river lamprey, silver bream, dace and grayling (Tables 2b and 3). The pollution tolerant species which were present in the 1990s but not the 1970s were: crucian carp, ten spined stickleback, pike and bleak. Reasons for the absence of these species in the 1970s are described in section 2.3.3 and include: slow colonisation of impounded river sections by lentic species; biases due to low value to recreational anglers; and the greater chance of recording visitor species as survey efforts increased. Surprisingly the number of pollution sensitive species recorded in the 1980s was lower than the number recorded in the 1970s despite much work to reduce pollution being conducted over these two decades. This further suggests that changes in the number of pollution sensitive and pollution tolerant species in this time period were driven by factors other than decreasing pollution.

The number of pollution sensitive species remained relatively constant over the next two decades whilst the number of pollution tolerant species fell by 22.2% from nine species in the 1990s and 2000s to seven species in the 2010s (Appendix A: Figure A.2b). One possible explanation for this decline is increased competition due to the recovery of pollution sensitive species driven by reduced pollution. However when the species concerned are considered individually, alternative explanations may be more likely. The pollution tolerant species which were present in the 1990s but not the 2010s were: crucian carp, ten-spined stickleback and tench (Tables 2b and 3). There have never been large numbers of records of these species from the River Don (Tables 2a and 2b). Crucian carp are found in lentic ecosystems and densely vegetated oxbows and backwaters of rivers which were destroyed by the drainage of wetlands adjacent to the River Don and channelisation (Kottelat and Freyhof, 2007). Tench require complex habitats for grazing and hiding from predators and are thus also likely to have been adversely affected by channelisation which reduced habitat heterogeneity (Davies *et al*., 2004). Ten spined stickleback are observed relatively rarely by the EA in Yorkshire and are more likely to be observed in ditches than large rivers (personal communications with EA Customer and Engagement Team, 2016).

2.3.2.3 Interest to recreational anglers

Prediction one: The proportion of fish species of minor interest to anglers which were recorded in the River Don increased through time as bias in recording due to interest to anglers decreased due to the adoption of more scientific surveying techniques.

I expected that recording biases would have a greater effect on the species which were recorded in the earlier centuries and decades within the 20th century as systematic scientific surveys have been undertaken by the EA since the 1980s but many earlier records were produced largely for the benefit of anglers (Tables 2a and 2b). The results confirmed this expectation. Fish species which were of minor or major interest to recreational anglers were recorded from the 14th century onwards (Appendix A: Figure A.3a). Species which were of no interest to recreational anglers or only used by them as bait were not recorded in the River Don until the 19th century. Surprisingly these were recorded in a book providing an overview of the current state of Sheffield called Vital Statistics of Sheffield which was published by Holland in 1837 (Table 3a). This suggests that the author believed fish community composition to be of at least some interest to a wide audience at this time. Further supporting the prediction all of the fish which were recorded in the first half of the 20th century were of minor or major interest to recreational anglers (Appendix A: Figure A.3b). The commencement of more systematic surveying by the EA in the 1980s surprisingly did not increase the number of recorded species which were of no interest to anglers or only of interest to them as bait (Table 3b; Appendix A: Figure A.3b). This suggests that from the 1970s onwards there was little bias in the species which were recorded due to their value to anglers. Due to the complete lack of records in the 1950s and 1960s it is also not possible to detect such bias. It can therefore be concluded that fish which were of no importance to recreational anglers were less likely to be recorded when present prior to the mid-20th century but these species have been relatively well recorded since the 1970s. It would be particularly unlikely that ruffe and three spined stickleback had not been present on the River Don prior to the 1970s as they are not known to be sensitive to physical degradation and are pollution tolerant (Tables 2b and 3).

2.3.2.4 Extent to which species were eaten by people

Prediction one: The proportion of fish species which were not historically eaten in the UK to a great extent recorded in the River Don increased through time as bias in recording due to values as a food source decreased due to the adoption of more scientific surveying techniques.

Firth (1997) recorded that the River Don was an abundant food source, particularly with regards to salmon until the mid-19th century and there is no evidence to suggest that the River Don has become an important food source again as fish populations have recovered. However, analysis of the historical records yielded relatively little evidence to support this prediction. All the species which were recorded in the River Don in the 14th century were either eaten in the UK to a major or unspecified extent historically (meaning that their role as a food source is mentioned but not quantified in the sources listed in the method and Table A.2 in Appendix A) (Appendix A: Figure A.4a). However, this result should be interpreted with caution as it pertains to a single fishing trip (Table 3a; Firth, 1997). No species were recorded in the 15th or 16th centuries but from the 17th century to the 21st the number of species which have never been eaten in the UK to any substantial extent increased from one to five whilst the number of species which were historically eaten to a major extent in the UK increased from six to 14 (Appendix A: Figure A.4a). As expected there is no evidence that species which were eaten to a greater extent were more likely to have been recorded when present in the 20th century. The number of species by the extent to which they were historically eaten followed very similar trends through the 20th century and the first decade of the 21st century (Appendix A: Figure A.4b).

2.3.3 Results by Presence Trajectory Type

Species with different presence trajectory types on the River Don were generally very similar in terms of their individual functional traits, habit preferences and the extent to which they were eaten (Appendix A: Tables A.3 and A.4). Of the 17 functional traits, 11 habitat preferences and two utilitarian values which were analysed the only individual variables which were found to significantly differ between presence trajectory type categories were: the extent to which species were of interest to recreational anglers; maximum body length; and flow preferences of adults (Appendix A: Tables A.3. and A.4; Figures A.5, A.6 and A.7 respectively).

ANOVAs using PCs confirmed that the presence trajectory type categories differed little in terms of functional traits and habitat preferences. PCs from the full PCA and the likelihood of being recorded PCA simply confirmed that presence trajectory types were significantly different in terms of body length and interest to recreational anglers (Table 3; Appendix A: Tables A.6, A.7, A.11 and A.12; Figures A.8 and A.12). The results of these PCAs and ANOVAs will therefore not be discussed in any more detail. The life history PCA further confirmed differences in body length but also found that these were associated with differences in lifespan with larger species generally being longer lived (Appendix A: Tables A.7 and A.8; Figures A.9 and A.10). ANOVAS using PCs from the physical degradation PCA confirmed that presence trajectory type categories differed significantly in terms of interest to anglers but also found that greater interest to recreational anglers was associated with lower levels of hiding behaviour (Appendix A: Tables A.9 and A.10; Figure A.11). Hiding behaviour was only included in this analysis as it was expected to help explain how reduced habitat complexity and reduced vegetation would affect species responses to environmental degradation. However, as the latter two variables were found not to be significant this PCA and its associated ANOVAs will not be discussed in any more detail. The chance of being recorded PCA simply confirmed that species with different trajectory type differed significantly in terms of body size and interest to recreational anglers (Appendix A: Tables A.11 and A.12; Figure A.12).

Changes in the sources of information through time suggest that a greater proportion of records were produced by people and for audiences other than recreational anglers through time (Tables 3a and 3b). Unfortunately, the earliest records provide very little information on who produced the records and the intended purpose of these records. However, all records from the 14th century pertained to a single angling trip undertaken by the ex-King of Scotland (Table 3a; Firth, 1997). The earliest records which were clearly written for an audience with a general interest in natural history rather than recreational anglers were published in Vital Statistics of Sheffield by Holland in 1843 (Table 3a). The EA began undertaking comprehensive scientific surveying in the 1980s (personal communications with Nia Hughes, 2013).

2.3.3.1 Extirpated species

This study classified a total of four species as having been extirpated from the River Don as they had not been recorded there since the 19th century. These were: burbot, smelt (*Osmerus eperlanus*), spined loach, and sturgeon. With the exception of sturgeon these species were not included in Table 3a because it was not clear which century they were recorded in. Firth (1997) simply stated that they had all been identified on the River Don before 1850. It is questionable that spined loach was ever actually present in the River Don although for the purpose of this analysis it was classified as an extirpated species as it met the criteria of having been last recorded on the River Don prior to the 19th century and I am interested in the effects of recording biases on the inferences which can be drawn from the data. According to Davies *et al*. (2004) spined loach only occur naturally in five major catchments within the UK. These are all South of the Humber Estuary. They have been introduced to few other catchments within the UK as they are of little interest to recreational anglers. The fact that Davies *et al*. (2004) believed that some of the spined loach records which were made in 1972 inaccurately indicated presence when the species was not present suggests that it is relatively easy to mistake other species for this species. Its small size is likely to contribute to recording difficulties (Table 4). It is also important to recognise that whilst sturgeon may well have been recorded on the River Don, sturgeon do not spawn in British freshwaters so any individual found in British freshwaters is considered to be a vagrant (Davies *et al*., 2004). Of the remaining two species which have been extirpated from the River Don, the only species to have been extirpated from the UK is burbot which was last recorded in 1969 more than a century after it was last recorded in the River Don.

Prediction one: Extirpated species have functional traits and habitat preferences which increase their vulnerability to pollution and physical habitat degradation to a greater extent than extant species.

Surprisingly little evidence was found to support this prediction. A comparison of the functional traits and habitat preferences between the species which were extirpated with the remainder of the fish species which have been recorded on the River Don found that the former had much in common with the latter (Appendix 2: Tables A.3 and A.4). They did not differ from species with other presence trajectories in terms of habitat preferences and functional traits in ways which were likely to increase their vulnerability to physical degradation. Furthermore, none of them required high flow speeds in their adult stages (Appendix A: Figure A.7), a difference which would be expected to be more likely to decrease rather than increase the extent to which they were adversely affected by impoundment. As a group extripated species also differed significantly from species with other presence trajectories in terms of their maximum length (Appendix A: Figure A.6). This was because sturgeon and burbot are the species with the two greatest maximum lengths ever to have been recorded in the River Don (Table 4). Sturgeon has a maximum length of 600cm but burbot has a maximum length of 152cm which is only marginally greater than that of salmon, 150cm. Large size is recognised by Firth (1997) to have increased the risk of suffocation when the river bed frequently dried up due to abstraction for the adjacent mills around the early 18th century.

Prediction two: The life history traits of extirpated species significantly differ from those of other species in ways which increased their risk of extirpation.

I expected species with large body size and long lifespans to be more likely to have been extirpated as these traits have been cited as determining factors in many extirpations (McKinney, 1997) and are known to reduce the resilience of freshwater fish to disturbances (Schlosser, 1990; Detenbeck, *et al*., 1992). However, although sturgeon had a high life history PC1 value indicating its long length and lifespan, spined loach and smelt both had low PC1 values (Appendix A: Tables A.7 and A.8; Figures: A.9 and A.10). These two species had the third and 13th smallest maximum lengths of all 21 of 33 species which have ever been recorded on the River Don for which the maximum length is known (Table 4). This suggests that life history traits which have been shown to increase the vulnerability of many species to extinction including large body size and long lifespans did not play an important role in determining which species were extirpated from the River Don (McKinney, 1997).

Prediction 3: Extirpated species had utilitarian values and functional traits which increased the likelihood of them being recorded when present

With regards to recording bias I expected that the extirpated species which appeared in the records would have had functional traits and utilitarian values which increased the likelihood of them being recorded as other species may have been extirpated from the River Don without ever having been recorded. There was relatively little evidence to support this prediction. Whilst burbot and sturgeon both have long lengths which may have increased the likelihood of them being recorded as large species are highly visible and often charismatic (Table 4; Sergio *et al*., 2006; Linnell *et al*., 2000), stone loach and smelt both had relatively short lengths. Furthermore, none of the extirpated species unlike the majority of other species was reported to have been of major interest to recreational anglers (Appendix A: Figure A.5). ANOVAs using PCs from the likelihood of being recorded when present PCA found that extirpated species did not significantly differ from other species which have been recorded on the River Don in any other ways which were expected to affect their likelihood of being recorded (Appendix A: Tables A.11 and A.12; Figure A.12).

2.3.3.2 NISs

Four NISs were recorded on the River Don: crucian carp, carp, rainbow trout and ide (Tables 2a and 2b). It is disputed as to whether crucian carp is native to the UK or not (Davies *et al.*, 2004). However, if it is native it is only native to south-east England and has been introduced across the UK for recreational angling. It was therefore treated as a non-indigenous species for the purpose of this study. The remaining three species were first recorded in the River Don in the 19th century, 1970s and 2000s respectively (Tables 2a and 2b). This was much later than they were first introduced to the UK: some time before 1500, 1880s and 1874 respectively (Davies *et al*., 2004).

Prediction one: NISs have functional traits which enable them to thrive in the anthropogenically modified habitat conditions provided by the River Don

This prediction was based on findings by Clavero *et al.* (2004) and Marchetti and Moyle (2001) that non-indigenous freshwater fish species benefited from impoundment in terms of increased abundances as they were well adapted to lentic ecosystems. However, the only evidence found in this study to support this expectation was that none of the NISs for which such information was available required moderate to fast flowing water during their adult stages (Appendix A: Figure A.7). This was the only life stage for which statistically significant differences between species with different presence trajectory types for flow speed preferences was found (Appendix A: Table A.3). ANOVAs using the physical degradation PCs found no evidence that NISs were suited to impounded conditions to significantly different extents to other species which have been recorded on the River Don (Appendix A: Tables A.9 and A.10; Figure A.11).

However, the lack of statistically significant differences in functional traits and habitat preferences which I expected to enable NISs to thrive in the impounded River Don (Appendix A: Tables A.3 and A.4) may be partially explained by the low number of records of NISs which further suggested that they were not suited to this habitat (Tables 2a and 2b). The greatest number of records of an NIS in any one decade was 16 indicating that no non-indigenous fish species has ever reached high population densities in the River Don. No more than five records of any NIS were recorded in any other decade despite the EA recording whatever they caught when performing surveys from the 1980s onwards. Two NISs, rainbow trout and ide both require moderate to fast flowing water for spawning reducing the suitability of impounded river sections as a habitat for these species. A more in depth consideration of the suitability of the anthropogenically modified River Don for the NISs which have been recorded on it provided further evidence of the unsuitability of the habitat. Crucian carp is usually restricted to densely vegetated backwaters and oxbows (Kottelat and Freyhof, 2007), many of which would have been lost from the River Don as a result of channelisation (Firth, 1997). Ide usually inhabits large lowland rivers but migrates upstream to spawn in upstream tributaries which the impoundments are likely to prevent it from doing on the River Don (Kottelat and Freyhof, 2007; Firth, 1997) . Carp larvae are only able to survive in very warm water and in the UK only lentic ecosystems are likely to be able to sustain such conditions (Kottelat and Freyhof, 2007). Furthermore, it is legal to introduce carp and ide to lentic ecosytems but not lotic ecosystems in the UK so propagule pressure on rivers is likely to be lower, particularly now that channelisation of the River Don prevents many opportunities for fish to colonise it from lentic ecosystems within the catchment (Wheeler, 2000). Despite high propagule pressure for more than 120 years few self-sustaining rainbow trout populations have established themselves in the UK (MacCrimmon, 1971). Whilst there is much discussion regarding the factors which have prevented this, it is more likely that it is due to over fishing or biological interactions with predators, competitors or pathogens particularly in early life stages than abiotic changes (Fausch, 2007). Although summer floods displace fry in some UK rivers they are unlikely to have a substantial effect on the River Don which has a long history of flood defence engineering (Firth, 1997).

Prediction two: NISs have life history traits which enable them to quickly form self-sustaining populations

I expected that the non-native fish species on the River Don would have life history traits which facilitated their ability to form self-sustaining populations in geographical areas to which they were introduced. Theoretically non-native species are expected to have short lifespans which are related negatively to body size(Pimm, 1989). This enables populations to grow rapidly from a few colonisers to a size which enables them to recover from disturbances which kill a substantial number of individuals. This theory is supported by a global study of freshwater fish conducted by Ruesink (2005) which found that attempts to introduce fish species with smaller body sizes had generally been more successful. In line with the theory, Ruesink (2005) suggested that these fish were likely to have shorter lifespans and generation times which facilitate rapid population growth. However, I found that the NISs in the River Don had relatively long bodies and lifespans as indicated by their relatively high life history PC1 values (Appendix A: Tables A.7 and A.8; Figures A.9 and A.10). An ANOVA also found that body length as an individual variable differed significantly between presence type categories (Appendix A: Table A.4) and Figure A.6 in Appendix A also shows that NISs had generally long body lengths relative to other fish species which have been recorded on the River Don. Ribeiro *et al*. (2008) also found that many introduced fish species had particularly large maximum lengths which they reasoned was due to the higher value attributed to such species by anglers. This is likely to apply to the NISs which have been observed on the River Don as they are all of major interest to recreational anglers (Appendix A: Figure A.5).

2.3.3.3 Recently appeared

Species were classified as "*Recently Appeared*" when they first appeared in the River Don records in the 19th century or later. This applied to fourteen species. Of these, seven first appeared in the 19th century and the remainder in the second half of the 20th century (Tables 2a and 2b). Of the species in this category the only species which was unlikely to have been naturally present on the River Don prior to environmental degradation was rudd. Its natural range within the UK was likely to have been limited to the south-east of England but it has been distributed across the country for the benefit of recreational anglers and is likely to have been introduced to the River Don for this purpose (Davies *et al*., 2004). The inability of the River Don to support recreational fisheries for much of its history largely due to severe pollution is likely to have delayed its introduction, whether it was deliberately introduced to the River Don or dispersed naturally from other watercourses within the region to which it was intentionally introduced (Firth, 1997).

Prediction 1: Species which only appeared recently had functional traits, habitat preferences and utilitarian values which minimised the likelihood of them being recorded when present when recording biases were strongest.

As predicted native species which first appeared in the River Don during the 19th century or later were found to be of significantly lower interest to recreational anglers than native species which had been recorded on the River Don earlier (Appendix A: Table A.3; Figure A.5). Furthermore, species with shorter body lengths were more likely to have only recently appeared in the historical records (Table A.4; Figure A.6). Their small size is likely to have reduced their value to anglers and thus reduced the likelihood of them being recorded when recording biases were stronger (Appendix A: Tables A.11 and A.12; Figure A.12). However, the absence of tench, eel, river lamprey and flounder from earlier records cannot be attributed to recording biases as they were of major interest to anglers (Table 4). Reasons why these species were not recorded earlier will be explored within this section below.

Prediction two: Species which only appeared recently had functional traits and habitat preferences which mean that they are better suited to the River Don in its anthropogenically modified state than its reference conditions and were slow to colonise this novel habitat.

If species which were only recorded recently were truly absent or present only at much lower abundances than they are today it would be expected that this prediction would be true. In support of this prediction species which were not observed in the River Don until recently showed statistically stronger preferences for still to slow water in their adult stages relative to other species which have been recorded on the River Don (Appendix A: Table A.3; Figure A.7). Impoundments create more river sections with slow flowing water and it has been shown that consequential increases in the number of fish species which prefer lentic conditions may not occur immediately but may occur over a number of decades (Quinn and Kwak, 2003). The establishment of such species on the River Don may have been further slowed by the disconnection between the River Don and lentic ecosystems within its floodplain (Sedell *et al*., 1990) and the few opportunities which it provided for angling which may have otherwise facilitated the spread of such species (Firth, 1997; Wheeler, 2000). Of the species which are of major interest to anglers but are classified as "*Recently Appeared*" tench is most likely to benefit from impounded conditions (Pilcher and Copp, 1997).

It is likely that some of the species which only recently appeared in the River Don had been abundant on the river prior to anthropogenic habitat degradation when they were less likely to have been recorded due to lower recording efforts, decreased greatly in abundance due to anthropogenic degradation and have recently begun to appear in the records due to habitat restoration. River lamprey and eels are likely to have previously been abundant on the River Don prior to its degradation as according to Davies *et al*. (2004) eels were ubiquitous throughout the UK prior to the impoundment and pollution of rivers. Large rivers within the UK supported commercial eel fisheries and there was a substantial river lamprey fishery on the River Ouse to which the River Don is a tributary (Masters *et al*., 2006). Their abundances are likely to have greatly declined from the early 18th century onwards if not before due to a combination of pollution, impoundment which blocks migratory pathways, land drainage and over-fishing (Witkowski, 1992; Renaud, 1997; Feunteun, 2002). In recent decades their abundances are likely to have increased somewhat in response to reduced pollution (Firth, 1997) and the construction of an eel pass (EA, 2014a).

Species which have never been abundant on the River Don are also more likely to be recorded recently due to increased surveying and recording efforts. The River Don probably never supported self-sustaining populations of flounder but is visited occasionally by them as they mainly live in estuaries (Wheeler, 1978; Kottelat and Freyhof, 2007). In addition to a greater likelihood of being recorded when present in recent years, there are likely to have been more recordings due to reduced pollution as they are pollution sensitive (Davies *et al*., 2004).

Prediction three: Species which only appeared recently had life history traits which increased their susceptibility to environmental disturbances and/or reduced their ability to rapidly colonise novel habitats

Given that some species which recently appeared in the records are likely to have been previously abundant but then declined greatly due to anthropogenic disturbances before somewhat recovering as these disturbances have begun to be abated, it may be expected that species which were classified as "*recently appeared"* would have life history traits which reduced their ability to resist or recover from disturbances. Given that some species are likely to have colonised the River Don following its impoundment as they were better adapted to its more lentic conditions than its natural lotic conditions, life history traits may be expected to have slowed the speed with which some species colonised. Shorter generation times which are associated with smaller body size are likely to have facilitated the recovery of fish populations following disturbances and the formation of self-sustaining populations following colonisation of the River Don's novel environment (Pimm, 1989; Schlosser, 1990; Detenbeck *et al*., 1992; Ruesink, 2005).

Whilst an ANOVA using PCs from the life history PCA found that as a group species which were classified as "*Recently Appeared"* were significantly smaller and had shorter lifespans than other fish species which have been recorded on the River Don (Appendix A: Tables A.7 and A.8; Figures A.9 and A.10), this group did not differ significantly from other species in terms of lifespan when it was tested as a single variable (Appendix A: Table A.4). As discussed within this section above species which only appeared in the records recently are more likely to be small as this would probably have reduced the likelihood of them being recorded when present in earlier centuries. Furthermore, the species which were classified as "*recently appeared"* which were of major interest to anglers and not just visitors to the River Don, namely tench, eel, river lamprey and rudd were relatively large and long lived (Table 4). Their maximum lengths ranged between 50cm and 100cm and their lifespans between 12 and 20 years although no data was available on the lifespan of river lamprey. Therefore this study found little evidence to support this prediction.

2.3.3.4 Resident

The only two species which were classified as "*resident*" species were salmon and pike. This study defines *resident* species as species which were recorded before the 19th century, during the 19th century and in each subsequent century. However, all of the restocked species with the exception of bleak also met these criteria (Table 3a) so to understand why these species showed *resident* trajectory types in historical records from the River Don it is important to consider two questions: 1) Why were salmon and pike recorded so persistently through time? and 2) Why were they not restocked?

Prediction one: Resident species have functional traits and habitat preferences which increase their ability to survive the pollution and physical degradation to which they have been subjected due to the anthropogenic modification of the River Don's environment through time.

I expected that the fish species which were persistently present in the River Don would be more likely than other species recorded on the River Don to have functional traits and habitat preferences which enabled them to be particularly tolerant towards pollution and physical habitat degradation. This was not the case as they were significantly longer in terms of maximum body length than the majority of other fish species which have ever been recorded in the River Don and they both required moderate to fast flowing water in their adult stages (Appendix A: Tables A.3 and A.4 and Figures A.6 and A.7 respectively). Both of these variables are likely to have increased their vulnerability to impoundment (Firth, 1997; Quinn and Kwak, 2003). They did not differ significantly from any other species in terms of their other functional traits or habitat preferences including pollution tolerance when these were tested independently and the physical degradation PCA found no evidence to suggest that they were more resistant to the anthropogenic changes which have occurred on the River Don (Appendix A: Tables A.3, A.4 and A.10).

Prediction two: resident species have functional traits and utilitarian values which increased the chances of them being recorded when present when recording bias was strongest on the River Don.

In support of this prediction pike and salmon are both of great importance to recreational anglers, which is likely in part to be due to their size (Appendix A: Tables A.3, A.4, A.11 and A.12; Figures A.5, A.6 and A.12). Therefore, I expect that these species had very high chances of being recorded when present.

Prediction three: resident species have life history traits which increase their resilience to anthropogenic disturbances on the River Don

Contrary to this prediction, the *resident* species had significantly longer maximum lengths and significantly higher PC1 values indicating longer lifespans than other species which have been recorded on the River Don (Appendix A: Tables A.4, A.7 and A.8; Figures A.6, A.9 and A.10). These traits are likely to have reduced their resilience to disturbances (Schlosser, 1990; Detenbeck, *et al.*, 1992).

Prediction four: resident species have functional traits and habitat preferences which reduced the likelihood of them being restocked on the River Don

In support of this prediction the EA Fisheries Technical Officer for South and West Yorkshire, Jerome Masters (personal communications, 2016), explained that the EA chose not to restock salmon at this stage because the weirs would prevent them forming self-sustaining populations and chose not to restock pike as breeding piscivorous fish in captivity which require live prey would be technically challenging and ethically questionable. Furthermore, as pike have been recorded in the River Don recently they saw no need to restock them. Both of the resident species require high flow speeds in their adult stages (Appendix A: Figure A.7). However, this is not likely to affect the difficulty of them being restocked in itself as they both spawn in still to slow flowing waters.

2.3.3.5 Restocked

Species were classified as having been "*restocked*" when the historical records of restocking work undertaken by the EA or their predecessors and collaborators evidenced that they had been (Trudgill, 2006). Other sources provided no evidence to suggest that any other restocking was undertaken. The first species which were restocked into the River Don were trout in 1975 and grayling in 1983 (Trudgill, 2006). In total nine fish species were restocked into the River Don by the EA (Table 3b). This accounts for 27% of the fish species which have ever been recorded on the River Don. According to Jerome Masters (personal communications, 2016), restocking projects on the River Don have been successful in that fish are now found at all the EA's survey sites along the full length of the river. However, detailed monitoring is prohibitively expensive.

Prediction one: Fish with greater value to recreational anglers were more likely to have been restocked into the River Don

As the EA has responsibility for the management of fisheries as well as conservation and ecology it is likely that decisions regarding which species to restock were influenced by differences in their utilitarian value to anglers (EA, n.d.). This view is supported by personal communications with Jerome Masters (2016). The majority of the fish species which were restocked were of major interest to recreational anglers and as a group they were statistically significantly of greater interest to recreational anglers than other fish species which have been recorded on the River Don (Appendix A: Table A.3 and Figure A.5). Furthermore, the Salmon and Trout Association who represent game angling and fisheries worked collaboratively with Yorkshire Water on the initial trout restocking (Trudgill, 2006; Salmon and Trout Conservation UK, n.d.). Conversely, three of the nine fish species which were restocked, bleak, dace and perch were classed as being of minor interest to recreational anglers as this was how they were described in the sources which were used when compiling information on the species for this analysis (Table 4; Appendix A Figure A.5) (Wheeler, 1978; Welcomme, 1988 in Fishbase, n.d.; Davies *et al*., 2004). However, Jerome Masters (personal communications, 2016) stated that they were targeted by coarse anglers so it is likely that even these species were restocked in the River Don partly due to their value to recreational anglers. As a group restocked species were significantly larger than other species which have been recorded on the River Don in terms of their maximum body length (Appendix A: Table A.4 and Figure A.6). This is probably because their large size increases the extent to which they are attractive to anglers (Appendix A: Tables A.11 and A.12; Figure A.12).

Prediction two: restocked species have functional traits which meant that they were easier to restock in terms of being reared in captivity and forming self-sustaining populations in the River Don

Although it is often easier to create lentic habitat conditions in captivity restocked species showed a statistically significant preference for faster flowing water in their adult stages (Appendix A: Table A.3 and Figure A.7). None of them required still to slow flowing water at this life stage. Although other studies have found that impounded rivers favour species with preferences for still to slow flowing waters (Gillette *et al*., 2012; Anderson *et al*., 1995) recent records suggest that species with this habitat preference do not thrive in the River Don. In total only one of the 11 species ever recorded on the River Don which required still to slow flowing water in their adult stages was recorded every decade from the 1980s onwards (Tables 2b and 3). This species was eels and the maximum number of records made of this species in any decade since the 1980s was 19. This was also the maximum number of records made for any of these individual species in any one decade since the 1980s. Eel populations on the River Don are known to be depleted in part due to weirs blocking their migratory pathways (Firth, 1997). It can therefore be surmised that currently the River Don does not provide habitat which is well suited to meet the needs of fish species which require still to slow flowing water in their adult stages. This may be because these species are more dependent than other species on backwater habitats which have been destroyed through channelisation.

As discussed in section 2.3.3.4, piscivorous fish are challenging to raise in captivity and obligately migratory species are unlikely to form self-sustaining populations on the River Don following restocking as their migratory pathways are blocked by weirs. Although restocked fish species did not significantly differ from other species recorded on the River Don in terms of their lowest trophic level or migratory behaviour (Appendix A: Table A.3), none of the restocked species was obligately migratory and they all ate plankton, detritus or plant material with the exception of trout which ate nothing with a trophic level lower than macroinvertebrates.

In terms of life history traits fish which were restocked into the River Don were significantly larger in terms of their maximum body lengths and had significantly higher life history PC1 values indicating both longer lifespans and longer bodies. The restocked species had relatively high life history PC1 values indicating that they had long bodies and lifespans (Appendix A: Tables A.7 and A.8; Figures A.6, A.9 and A.10). These traits are likely to limit their ability to form self-sustaining populations following stocking.

Prediction three: Restocked species have functional traits which are likely to reduce their chances of recolonising the River Don naturally

Although long lifespans may have increased the difficulty for conservation practitioners of re-establishing self-sustaining populations this may have also necessitated human intervention by greatly slowing the natural recolonization process (Pimm, 1989; Ruesink, 2005).

2.4 DISCUSSION

2.4.1 What Can Be Learned from Historical Records About Reference Community Composition?

Unfortunately, given the early dates from which the River Don was degraded and the scarcity of records from this time period, relatively little information can be gained from the historical records regarding the composition of the River Don’s fish community (Firth, 1997). The implications of scarce historical records for describing reference riverine fish communities are also recognised by Carrel (2002). The most useful information regarding the river’s reference community composition is the identification of some of the species which were previously present but have since been extirpated. However, of the four species which were categorised as “extirpated” spined loach was very unlikely to have been ever present on the River Don and thus probably recorded erroneously and assuming that sturgeon was actually recorded on the River Don it would have only ever been present as a vagrant. The main limitations which prevented the composition of the River Don’s reference community being inferred from the historical records were: the omission of species which were of low interest to recreational anglers as discussed in section 2.4.3; the likely severe declines of species which required still to slow flowing water in their adult stages potentially before more than three fish species which were caught during a single fishing trip had been recorded due to loss of habitat through drainage and channelisation.

2.4.2 What Can Be Learned from Historical Records About Ecological Degradation and Recovery?

Changes in the extent to which the habitat preferences and functional traits of species matched the habitat provided by the River Don as it became increasingly polluted and physically degraded influenced presence-absence trends in historical records from the River Don surprisingly little. A coarse analysis of the species which were present each century found that all three native salmonids which were ever recorded in the River Don were all present in the 17th century and the 19th century onwards. Conversely, only approximately one quarter and one half of the native coarse fish which were ever recorded on the River Don were present in these centuries respectively. In a polluted and physically degraded river individual salmonid species would be expected to be less abundant than individual coarse fish species as they are frequently reported to be particularly sensitive to both pollution and physical habitat degradation including impoundment (DeYoung, 2007; de Leaniz, 2008; Kemp *et al*., 2011). However, a more detailed analysis of presence-absence patterns over recent decades, permitted by greater coverage of this time period in the historical records found that salmon was only recorded four times in the 20th century and personal communications with an angler and a review of literature aimed at anglers concerning the River Don focused entirely on coarse fish. A comparison between statements that salmon were once so abundant on the River Don that apprentices prohibited their employers from feeding it to them too frequently and the sparsity of records now suggests that they have been severely affected by anthropogenic degradation even if they have not been extirpated (Firth 1997). Unfortunately I was unable to find any papers which compared the population or presence-absence trajectories of salmonids and coarse fish through time.

This study found a much greater increase in the number of pollution sensitive species compared to pollution tolerant species recorded in the River Don from the 19th century to the 20th century. This could be interpreted as evidence that pollution sensitive species were more likely to be absent from the river when it was more polluted. However, closer analysis revealed that other explanations could be provided for each species which was recorded in the 20th century and not in the 19th century including slow colonisation of lentic habitats produced by weirs, the introduction of an NIS and greater recording efforts, highlighting the need for these results to be interpreted with caution. Though pollution levels fell greatly from the 1970s to the 1990s (Firth 1997), the number of pollution sensitive and pollution tolerant species increased to a similar extent from the 1970s to the 1990s which would not be expected if the increases were largely due to reduced pollution. Increased recording efforts and the slow colonisation of impounded habitats are also likely to have contributed to these increases. Other studies have found that in recent decades pollution sensitive species have recovered more rapidly than pollution tolerant species as pollution levels have decreased (Turnpenny and Williams, 1981; Ryon, 2011). Collectively these studies demonstrated how greater systematic sampling efforts from before the commencement of effective action to reduce pollution including the measurement of a range of quantitative variables such as abundances and biomass at finer spatial resolutions can enable true changes in community composition to be described and attributed to reduced pollution with greater confidence.

Comparisons between presence trajectory type categories found relatively little evidence that functional traits and habitat preferences influenced the responses of species to anthropogenic disturbances as evidenced by presence-absence patterns shown by different species in the historical records through time. However, given the great extent to which the River Don's physical and chemical environment has been anthropogenically altered this is likely to have been in large part due to recording biases rather than a lack of true relationships between functional traits, habitat preferences and vulnerability to different forms of anthropogenic environmental degradation (Firth 1997). The only individual variables which significantly differed between presence trajectory types were: flow preferences of adults, maximum body length, and interest to recreational anglers.

In impounded rivers the number of species which require slow flowing water would be expected to increase through time whilst the number of species which require fast flowing water would be expected to decrease through time as impoundment decreases flow velocities (Giller and Malmqvist, 1998). Such trends have been reported in the United States by Anderson *et al*. (1995) and Gillette *et al*. (2012) However, this study found much evidence to the contrary: none of the extirpated species required fast flowing water in their adult stages and resident species both required moderate-fast flowing water in their adult stages. A comparison of all species requiring still to slow flowing water in their adult stages with all other fish ever recorded on the River Don regardless of presence trajectory types found that since the 1980s only one of the 11 species with this habitat requirement was recorded every decade and none of the species had more than 19 records from any one decade. Although no NISs required moderate to fast flowing water in their adult stages their sporadic records suggest that the River Don did not provide habitat to which they were well suited. Only one NIS, rainbow trout, was recorded more than five times in any one decade in the River Don and ide was the only NIS which was recorded every decade since it was first recorded there.

Species with small body lengths and short lifespans were expected to be better able to form self-sustaining populations from a few individuals facilitating recovery of indigenous species and invasion of NISs whilst those with large body lengths and long lifespans were expected to be less resilient to anthropogenic disturbances and thus at greater risk of extirpation (Pimm, 1989; Schlosser, 1990; Detenbeck *et al*., 1992; McKinney, 1997; Ruesink, 2005; Olden *et al*., 2006).

However, although burbot and sturgeon have particularly long body lengths and sturgeon has the second longest lifespan of all the species which were ever recorded on the River Don for which such information is available, stone loach and smelt are relatively small and short-lived. This corroborates with studies undertaken by Angermeier and Winston (1999) and Parent and Schriml (1995) which found no significant relationship between a number of life history traits including body size and lifespan and vulnerability to anthropogenic threats in freshwater fish as indicated by actual extirpations or conservation statuses. Furthermore, NISs had statistically longer body lengths and lifespans than other species which have been recorded on the River Don. Counter to expectations, resident species were significantly longer bodied and had longer lifespans than other species recorded on the River Don. However, those species which recently appeared with no active intervention had significantly shorter bodies and lifespans than those which were restocked. This may indicate that these traits facilitated natural recovery though it may simply indicate recording biases and efforts to restock species which were of high interest to recreational anglers.

Given the difficulty in inferring the factors which influenced extirpations through comparisons between the functional traits and habitat preferences of extirpated and extant species an alternative approach was taken. This involved researching why they had been extirpated from other rivers and assessing the extent to which these reasons were likely to have been applicable to the River Don. This approach yielded more evidence to suggest that these species were extirpated from the river as a result of environmental degradation caused by human activities including both pollution and physical habitat degradation. Burbot is most likely to have been extirpated from the River Don by a combination of pollution and impoundment (Firth, 1997) as it was extirpated from the UK due to a combination of pollution, barriers to migration and climate change (Davies *et al.*, 2004). However, it was last recorded in the UK in 1969 but last recorded in the River Don before 1850 which is unsurprising given the extent to which the River Don was impounded and polluted from before the industrial revolution onwards (Firth, 1997). Smelt normally inhabit unpolluted estuaries and migrate upstream only as far as the upper limit of tidal influence for the purpose of spawning (Davies *et al*., 2004). It is likely that they were extirpated from the River Don as a result of pollution of both the River Don and the Humber Estuary, the loss of spawning grounds on the River Don due to siltation and dredging and overfishing on the Humber Estuary (Maitland, 2003). Sturgeon are globally threatened by river pollution, over fishing and impoundments to the extent that they are classified as critically endangered by the IUCN (Gesner *et al*., 2010). This may explain why no vagrant sturgeon have been recorded in the River Don recently (Firth, 1997).

2.4.3 To What Extent Are Historical Fish Records Influenced by Recording Biases?

This study found that historical fish records from the River Don are influenced by recording biases to a great extent. These recording biases greatly obscured the relationships between functional traits, habitat preferences and responses to anthropogenically driven chemical and physical habitat degradation and habitat improvements on the River Don. The factor with the greatest effect on recording biases was interest to anglers which was positively related to large body size. Karr *et al*. (1985) also recognised that freshwater fish records prior to the 20th century were often limited to commercially and recreationally important fish species. However, this study found that no fish which were of no interest to recreational anglers or only of interest to them as bait were recorded prior to the 1970s suggesting that even relatively recent historical records were greatly affected by this recording bias. The River Don is particularly likely to have provided suitable habitat for ruffe and three spined stickleback prior to the 1970s as these species are tolerant of both pollution and physical degradation.

This relationship between small size, low interest to anglers and low likelihood of being recorded was also found by Cooper and Wheatley (1981). They reported that fish of less than 12cm were rarely caught as their mouth gape was too small to accommodate the smallest bait which was used by recreational anglers. Amongst those with body lengths greater than 12cm, there is little evidence to suggest that there is selective bias with regards to the size of fish species which are caught by recreational anglers relative to those which are captured using common scientific surveying techniques such as gill netting and electric fishing (Hamley, 1975; Axford, 1979). However, it is likely that smaller species were less highly valued by recreational anglers and thus less likely to be recorded when caught (Cowx and Broughton, 1986). Furthermore, it is common practice in citizen science projects involving recreational anglers for researchers to stress the importance of recording all species, however small (e.g. Cowx and Broughton, 1986). This study found no evidence of scientists communicating with those who recorded their observations prior to the 19th century and it is unlikely that such communications occurred. However, the strength of these recording biases was much greater before the 19th century when Vital Statistics of Sheffield described assemblage composition from a natural history rather than an angling perspective (Holland, 1843). Although it was initially predicted that hiding behaviour, gregariousness and circadian rhythms would affect the likelihood of species being observed and thus recorded there was no evidence that this was the case.

While it was expected that extirpated species would have functional traits and utilitarian values which increased the likelihood of them having been recorded prior to their extirpation this was not found to be the case. If human activities did not cause extirpations of fish species from the River Don prior to the 19th century when recording biases were already much smaller than they had been in previous centuries as evidenced by the number of species of low interest to anglers which were recorded in this century the chances of fish having been anthropogenically extirpated without being recorded would have been much smaller. Unfortunately the historical records do not provide enough information to date the extirpations even to the century. However, the records do not preclude the possibility that all extirpations occurred in the 19th century. According to Mander (1973) sturgeon were last recorded in the 19th century but the remaining extirpated species are simply known to have been recorded at some point prior to 1850 (Firth 1997).

2.4.4 To What Extent Are Historical Records Useful for Informing Future Environmental Management?

It was hoped that comparing the historical presence-absence trajectories of different fish which have been recorded on the River Don with regards to species functional traits and habitat preferences would be useful in terms of predicting likely responses of species to the chemical and physical degradation and restoration of rivers. Unfortunately the utility of the results of this study was greatly limited by recording biases. However, the results were particularly useful in terms of: identifying which species had been greatly depleted including those which had been extirpated which may be a good starting point for re-establishing them; and identifying the current environmental constraints on NISs.

Low abundances of species which were previously abundant such as salmon (Firth 1997) and extirpated species such as sturgeon, smelt and burbot demonstrate the need for further action if the River Don's fish community composition is to be restored to reflect reference conditions. There are certainly plans to restore salmon populations. For example, DCRT (n.d.a) are acting to bring about the necessary environmental improvements for the recovery of migratory fish, particularly salmon, by installing fish passes to prevent the weirs blocking their migratory pathways. The DCRT (n.d.a) website states "*Tighter environmental regulation and investment in water quality by water companies has resulted in river water quality being sufficiently good to once again support all river life. This includes migratory fish, particularly salmon, but they cannot return to historic upstream spawning gravels because the remaining weirs obstruct the free passage of fish along the river."* From 2000 onwards at least seven fish passes have been installed on the River Don with the aim of facilitating the recovery of migratory fish populations (Canal and River Trust, 2016). However, extirpated species are currently not mentioned in key management plans for the River Don such as the *Humber river basin district river basin management plan* (EA, 2009) and the River Don and South Yorkshire Navigation Biodiversity Action Plan (Sheffield Local Biodiversity Action Partnership, n.d.).

The role of understanding the causes of extirpations in re-establishing populations is recognised by Worthington *et al*. (2010a) and Osborne (2005). Comparisons of the functional traits and habitat preferences of extirpated species and other species which have been recorded on the River Don were not very insightful in terms of identifying causes of extirpations. However, useful insights were derived by assessing the relevance of threats to the species elsewhere to the River Don. Of the three extirpated species which I am confident were previously present on the River Don smelt will probably be the easiest to restore, burbot will be more challenging due to the difficulties of re-establishing wetlands in developed areas and it may not be possible to restore sturgeon whilst large quantities of water are abstracted from the River Don as they require deep fast flowing water (de Groot 2002).

The restoration of smelt is likely to require physical habitat restoration of the River Don and water quality improvements of the Humber Estuary (Hull Biodiversity Partnership, 2008; Maitland, 2003; Howes and Kirks, 1991, cited in Maitland, 2003). One of the limitations of basing restoration plans on the environmental history of a single ecosystem could therefore be failing to recognise interdependencies between ecosystems. On the river itself it is likely to be necessary to reverse the impacts of impoundments on sedimentation and the impacts of dredging on the loss of spawning grounds. Such improvements may include: the replacement of large boulders, cobbles and gravel (Erkinaro et al. 2011) and dredging sediment which has accumulated upstream of weirs or the installation of sediment bypasses (Kondolf et al. 2014). Measures to improve the condition of channel beds and manage sedimentation in the Don catchment have recently been proposed by the EA (2009). Unfortunately they do not provide enough detail of their planned actions to evaluate the likely effectiveness of these strategies.

Burbot is likely to have been extirpated from the River Don before 1850 largely due to pollution and barriers to migration (Davies *et al.*, 2004) but although burbot use fish passes (Slavík and Bartoš, 2002) the installation of fish passes and improved water quality alone are unlikely to enable the formation of self-sustaining populations as wetland habitats adjacent to rivers provide important spawning nursery grounds (Worthington *et al.*, 2012). Although there are efforts to restore wetland habitats along the River Don the potential to restore large areas of wetland is severely limited by urbanisation (Firth, 1997). This highlights the potential ineffectiveness of reversing the factors which caused extirpations when other factors may limit recovery and that reversing drivers of environmental degradation may not always be socially viable. This view is supported by Gore and Shields (1995).

The value of the historical records of extirpated species in this study and other studies to inform future environmental management decisions is also limited by a lack of quantitative data and erroneous records. If a species was present but not naturally abundant before it was affected by anthropogenic activities it may not have been well adapted to the ecosystem's reference conditions and thus attempts to establish self-sustaining populations may be futile or may move community composition further away from reference conditions (Worthington *et al.*, 2010a). Old records of species which are no longer present should be interpreted with caution as it is possible that these records are erroneous and species which were never present may be falsely thought to have been extirpated as is likely to be the case for spined loach in this study. Worthington *et al*. (2010a) also reported erroneous records of burbot in the UK which they attributed to species misidentifications. This highlights the need to interpret all historical records, even those of large vertebrate species with caution. The dangers of basing restoration goals on a false understanding of reference conditions is recognised by Wohl (2005). Erroneous records may also prevent significant differences being observed between extirpated and extant species, particularly when the number of extirpated species is small.

The extent to which the non-indigenous species which have been introduced to the River Don are poorly matched to the habitat which it provides and lack life history traits which are likely to increase their ability to rapidly form self-sustaining populations together with the fact that there have never been large numbers of records of them suggests that they are unlikely to pose a substantial threat to native species. However, there are concerns that climate change may enable non-native fish species which have been present at relatively low abundances for long time periods to rapidly increase in abundance and thus pose a greater threat to native fish species (Britton *et al.*, 2010). Although populations of NISs on the River Don are currently constrained by a range of factors including impoundments which block migratory pathways, channelisation and the loss of adjacent wetlands they may benefit from increased water temperatures, particularly as the other factors are addressed or partially addressed through time for the benefit of native species (Firth 1997; Kottelat and Freyhof 2007; EA, 2009). Britton *et al*. (2010) predicted that carp was particularly likely to benefit from increased temperatures of UK waters by 2050. They fear that the consequences of carp becoming much more abundant on UK rivers would pose a threat to native fish species through competition and environmental degradation. The River Don may be particularly vulnerable as the species benefits from the lentic conditions afforded by the impoundments. The other constraining environmental factors are also likely to be somewhat reversed in the near future for the benefit of native fish species.

By comparing the functional traits, habitat preferences and invasion history of other species which may be introduced into an ecosystem or region in the near future with those of species which have already been introduced, it may be possible to predict how likely they are to be invasive relative to previous introductions (Pheloung *et al.*, 1999). Unfortunately the utility of historical records from the River Don for this purpose is limited by small sample size and the fact that none of the species which have been introduced to date has been invasive. However, recognising differences between species which are likely to be introduced in the future and those which have already been introduced may reduce the risk that the lack of threat posed by NISs in the past lulls environmental managers into a false sense of security. It is likely that additional fish species will be introduced to the River Don in the relatively near future as unwanted pets are particularly likely to be released into urban streams due to their proximity and easy accessibility to large numbers of the public (Arthington *et al*., 1983) and legislation to minimise this risk is thought to be relatively ineffective (Copp *et al*., 2005). One species which may be particularly likely to invade the River Don in the relatively near future is sunbleak (*Leucasius delineatus*) (Pinder and Rodolphe, 2003). It was only introduced to the UK in the mid-1980s through the aquarium trade and has already become invasive and poses a major threat to native fish in UK rivers as a competitor and pathogen carrier (Gozlan *et al*., 2003 cited in Pinder and Gozlan, 2004; Zięba *et al*., 2010). Functional traits and habitat preferences which may increase the likelihood of it being introduced to the River Don include: small body size which facilitates dispersal from lentic to lotic ecosystems and the ability to lay eggs on floating vegetation, the hulls of boats and angling equipment (Pinder and Rodolphe, 2003). Functional traits and habitat preferences which would enable it to thrive in the River Don following its introduction include its tolerance of a range of flow speeds from still to moderate throughout its lifecycle and its utilisation of anthropogenic structures such as bridge foundations as refuges (Kottelat 1997). The historical data in this study found that it was likely that NISs were generally large because this trait increased their value to anglers. However, as the aquarium trade may be becoming more important than angling in the introduction of new species in recent decades the functional traits may be expected to change (Padilla and Williams, 2004). Topmouth gudgeon and sunbleak are both small species which were introduced to the UK in the mid-1980s through the aquarium trade (Pinder and Rodolphe, 2003). This may increase the likelihood that non-native fish species will rapidly become abundant following introduction and pose a threat to native species (Pimm, 1989; Ruesink, 2005).

The prevalence of fish species which are of great interest to anglers today in the earlier records from the 14th century onwards which were attributed to recording bias provides evidence that the same species have been valued by recreational anglers for centuries. This suggests that these species will continue to be valued by anglers well into the future, thus helping conservation practitioners to prioritise the restoration of the ecosystem functions which are likely to be of the greatest value to future generations.

The increased number of species recorded from the 1970s onwards provides strong evidence that reduced pollution levels can enable depleted fish communities to recover to a great extent even when the river remains highly physically degraded in terms of impoundment, channelisation and the loss of connected wetlands. Britain has a long history of addressing river pollution before addressing physical habitat degradation and evidence that this appears to be effective in facilitating the recovery of fish communities suggests that this approach should be repeated in industrialised areas where neither the chemical or physical degradation of rivers has yet been effectively addressed (Dudgeon, 1992; Langford *et al*., 2009)

2.5 Conclusion and Implications for Future Research

This study demonstrated that historical records can be useful for identifying drivers of population declines and extirpations and evaluating the effectiveness of restoration projects. The use of historical records to evaluate restoration projects may be particularly fruitful as it is widely recognised that fish communities derive benefits from the reversal of physical and habitat degradation slowly over many decades but they are rarely evaluated over such time scales

(Thompson, 2002; Palmer *et al*., 2005; Klein *et al*., 2007). Unfortunately their use for both of these purposes is greatly restricted by recording biases, particularly with regards to interest to recreational anglers. Comparing species which show different presence trajectory types in terms of their functional traits and habitat preferences could be potentially useful for identifying the habitat changes behind their degradation and restoration but the effectiveness of this approach was limited in this study by small sample sizes in terms of the number of species exhibiting each presence trajectory type.

Under such circumstances a more in-depth consideration of each individual species showing a presence trajectory type is likely to be more fruitful. This study found this approach particularly useful with regards to those species which had been extirpated. Historical threats to species which caused their demise and may be identified with greater confidence and the benefits brought by restoration may be described more accurately if the records permit more detailed analysis for example in terms of abundances and spatial distribution (Turnpenny and Williams, 1981; Anderson *et al*., 1995; Ryon, 2011; Gillette *et al*., 2012). However, on the River Don information on surveying efforts is not available until the commencement of work undertaken by the EA in the 1980s and there are not enough records to allow spatial distributions to be described prior to the publication of *Freshwater fishes of the Sheffield Area* in 1976 by which point the River Don was already beginning to recover. Data collected through palaeoecolgical surveys may permit more accurate descriptions of historical fish assemblages when used to complement limited historical records (Reid and Ogden, 2006). Other studies which have identified functional traits which may have led to the decline and extirpation of some species and the successful introduction of others have benefited from a greater number of species due to the analysis of records collected from much larger geographical areas (Anderson *et al*., 1995; Ruesink, 2005; Gillette *et al*., 2012). Future studies may benefit from analysing historical records from a large number of rivers which flow through post-industrial cities collectively.

3 UNDERSTANDING CHANGING RELATIONSHIPS BETWEEN PEOPLE AND THEIR LOCAL NATURAL ENVIRONMENT USING NEWSPAPER ARTICLES

3.1 INTRODUCTION

Given that the structure and function of the vast majority of ecosystems today are determined in large part by historical interactions between people and nature, knowledge of this history is essential to understand fully their current state and thus manage them (Vitousek *et al*., 1997; Foster *et al*., 2003). As all ecosystems are dynamic and many are on a trajectory recovering from past degradation such knowledge can also help scientists and conservation practitioners to predict future community composition and ecosystem functioning and thus ecosystem service provisioning and ecosystem disservice threats (Hobbs and Harris, 2001; Langford *et al*., 2009). This is essential for setting goals and strategies for their medium and long term management.

3.1.1 Social and Economic Benefits Derived from and Harm Caused or Partially Caused by Nature

The extent to which social and economic benefits are derived from the living and non-living components of nature; and nature poses social and economic threats to local people at any given time often reflects the extent to which aspects of nature are currently degraded in terms of both the abundances of species and levels of particular abiotic variables such as pollutants (Benayas *et al*., 2009). For example, fisheries depend on fish populations of commercially valuable fish which are large enough to provide economically viable returns on investment. The provisioning of drinking water relies on water supplies which are not polluted beyond a threshold acceptable to the community which consume them. Such thresholds will be determined in part by knowledge of water borne pathogens together with the ease with which less polluted water can be obtained from other sources. Reports of cholera endemics indicate the presence of the non-indigenous pathogen *Vibrio cholerae* (Clapp, 1994). Given a lack of historical direct measurements of biotic and abiotic variables inferences drawn from historical reports of interactions between people and their local natural environment may play an important role in enabling historical environments to be described more comprehensively than the analysis of sparse records of species and attributes of the chemical and physical environment would allow (Anderson, 2009; McPherson and Ransom, 2009). For example, the concentration of air pollutants was not measured quantitatively until the 20th century (Anderson, 2009). Prior to this there are anecdotal accounts of smogs and associated human mortalities. From this the approximate extent of air pollution at different times can be inferred and the likely impacts of this on local biota can be considered. Similarly, Burton (2003) used anecdotal reports of high fisheries yields in the Mersey Estuary in the 17th century to surmise that fish were still relatively abundant and the estuary relatively unpolluted at this time.

Utilising and managing ecosystems to maximise the social and economic benefits which can be derived from them can also greatly alter ecosystem structure and function in relatively predictable ways. Historical studies can demonstrate the long term effects of such activities. For example, in an international historical study of deforestation and afforestation Mather (1992) recognised substantial differences in the community composition of primary forest and secondary forest which had grown when agricultural land was abandoned. They used this information to warn that although it is likely that some of the land in the tropics which will be deforested in the near future is likely to be ultimately reafforested, the deforestation will cause irreversible changes. Historical studies can also demonstrate the long term effects of the cessation of management for particular ecosystem services. For example, a decline in the proportion of land utilised for agricultural purposes across Europe has allowed afforestation and thus contributed towards the reduction of habitat available for many avian species dependent on open habitat which have consequently declined in abundance (Butler *et al*., 2010). By contextualising the extent to which ecosystems were managed and utilised to derive different anthropocentric benefits through time it may be possible to identify the social, economic, technological and political drivers of such changes. This could be useful in making predictions regarding the future of other ecosystems. Mather (1992) suggested that it may also be useful in developing our understanding of the ways in which the functional traits of taxa influence their response to such activities.

Similarly, historical studies of the social and economic harm caused or partially caused by nature can increase our understanding of the relationship between human activities which have unintentionally increased their extent and the effectiveness of human activities which have aimed to reduce their extent. Increased understanding of such relationships can increase the effectiveness of future management to minimise such social and economic harm. For example, over the last century floodplains have increasingly been used for urban and agricultural purposes (Wheater and Evans, 2009). This has increased the social and economic value of the land but also increased the social and economic damage caused by flooding and thus necessitated the construction of flood defences which disconnect rivers from their floodplains with severe ecological consequences (Kundzewicz, 2001). Unfortunately despite these flood defences the damage caused by flooding has increased over the last century by preventing floodplains from slowing land drainage. Learning from past mistakes has contributed to decisions to reduce reliance on hard engineering flood defences and increase the use of floodplains for flood attenuation. More broadly, Mauch (2009) claimed that historical records demonstrate that no preventative measures to mitigate against the effects of natural hazards have been consistently effective. This suggests that society should rely on defences not just to flooding but to all natural hazards to a lesser extent and a more holistic approach should be taken to minimise the social and economic impacts of natural hazards in future.

Another management technique used to mitigate against ecosystem disservices which has been evaluated from a historical perspective is the lethal control of species which pose a threat to people and their livelihoods, for example by destroying crops and livestock and even claiming human lives (Treves and Naughton-Treves, 2005). Historical evidence proves that this technique can be effective. For example, the extirpation of wolves (*Canis lupus*) from Scotland prevented them from killing sheep (*Ovis aries*). However, it also provides warnings that mitigating against one ecosystem disservice can increase the impact of another ecosystem disservice in the long term. Treves and Naughton-Treves (2005) gave several examples of how reducing predator populations have increased prey populations which have adverse effects on human enterprises. These include: the increased predation of wildfowl by skunks (species unspecified) which were previously controlled by the now eradicated red fox (*Vulpes vulpes*) and coyotes (*Canis latrans*) in the Prairie Pothole region of Canada (Greenwood *et al*., 1995 cited in Treves and Naughton-Treves, 2005); and increased damage to crops caused by bush pigs (*Potamochoerus larvatus*) and baboons (species unspecified) in Uganda due to the widespread removal of lions (*Panthera leo*) and leopards (*Panthera pardus*) (Naughton-Treves, 1999 cited in Treves and Naughton-Treves, 2005).

Another key message which can be taken from the evaluation of historical evidence concerning social and economic harm attributed at least in part to nature is that its interpretation can be used to support opposing arguments regarding future actions. For example, incidents of cattle (*Bos taurus*) infected by tuberculosis in the UK increased since the mid-1980s despite the implementation of national policy to cull badgers (*Meles meles*) which have spread the virus since the 1970s (Lodge and Matus, 2014). This evidence was used to support the animal welfare lobbyists' argument that badger culling should cease as it is does not achieve its intended objectives; whilst farmers used the same evidence to argue that a greater number of badgers needed to be culled to achieve these objectives.

International historical studies of attitudes towards natural hazards through time may also be useful in predicting future attitudes and associated management strategies. Broadly the development of attitudes towards natural hazards can be divided into three stages: 1) a fearful phase during which hazards are perceived as acts of gods and supernatural forces and management techniques involve prayer and ritual; 2) a controlling phase during which people aim to mitigate against natural hazards through dominionistic techniques such as structural flood defences; 3) a phase of harmony during which people accept the ineffectiveness of attempts to control nature and instead take a more holistic approach to minimising both the negative impacts of nature on people and those of hazard mitigation on nature (Correia *et al*., 1998). These stages are characteristic of pre-industrial, industrial and post-industrial societies respectively (White, 1973). Historical knowledge may also play an important role in determining current public attitudes towards types of harm attributed at least in part to nature. For example, repetition of natural hazard events increases demand for action to mitigate against their effects (Mauelshagen, 2009). Bernardo *et al*. (1993 cited in Correia *et al*., 1998) reasoned that because the frequency of flood events has been relatively high historically in comparison to that of other natural hazards the public are more willing to engage in participatory management.

3.1.2 Environmental Management

In addition to increasing our understanding of responses of the natural environment to its utilisation and management for maximising the social and economic benefits which are derived from it and minimising the social and economic harm for which it has a causal role, historical studies can be used to evaluate the long term effectiveness of actions to mitigate against adverse anthropogenic impacts on the natural environment. For example, Langford *et al.* (2009) studied the chemical and biological recovery of three rivers in the Midlands of England from 1952 onwards following the reduction of the discharge of industrial and domestic effluents into them which they largely attributed to the Rivers (Prevention of Pollution Act) 1961. They demonstrated that recovery rates of macroinvertebrate communities were dependent on the presence of pollution sensitive species further upstream to enable suitable habitat to be colonised as it became available. At one site no pollution sensitive invertebrate species were present thirty years after effluents from the main source of pollution had last been discharged into the river. They used these findings to evaluate methods of water quality monitoring and target setting under the Water Framework Directive which rely on current invertebrate community composition, stressing the need to consider the history of the river and its connection with sites from which invertebrates may be expected to colonise.

Other lessons from the past concern the abilities of scientists and environmentalists to influence decision makers. For example, Parlour and Schatzow (1978) evaluated the role of the media in fostering public environmental concern in Canada from 1960 to 1972. They used their finding to produce the Elite Mass Media Public Interaction Model, the main premises of which are: the elites including government professionals and university academics perceive environmental problems which they communicate either directly to the media or to the media via interest groups which then publish it, increasing the public's environmental awareness. Lowe and Morrison (1984) described the developments which facilitated increased reporting of environmental issues in the UK since the 1950s in more detail. They recognised that environmental groups formed since the 1960s were immediately very keen to engage the media, orientating their campaigns to gain media coverage and thus foster public support. Older environmental groups saw the success of the newer groups and soon followed suit. They also described the active role of media organisations and professionals in strengthening relationship with environmental groups. For example, the BBC funded Council for Nature's Intelligence Unit was created in 1959 with the aim to publicise nature conservation issues by strengthening relationships between conservationists and programme makers. In 1972 ECO (Environmental Communicators' Organisations) was established by journalists and held talks for journalists to learn more about environmental issues and gave advice to environmental groups on how to approach the media. They concluded that good relationships with the media are essential to successful campaigning. Such successes have included: the passing of legislation to reduce the dumping of cyanide waste following the collaborative work of the Conservation Society and the media in reporting the problem (Kimber *et al*., 1974 cited in Lowe and Morrison, 1984); and the reversal of a government decision to cull seals off Orkney for the benefit of the fisheries following the publication in the media of pictures taken by Greenpeace (Lister-Kaye, 1979 cited in Lowe and Morrison, 1984).

3.1.3 Why Newspapers?

Although the most obvious role of newspapers is to inform and shape public attitudes and, by this means potentially influence government policy, they also provide a way of addressing a key need for environmental historians: documenting historic events, circumstances and attitudes. Newspapers can be expected to reflect societal attitudes at the time of writing to a relatively great extent as their content is orientated towards their readers (Kellert, 1985). Hannigan (1995) reasons that it is unlikely that an environmental issue will enter the "*arena of public discourse"* unless it is reported in the media. Suhonen (n.d. cited in Lahtinen and Vuorisalo, 2004b) found a relatively strong positive relationship between the extent of newspaper coverage of environmental issues in Finland and societal environmental concern measured through survey responses between 1972 and 1992. All three of the categories of interactions between people and nature discussed in sections 3.1.1 and 3.1.2: social and economic benefits derived from nature; social and economic problems caused at least in part by nature; and environmental management have previously been studied using newspapers.

The importance of the anthropocentric benefits derived from nature in shaping attitudes towards it expressed through the newspapers was highlighted by Kellert's (1985) finding that a utilitarian attitude towards animals was expressed in more articles than any other attitude in the 20th century. Collectively articles which analysed the content of historical newspaper articles covered a wide range of social and economic benefits derived from nature including: waste removal, drinking water, washing clothes, fisheries, pest control, hunting, recreation and aesthetics and the taking of animals from the wild to be kept as pets (Parlour and Schatzow, 1978; Kellert, 1985; Knott *et al*., 1998; Jensen, 2000; Vuorisalo *et al*., 2001; Lahtinen and Vuorisalo, 2004b; Pohja-Mykrä *et al*., 2005; Lahtinen and Vuorisalo, 2011; Vuorisalo *et al*., 2014). These journal articles explained how deriving particular benefits from local nature resulted in environmental degradation and reduced the ability of local natural resources to provide other benefits to society. For example, Jensen (2000) used historical newspaper articles published in Denmark from the 1910s to the 1970s to describe the impacts of the use of rivers, lakes and coastal waters for waste disposal and removal on their ability to support fish populations and provide drinking water and recreational opportunities. Similarly, Lahtinen and Vuorisalo (2004b) described the effects of using rivers for the removal of waste in Finland from the 1880s to the 1930s in terms of fish kills and reduced provisioning of anthropocentric benefits, particularly drinking water, clothes washing and recreation. Surprisingly there has been very little written on the portrayal of benefits derived from nature by agricultural and manufacturing industries in historical newspapers. The only example I found was that Vuorisalo *et al*. (2014) analysed an article published in Finland in 1893 which acknowledged the role of red foxes in pest control through their consumption of small rodents which would otherwise eat stored grain.

The portrayal of anthropocentric harm attributed at least in part to nature in historical newspaper articles has been discussed with regards to human health, agricultural production, buildings and environmental aesthetics (Jensen, 2000; Vuorisalo *et al*., 2001; Lahtinen and Vuorisalo, 2004b; Pohja-Mykrä *et al*., 2005; Vuorisalo *et al*., 2014). A negativistic attitude towards animals characterised by fear or dislike was expressed in approximately one seventh of the American articles published between 1900 and 1946 analysed by Kellert (1985). These discussions clearly demonstrated the role of human activities in degrading nature and ultimately both human and natural factors interacting to cause social and economic harm. For example cholera and typhoid were believed to be consequences of pollution (Jensen, 2000; Vuorisalo *et al*., 2001). However, it was also recognised that nature could cause harm to people without the need to be modified by them. For example, several Finnish people had reportedly been bitten by a native species of snake, common vipers (*Vipera berus*), in or around the city of Turku between 1890 and 1920 (Vuorisalo *et al*., 2001). The threats which nature posed to agriculture were recognised to a much greater extent than the benefits which agriculture gained from ecosystem service provisioning. This reflects the attitude to nature traditionally held by farmers that it was a threat to productivity which needed to be controlled and where possible removed from farmland (Thomas, 1991). Complaints about damage to agriculture focused on the role of mammals including red foxes, rats (species unspecified) and moose (*Alces alces*) as pests which killed livestock and fed on grain stocks (Vuorisalo *et al*., 2001; Vuorisalo *et al*., 2014). In addition to the tangible ecosystem disservices, some wildlife observations were also interpreted as bad omens. For example, observations of red squirrels in urban areas in Finland were interpreted as evidence of upcoming disaster such as fire, war or plague (Vuorisalo *et al*., 2001). Attempts to minimise the negative social and economic impacts of nature included culling pest species and reducing the pollution which created better habitat conditions for pathogens (Jensen, 2000; Vuorisalo *et al*., 2001; Pohja-Mykrä *et al*., 2005; Vuorisalo *et al.*, 2014). This was effective for preventing future epidemics of cholera and reducing future incidents of typhoid but culling pest species was largely abandoned due to changes in attitudes towards them. With the exception of disease and agricultural production there was little discussion of the negative effects of nature on people and property. The portrayal of floods in historical newspapers was discussed by Shrubsole *et al*. (1993) but they did not consider the effects of floods or flood defences on nature.

In terms of ecosystem management previous studies have discussed various efforts to reduce river pollution conveyed through historical newspaper articles including: discharging waste at sea, naming and shaming factories responsible for pollution and legislatively controlling the quantity of effluents which industrial organisations were allowed to discharge (Parlour *et al*., 1978; Jensen, 2000; Lahtinen and Vuorisalo, 2004b). These studies indicated that mitigating against the effects which pollution had on human health and recreational opportunities was probably a greater motivation for such actions than nature's intrinsic value. Incentives to cull bird and mammal species which were considered as pests were removed to facilitate population recovery as societal attitudes towards these species changed (Pohja-Mykrä *et al*., 2005). Newspaper articles also encouraged bird feeding and the construction of nest boxes (Vuorisalo *et al*., 2001). There was no discussion of efforts to eradicate or control non-indigenous species or reverse physical environmental degradation.

Given: 1) the importance of historical knowledge regarding both positive and negative interactions between people and ecosystems in informing decisions regarding current and future environmental management; 2) that other studies have proven that historical newspaper articles are a valuable source of such information; and 3) that many of these interactions which are important both historically and today have been understudied using this information source the aim of this study is to answer the question: how have interactions between the River Don and local people changed through time? These interactions include social and economic benefits derived from the river; social and economic damage and problems attributed fully or in part to the river, efforts to reduce these; reports of damage caused to the river as a result of human activities; and efforts to manage the river from an environmental perspective. The implications of this research will then be considered with regards to the future management of the River Don. The River Don was chosen as a case study as it has a long history of substantially both benefiting and adversely affecting local communities and the local economy and its environmental degradation has been reversed to a large extent particularly with regards to pollution but also with regards to physical degradation albeit to a lesser extent (Sheffield Local Biodiversity Action Partnership, n.d; Firth, 1997; DCRT, n.d.b). The research question was deliberately very broad to minimise the effects of the researcher's prior conceptions on the outcomes of the research. This decision is in line with Eisenhardt's (1989) recommendation that researchers aiming to build theory from case studies should "*formulate a research problem and possibly specify some potentially important variables, with some reference to the extant literature. However, they should avoid thinking about specific relationships between variables and theories as much as possible, especially at the outset of the process*".

3.2 METHOD

3.2.1. Sourcing and Sampling Newspaper Articles

Local newspaper articles were sourced from the British Newspaper Archive's online database (British Newspaper Archive, 2016) and Sheffield Star Archives within the Sheffield Star Offices. National newspaper articles were sourced from the Times (2016), the Daily Mirror (2016) and the Guardian online databases (The Guardian and Observer, 2016). The time periods in which these articles were published is shown in Table One. Collectively these newspapers provided a broad range of perspectives as the Times has a predominately right wing readership whilst the Daily Mirror and Guardian both have predominately left wing readerships (Bakker *et al*., 2014; Hammett, 2015).

All online databases and the computer database at Sheffield Star Archives were searched using the search term "*River Don"* and each individual time period listed in Table One. Each time period began on 1st January of a year ending in a zero and ended on 31st December of a year ending in a nine. Those articles which were published before 1850 were categorised separately from those which were published between 1850 and 1950 as it is widely agreed that the Industrial Revolution occurred in the UK from approximately 1750 to approximately 1850 (Deane, 1979). From 1950 onwards I shifted the focus from one hundred year periods to decades as I had analysed the fish records from this period by decade and from Firth (1997) I knew that considerable effort to restore the River Don began in the 1970s so I wanted to study the two decades leading up to this in more detail than previous decades to better understand the social, economic and political factors which may have led to such change in the 1970s. Since the 1970s the River Don and the way in which people interact with it has rapidly changed so I wanted to describe this change on a finer timescale. As the paper newspaper articles which feature the River Don had already been separated from those which do not by archivists at Sheffield Star Archives there was no need to search them using the search term "*River Don*". The number of articles in each time period was counted and the number which were published in each decade was estimated using the assumption that the proportion of articles within a time period which were published within a decade was proportional to the number of years in that decade in the time period. The results for each computer source were sorted in ascending publication date order. When this gave more than 25 results a sample of 25 articles roughly evenly distributed through the list was selected and the proportion of these 25 articles which were relevant was calculated. Articles were deemed to be relevant when they discussed any part of the River Don between the Peak District and Goole but those who only mentioned it due to its geographical proximity to another place or event of interest were excluded from the analysis. Things named after the River Don such as the River Don Engine and the River Don Works were not deemed relevant. Although these names reflect the importance of the River Don classing all articles which mentioned these was likely to bias the results, especially given the large number of articles which mentioned the River Don Works in later years when it was no longer dependent on the river. The proportion of the 25 articles which were relevant was multiplied by the total number of results yielded by the search to give an estimated number of relevant articles for the source and time period. When fewer than 25 results were yielded by the initial search the number of relevant articles was counted rather than estimated. The paper articles were stored in envelopes spanning a few years but sorted within the envelopes. To save time I simply analysed every *n*th article in the order in which they were.

Every *n*th article was selected from the list of articles organised in ascending publication date order to ensure that the distribution of publication dates of the sampled articles rougly reflected the distribution of publication dates of all articles from each source within each time period. For the first two time periods (pre 1850 and 1850-1950) the same number of articles were selected from both local and national newspaper articles. 100 articles which had been published before 1850 were analysed and 200 articles which were published between 1850 and 1950 were analysed. This was because the previous chapter found that the composition of the fish community had changed greatly during the second time period. The searches only yielded a total of 17 articles for the 1960s. From the 1970s onwards 25 articles were analysed each decade. Where possible 15 were analysed from local newspapers and 10 from national newspapers. This reflected the much greater number of articles which were published in local newspaper articles during this time period.

Table 1. Number of articles analysed and total number of relevant articles by source and time period (in brackets). When the total number of relevant articles was estimated rather than counted it is shown in italics.

Time period	British Newspaper Archive	Sheffield Star Archives (Paper)	Sheffield Star Archives (Computer)	Times	Daily Mirror	Guardian
Pre 1850	50, (*615*)	0, (0)	0, (0)	30, (*33*)	0, (0)	20, (*26*)
1850-1950	100, (*6443*)	0, (0)	0, (0)	49, (*90*)	5, (*13*)	46, (*91*)
1960s	0, (0)	0, (0)	0, (0)	4, (4)	1, (1)	12, (12)
1970s	0, (0)	17, (*123*)	0, (0)	2,(2)	1,(1)	5, (5)
1980s	0, (0)	15, (*202*)	0, (0)	4, (*6*)	2, (3)	4, (*6*)
1990s	0, (0)	15, (*140*)	0, (0)	3, (*14*)	1, (2)	6, (*23*)
2000s	0, (0)	2, (*12*)	13, (*1426*)	5, (*19*)	3, (*11*)	2, (*9*)
2010s	0, (0)	0, (0)	25, (*2276*)	0, (0)	0, (0)	0, (0)

3.2.2 Analysing Individual Newspaper Articles

For each newspaper article: the name and date of the publication; and the social and economic benefits and harms which were attributed to the River Don and actions including proposed actions and enforcement of legislation as well as practical actions which were mentioned within the article were recorded. This yielded the subthemes which are listed in Table Two. Notes and quotes were also recorded to facilitate more detailed quantitative and qualitative analysis with regards to more specific activities associated with and threats posed by the River Don, the reasons why they were mentioned and the ways in which they were portrayed.

Table 2. Themes and sub themes used for thematic analysis of the newspaper articles

Theme	Subtheme
Non-cultural social and economic benefits derived at least in part from the River Don (Theme A)	Hydropower Abstraction Waste removal Navigation Drainage Other
Cultural social and economic benefits derived at least in part from the River Don (Theme B)	Angling Other recreation Heritage Other cultural benefits
Social and economic threats and harm attributed at least in part to the River Don (Theme C)	Death Floods Drought Damage to property or infrastructure Physical barrier Crime
Environmental management of the River Don (Theme D)	*Environmental issues* Pollution Physical degradation Depleted or extirpated wildlife *Taxa* Fish Birds Mammals Plants Unspecified wildlife

3.2.3 Analysing Trends Through Time

The number of articles which mentioned each of the themes listed in Table 2 in each time period was counted. The term conservation was used broadly to include environmental preservation, restoration and improvements. The proportion of articles in each of these time periods which mentioned these themes was calculated using these counts enabling trends to be described through time. Several articles mentioned more than one of these so the sum of the proportions is greater than 100%. The number of articles which mentioned each of the subthemes in table 2 in each time period was counted. These counts were used to calculate the proportion of articles in each theme, century and decade which mentioned each of the corresponding subthemes.

3.3 RESULTS AND DISCUSSION

3.3.1 Overview

Collectively the articles indicated that public attitudes towards the River Don, the benefits which it provides, the threats which it poses and its management drivers changed greatly through time (Figure 1a). Overall threats and harm posed by the river were mentioned in approximately half of all articles, non-cultural benefits afforded by the river were mentioned in approximately two fifths, cultural benefits afforded by the river were mentioned in approximately one quarter and conservation was mentioned in approximately one eighth. Approximately two thirds of all articles mentioned at least one type of benefit derived from the River Don whether it be cultural or non-cultural.

Only two articles from the 18th century were analysed. They both mentioned Theme C but did not mention any other theme. From the 19th century to the 21st century the proportion of articles that mentioned Theme A approximately halved, the proportion of articles that mentioned Theme B tripled and the proportion of articles that mentioned Theme C each century stayed relatively constant (Figures 1a: ii, iv and vi respectively). Theme D was mentioned in nine articles before the 20th century, one quarter of the 169 articles published in the 20th century and five articles in the 21st century (i.e. 10%) (Figures 1a: vii and viii respectively).

From the 1960s onwards Theme B and Theme C were each mentioned in approximately two fifths of newspaper articles, Theme D was mentioned in approximately one third and Theme A was mentioned in approximately one quarter. The proportion of articles which mentioned themes A and B showed no clear trends from the 1960s to the 2010s (Figures 1b: iv, vi, viii and ii respectively). The content of newspaper articles published in the 1960s was heavily dominated by Theme C (Figure 1vi). Eight of the 14 Theme C articles published this decade portrayed the River Don and its flood waters as a physical barrier. Five of these referred to the construction of a motorway viaduct. The effect of this project on the proportion of articles which mentioned Theme C and the proportion which did not mention Themes A and B is likely to have been exaggerated by the small sample size as only 17 articles were available from this decade. From the 1970s through to the 1990s the proportion of articles which mentioned Theme C was at its lowest and did not exceed one quarter whilst the proportion of articles which mentioned Theme B was at its highest and did not fall below one half. Theme D was only mentioned in one and four of the 25 articles published in the 2000s and 2010s respectively. This may be because pollution was a lot less severe than it had been in previous decades and no other threat to the River Don's ecology has ever received much attention in the media. It may also be due to the attention given to the 2007 floods reflected in the high proportion of articles which mentioned Theme C in the 2000s and to a lesser extent efforts to reduce the risk of further flooding reflected in a relatively high proportion of articles which mentioned Theme A that decade (Figure 1b: vi and ii respectively). Eleven of the 17 articles which mentioned Theme C in the 2000s mentioned flooding. These were all published from 2007 onwards. All seven of the Theme A articles which were published in the 2000s mentioned drainage. They were also all published from 2007 onwards.

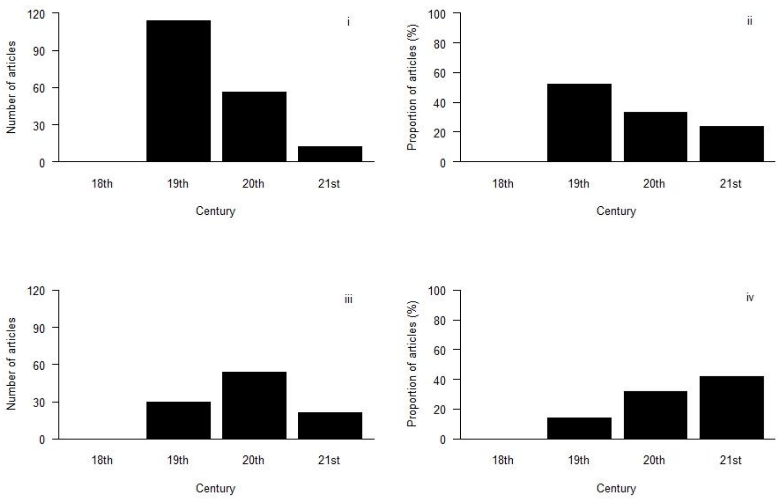
The decrease in the proportion of articles which mentioned Theme A and the increase in the proportion of articles which mentioned Theme B from the 19th century through to the 21st reflected changes in the use of rivers throughout Europe as economies have transitioned from being primarily manufacturing sector based to primarily service sector based (Bothmann *et al.*, 2006) as well as Firth's (1997) historical account of the River Don itself. Similar trends of decreased focus on non-cultural benefits derived from nature and increased focus on cultural benefits derived from nature have also been described in other ecosystems. For example, forests which were traditionally managed for timber production are now increasingly managed holistically for both timber production and recreation (Bengston *et al.*, 1999).

Overall approximately half of the articles mentioned Theme C. This relatively high proportion is likely to be in part due to the widely recognised propensity of the media to report negative news (Anderson, 2002). This propensity may have particularly affected the relatively high proportion of articles which mentioned actual or potential human deaths which were mentioned in 39% of Theme C articles and floods which were mentioned in 31% of these articles. The proportion of Theme C articles published each century changed little through time. The river's role as a physical barrier was not generally portrayed particularly negatively and the majority of articles which portrayed the role of the river in this way simply acknowledged the need to construct bridges and reported relevant actions.

Unfortunately I was unable to find any other studies which have previously described changes in the proportion of newspaper articles which mention social or economic harm or problems in part attributed to local nature through time for comparison. However, studies which have used newspaper articles to describe changes in relevant attitudes, legislation and behaviour through time indicate that the extent to which nature is perceived as a threat has decreased in recent centuries and decades. For example, Kellert (1985) found that the expression of negativistic attitudes which they defined as "*primary orientation a dislike or fear of animals*" towards wildlife approximately halved from the 1910s to the 1960s in America. From an analysis of newspaper and magazine articles and legal documents produced between the 1770s and 1930s Pohja-Mykrä *et al*. (2005) identified a substantial decline in support for hunting mammalian species which had been classified as pests prior to the 1920s and greater support for their conservation. Furthermore, den Otter (2012) stated that in mid-19th century Britain wilderness was perceived to be "*hostile"* and that nature in general was to be "*tamed"*. The River Don study differed substantially from these two studies in that it considered a much broader range of ways in which harm or potential harm caused to local people and the local economy were attributed at least in part to nature. The vast majority of Theme C articles reported harm or potential harm attributed at least in part to the abiotic environment rather than animals or other living things. As discussed in section 3.3.4 the proportion of articles which mentioned flooding and damage to infrastructure or property most of which was caused by flooding increased through time counterbalancing the decreased proportion of articles which mentioned actual or potential human deaths associated with the river and the role of the river as a physical barrier. It is important to realise that social and economic harm associated with the River Don have always received much public attention as it suggests that efforts to manage the river without considering the ways in which it can cause such harm are unlikely to gain the necessary public support on which their success will rely and may even be actively opposed. The need to consider harm attributed to nature more generally in urban ecosystem management for these reasons is highlighted by Lyytimäki *et al*. (2008).

The first Theme D articles were published in the late 19th century. This reflected the widespread recognition that nature was not as resilient as previously believed and the increased expression of conservation ethics in western societies (Lowe, 1983 cited in Jepson and Whittaker, 2002). This increased recognition was facilitated by advances in technology which enabled people to travel to far less degraded ecosystems such as the Alps and thus realise how degraded the ecosystems to which they were accustomed actually were (Jepson and Whittaker, 2002). The extent to which nature was previously believed to be resilient to anthropogenic threats is expressed well in this statement which was made by Sim in 1864 (cited in Jepson and Whittaker, 2002): "*the vast domain of nature can never be fully explored, her attractive resources being infinite and inexhaustible"*. Firth (1997) recognised that action to conserve the river had a long history but until the 20th century relatively little action had been taken and it had had very little effect. He stated that the Commission of Sewers which was created in 1531 was responsible for ensuring that rivers were not polluted with sewage on a national scale but he did not specify any actions which they took locally and made it clear that they were very ineffective in achieving this aim with regards to the River Don. The first action to conserve the River Don which Firth reported was in 1868 when a Doncaster MP raised the matter of upstream towns polluting the river in Parliament but as far as Firth was aware no action was taken as a result of this.

The extent to which Theme D was mentioned in newspaper articles was greatest from the 1970s to the 1990s. In 1965 it was reported that the Rivers (Prevention of Pollution Act) 1961 was coming into effect and companies were legally obliged to enter into agreements with the River Authorities to ensure that their effluents met strict standards, minimising the extent to which they polluted the River Don (The Guardian: 8th October 1965). The delay between these efforts and the greater reporting may partly be due to the fact that only 17 articles were available from the 1960s whilst 25 were analysed from the other decades and the high level of attention given to the construction of the motorway viaduct which was mentioned in five of the 17 articles. It may have also been due to the delay between the Rivers (Prevention of Pollution Act) 1961 coming into effect in 1965 but many companies being given five years to develop their machinery and processes in order to comply (The Guardian: 8th October 1965). Reflecting the increased interest in conserving the River Don in the 1970s Firth's (1997) account of the substantial restoration of the River Don began in 1975 with an abstraction licence being challenged because trout (*Salmo trutta*) were present and there were fears that abstraction could increase the concentration of pollutants and thus threaten trout. However, Firth did acknowledge that the section of the River Don upstream of Doncaster was likely to have been better than it would have otherwise been in the first half of the 20th century due to improved sewage treatment as indicated by the use of this area for recreational swimming and angling matches. The first newspaper article which recognised that pollution in the River Don had actually decreased was published in 1976 (Sheffield Star: 31st July 1976). Although the newspaper articles recognised the role of deindustrialisation to a very low extent the decline of South Yorkshire's manufacturing industries from the late 1970s onwards probably increased the effectiveness of conservation actions and it is common for post-industrial rivers to be managed to a greater extent for conservation and recreational activities which are dependent on environmental quality (Watts, 2004; Bothmann *et al.*, 2006). National issues which may have fostered efforts to conserve the River Don in the 1970s include: the creation of the Royal Commission on Environmental Pollution and the Water Authorities who had responsibility for controlling river pollution; the passing of the Control of Pollution Act 1974; and the availability of government grants of up to 95% for the rehabilitation of brownfield sites (Evans, 1992). Media attention may also have increased as a result of the European Conservation Year 1970 which galvanised broad public support for conservation. The decreased attention paid to conservation in the last two decades suggests that less is being done to conserve the river. This is likely to partly be due to the reduced severity of the threats posed to wildlife now that pollution has decreased greatly and partly due to reduced funding due to the economic recession (Firth, 1997; Somper, 2011). However, the apparent decline in the proportion of articles mentioning conversation in the last two decades may partly be due to small sample size.



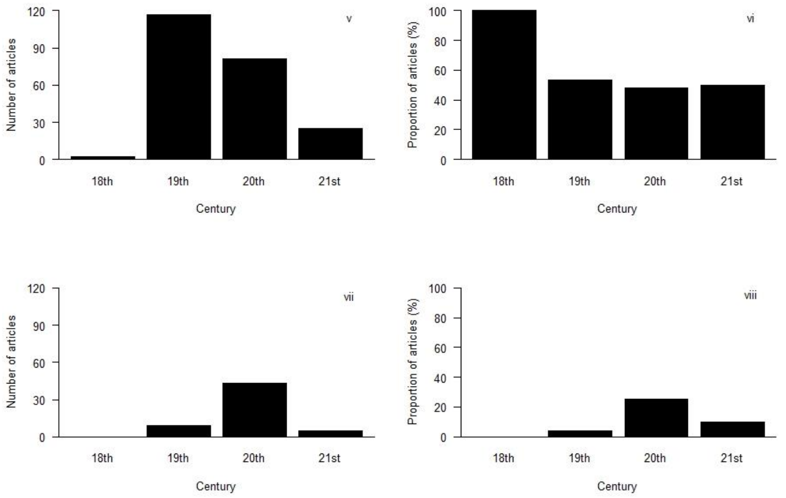


Figure 1a. Number and proportion of articles mentioning each theme by century (i and ii= Theme A ; iii and iv= Theme B; v and vi=Theme C; vii and viii=Theme D) (n=two 18th century, 218 19th century, 169 20th century and 50 21st century articles).

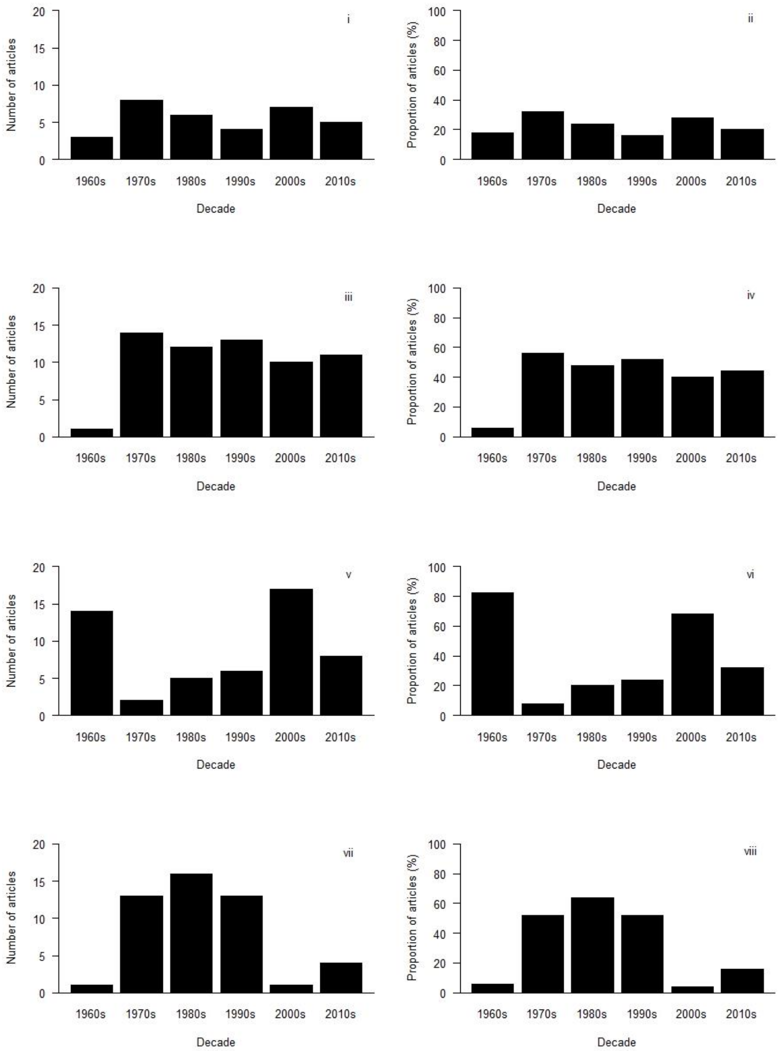


Figure 1b. Number and proportion of articles mentioning each theme by century (i and ii=Theme A; iii and iv=Theme B; v and vi=Theme C; vii and viii=Theme D) (n=17 1960s articles and 25 articles from each other decade).

3.3.2 Theme A

Overall navigation, which was mentioned in more than one third of all Theme A articles, was the most frequently mentioned Theme A subtheme. No Theme A articles were published in the 18th century. In the 19th century navigation was the most frequently mentioned Theme A subtheme followed by abstraction (Figure 2a). They were mentioned in approximately one half and one quarter of Theme A articles respectively. In the 20th century abstraction, navigation and drainage were the most commonly mentioned Theme A subthemes (29-30% of Theme A articles) and in the 21st century drainage was the most commonly mentioned (78% of Theme A articles).

From the 1960s onwards the Theme A subthemes which were mentioned in the greatest number of articles were waste removal and drainage (14 and ten articles respectively) (Figure 2b). The proportion of Theme A articles which mentioned waste removal peaked in the 1980s and 1990s (83% and 75% respectively; Figure 2biii). The proportion which mentioned drainage peaked at 100% in the 2000s (Figure 2bv). The only Theme A subthemes which were mentioned in articles published in three or more decades were: abstraction, waste removal and drainage (Figure 2b). None of these showed a clear trend through time (Figures 2bii, iii and v).

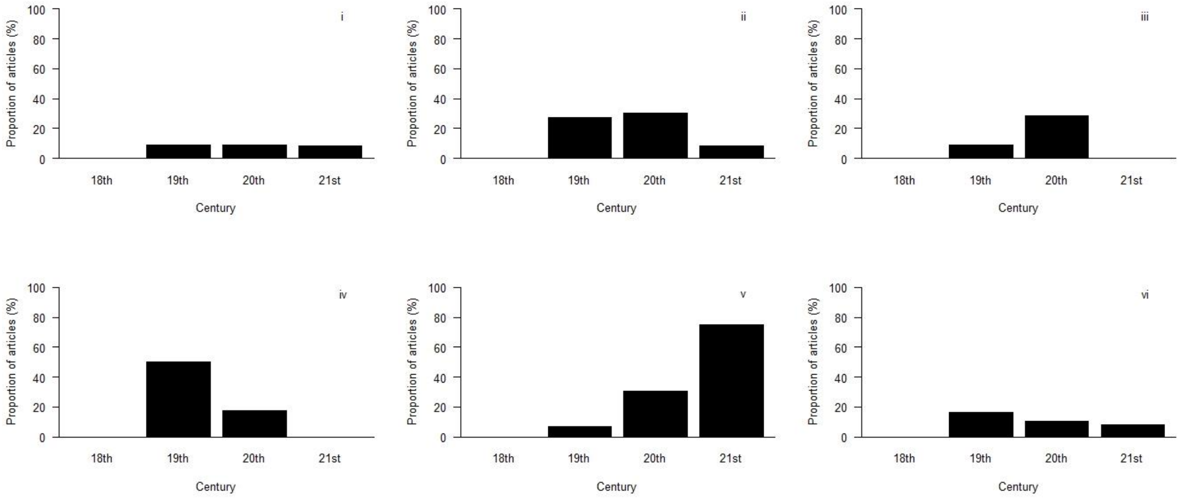


Figure 2a. Proportion of Theme A articles which mention each subtheme by century. (i=Hydropower, ii=Abstraction, iii=Waste Removal, iv=Navigation, v=Drainage and Flood defence, vi=Other) (n=114, 56 and 12 Theme A articles from the 19th, 20th and 21st centuries respectively).

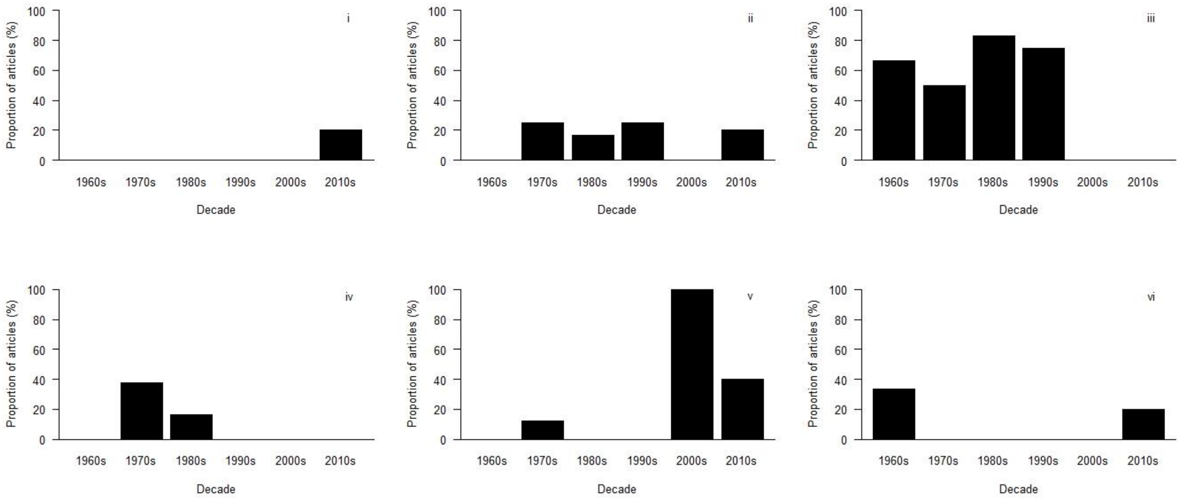


Figure 2b. Proportion of Theme A articles which mention each subtheme by decade from the 1960s onwards. (i=Hydropower, ii=Abstraction, iii=Waste Removal, iv=Navigation, v=Drainage and flood defence, vi=Other) (n=3, 8, 6, 4, 7, 5 Theme A articles from the 1960s, 1970s, 1980s, 1990s, 2000s and 2010s respectively).

3.3.2.1 Hydropower

The relatively low proportion of articles which mentioned hydropower (Figure 2ai) did not reflect the historical importance of this use of the river. According to Firth (1997) the River Don provided better opportunities for power generation than the majority of other rivers in the UK and by 1722 there were already 13 major impoundments on the River Don between Sheffield and Doncaster (Palmer 1722 cited in Firth, 1997). It was clear from the articles which mentioned hydropower that a wide range of industries including heavy manufacturing industries (Leeds Mercury: 26th July 1851; Sheffield Independent: 29th August 1871, 19th March 1880, 4th May 1880; The Guardian and The Observer: 14th May 1851), paper millers (The Guardian: 9th March 1867; 13th April 1867; 27th April 1867) and corn millers (Leeds Mercury: 26th July 1851; The Guardian: 2nd November 1836; The Guardian and The Observer: 14th May 1851) were attracted to the River Don as a source of power.

The proportion of articles which mentioned hydropower was probably low because hydropower was rapidly replaced by steam power in Britain from the beginning of the 19th century and the use of steam power was already widespread in the steel industry, Sheffield's dominant industry, by 1855 (Truan 1855 cited in Birch, 1967; Walton, 1952; Simmons, 2001). The difficulty of establishing whether mills were powered by water power or steam power may have also reduced the proportion of articles which were recognised to have mentioned hydropower.

The presence of weirs greatly alters many features of the abiotic environment including: flow speeds including seasonal variation patterns, the extent of flooding, channel depth, channel width, sediment structure, water temperatures and the availability of allochthonous nutrients and thus the composition of ecological communities (Fraser, 1972; Hayes *et al.*, 1998). However, no newspaper articles considered their environmental impacts. This was not due to a lack of knowledge as it has been a legal requirement since the mid-19th century to install a fish pass on any new impoundment which could otherwise block salmonid migration (Firth, 1997). It was more likely to be due to the perceived importance of economic considerations over ecological considerations. Conversely, there were also suggestions that demands for hydropower prevented over-abstraction to some extent. The river was perceived to have a high level of compensation water and there were concerns that if Wakefield, a town to the North West of the Don Catchment, were allowed to abstract water from part of the Don Catchment there would not be enough water to meet the needs of the mill owners (Sheffield Independent: 8th July 1874).

Today the weirs which historically provided hydropower to manufacturers are highly valued from a heritage perspective. This has the potential to cause conflict between the desire to conserve industrial heritage and the desire to reverse historical physical environmental degradation including impoundment. However, extensive public consultation undertaken by DCRT (Don Catchment Rivers Trust) found very little if any opposition towards the installation of fish passes on heritage grounds (personal communications with Edward Shaw, DCRT Trustee, 2016). Furthermore, recognition of the extent to which the River Don previously generated hydropower could foster public support for its use in the future generation of microhydropower, an increasingly popular less environmentally harmful alternative to fossil fuels (Paish, 2002). An article published in 2011 which found that proposals to harness the rivers energy to power 80 homes had failed to secure funding highlighted the need to increase public support if the river's energy is to be harnessed for the benefit of the wider environment and society (Unspecified publication available from Sheffield Star Archives: 6th December 2011).

3.3.2.2 Abstraction

In the 19th and 20th centuries water abstracted from the River Don was used to manufacture a wide range of products including: iron and steel (e.g. Sheffield Independent: 6th April 1822, 29th August 1871; The Manchester Guardian: 1st June 1872), paper (Manchester Guardian: 9th March 1867, 13th April 1867, 27th April 1887), boilers (The Manchester Guardian: 4th November 1911), wagons (Sheffield Telegraph: 2nd May 1874), leather (Sheffield Independent: 10th January 1882; The Manchester Guardian, 22nd January 1876), flour (e.g. Sheffield Independent: 21st June 1845; The Times: 26th June 1845, 10th June 1844), beer (e.g. Sheffield Independent: 1843; York Herald: 1st January 1831, 12th October 1833) and refined sugar (e.g. The Times: 25th March 1844; 2nd April 1844, 18th June 1845). Opportunities to abstract water from the River Don were also used to market an agricultural and domestic property during the 20th century (The Manchester Guardian: 24th May 1902). The important role of opportunities to abstract water directly from rivers in determining the location of industry is recognised by Hassan (1998). Abstraction of water for domestic purposes probably received little attention in the newspaper articles because water for these purposes was abstracted from other sources such as reservoirs, wells and springs, in large part because the River

Don was so polluted (Firth, 1997; Munford, 2000). The earliest reservoirs were built in Sheffield in the mid-18th century (Firth, 1997).

The attitude that water did not need to be conserved was expressed strongly in an advertisement for a sugar refinery for sale in 1845 which stated that the River Don provided "*an ample supply of water free from expense*" (The Times: 18th June 1845). This contrasts with the prevalent view on a national scale that piped water resources were expensive and not of sufficient quantity (Taylor *et al.*, 2009). However, it was soon also recognised by local industries that water was at times a limited resource. The earliest concerns were raised in 1864 and concerned the effects of abstraction on increasing the concentration of pollutants (Sheffield Telegraph: 29th October 1864). On 8th July 1874 it was stated in the Sheffield Independent that the Sheffield Water Company built as few reservoirs and made the most stringent regulations that they could as "*every drop of water that could run down the river was valuable"* and if the population of the Don Valley continued to increase as it had done in the past the whole of the water in the valley would be wanted. Taylor *et al*. (2009) recognised that from the 19th century onwards droughts have always strengthened the desire to conserve water and led to water being used more prudently. This is in line with the depletion crisis model as it is likely that this change in attitude resulted from over exploitation of the river's water (Berkes and Turner, 2006). Firth (1997) described sections of the River Don running dry because so much water was being abstracted from the river. In the early 20th century an article in the Guardian reported that Sheffield had surplus to sell to water deficient areas due to water recycling, suggesting that water conservation was highly successful (The Guardian: 13th December 1924). Although this change in practices was likely to have benefited the River Don from an ecological perspective it was entirely driven by the needs of industry and local residents with regards to abstraction and to a lesser extent hydropower.

Only five analysed articles published from the 1960s onwards mentioned abstraction. However this low number of articles does not mean that water abstracted from the River Don is no longer an important resource. It is likely that fewer articles mentioned the benefits which industry gained from the opportunity to abstract water from the River Don as fewer industrial premises were advertised in newspapers. Between 1974 and 1994 the volume of surface water abstracted from the River Don Catchment increased by approximately 20% from approximately 104 billion cubic metres to approximately 125 billion cubic metres (Firth, 1997). These were fairly evenly distributed throughout the time period (Figure 2bii). Four of these articles were concerned with the quality of the water and one was concerned about a drought. The quality of the water was so poor that there were concerns that the European Court would take action and it was not economically viable to clean the water enough to make it potable (Unnamed publication available from Sheffield Star Archives: 29th September 1989). This concern may have played an important role in fostering support for the reduction of pollution. Severe water shortages are likely to be more common in future due to increased demand for water and climate change (Ofwat, n.d.) Domestic water recycling may be an important part of the solution but currently public opposition is the greatest barrier to its implementation (Jefferson *et al*., 1999). Knowledge that Sheffield benefited from water recycling in the past may help foster local support for such schemes in the same way that an interview participant was inspired by the past to harness the River Don's hydropower (Chapter Four). Drought and pollution are considered in detail in sections 3.3.4.2 and 3.3.5.1.1 respectively.

3.3.2.3 Waste removal

The first analysed article which mentioned waste removal in the mid-19th century stated "*From time immemorial the town sewerage had been discharged into the River Don, which in dry times became filthy, and they depended upon the flood waters to wash the river clean. The flood waters did so, and when the Water Company dammed up those waters they interfered with the vested right of the Corporation, and the Council had therefore special reasons for seeing that the interests of the town* *were not sacrificed"* (Sheffield Telegraph: 29th October 1864). This reflected national beliefs as before river pollution became severe in Victorian Britain it was generally believed that the volume of water in the rivers was enough to dilute pollutants to the extent that their effects were negligible (Clapp, 1994). Recognition that abstraction increased the concentration of pollutants was called "*negative pollution"* in Victorian Britain (Sheail, 1984 and 1986 both cited in Sheail, 1996). The use of the River Don for the removal of sewage at this time reflects the national introduction of the water-carriage method of waste disposal in Britain around the turn of the 19th century (Johnstone and Horan, 1996). At this time there were no controls limiting the extent to which industry was able to discharge effluents into rivers. According to Johnstone and Horan (1996) the ecological consequences of this were so grave that most rivers were unable to support fish life. However, the water-carriage method was viewed positively in terms of public health as previously sewage had simply flowed through the streets (Clapp, 1994). The belief that the River Don would be able to accommodate the quantity of effluents which was being discharged into it if water was not being abstracted from it was not reflected in any later articles and many took a critical view of those who benefited from using the river for waste removal unless they were praising them for reducing impacts of their effluents.

Unlike hydropower and abstraction, waste removal opportunities afforded by the river were never used to advertise the commercial premises which benefited from it when they were for sale or let although this use of the river would have brought great financial advantages over using technological methods to treat industrial effluents (Hassan, 1998). This may explain why it was only mentioned in 9% of Theme A articles in the 19th century. The lack of advertising of the river's potential to be used for the removal of waste may indicate that polluters always felt a sense of shame even if they believed that their actions were justified by the social and economic benefits brought by using the river for waste removal. Efforts to improve the quality of effluents entering the River Don are discussed in section 3.3.5.1.

3.3.2.4 Navigation

Although the River Don was naturally too shallow to be well suited for navigation and the first Act to improve the River Don's navigation was not passed until 1726 when the navigability of many British rivers had already been substantially improved in the 17th century, by the 19th century the river's navigation was highly valued (Walton, 1952; Simmons 2001). Its importance was reflected in the fact that it was the most frequently mentioned Theme A subtheme overall and was reported in half of the Theme A articles which were published in the 19th century. However, its importance declined through time and it was mentioned in less than one fifth of Theme A articles which were published in the 20th century and no articles which were published in the 21st century (Figure 2aiv). In the 19th century navigation opportunities provided by the river were used to market a wide range of industrial premises for sale or let including: manufacturing premises (e.g. Leeds Mercury: 26th July 1851; York Herald: 1st January 1831; Sheffield Independent: 6th April 1822), farms (Leeds Mercury: 1st January 1817; York Herald: 11th February 1815; The Times: 1st November 1813) and collieries (Leeds Intelligencer: 29th January 1842; Sheffield Independent: 21st November 1840). This demonstrated that navigation was highly valued by a broad range of businesses which used the river to transport both raw resources and products. Substantial financial benefits were also accrued by the companies responsible for the management of the navigation and their shareholders (e.g. The Manchester Guardian: 22nd March 1843; The Times: 3rd April 1843; Sheffield Telegraph: 27th April 1876) and logistics companies (Sheffield Independent: 30th June 1832). Additionally three articles even used access to the River Don navigation to market "*The Great and Small Tithes"* of a portion of the township of Hooke (The Times: 26th September 1818, 3rd October 1818; 10th October 1818).

However, none of the analysed newspaper articles which were published in the first half of the 20th century used the navigation to market industrial premises. This suggests that the opportunities afforded by the River Don for navigation were valued much less in the 20th century than they were in the 19th century. This is also reflected in the much lower proportion of Theme A articles which mentioned navigation in the 20th than in the 19th century. Although it is relatively likely that articles published in this time period which were not analysed used the navigation to market industrial premises, the great difference in the number of analysed articles which used navigation to market industrial premises in the 19th and 20th centuries suggests a marked decline in the number of published articles which used the navigation as a marketing tool for industrial premsies between these time periods. However, the following quotation from a newspaper article published in the Times on 3rd October 1929 recognised that the River Don would complement the road and railway which were to be constructed: "*This road and the railway will run 200 yards from the River Don, thus providing road, rail, and water transport"*.

The River Don was substantially modified for the benefit of navigation. Recorded improvements included deepening the channel (York Herald: 17th March 1838) and creating the New Junction Canal (The Times: 22nd November 1911). Proposed improvements included: widening the channel, diverting and altering the course of the channel, constructing new cuts and installing locks and flood gates (Sheffield Independent: 19th November 1925; The Times: 13th November 1973; The Times: 7th December 1973). It is important to note how late substantial improvements for the benefit of navigation were proposed. An article published in The Times on 7th December 1973 stated that The British Waterways Board was applying to parliament to introduce a Bill which would enable them to improve the River Don for navigation. Their proposals included: diversion, widening and realignment of sections of the River Don. They also applied for the rights to "*divert, stop up and interfere with*" the waters of the River Don. The desire to improve the River Don for navigation in the 1970s reflects the fact that the Sheffield and South Yorkshire Navigation was still used commercially when the use of many other waterway systems in the UK for navigation had ceased (Collins, 1984). Under the Transport Act 1968 the Sheffield and South Yorkshire Navigation was to continue to be managed as a commercial waterway, "*principally available for the commercial carriage of freight"* and in 1983 the section of the navigation downstream of Rotherham was improved to enable the passage of vessels weighing up to 700 tonnes. However, despite this strong interest in navigation on the River Don in the 1970s only one article mentioned navigation in the 1980s and it was not mentioned in any later articles (Figure 2aiv). The short lived resurgence of interest in the River Don for navigation in the mid-1970s reflected a small increase in the use of Britain's waterways for navigation at this time.

The ecological consequences of these improvements are likely to have included: habitat fragmentation, increased habitat homogeneity, loss of spawning and nursery habitats for fish and blocked migratory pathways (reviewed in Wolter and Arlinghaus, 2003). These factors have been demonstrated to reduce fish species richness and abundances. However, the extent to which the ecology of the River Don had already been modified for drainage, flood defence and hydropower as discussed in sections 3.3.2.5 and 3.3.2.1 respectively by the time that it was modified for navigation is likely to have greatly reduced the ecological impacts of infrastructure and deliberate channel changes associated with navigation. Navigation can also cause fish mortalities through: direct collisions between vessels and fish; and the generation of waves and currents which cause collisions with substrate and force fish out of the water causing them to suffocate (reviewed in Wolter and Arlinghaus 2003). Behavioural changes in response to vessels such as reduced feeding and nest-guarding behaviour may also be detrimental to fish survival and reproduction.

Despite the number of industries which benefited from using the River Don for navigation, the river was far from ideal for navigation. For example, in the Yorkshire Gazette on 29th March 1845 it was stated that "*it can be proved in evidence before parliament that vessels with standing masts have never ascended above Stainforth, where this is a fixed bridge"*. Stainforth is downstream of

Doncaster. Furthermore in the Sheffield Independent on 28th August 1841 it was reported "*It is a matter of no slight gratification to perceive, that the improvements connected with the River Don, which have been in contemplation during a period extending almost through half a century are at length resolved upon. We have frequently taken upon ourselves to advocate that Doncaster possessed the elements of prosperity, and only required that they should be rendered available."* Navigation was adversely affected by natural factors such as floods (Huddersfield Chronicle, 7th March 1891; Sheffield Star Archives publication not specified: 5th January 1990) and frost (The Times: 21st January 1867). There was also conflict between those who had vested interests in the use of the River Don for navigation and those who prioritised other opportunities afforded by the river such as its use for waste removal and the uses of the adjacent land, particularly rail transport. The Doncaster Corporation were "*threatened with an injunction by the South Yorkshire Railway and River Dun Company if they persist*[ed] *in throwing the town sewage into the River Don*" (Sheffield Telegraph: 22nd July 1870). The impact of the use of rivers for waste removal on navigation was also recognised to have been a problem on the River Fleet in London (Clapp, 1994). Between February and March 1845 there was much discussion about the potential impacts of the construction of a railway bridge on the navigation (The Times: 1st February 1845, 4th March 1845; Yorkshire Gazette, 29th March 1845). There were also reports of actual and potential deaths and damage to boats and cargo due to the dangers of the navigation including those caused by a collision between a boat and a bridge in 1871 (e.g. The Guardian: 19th December 1871; 5th February 1853; The Times: 28th December 1843; Yorkshire Gazette: 2nd June 1838). Criminal damage associated with navigation was only reported in one article which was published on 27th July 1983 and is available at Sheffield Star Archives but unfortunately the name of the publication is unspecified. It reported criminal damage being done to a boat used to transport coal.

3.3.2.5 Drainage and flood defence

The proportion of Theme A articles which mentioned drainage and flood defence increased greatly through time from 7% in the 19th century to three quarters in the 21st century (Figure 2av). These high proportions indicate that minimising the risk of flooding largely by increasing the efficiency with which it was drained by the River Don has always been an important management goal though the increase through time is likely to be in part due to the reduced reliance of industry on the river. Without flood defences the drainage afforded by the River Don would have been far from adequate in preventing floods especially given the replacement of wetlands with impervious surfaces and subsidence caused by coal mining. Thus newspaper articles published from the mid-19th century onwards evidence that much work has been done to artificially increase the river's ability to cope with large quantities of water without flooding (Firth, 1997).

The number of articles which mentioned drainage and flood defence clearly peaked when severe floods occurred. For example, as discussed in section 3.3.4.1 severe floods occurred in 1931, 1932 and 1933 and ten of the 17 articles which mentioned drainage and flood defence in the first half of the 20th century were published between 1931 and 1934. This quotation demonstrates the relationship between recent floods and the perceived increased need to reduce future flooding well: "*During the past few months … the area had been seriously flooded on two occasions. Something must be done to prevent a repetition of the recent flooding"* (The Times: 16th June 1932). Similarly, seven of the nine articles which mentioned drainage and flood defence in the 21st century were published in 2007 and 2008 during or after the severe floods which occurred in 2007. Wheater (2006) also recognised that public and political awareness of the need to better manage the flood risk is often elevated following recent floods. Recognition of when demand for flood defences is likely to be increased is important for aligning environmental conservation and public priorities to maximise support and minimise opposition for the River Don's environmental management.

Societal responses to minimise the impacts of natural hazards can generally be divided into three phases as societies involve: firstly a fearful phase characterised by activities such as praying to deities; secondly a controlling phase characterised by technocentric approaches aimed at controlling nature; and thirdly a phase of harmony in which a better balance is reached between meeting the needs of nature and the needs of society as attempts to control nature are found to be ineffective (White 1973 cited in Correia *et al*., 1998). Although this study focused exclusively on the late 18th century onwards, by which point the drainage of the Don catchment had been greatly altered by the work of Vermuyden described in Chapter One, indicating that it was in the controlling phase, it did find evidence of all three management approaches. The only reference to management approaches associated with the fearful phase was surprisingly late. In 1933 an article stated "*At some of the churches in South Yorkshire yesterday prayers were offered for the abatement of the flood waters, which have spread for miles in the Doncaster district"* (The Times: 6th March 1933). The small sample size means that it is possible that this is not the only article which mentioned such an approach to the management of flooding. However, it is clear that the dominant management method mentioned from the mid 19th century onwards was technocentric.

Collectively the newspaper articles evidenced that a wide range of technocentric approaches were used to manage the flood risk on the River Don including: the construction of flood walls, dams and dykes; and dredging (eg. Sheffield Telegraph: 21st August 1857; The Times: 27th May 1932; York Herald, 8th February 1845; Yorkshire Post and Leeds Intelligencer: 2nd March 1933, 13th November 1936). This heavy reliance on technocentric approaches to flood management reflected the national dominant paradigm (Nixon 1963 cited in Werritty 2006; Purseglove, 1988; Mitchell 2003; Tunstall *et al*., 2004). The faith which people had in the effectiveness of proposed technocentric flood defences is expressed well through this quote: "*such an extent as is necessary to ensure that in times of maximum floods the river will not overflow its banks at any point*" (Yorkshire Post and Leeds Intelligencer: 1st March 1934). It refers to the Ouse Catchment Board's approval of plans to deepen, widen, regrade, embank and straighten the channel of the River Don between Doncaster and Goole. Even in the 21st century the river was dredged (Unspecified publication available from Sheffield Star Archives: 30th December 2010) and structural flood defences were bolstered, repaired and maintained (Doncaster Star, Sheffield Star: 2008 – specific date unspecified). No newspaper articles explicitly considered the effects of these practices from an environmental perspective. However, these approaches have the potential to destroy aquatic and bankside vegetation, reduce habitat heterogeneity and ultimately greatly reduce biodiversity (Hey, 1987 and Hey *et al*., 1990 both cited in Hey, 1994). With reference to the 2007 floods the Sheffield Local Biodiversity Action Partnership stated that "*Much riverside habitat was lost as a direct result of the floods or the subsequent repair and flood risk management work. Investment in flood defences has been prioritised over habitat enhancement"* (Sheffield Local Biodiversity Action Partnership, n.d.). It is unlikely that technocentric approaches to flood management can be completely replaced by holistic approaches given the extent to which the area is urbanised which greatly reduces the area of land which can feasibly be used for flood water attenuation (Correia *et al.*, 1998). However, it is important that the potential of holistic approaches is realised. In addition to the environmental impacts of structural flood defences their ineffectiveness will have increasingly severe social and economic consequences if society continues to rely on them given the predicted increased risk of flooding due to climate change and a greater proportion of the world's population living on floodplains (Kundzewicz, 2001).

Despite societal reliance on structural flood defences along the River Don, the newspaper articles evidenced that local people have lacked faith in these defences for a long time. Although structural defences were often constructed or developed following floods to reduce the perceived likelihood of future occurrences previous action taken to improve drainage and flood defence was not recognised to reduce recent flood damage in any of the analysed articles. Furthermore, on 15th November 1852 it was reported in The Times that "*The Flood-dike overflowed its banks, and the waters, rising above* *the canal-lock swept over it, and it was feared that the lock itself must give way, as it had done before under similar circumstances*". On 21st August 1857 it was even reported that a hole was knocked into a flood wall by mariners and inhabitants to minimise the potential damage caused by the build-up of water and as a result of the 2007 floods retaining walls collapsed (The Times: 26th June 2007). Recognition of the ineffectiveness of structural flood defences played an important role in generating interest in holistic approaches to flood management on a national scale so greater awareness of the history of failed structural flood defences on the River Don is likely to foster local support for holistic approaches (Johnson *et al*., 2005). The newspaper articles also suggest that the expense of constructing structural flood defences may have somewhat limited the extent to which they were used. For example, reporting on a debate regarding the funding of future flood defences an article published in 1932 stated that "*the setting up of Catchment Boards was a step in the right direction from the point of view of machinery, but money was required. The boards had the power to rate, but in the present position of agriculture it was impossible to expect to raise an adequate sum by rates from land which was flooded or was liable to flooding"* (The Times: 16th June 1932).

Although land development and mining have long been recognised to increase the risk of flooding (The Manchester Guardian: 13th January 1926; The Times: 27th May 1932; 16th June 1932), only three schemes taking a more holistic view towards flood management were considered in the analysed articles. Although more may have been considered in articles which were not analysed this low figure still strongly suggests that addressing these causes of flooding received less attention in the newspapers than structural flood defences did. A scheme was considered in 1933 which would allow controlled flooding onto low lying land before being rejected and replaced with the technocentric scheme approved by the Ouse Catchment Board in 1933 described within this section above. A holistic approach to flood defence become nationally popular in the 1980s and 1990s (Tunstall *et al*., 2004; Johnson *et al*., 2005). However, with the exception of the plans which were rejected in 1933 only two plans to use a holistic approach to manage flooding on the River Don were discussed in the analysed articles. Both of these were discussed in 2008 and as one project was in its planning stages, the newspapers only unambiguously evidence that a holistic approach to flood management has been taken with regards to the removal of a single bridge. Plans to create a "*wetland/wildlife corridor to serve local communities"* and reduce flood risk were proposed and a disused bridge was removed to reduce the risk of flooding (Sheffield Star, 2008 specific date unspecified; Sheffield Telegraph, 2008 specific date unspecified).

Although the very low number of analysed articles which mentioned holistic approaches to flood management may in part be due to the small proportion of articles published in recent decades which were analysed it is clear that the potential and actual use of holistic approaches to flood management on the River Don have received little media attention relative to structural defences. Further evidence of a holistic approach to flood management in the Don Catchment is provided by Firth (1997). He reported that controlled washlands had been constructed along the River Don between Sheffield and Doncaster since the 1950s and the EA (2010) reported that washlands currently provide over 3.5 million cubic metres of flood water storage across the catchment. Greater newspaper coverage may increase public understanding of the benefits of such approaches and thus support for them. The creation of washlands for flood defence has the potential to benefit wildlife through increased habitat heterogeneity and provide good opportunities for recreation (DEFRA 2004 cited in Wharton and Gilvear, 2007; Tunstall *et al*., 2004). According to Tockner and Stanford (2002) wetlands are the most species rich landscape units in most regions. They also play important roles in maintaining the ecological integrity of lotic and adjacent terrestrial ecosystems (Swift, 1984, Naiman and Decamps, 1990 and Lachavanne, 1993 all cited in Large and Petts, 1994).

It is likely that the detrimental effects of bridges on the flood risk in the Don catchment will increase in future due to efforts to restore vegetation on the river banks which may increase the amount of debris in the river channel (Schmocker and Hager, 2011) and elevated flood risk due to climate change (Kundzewicz, 2001). To minimise public opposition towards the restoration of river bank vegetation it will be essential for the relationship between bridges, vegetation and flood risk to be well managed. This may involve: designing and modifying bridges so they are less likely to trap vegetation (Schmocker and Hager, 2011); promoting the growth of shorter and more flexible plant species which are less likely to get trapped under bridges (Darby, 1999); where necessary restricting vegetation growth to one river bank (Purseglove, 1988); and potentially removing debris from river channels to prevent it from becoming trapped behind and under bridges although the effectiveness of the latter strategy may be reduced by the tendency of flood waters to wash additional debris into streams and the presence of woody debris in stream provides nutrients and increases habitat heterogeneity (Triska *et al*., 1982 and Swanson and Lienkaemper, 1978 both cited in Harmon *et al*., 1986; Young, 1991 Gippel, 1995 and Dudley *et al*., 1998 and Bradley *et al*., 2005 all cited in Lassetre and Knodolf, 2012). Greater communication of the pros and cons of these management strategies in the newspaper articles could facilitate more informed stakeholder engagement.

3.3.2.6 Other

The main reason why Theme A articles were determined to have mentioned the subtheme "*other*" was because they did not provide enough information to be classified under one of the subthemes discussed above within section 3.3.2. 13 of the 19 articles which were determined to have mentioned Theme A subtheme "*other"* in the 19th century and two of the six in the 20th century mentioned that industries were powered by the River Don without specifying whether they used hydropower or steam power (e.g. Sheffield Independent: 18th October 1828; The Guardian: 6th June 1819, 24th May 1902, 19th July 1929; York Herald: 17th March 1838). One article published in the 19th century recognised that industry benefited from the River Don generally without being any more specific (2nd July 1853).

In total five articles mentioned the use of water from the River Don to extinguish fires (Sheffield Evening Telegraph: 27th December 1887; The Guardian: 1st August 1966; The Times: 7th July 1865, 27th December 1887; Yorkshire Post and Leeds Intelligencer: 18th November 1916). Other benefits derived from the river in the Theme A subtheme "*other"* category were each only mentioned once across the whole time period. They included: mineral abstraction, medical isolation, washing livestock and domestic animals and fertilising agricultural land. In the 19th century one article described a miner drowning in a drift-way which terminated in a part of the River Don channel which was usually dry when it flooded, evidencing the river's role in mineral abstraction (Manchester Guardian: 25th August 1849). At a Thorne Rural Council meeting it was suggested that a boat on the River Don be used to provide medical isolation for a patient with scarlet fever but the medical officer said that this would be most unsuitable so the council decided against this potential use for the river (Sheffield Independent: 6th February 1902). Non-cultural benefits which individuals derived directly from the river without intervention from large public or private sector organisations were generally only mentioned in newspaper articles when something went wrong. For example, a farmer had taken his sheep to the River Don to wash them but ten had been run over by a train on the way (Sheffield Telegraph: 23rd May 1868). People accused of poaching claimed that they had been washing their pet dog in the adjacent river; whether or not this was a fabrication is unknown though it indicates that the River Don was used for this purpose at some point (Sheffield Telegraph: 23rd March 1903). Generally the environmental impacts of these uses of the river would have been fairly negligible given the impacts of the uses discussed in the previous sections.

Although only mentioned in one article the use of the River Don to fertilise land is of particular interest as it provides counter evidence albeit to a small extent to the main narrative that the flooding of agricultural land was viewed wholly negatively and thus necessitated the construction of environmentally harmful flood defences as discussed in sections 3.3.4.1 and 3.3.2.5 respectively and

Vermuyden's drainage of land in the lower Don Catchment in the 17th century in order to improve the land for agriculture (Thirsk, 1953; Firth, 1997; Munford, 2000). This local narrative reflects the emphasis which has been put on the drainage of land in north-west Europe for the benefit of agriculture from the 19th century onwards (Verhoeven and Settler, 2010). However, Rustan (1934 cited in Purseglove 1988) also recognised that rivers were used for fertilising agricultural land in Victorian Britain. The use of the River Don for this purpose was evidenced in an article which was published in 1870 which reported that a farmer had claimed compensation when a railway was built against his land and prevented his land from being fertilised by the flooding of the River Don as it had been previously (The Times: 24th November 1870). Taking this largely forgotten benefit derived from rivers into consideration may help reduce public opposition towards the creation of washlands and the cost of compensating farmers whose land is used for this purpose (Morris *et al.*, 2004; Verhoeven and Settler, 2010). Verhoeven and Settler (2010) attributed the decreased use of wetlands for low-intensity agriculture which benefited from soils fertilised by flood deposits to agricultural intensification and an increased use of chemical fertilisers. However, changing attitudes towards: managing farmland to promote managing agricultural land with greater emphasis on wildlife and reduced emphasis on maximising productivity; and managing previously drained areas to attenuate flood waters and thus minimise the social and economic damage caused by flooding (Section 3.3.2.6) may increase the extent to which farmers benefit from the nutrient load of flood waters in future (Dobbs and Pretty, 2004).

3.3.3 Theme B

Overall recreational activities other than angling was the most frequently mentioned Theme B subtheme as it was mentioned in more than 47% of all Theme B articles (Figure 3a). However, other recreational activities were mentioned in the same proportion of Theme B articles as angling in the 20th and 21st centuries (35% and 48% respectively). Overall angling and other recreational activities were also the most frequently mentioned Theme B subtheme from the 1960s onwards (33% and 38% respectively Figure 3b). They were the only two Theme B subthemes which were mentioned in the only Theme B article which was published in the 1960s. In the 1980s and 1990s wildlife sightings were the most frequently mentioned Theme B subtheme (42% and 46% of Theme B articles respectively) but in all other decades either angling or other recreational activities was the most frequently mentioned Theme B subtheme.

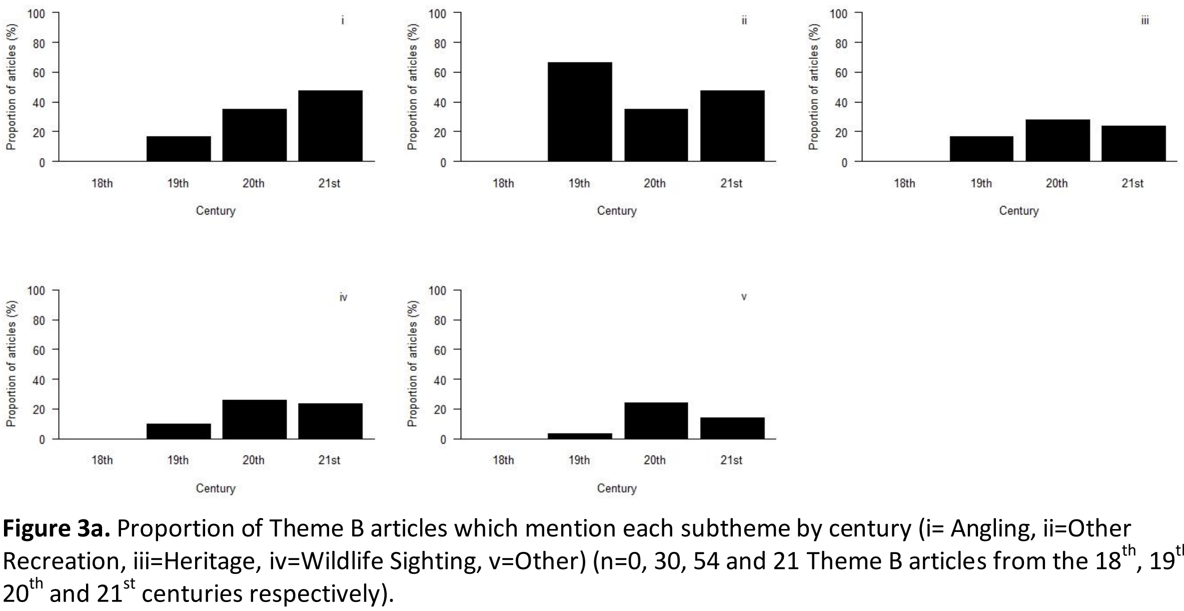


Figure 3a. Proportion of Theme B articles which mention each subtheme by century (i= Angling, ii=Other Recreation, iii=Heritage, iv=Wildlife Sighting, v=Other) (n=0, 30, 54 and 21 Theme B articles from the 18th, 19th, 20th and 21st centuries respectively).

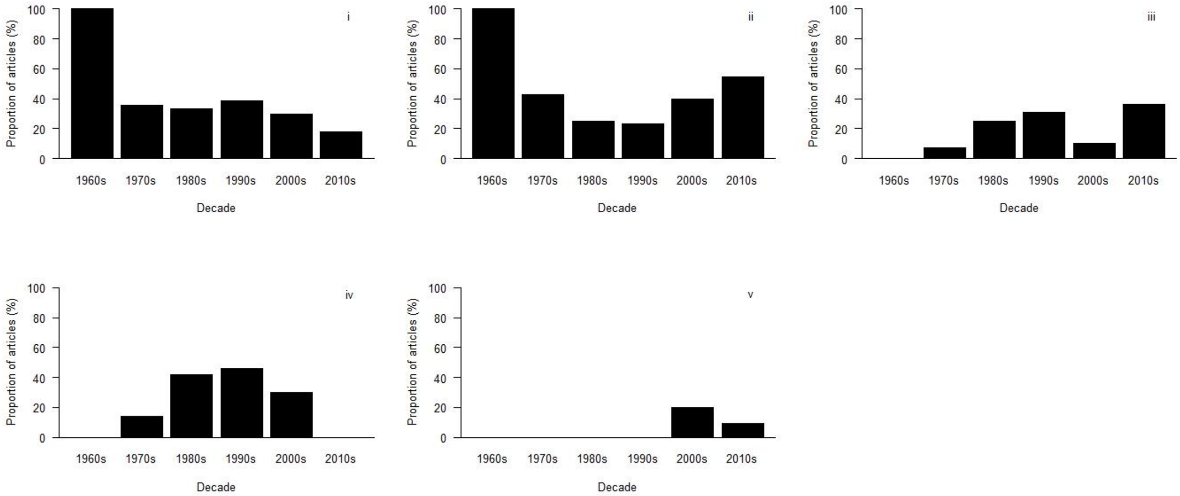


Figure 3b. Proportion of Theme B articles which mention each subtheme by decade from the 1960s onwards (i= Angling, ii=Other Recreation, iii=Heritage, iv=Wildlife Sighting, v=Other) (n=1, 14, 12, 13, 10, 11 Theme B articles from the 1960s, 1970s, 1980s, 1990s, 2000s and 2010s respectively).

3.3.3.1 Angling

From the 19th century to the 21st the quality of the River Don's recreational fisheries was reflected in the newspaper articles. Broadly they were good in the 19th century but had deteriorated greatly by the 1970s when they began to recover. This reflects the history of the fish communities as they were described in Chapter 2 in that many species including salmon (*Salmo salar*) and trout were present in the 19th century but very few species were recorded in the 20th century before the 1970s but many species were recorded in the 1970s indicating substantial recovery and more species were recorded in the 1990s indicating further recovery. In the 19th century angling was only mentioned in five articles, two of which marketed an estate for sale which afforded good angling opportunities particularly for trout (Sheffield Independent: 20th May 1899; The Guardian: 6th May 1899) and one of which provided a sports commentary on an angling match (The Guardian: 25th October 1858). Angling was not reported at all during the first half of the 20th century and articles which were published in the 1970s made it clear that river's recreational fisheries had declined greatly since the late 19th century but were now beginning to recover. Four of the five newspaper articles which mentioned angling in the 1970s discussed how recreational fisheries were affected by pollution. Two articles stated that fish were returning but one of these said that numbers were too low to support a fishery (Unspecified publication available from Sheffield Star Archives: 7th August 1979), whilst the other said that a Sheffield section of the River Don was "*on the threshold of being a fishery, supporting coarse fish and some trout*" (Sheffield Star: 30th June 1976). Despite some improvements in the recreational fisheries from the 1970s onwards this quote made it clear that in the 1980s they were still greatly depleted: "*Nowadays anglers tend to avoid the Don, one of Britain's most polluted rivers.*" (Unspecified publication available from Sheffield Star Archives: 23rd August 1985). However, by the 2000s angling opportunities had improved enough to enable newspapers to publish commentaries of matches which had taken place there (Doncaster Free Press: 2009; Sheffield Star: 13th November 2001). By 2011 recreational fisheries had improved to the extent that a commentary of a fishing match was able to report "*good weights from a consistent venue*" (Scunthorpe Telegraph: 19th July 2011). Only one article which was published in 2013 reported a narrowly avoided human death and no articles reported actual human deaths which occurred whilst angling (Doncaster Free Press, 4th July 2013).

The direct contributions of anglers towards the recovery of the fish populations are discussed in section 3.3.5.1.1. In addition to describing the demise and recovery of the fisheries the newspaper articles evidenced that in the 19th century: people were fined for having been fishing illegally with drag nets (Sheffield Independent: 7th June 1873); and anglers witnessed a boy drowning whilst bathing (The Guardian: 6th May 1899). Deaths and crime are discussed further in sections 3.3.4.5 and 3.3.4.6 respectively. In the 20th century it was reported that anglers had seen many charismatic species such as otter (*Lutra lutra*), seals (unspecified species) and salmon. These sightings will be discussed further in section 3.3.3.4. Despite anglers' contributions towards the conservation of the River Don it is important to recognise that, although not discussed in the analysed newspaper articles, recreational angling does have the potential to cause environmental harm. For example, injuries and behavioural changes may increase fish mortality and decrease their fecundity (reviewed in Lewin *et al.*, 2006). Angling can also contribute to vegetation clearance and bank erosion, whilst the mere presence of people disturbs wildlife. The lack of discussion of the environmental impacts of angling in the newspapers reflects Lewin *et al*'s (2006) assertion that they are underestimated in public discourse. Whilst the potential environmental impacts of using the River Don for angling may have been mentioned in newspaper articles which were not included in the sample, it is clear that improved angling opportunities and the effects of other drivers of environmental degration, particularly pollution received much more attention in the newspapers overall.

3.3.3.2 Other recreation

The newspaper articles demonstrated that since the 19th century people have participated in a range of recreational activities other than recreational angling in, on or by the River Don. Recreation was first reported in an article published in 1839 (Sheffield Independent: 29th June 1839). Although the proportion of articles which mention recreational activities other than angling fell considerably from the 19th to the 20th century this largely reflects increased interest in wildlife sightings and other cultural benefits derived from the river rather than decreased interest in these recreational activities. Eaton (1999) reported that the extent to which water bodies in the UK were used for recreation had increased substantially through the 20th century and said that it was generally expected to increase further in the 21st century. Drivers of this trend include increased leisure time, disposable income and personal mobility (Seeley, 1973; Eaton 1999). The newspaper articles indicate that recreation is likely to have increased on the River Don in recent decades to an even greater extent than it has on other rivers due to the extent to which it was previously limited by pollution. This increased recreational use is likely to foster support for the river's environmental management (Haslam, 1997).

Although the overall extent to which the River Don was used for recreation increased through time the frequency with which particular recreational activities were mentioned in newspaper articles showed different trends through time. Walking was the only activity which was mentioned with increasing frequency from the 19th century to the 21st (i.e. 0, then 4 then 6 articles). Conversely, swimming or bathing was mentioned with decreasing frequency through time (i.e. 10 then 4 then 0 articles). Given that swimming in the once heavily polluted River Thames declined from the 1950s as it was perceived to be too dangerous but it is now on the increase again due to reduced pollution the desire to swim in the River Don may increase in future and foster support for minimising pollution (Davies 2015). Realisation that the River Don used to be used for swimming may foster public support for opportunities for this activity to be restored due to a sense of nostalgia (Petts, 2006). The frequency with which children were reported to have been playing by the river remained fairly constant but low (i.e. 2 or 3 articles per century). Children playing by the River Don could greatly increase public support for conservation which is in large part fostered through positive early experiences gained through participation in unstructured play in outdoor natural or semi-natural environments (Fishman, 2001 cited in White, 2004; Malone and Tranter, 2003). The number of articles which mention children playing probably under-represents the extent to which the River Don was used for this purpose as it was generally only reported when children died or nearly died as a consequence as will be discussed in the section 3.3.4.5. The number of articles which mentioned boating increased from two to eight from the 19th century to the 20th century but then fell back to two in the 21st century. Picnicking was only reported in the 19th century in an article which was speaking positively of the aesthetics and heritage of Conisbrough Castle and the surrounding land (Yorkshire Post and Leeds Intelligencer: 9th October 1869). Cycling was only reported in one newspaper article published in an unspecified publication available from Sheffield Star Archives on 5th July 1995. The only recreational activities which were mentioned more than twice in any decade from the 1960s onwards were walking which was mentioned in five articles in the 2010s (Sheffield Star: 29th November 2013, 10th January 2015; Sheffield Telegraph: 27th February 2014; Unspecified publication available from Sheffield Star Archives: 23rd September 2010, 20th September 2012) and boating which was mentioned in three articles in the 1970s (Sheffield Star: 17th March 1975; The Guardian: 21st December 1971; The Guardian: 3rd May 1976).

Recreational activities were not always reported positively. However, the proportion of articles reporting recreational activities other than angling for negative reasons, particularly deaths of participants decreased through time whilst the proportion mentioning them for positive reasons increased. Newspaper coverage of deaths incurred and narrowly avoided when participating in recreational activities will be described in section 3.3.4.5. The only article which connected crime with recreation reported that children had found the body of a baby in a bag whilst playing on the banks of the River Don (Sheffield Telegraph: 27th May 1890). The River Don was only portrayed as a health threat to recreational users in two articles published in the 1970s and 1980s. The first article warned that temporarily severe pollution due to sewage works strikes may pose a health threat to children who are playing near it if they fall in (Sheffield Telegraph: 9th October 1970). The second article stated that due to severe pollution the River Don was not safe for swimming (Unspecified publication available from Sheffield Star Archives: 12th March 1987). None of the articles reported that anyone had actually become ill as a result of exposure to pollution when visiting the River Don though this may well have been reported in newspaper articles which were not analysed and in Chapter Four an interview participant reported that her mother had become ill when participating in a raft race.

From the 1960s to the 1980s there was considerable discussion of proposed and actual improvements to benefit those who use the River Don for recreational purposes. There were plans to reduce pollution (The Guardian: 8th October 1965; Unspecified publication available from Sheffield Star Archives: 9th September 1987) and create a park and marina (The Guardian: 21st December 1971) and the Five Weirs Walk (Unspecified publication available from Sheffield Star Archives: 12th March 1987). Optimism about the proposed changes is expressed well through this quote which was published in the Sheffield Star on 19th March 1975: "*polluted river is to be turned into a people's playground that could be the pride of the city*". Despite this, the only plan which was reported to have been implemented during this time period was the creation of a water bus service (The Guardian: 3rd May 1976). The opening of the Five Weirs Walk in 2007 (BBC News, 2007) may help to explain why the proportion of Theme B articles which mentioned recreation other than angling nearly doubled from the 1990s to the 2000s (23% and 40% respectively).

Organised events may explain why this proportion further increased to 55% in the 2010s. Five of the six articles which mentioned recreation other than angling in the 2010s promoted events including walks (Sheffield Star: 10th January 2015; 6th June 2014; 29th November 2013) and events at Kelham Island Museum which included kayaking on the River Don (Unspecified article available from Sheffield Star Archives: 20th September 2012, 23rd September 2010). Kelham Island Museum did not arrange events involving the River Don prior to 2005 as they did not have the funding to do so (personal communications with Richard Steward, Business Services Manager for Sheffield Industrial Museums Trust, 2016). Organised walks have only been advertised in the press recently as previously poor access and the aesthetic impacts of littering and pollution deterred walking groups from organising walks in the area (personal communication with Terry Howard, 2016). Greater involvement of the River Don in organised events is likely to provide greater opportunities for environmental education, the content of which may include environmental history presented in a way which is likely to foster support for conservation. The potential use of information on the environmental history of the River Don in fostering support for its conservation is discussed in detail in the chapter four.

There was no discussion of the potentially adverse environmental impacts of recreation on the River Don within the newspaper articles although such impacts on rivers are widely recognised within the academic literature. Such impacts include: direct disturbances and erosion of river banks (Haslam, 1997) whilst the environmental impacts of recreational boating are similar to those of navigation discussed in section 3.3.2.4. Furthermore, the potential creation of a marina and a park which was discussed in the 1970s has the potential to destroy habitats and concentrate recreationalists and their environmental impacts. Gobster and Westphal (2004) stressed the need to strike an appropriate balance between managing urban river corridors for recreation and wildlife. There has also been relatively little discussion of the adverse environmental impacts of recreational activities in other studies which have analysed historical newspaper articles. For example, Jensen (2000) reported discussions of the impacts of industrial effluents and domestic sewage on swimming in the Danish press but did not report any recognition of potentially adverse impacts of aquatic recreational activities on the natural environment. Furthermore, discussion of the effects of recreational activities on terrestrial ecosystems has largely been limited to the direct persecution of animals (Vuorisalo *et al*., 2001). This probably reflects the relatively small effects of recreation relative to industrial and public authority actions which have caused rivers which flow through industrial areas to become severely polluted and environmentally degraded (Brookes *et al*., 1976; Firth, 1997; Jensen, 2000; Lahtinen and Vuorisalo, 2011). However, as much action has been taken to reduce these as discussed in section 3.3.5 the relative importance of the environmental impacts of the use of the River Don for recreation may increase in future.

3.3.3.3 Heritage

Although the newspaper articles indicated that the River Don and its associated infrastructure have been valued from a heritage perspective since the 1820s and the river's heritage may well have been valued long before that, the ways in which its heritage has been valued has changed greatly through time. Only three articles mentioned heritage in the 19th century. One described Conisbrough Castle and the surrounding land as a nice place to visit (Yorkshire Post and Leeds Intelligencer: 19th October 1869). The other two mentioned that corn mills were long established in relation to a new market opening in Penistone, presumably to communicate their prestige (Sheffield Independent: 18th October 1828; The Guardian: 18th October 1828). Recognition of long established industries continued into the first half of the 20th century with the celebration of the 150th anniversary of a business within the steel manufacturing industry (The Guardian: 6th April 1942; The Times: 29th April 1942). There was also general interest in evidence of much earlier human activities including: Vermuyden's work on straightening the lower section of the River Don (Hull Daily Mail: 29th May 1925); and a Roman Camp at Templeborough (Sheffield Telegraph: 15th June 1911) and Sheffield Castle (Manchester Guardian: 26th October 1927) the latter two of which had both benefited from defence afforded by the river. These articles may reflect increased interest in heritage at a national scale in Victorian Britain although the first was published ten years after her reign which ended in

1901. It is possible that similar earlier articles were not included in the sample given the large number of articles which were published in this time period (Rappaport, 2003; Dellheim, 2004).

The earliest analysed newspaper articles which mentioned industrial remnants were published in the late 1980s and industrial heritage was only mentioned in seven articles in total. It is possible that industrial heritage was mentioned in earlier newspaper articles but probable that this was rare as Sheffield's manufacturing industries along the River Don were thriving until the late 1970s when Sheffield's deindustrialisation began (Watts, 2004). One described a visit to the River Don in which the journalist appreciated its industrial heritage (The Guardian: 13th April 1989). Another described proposals to create the Five Weirs Walk which would showcase the River Don's industrial heritage (Unspecified publication available from Sheffield Star Archives: 9th September 1987).   Although the name Five Weirs Walk indicates the presence of the weirs none of the analysed articles explicitly recognised their heritage value. This was surprising as weirs are valued across the country from a heritage perspective (Purseglove, 1988). There is a relatively high chance that the heritage value of the weirs was mentioned in other newspaper articles which were published since the 1970s as the proportion of articles pubished in this period which were analysed was quite small. Fig trees (*Ficus carica*) which were attributed to domestic sewage pollution and heat pollution were mentioned in three articles, all of which were published in the 1990s (The Guardian: 27th April 1990, 30th August, 1998; The Times: 28th March 1992). The article which was published in the Times stated that the fig trees were "*as much part of Sheffield's industrial history as steam hammers*". In the last three decades both industrial remnants such as steel works (Sheffield Star: 29th November 2013; The Times: 10th May 2003); and pre-industrial remnants such as bridges (The Guardian: 20th October 1998) and the river's role as a border between the Brigantes and Coritani tribes (Sheffield Star: 29th November 2013) have been appreciated in newspaper articles.

The desire to conserve this heritage has the potential to foster both support for and opposition towards efforts to conserve and restore nature. The fact that the River Don has been valued for heritage purposes for nearly two centuries suggests that it will continue to be well into the future. It is therefore important to ensure that the heritage is maintained for future generations. The potential adverse environmental impacts of maintaining weirs even when they are not in operation are similar to their impacts when they were in operation which are discussed in section 3.3.2.1. However, Purseglove (1988) recognised that the fast moving water which flows over weirs provides habitat for willow moss (*Fontinalis antipyretica*) and liverworts (species unspecified) and oxygenates the water which is particularly beneficial for bullheads (*Cottus gobio*). The structures also provide habitat for grey wagtail (*Motacilla cinerea*). Furthermore, if heritage attracts more people to the river it could potentially play a valuable role in generating support for conservation (Haslam, 1997). Before the 2010s no articles mentioned events to educate people about the river's heritage but in the 2010s both a walk to see the River Don's industrial heritage (Sheffield Star: 29th November 2013) and a talk on the lost village of Levitt Hagg (Unspecified publication available from Sheffield Star Archives: 27th October 2011) were advertised. Furthermore, a sculpture was inspired in part by the role that the River Don had played historically as a border between the Brigantes and Coritani tribes (Unspecified publication available from Sheffield Star Archives: 29th May 2012). It may be possible to work in partnership with historians and artists to inform local people who are interested in the river's heritage about its environmental legacy and thus foster support for its restoration.

3.3.3.4 Wildlife sightings

Articles were deemed to have mentioned wildlife sightings when they stated that a species had been observed and appreciated because it was charismatic or unusually observed at the site or of interest from an ecological or heritage perspective rather than because of the utilitarian benefits which it affords. The only analysed article which met these criteria which was published before the 1970s concerned a pike (*Esox lucius*) which ate a snake (unspecified species) which was swimming in the

River Don then died (Sheffield Independent: 18th May 1839). This was to demonstrate that pike were voracious predators and contextualise a recent occurrence of a calf which was lacerated by one. It was the only example of a wildlife sighting in which the observed species was perceived negatively although it is likely that other wildlife sightings were described negatively in newspaper articles which were not included in the sample. This is reflective of Kellert's (1985) finding that the frequency with which negativistic attitudes towards wildlife were expressed in American newspaper articles had fallen through the 20th century. This change in attitudes is likely to reduce opposition towards restoration of the River Don. However, caution should be taken when extrapolating this trend into the future as there is the potential for more negativistic attitudes in future particularly as populations of piscivorous birds and mammals recover and have a greater effect on recreational fisheries (Cowx *et al*., 2010; Serfass *et al.,* 2014). The media has the potential to either exacerbate or mitigate against this so it is important that environmental managers engage with them as piscivore populations recover (Serfass *et al*., 2014).

Sightings of charismatic species from the 1970s to the 1990s generated much public excitement and were generally seen as evidence that pollution had been reduced and fish populations which provided food for salmon, otters and marine mammals were recovering as a result. The first wildlife sighting viewed positively was that of a salmon in 1978 (Sheffield Star: 1st March 1978). Although it is relatively likely that a wildlife sighting which was viewed positively by the public was reported in the newspaper articles which were not analysed earlier than this it is unlikely that many incidents were. Whilst Franklin (1999) recognised that interest in urban wildlife increased from the 1960s, charismatic species may have been largely absent from the River Don at this time due to the severity of its pollution (Firth, 1997). In the 1980s several sightings of fish and marine mammals were reported including: minnow (*Phoxinus phoxinus*), pike and roach (*Rutilus rutilus*), seals (unspecified species) and a porpoise (unspecified species but most likely *Phocoena phocoena* as it is the only species of porpoise native to Britain (The Mammal Society, n.d.)) (The Daily Mirror: 8th June 1983; The Guardian: 27th April 1989; The Times: 8th June 1983; Unspecified publication available from Sheffield Star Archives: 5th September 1980, 1st June 1983). Sightings of otters (*Lutra lutra*), seals and a salmon were also reported in the 1990s (Unspecified publication available from Sheffield Star Archives: 5th July 1995, 2nd September 1998, 4th February 1999, 1st November 1999). From the 1990s to the 2000s the proportion of Theme B articles which mentioned wildlife sightings fell from 46% to 30% and no wildlife sightings were reported in the 2010s (Figure 3biv). This fall may simply be due to relatively small samples though it is also interesting to note that wildlife sightings were reported by journalists rather than members of the public in the 2000s, further suggesting reduced public interest in wildlife sightings. One journalist was pleased to see a kingfisher (*Alcedo atthis*) on a visit to the River Don in 2003 (The Times: 10th May 2003). Another journalist described the birds which he saw at wetlands adjacent to the River Don. These included: blackbirds (*Turdus merula*), magpies (*Pica pica*), a carion crow (*Corvus corone*) and small birds of which the species were unspecified. He also saw bats which he thought were most likely to be noctule bats (*Nyctalus noctula*) (Guardian: 22nd November 2003). He said "*We shall pass this information to the local bat workers. The time of day and year will be of interest and in a tiny way, will help our understanding of what makes bats tick*" thus recognising the value of wildlife sightings for scientific research. The lack of attention given to the effects of environmental degradation on flagship species more recently may limit the extent to which they currently foster support for the river's restoration (Yamanoto, 2011).

However, three articles which were published in the late-1970s and early-1980s expressed concern that individual charismatic species observed had suffered severely as a result of the pollution. The earliest reported "*one bold fish* [salmon] *penetrated the River Don only to die of oxygen starvation at Doncaster*" (The Guardian: 5th November 1979). The remaining two were concerned that a porpoise observed in 1983 had not been feeding as the river was so polluted so it was rescued and transported back to sea (The Daily Mirror: 8th June 1983; The Times: 8th June 1983). Recognising that flagship species are adversely affected by environmental degradation may increase public support for the environmental degradation to be reversed to the benefit of both the flagship species and many other species (Dietz *et al*., 1994; Ginsberg, 2001 and Zhi *et al*., 2000 all cited in Smith and Sutton, 2008). However, caution must be taken when using flagship species as a conservation tool, particularly when assuming that enhancing habitat for them will meet the needs of all other species within an ecosystem, as such conservation actions may fail to yield intended benefits with regards to restoring ecological sustainability (Simberloff, 1998).

With the exception of an article which reported that a haystack had been affected by rats from the river which is discussed in section 3.3.4.4 only one article recorded the presence of a non-indigenous species. Whilst it is relatively likely that non-indigenous species were mentioned in articles which were not analysed, the small number of analysed articles in which they were mentioned suggests that they were mentioned in few articles overall. In 2000 an urban ecologist wrote a letter to the Times in response to an article on the negative impacts of Japanese Knotweed (*Fallopia japonica*) touting its benefits and largely dismissing the environmental harm which it causes (The Times: 1st July 2000). He used his sighting of two different species of caterpillar (unspecified species) eating its leaves on the banks of the River Don as evidence that it supported biodiversity. He also used examples from elsewhere in the UK to reason that because Japanese knotweed had late leaf expansion native species such as bluebells (*Hyacinthoides non-scripta*) were able to grow underneath it and that it provided good cover for otters. Andrews (1989) also stated that Japanese Knotweed affords protection for otters. However, Braatne *et al.* (2007) recognised that Japanese Knotweed has several features which enable it to outcompete native plants for sunlight, nutrients and water including emerging in the spring and rapid growth which can enable it to form monospecific stands along riparian corridors. DCRT (n.d.c) also recognises it as an invasive species and a threat to the river's ecology.

3.3.3.5 Other

In the mid-19th century two articles used the aesthetic appeal of the River Don to market an estate (Sheffield Independent: 2nd July 1853) and a plot of land with six houses (The Times: 24th May 1851). These articles indicated that at least parts of the River Don were still aesthetically pleasing at this time despite the degradation described in section 3.3.5. This perception of the River Don is supported by Harrison (1864). The image of the River Don flowing through large estates is in keeping with Lowenthal and Prince's (1965) description of the landscape traditionally favoured by the English upper class as expansive meadow with streams flowing through it.

The aesthetic appeal of the River Don was also used to market apartments in 2006 (The Times: 5th May 2006). This reflects the numerous studies which have found that a view of an attractive river section can increase residential property prices (Kulshreshtha and Gillies, 1993; Mahan, 1997; Bourassa *et al*., 2004). Local residents' appreciation of the aesthetic value of the River Don could potentially foster support for its maintenance and further enhancement (Haslam, 1997).

Comedy and artwork were also inspired by the River Don. An article which was published at the start of the 20th century stated that a comedian said of the River Don "*You can fairly hear it talk*" but unfortunately did not explain why (Sheffield Evening Telegraph: 26th August 1902). The artwork was inspired by the River Don's role as a boundary between different tribes as described in the section 3.3.3.3 (Unspecified publication available from Sheffield Star Archives: 29th May 2012). This is an example of public art which has been defined as site-specific art in the public domain (Hall and Smith, 2005 cited in McCarthy, 2006). There has been greater investment in public art nationally in recent decades and many works have been commissioned as part of wider regeneration projects (Evans, 2005 cited in McCarthy, 2006; McCarthy, 2006). Public art work is believed to foster place identity, civic identity and inspire positive social change (Hall and Smith, 2005 cited in McCarthy, 2006). Heritage is one aspect of local identity which is often depicted in public art. The artwork reported in 2012 was in part inspired by the role which the river played as a boundary between the Brigantes and Coritani tribes in ancient history. Other public art work close to the River Don depicts its role as an important commercial salmon fishery and the steel industry although it does not explicitly state that the river benefited it (Ball 2006a; Ball 2006b). Unfortunately the lack of reporting of such artwork within the local media is likely to reduce the number of people who are aware of it and thus the benefits which it brings to the river and the local community. Greater awareness could increase the number of people who visit the artwork and thus experience and learn more about the River Don which may in turn foster support for its environmental management (Haslam, 1997).

The use of the River Don for scientific research has also been mentioned in two newspaper articles. As stated in section 3.3.3.4 a sighting of bats in 2003 was used to inform scientific research (Guardian: 22nd November 2003). The geology of the River Don was also the subject for a scientific paper published in the early 20th century (The Times: 23rd August 1904). Such information could be communicated to the public using the information boards to add interest to their visits and increase the likelihood of them visiting more frequently thus fostering support for its conservation (Haslam, 1997).

3.3.4 Theme C

Overall the most frequently mentioned Theme C subtheme was the role which the river and its flood waters played as a physical barrier (44% of all Theme C articles; Figure 4a). The second and third most frequently mentioned Theme C subtheme were actual and potential human deaths and flooding (39% and 31% of all Theme C articles respectively). Both of the articles which were published in the 18th century mentioned Theme C. The role of the River as a physical barrier was portrayed in both articles. Flooding, damage to property or infrastructure and actual or potential human death were each reported in one of these two articles. The role of the river as a physical barrier was the most frequently mentioned Theme C subtheme in the 19th and 20th centuries (50% and 40% of Theme C articles respectively). Flooding was the most frequently mentioned Theme C subtheme in the 21st century (60% of Theme C articles).

The three Theme C subthemes which were mentioned the most overall were also mentioned in the greatest number of articles which were published from the 1960s onwards. Flooding was mentioned in 40% of Theme C articles published from the 1960s onwards; the role of the river and its floodwaters as a physical barrier was portrayed in 38% of Theme C articles; and actual and potential human deaths were reported in 21% (Figure 4b). The only decades from the 1960s onwards in which eight or more Theme C articles were published were the 1960s, 2000s and 2010s 4, 17 and 8 respectively). The role of the River Don and its floodwaters as a physical barrier was the Theme C subtheme which was mentioned the most frequently in the 1960s but flooding was mentioned the most frequently in the 2000s and 2010s (57%, 65% and 50% of Theme C articles).

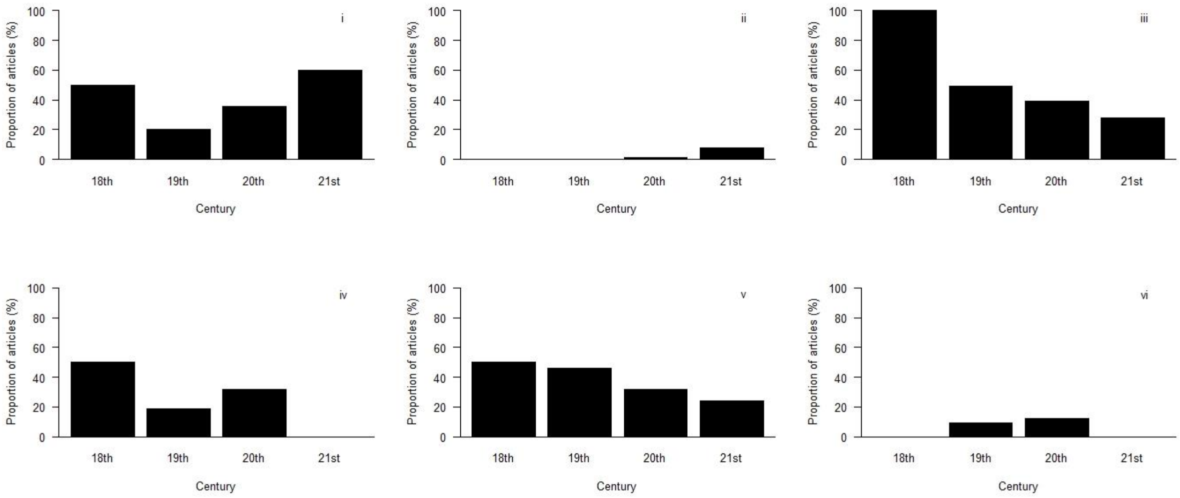


Figure 4a. Proportion of Theme C articles which mention each subtheme by century (i=Flooding, ii=Drought, iii=Physical barrier, iv=Damage to Property or Infrastructure, v=Death, vi=Crime) (n=2, 117, 81, 25 Theme C articles from the 18th, 19th, 20th and 21st centuries respectively).

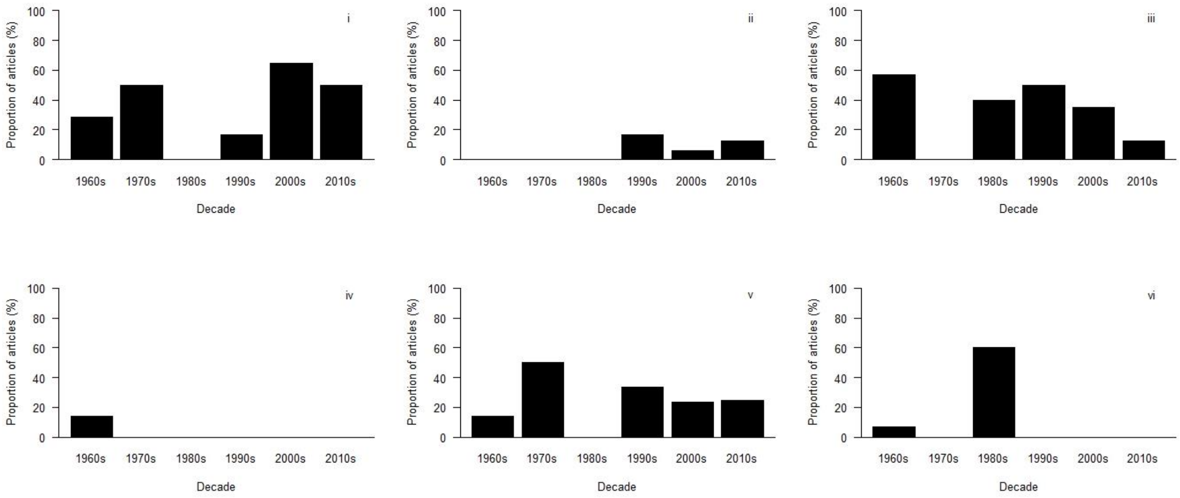


Figure 4b. Proportion of Theme C articles which mention each subtheme by century (i=Flooding, ii=Drought, iii=Physical barrier, iv=Damage to Property or Infrastructure, v=Death, vi=Crime) (n=14, 2, 5, 6, 17 and 8 Theme C articles from the 1960s, 1970s, 1980s, 1990s, 2000s and 2010s respectively).

3.3.4.1 Floods

As flood management is discussed in section 3.3.2.5 and deaths are discussed in section 3.3.4.5 this section will focus on the effects of flooding on property and infrastructure. The flooding of the River Don was a relatively frequent event through the 19th and 20th century, with actual floods being reported in six decades each century and it is relatively likely that less severe floods were reported in the newspaper articles which were not analysed in additional decades. Damage was defined as damage to property or infrastructure other than flood defences or disruption to services or transport. The only article which reported a flood which had occurred in the 18th century reported that it had destroyed a bridge (The Times: 25th November 1791). Of the 23 articles which mentioned flooding in the 19th century, 18 reported recent floods, 14 of which reported that they had done some damage. Disruption to transport including the destruction of bridges was reported in nine articles; whilst damage to agricultural premises were only reported in six articles; damage to domestic property was only reported in five; and surprisingly given the importance of the River Don to industry damage to manufacturers including artisans was only reported in four and damage to retail establishments one. The worst damage was reported in 1886 and resulted in four thousand people being temporarily out of work, workmen being unable to get home to their families overnight and Rotherham being in "*chaos*" (Sheffield Independent: 15th May 1886).

In the 20th century floods were mentioned in 26 articles, 18 of which reported recent floods and 15 of which reported damage which they had caused. Damage to infrastructure was reported in eight articles, damage to domestic property six, damage to industrial premises including manufacturing premises and a colliery three and agricultural premises three. Eight articles published from 1916 through to 1990 inclusively reported disruption to road transport and one reported disruption to rail transport. Particularly severe floods in 1931 and 1993 resulted in people being marooned in their houses (The Guardian: 5th September 1931) and several hamlets and villages being only accessible by boat (The Times: 6th March 1933) respectively but no bridges were reported to have been destroyed. Damage to a wide range of other infrastructure was also reported including: disruption of the electricity supply and consequently to the tramcars (The Mirror: 10th August 1922); damage of the sewage mains (The Guardian: 14th August 1922); and damage of a school heating system (Yorkshire Post and Leeds Intelligencer: 2nd March 1933). Damage to domestic properties caused by floods in 1932 resulted in approximately three thousand people being made temporarily homeless (The Times: 31st May 1932); whilst damage to industrial premises in 1931 resulted in approximately 2,000 people being temporarily without work (The Guardian: 15th September 1931).

In the 21st century 15 articles mentioned floods, five of which reported actual recent flood and four of which reported that these had caused damage. All five of the articles which reported actual floods were published in 2007 or 2008. These floods were so severe that people had to be airlifted from their offices by the RAF and the electricity supply for 35,000 people was cut off (The Times: 26th June 2007). The large out of town shopping centre, Meadowhall, was also flooded (Times: 6th July 2007). Following the floods those who were made homeless had to be housed in caravans for two years (Sheffield Star: 2008, specific date unspecified) and a collapsed bridge had to be repaired at a cost of £4 million (Telegraph: 2008, specific date unspecified).

From these articles it could therefore be surmised that the worst damage to property or infrastructure was caused by floods which occurred in 1886, 1931-1932 and 2007. However, it is likely that the 1864 floods caused more damage to property and infrastructure than is recognised in the two newspaper articles which mentioned floods in 1864 as they were more concerned about deaths and preventing a future dam burst like the one which had caused the floods than they were about reporting material damage (The Guardian: 20th March 1864, 28th March 1864). Damage to property or infrastructure may have been reported in articles which were published soon after the event but not analysed. It was clear from the newspapers that small industrial premises such as artisan workshops and shops had been damaged as grants of up to £5 were made available to replace what had been lost (The Guardian: 28th March 1864). Indirect evidence of the extent of the damage was that more than £19,000 (approximately £820,040 in today's money) was raised to manage the aftermath (The Guardian: 20th March 1864). The actual extent of the damage according to the Chief Constable's records cited in Sheffield City Council (2009) included: the destruction of 100 buildings and 15 bridges and the flooding of 4,000 houses. The history of the damage caused by the most severe floods of the River Don from the 19th century onwards does not therefore reflect Mitchell's (2003) finding that the economic consequences of flooding increased in Europe through the 20th century. However, caution should still be taken as the amount of damage caused by flooding is likely to increase in the future due to climate change and people increasingly living on floodplains (Kundzewicz, 2001).

3.3.4.2 Drought

The fact that drought was only reported in four analysed newspaper articles suggests that it has never caused great concern to local people. Though it may have been reported in articles which were not analysed, the small number of analysed articles in which it was reported relative to flooding suggests that it has not received much attention in the newspapers over the last two centuries. It is also possible that only a small proportion of the articles which mentioned drought within the Don Catchment mentioned the River Don. However, three of the four articles which mentioned drought were published from the 1980s onwards suggesting that people are now more concerned about water shortages than they were in the past. Furthermore, in 2012 the Don Catchment experienced the second driest 12 months. The earliest article reported on a court case in which an iron works was accused of using too much water (Sheffield Independent: 19th March 1880). It stated "*Every riparian proprietor had to submit to seasons of drought; he could only have such water as God Almighty in his mercy saw fit to send him*". This suggests that although people believed that the Christian God had control over droughts which is indicative of the fearful phase of natural hazard management they responded by using water more stringently rather than through prayer or other religious acts (White 1973 cited in Correia *et al.*, 1998). This relationship between drought and water use is in line with the depletion crisis model (Berkes and Turner, 2006). An alternative suggestion to mitigate against the effects of flooding was made in a letter by a Guardian reader recommending that Yorkshire Water dumped snow into the River Don as had been done previously (The Guardian: 6th February 1996). They argued that this would remove snow from the streets, alleviate the drought and create work for the unemployed. However, this strategy could potentially increase the concentration of pollutants within the river as the concentration of air pollutants in snow can be high (Elgmork *et al*., 1973).

The third was concerned about the effects of drought on wetlands (The Guardian: 22nd November 2003). It stated: "*This huge wetland, tight by the River Don, is suffering from the lack of rainfall affecting the rest of the countryside; large exposure of bare mud and silt are bright green with vegetation, so long have the water levels been low"*. Although the newspaper article did not explain in what way the wetland was adversely affected by the drought previous studies have reported that drought can severely adversely affect wetlands in terms of reduced biodiversity and abundances of plants, fish and birds and increased colonisation of non-indigenous terrestrial species (Jenkins and Boulton, 2007 cited in Middleton and Kleinebecker, 2012; Middleton and Kleinebecker, 2012; Catford *et al.*, 2011 and Lunt *et al*., 2012 both cited in Catford *et al*. 2014). The most recent article simply reported drought in the Don Catchment which had experienced the second driest 12 months since 1910 (27th March 2012). Although reducing the volume of water in a river can adversely affect its ecological community composition by altering its water velocity, depth, wetted channel width, water temperatures and sediment structure, effects of droughts on riparian communities were not considered in the newspaper articles (Dewson *et al*., 2007).

3.3.4.3 Physical barrier

The role of the River Don and its flood waters as a physical barrier was the Theme C subtheme which was conveyed in the greatest proportion of Theme C articles (44%). The River Don was most frequently portrayed as a physical barrier with reference to bridges though it was also crossed by boat, horseback and walked across when it was frozen over. All but 12 of the 93 articles which portrayed the River Don and its flood waters as a physical barrier mentioned bridges. The river was also crossed on horseback (The Times: 16th July 1798) and by boat (The Guardian: 1st August 1829; The Times: 31t July 1829; The Times 25th August 1856; 26th November 1964). This included a regular ferry service which crossed the River Don at Mexborough, a town between Rotherham and Doncaster (The Times: 26th November 1964) but the other articles all reported attempted crossings by individuals and small groups which resulted in death. The environmental impact of the ferry was not considered in this article.

Eleven articles which were published in the 19th century and six articles which were published in the 20th century discussed plans to construct bridges or viaducts. These included tendering for funding. Six articles published in the 19th century and four in the 20th century reported construction of bridges or viaducts either under way or recently completed. The earliest of these articles was published in 1845 and reported the death of a workman during the construction of a viaduct (York Herald: 8th February 1845). The latest was published in 1967 and conveyed the scale of the motorway viaduct project (The Guardian: 11th March 1967). It stated "*Work is expected to be completed at the end of October on the £4.2 millions Tinsley viaduct, in Sheffield, which will carry the Yorkshire extension of the M1 across the Don Valley. The two-level viaduct takes the motorway and a trunk road across the Sheffield to Keadby canal, the River Don and three railways. The top deck of the viaduct, 3,383ft. long, carries the motorway; the lower deck (3,010ft. long) carries an all-purpose trunk road and central footway connecting the A630 and A6109*". Plans to construct this viaduct were also referred to in four other articles which were published in the 1960s (The Guardian: 25th January 1962, 4th September 1962, 10th February 1965, The Times: 5th April 1963). However, the only other bridge which was reported to have been constructed since 1930 was a footbridge (The Guardian: 21st March 1947). It can therefore be surmised that the majority of the bridges on the River Don have been in place for a long time.

Despite the potentially severe environmental consequences of bridge construction there was no discussion of this in the analysed newspaper articles. Though there may have been such discussion in some of the articles which were not analysed it is clear that it was not generally an important issue to journalists who were reporting bridge constructions. Bridge construction activities can pollute and physically degrade rivers through: accidental losses of toxic construction materials such as industrial waste materials and shred tires (Wheeler *et al*., 2005); increased sedimentation (Tiemann, 2004); and the deliberate or incidental removal of vegetation (Stout and Coburn, 1989 and Hubbard *et al*., 1993 both cited in Wheeler *et al*., 2005). However, these effects are generally only temporary (Tiemann 2004; Wellman *et al.*, 2011). The operation of the machines involved in the bridge construction process is likely to generate pollution and their use for bridge maintenance probably creates further pollution (Wheeler *et al*., 2005). The continued presence of bridges has little environmental impact on the physical environment and the resulting formation of scour pools can even increase habitat heterogeneity which is beneficial for fish (Wellman *et al.*, 2011). However, the use of bridges by motor vehicles leads to a wide range of pollutants entering rivers including organic pollutants such as oil and grease and heavy metals such as iron, zinc and lead (Wheeler *et al*., 2005). The Sheffield Local Biodiversity Action Partnership (2003 cited in Sheffield Local Biodiversity Action Partnership, n.d.) identified road run-off as a source of pollutants which contributed towards the loss or decline of biodiversity on local waterways. However, the Sheffield Local Biodiversity Action Partnership (n.d.) did not explicitly state that bridges increased the amount of road run-off entering the river. Conversely, they recognised that bridges had been colonised by vegetation which they viewed positively.

An alternative way to manage the River Don when it presented an obstacle to human activities was to divert it. This option was only mentioned in one analysed article which was published in The Guardian on 30th December 1964. It stated that tenders were being invited for "*the diversion of the River Don over a length of 100 yards including a mass concrete retaining wall along the river bank"* but it did not make it clear why these works were necessary. No consideration was given to the diversion from an environmental perspective. Though diversions may have been mentioned in articles which were not analysed it is clear that river diversion received far less attention than bridge construction in the newspaper articles.

3.3.4.4 Damage to or loss of Property or Infrastructure

In total only 12 of the 50 articles which reported actual or potential damage to or losses of property or infrastructure associated with the River Don, reported damage which was not associated with flooding. Most were published in the mid-19th century and none was published from the second half of the 20th century onwards. As the reporting of damage caused by floods is described in section 3.3.4.1 this section will focus on these 12 articles. None of these articles reported extensive damage with the largest property damaged being boats (The Observer: 12th July 1841; The Times: 28th December 1843), a train (The Times: 3rd November 1862) and a single workshop (The Manchester Guardian: 19th January 1860). It may therefore be surmised that the River Don has never been much of a threat to property or infrastructure when not in flood. The most serious incident reported a new boat capsizing and killing 50 people (The Observer: 12th July 1841). Another boat capsized in 1843 (The Times: 28th December 1843). The two articles which were published in 1829 both concerned the same incident regarding a man ferrying a woman across the flooded river and being washed downstream (The Guardian: 1st August 1829; The Times: 31st July 1829). The most recent transport-related incident concerned a train coming off the track resulting in one carriage falling into the River Don (The Times: 3rd November 1862). Two articles published in the mid-19th century implied that construction materials had been lost downstream as a result of the death of the workers who were responsible for them. One article implied that a wheelbarrow full of mortar had been lost when a worker who had been pushing it along a piece of timber across the River Don fell in (Sheffield Independent: 5th August 1858). The other article reported that a worker had drowned when trying to prevent timber from being washed downstream (Sheffield Independent: 27th February 1867). In 1938 a dog was reported to have fallen through a small gap at a dam and to have only been rescued three days later (The Mirror 19th November 1938). Three articles published in the mid-19th century implied that the River Don may have facilitated crimes which resulted in damage to or loss of property or infrastructure. (The Guardian: 28th July 1856; The Observer: 4th August 1856; The Manchester Guardian: 19th January 1860). Crime is discussed in section 3.3.4.6.

Only one of the 12 incidents concerned the adverse effects of wildlife on human interests. It reported damage done to a haystack by rats (species unspecified) from the river in the early 20th century (Yorkshire Post and Leeds Intelligencer: 27th August 1919). Despite the lack of attention given to threats posed by invasive species in the newspaper articles analysed in this study, other studies have found that invasive species have received much negative attention in newspapers. Vuorisalo *et al.* (2001) found much evidence of non-indigenous rats being persecuted in Finland at the turn of the 20th century because they were viewed as pests. Furthermore, Larson *et al*. (2005) found 63 articles which used the term “*invasive species”* which had been published between 1999 and 2003 in British national newspapers, stressing the need for and justifying action against these environmentally harmful species. Wittenberg and Cock (2005) stressed the need for public education in determining the success of invasive species eradication or control programmes, partly to reduce public opposition and partly to increase understanding of regulations which reduce propagule pressure. Articles on the River Don could be used to more effectively address this educational need. However, Gobster (2005) warned that whilst the intention behind “*sensationalist”* articles on invasive species was often to motivate people to take action greater media attention could exacerbate the situation if people: resisted efforts to eradicate particular non-indigenous species; or were motivated by interest to visit the area where there was an outbreak thus increasing the risk that it would spread further so great care must be taken when using newspapers to raise awareness of the need to manage invasive species. He reasoned that articles which evoke fear of non-indigenous species were likely to be most effective when individuals could take effective action to contribute towards their control. Examples relevant to the River Don include opportunities to participate in formally organised volunteering opportunities; advice to visitors particularly those who enter or submerge equipment into the water such as anglers to clean their equipment; and signposting authorities to report sightings of NISs to (DCRT, n.d.c; Sheffield Partnership for Rivers in Town Environments (SPRITE), n.d.a).

3.3.4.5 Actual or potential deaths

The actual or potential deaths subtheme included deaths which occurred in the River Don, people who would have drowned in the River Don had they not been rescued; bodies which were found in or by the River Don; and people who died as a result of the river flooding. The number of articles reporting actual and narrowly prevented deaths associated with the River Don fell through time suggesting that the River Don has become safer (Figure 4biv). People died: when participating in recreational activities; when crossing or travelling alongside the river; due to accidents at work; as a consequence of floods; and as a result of crime or suicide. In the 19th century four articles mentioned people dying in the course of their work on the River Don.

In the 19th century 11 articles reported deaths which had occurred as a result of participating in recreational activities on, in or by the River Don. A further four articles reported deaths which were narrowly avoided due to successful rescues. Eight articles reported deaths which had occurred as a result of swimming in the River Don (e.g. Sheffield Independent: 29th June 1839; 14th March 1893; The Guardian: 13th July 1863; 15th August 1893). The relatively high number of deaths which have occurred as a result of swimming in the River Don should be taken into consideration if the river is used for swimming more in the future which may be expected given reduced pollution as discussed in section 3.3.3.2. It may be possible to have designated swimming areas staffed by lifeguards at times when swimming is likely to be most popular. Two articles reported deaths which had occurred as a result of boating on the River Don (Sheffield Independent: 24th October 1863; The Guardian: 17th April 1850). One article reported that a child had drowned as a result of falling into the river when playing (Sheffield Independent: 20th July 1876) and two reported children who were rescued, having fallen in whilst playing (Sheffield Telegraph: 26th September 1882; Sheffield Independent: 1st July 1848). A young man was also rescued from drowning when he fell in whilst ice skating (5th January 1893). Only two articles reported deaths associated with recreation in the 20th century. Both concerned boating incidents which occurred in the last quarter of the century (The Times: 8th August 1994; Unspecified publication available from Sheffield Star Archives: 8th November 1979). In the 21st century only one death was reported to have occurred as a result of recreation although it was reported in two articles (Daily Mirror: 29th April 2002; The Guardian: 28th April 2002). They reported the death of the same child who had died when playing on the steps of a weir with his friends unaccompanied by adults. In 2013 one angler was prevented from drowning by his friend (Doncaster Free Press, 4th July 2013). The reduction in the number of deaths which occurred whilst participating in recreational activities in, on or by the River Don reflects changes in the ways in which rivers are used for recreation particularly greater supervision of children (Kemp and Sibert, 1992; Wyver *et al*., 2010) and lower participation in swimming in rivers (Davies, 2015).

Deaths associated with using the River Don for recreational activities have the potential to decrease the extent to which it is used for them through increased fear of the potential negative consequences and in turn reduce support for its conservation (Valentine 1989; Haslam, 1997; Henley Centre Headlight Vision, 2012). It is important that the public understand that whilst the River Don does claim human lives, the risks incurred when participating in recreational activities alongside it with due regard to health and safety are likely to be very low and these activities bring substantial health and educational benefits. Whilst perceived risks are likely to have a greater effect on recreational visits than actual risks both could potentially be reduced through promotion of greater adult supervision and water safety education (Kemp *et al*., 2011; Henley Centre Headlight Vision, 2012). However, media focus on tragic events can increase the perceived risks of outdoor recreation whilst doing little to educate people on how to better manage these risks (Haras, 2010). This statement was supported by the number of deaths and narrowly prevented deaths which were reported in the historical newspaper articles and the lack of advice or reported actions taken by authorities which could have reduced the fear caused by these incidents.

Several deaths occurred as a result of travelling on or alongside or crossing the River Don. The earliest death occurred in the 18th century as a result of being washed downstream when crossing the river on horseback (The Times: 16th July 1798). In the 19th century six articles reported deaths which had occurred or been prevented by rescuers as a result of falling into the river when travelling alongside it. Alcohol is likely to have attributed to three incidents of people falling into the river and drowning, all of which occurred in the 19th century (Sheffield Telegraph: 5th April 1871; Sheffield Independent: 31st March 1877; Yorkshire Gazette: 2nd June 1838). However, it was also recognised that the river was a dangerous place. With regards to the death of two women night watchmen were reported in the Yorkshire Post and Leeds Intelligencer to have said "*they had to pass dangerous places on the bank. In the dark it was very easy to walk into the river.*" One article reported a newly constructed boat capsizing and killing 50 people (The Observer: 12th July 1841). This incident is described in detail in a book on Yorkshire disasters aimed at a broad lay audience (Teasdale, 2008). Three articles reported incidents which put lives in jeopardy without killing anyone which resulted from trains travelling alongside or crossing the River Don. An article published in the Sheffield Independent on 8th November 1862 reported that a train had come off the rail when travelling along what was described as "*nothing more nor less than an embankment running betwixt the River Don and the canal, and which all along its course from Doncaster to Thorne, is one series of dangerous curves*". The engine-driver and stoker disappeared under water but were fortunately not seriously hurt. The same incident was reported in The Times on 3rd November 1862. Two trains crashed on a bridge over the River Don because a driver had not seen a signal under foggy conditions but whilst 16 people were seriously injured fortunately nobody died (The Guardian: 8th August 1883).

Work accidents resulting in death included: the construction of a viaduct (York Herald: 8th February 1845), pushing a wheelbarrow along a piece of timber across the river (Sheffield Independent: 5th August 1848), trying to prevent timber from being washed away (Sheffield Independent: 27th February 1867) and the flooding of a colliery drift which opened out into a previously dry section of the river bed (The Guardian: 25th August 1849). On the 8th June 1935 it was reported in the Yorkshire Post and Leeds Intelligencer that a bridge on which several labourers were working collapsed but fortunately they all survived. No other articles attributed actual or narrowly avoided deaths to work activities other than those involving train drivers and other on board staff. It is likely that no incidents were reported after 1935 due to better safety at work (Health and Safety Executive, 2016).

The flood which occurred in 1864 was by far responsible for the greatest number of deaths as it claimed 242 lives (The Observer: 20th March 1864). Deaths associated with this flood were also reported in The Manchester Guardian on 28th March 1864 and Sheffield Evening Telegraph on 29th September 1864. On 15th May 1886 it was reported in the Sheffield Independent that it had not yet been possible to ascertain whether or not anyone had died as a result of floods in Rotherham due to the flooding of infrastructure which blocked communications. Only three other deaths were reported to have occurred as a result of flooding all of which were consequences of attempting to cross the river by boat when it was flooded (The Guardian: 1st August 1829; The Observer: 1st September 1856; The Times: 31st July 1829). The early dates of these deaths reflects the great decline in the number of fatalities attributed to flooding in Europe over the 20th century (Mitchell 2003). This is largely due to better warning and evacuation systems (Werritty, 2006).

In total fifteen articles reported deaths which were most likely to have resulted from criminal actions or suicide. Three bodies of people who were likely to have been murdered were found in the River Don in the 19th century or the early 20th century (Sheffield Telegraph: 5th August 1876; The Times:

13th April 1857; The Times: 25th July 1925). However, only one murder was reported to have actually occurred on the banks of the River Don. Though other murders on the banks of the River Don may have been reported in newspaper articles which were not analysed it is clear that such events were rarely reported in comparison to other causes of death. In 1828 a man solicited a woman, the woman killed the man with her clog and she and her husband disposed of the man's body in the River Don (The Times: 4th April 1828)! Three bodies of babies were also found in or by the River Don in the 19th century. Although only one article stated that the death of the baby had been deliberate (Sheffield Telegraph: 9th April 1881), it was clear in the other two cases that a crime had been committed even if the death had been natural as in one case the mother was charged for concealing the birth of a child (Sheffield Independent: 23rd June 1849) and in the other case the baby was found in a bag (Sheffield Telegraph: 27th May 1890). From the 19th century onwards two suicides were reported each century although one was unsuccessful as the individual was rescued having jumped (Doncaster Free Press: 27th October 2013; Daily Mirror: 16th January 2007; Sheffield Telegraph: 22nd January 1896; 23rd September 1903; The Guardian: 16th November 1928; The Times: 25th September 1880). An incident of a burglar being caught in the act, fleeing by jumping into the River Don then drowning was reported in two articles in 1856 (The Guardian: 28th July 1856; The Observer: 4th August 1856). The early dates of these incidents reflects decreased homicide rates in Europe over recent centuries (Gurr 1981, Rousseaux, 1999 and Spierenburg, 1996 and 2001 all cited in Eisner *et al.*, 2008); decreased infanticide rates through the 19th century and into the 20th in Britain (Rose, 1986); decreased suicide rates since the mid-20th century (Thomas and Gunnell, 2010). However, homicide rates in the UK particularly in public places have increased since 1970 so this may pose a greater threat to those visiting the River Don in the future (Eisner, 2008).

Despite the large number of deaths which occurred on the River Don there was surprisingly little discussion of how future deaths could be avoided. Although there may have been more discussion in some of the articles which were not published it is still clear that the vast majority of articles which reported potentially preventable deaths did not discuss ways in which the risk of death could be mitigated against in future. Even the death of a four year old and six year old child who fell through a hole in a bridge in 1883 did not prompt a call to action for the bridge to be repaired (Sheffield Telegraph: 26th July 1883)! However, the fall in the number of articles reporting deaths is in itself evidence that the River Don has become safer and/or that visitors have modified their behaviour to reduce their risk of death. Proposed action to reduce the likelihood of future deaths on the River Don included: a jury which concluded that a Private had drowned whilst bathing in the River Don arguing that the corporation should provide a public bathing place (Sheffield Independent: 14th June 1856); examining dams to reduce the likelihood of another dam burst following the 1864 floods (The Observer: 20th March 1864); and police planning to urge British Waterways to install barriers in 2002 following the drowning of an eight year old girl (Daily Mirror: 29th April 2002). Suicide was also discouraged, through legal enforcement. In 1880 a woman was sent to prison for having attempted suicide (The Times: 25th September 1880) and in 2007 an individual was tried for aiding and abetting his wife's suicide (Daily Mirror: 2nd July 2007).

3.3.4.6 Crime

Crime was not mentioned in more than 12% of Theme C articles in any century. Homicide and suicide are discussed in section 3.3.4.5 and relatively few other crimes associated with the River Don were reported. Theft was reported in two articles in the 19th century and two in the 20th century. The former two reported the same incident in which a house burglar had been caught in the act, attempted to flee the scene by swimming in the River Don and drowned (The Guardian: 28th July 1856; The Observer: 4th August 1856). The latter two concerned the theft of £30 from an individual (The Guardian: 2nd August 1966); and a tug boat which was used for dredging and transporting coal (Unspecified publication available from Sheffield Star Archives: 27th July 1983). The remaining three crimes had very little in common with each other. They were: an explosion in an outfall pipe was caused deliberately in 1860 (The Manchester Guardian: 19th January 1860); a criminal who escaped from a prison van attempted to flee by swimming in the river but was soon recaptured (The Mirror: 28th April 1943); and dogs which were deliberately drowned in the River Don in 1984 (Daily Mirror: 1st December 1984). It is clear that the frequency with which crime was reported in the newspaper articles was relatively low but analysing a larger sample of articles may have evidenced a broader range of crimes and indicated that certain crimes such as theft were reported more frequently.

The only crime which would generally be considered environmental which was reported in the analysed newspaper articles was illegal fishing using drag nets in 1873 (Sheffield Independent: 7th June 1873). Although it is illegal to fish on the River Don without a licence and in Spring 2014 965 were found to be fishing illegally in England, illegal fishing received no further attention in the newspaper articles (EA, 2014b). It is relatively likely that this was not the only article in which illegal fishing was reported but greater coverage of the consequences of illegal fishing could potentially help to reduce this crime. However, there is no evidence that overfishing is one of the main constraints on fish populations and money raised through fines contributes towards the conservation of the river (Page and Radomski, 2006).

Reassuringly no violent crimes have been reported in the analysed articles since the 1960s. Although violent crimes may have been reported in articles which were not analysed, the fact that they were not reported in any analysed articles suggests that they were reported in few articles overall from this time period. This may be beneficial for the natural environment as increased media coverage of violent crime in outdoor public spaces is often blamed for increasing the extent to which these places are feared by local people beyond that which is justified by true crime rates and thus decreasing the extent to which they are visited which in turn may reduce support for their environmental management (Valentine 1989; Haslam, 1997; Hillman, 1999; Zani, 2003 all cited in Prezza *et al.*, 2005; Prezza *et al.*, 2005).

3.3.5 Theme D

3.3.5.1 Issues

Pollution was mentioned in all 57 Theme D articles with the exception of three of the five which were published in the 21st century (Figure 5a). Conversely, physical habitat degradation was only mentioned in four Theme D articles all of which were published from the 1970s onwards (Figures 5a and 5b).

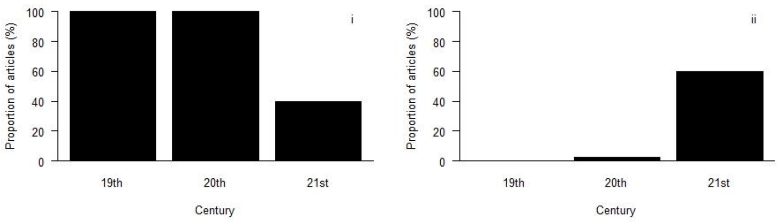


Figure 5a. Proportion of Theme D articles which mention each subtheme by century (i=Pollution, ii=Physical habitat degradation) (n=9, 43 and 5 Theme D articles from the 19th 20th and 21st centuries respectively).

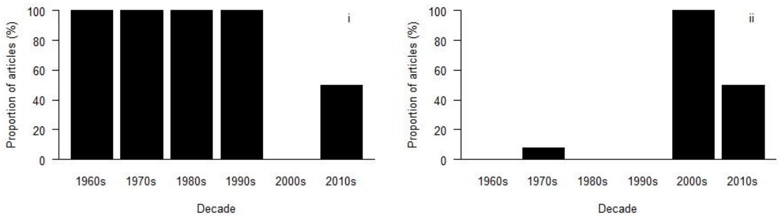


Figure 5b. Proportion of Theme D articles which mention each subtheme by decade (i=Pollution, ii=Physical habitat degradation) (n=1, 13, 16, 13, 1 and 4 Theme D articles from the 1960s, 1970s, 1980s, 1990s, 2000s and 2010s respectively).

3.3.5.1.1 Pollution

The dominance of pollution in the Theme D articles throughout the study period reflects both the extent to which it has been deemed an important issue and the extent to which it has been addressed through legal and practical action relative to physical degradation and the presence of non-indigenous species, the latter of which was not discussed in any analysed newspaper articles. From the newspaper articles and Firth's (1997) account of the restoration of the River Don it may be surmised that its recovery from a lifeless "*open sewer*" to a river able to support good quality gaming fisheries in 1984 was almost all due to decreased pollution. The long history of efforts to reduce pollution with very little effort to reduce physical habitat degradation until recent decades broadly describes the history of river management within the UK. Nationally efforts to reduce river pollution date back as least as far as the 14th century (Clapp, 1994) and Langford *et al*. (2009) described the work of the royal commissions in the 19th century as the "*Start of significant legislation to prevent or control pollution*". Dobbs and Zabel (1996) surmised "*Traditionally control of the chemical and biological quality of waters in rivers to protect different uses has been considered adequate to provide full environmental protection.*" Furthermore Langford *et al.* (2009) recognised that it was not until the 1990s and 2000s that the European Commission Habitats Directive (1992) and Water Frameworks Directive (2000) moved the conservation objective significantly away from a focus purely on pollution and towards the recovery of ecological conditions in rivers.

The content of conservation articles mentioning pollution changed greatly through time. As discussed in section 3.3.2.2 the first article, which was published in 1864, expressed the belief that the river would be able to accommodate the effluents which were discharged into it if its natural flow was not reduced through abstraction (Sheffield Telegraph: 29th October 1864). However, the next conservation article which was published only six years later stated that the Doncaster Corporation were threatened with court action by the South Yorkshire Railway and River Dun Company if they continued to discharge the town's sewage into the river (Sheffield Telegraph: 22nd July 1870). This was before the Rivers (Prevention of Pollution) 1876 Act was passed and thus likely to have been addressed under nuisance law (Langford *et al.*, 2009). Two other articles published in the 19th century concerned accusations against organisations regarding their disposal of waste into the river (Sheffield Telegraph: 30th January 1878; Yorkshire Post and Leeds Intelligencer: 8th August 1895). Both articles reported the dumping of solid waste such as sand and refuse by organisations in the heavy metal manufacturing industries. The first article reported a court case which was adjourned without the accused being punished and the second reported a court case which resulted in the accused being fined. In the earlier case the prosecutor was the owner of Rotherham Forge Mills in the latter case they were the West Ridings River Board. The roles of the South Yorkshire Railway and River Dun Company and Rotherham Forge Mills in these cases suggests that their actions were driven by threats posed to the river's potential to be used for purposes from which they benefited such as navigation and power generation. On a national scale Clapp (1994) also reported that the desire to use rivers for navigation prompted legal action to be taken against those who used rivers for fly tipping in this time period.

In the 19th century only two articles reported practical action which had been taken to reduce the quantity of pollutants entering the River Don. They both reported on sewage treatment. The first concerned Doncaster "*taking its own sewage from the river*" without making it clear how this was done (The Times: 23rd July 1875). The second celebrated the opening of the sewage works of the Rawmarsh Urban District Council and was most affirmative in its praise. It stated: "*The Urban District Council have carried out the work on their initiative and without press from the West Riding Rivers Board. They are therefore deserving of every praise for their determination, to keep pace with modern scientific requirements for the preservation of the health of the people"* (Sheffield Independent: 18th December 1896). However, evidence of Sheffield opening its first sewage works, Blackburn Meadows in 1886 was not found in the newspaper articles possibly reflecting the limitations of only analysing a relatively small proportion of newspaper articles (City of Sheffield Sewage Disposal Department, 1930). According to Firth (1996) when Blackburn Meadows opened in 1886 although it only operated in daytime and afforded 50% treatment they were considered a model and visited by interested parties from across the country. Further improvements to sewage treatment were reported in the early 20th century. These improvements included the replacement of the lime precipitation process with the bacteriological system at Blackburn Meadows sewage works in Sheffield (The Times: 22nd November 1911).

The quotation concerning the opening of Rawmarsh sewage works above suggests that in the late 19th century efforts to reduce the extent to which the River Don was polluted were driven at least in part by concerns regarding human health. The aesthetic effects of the pollutants may have also been influential and were reported very poetically. The nymph of the River Don was said to have said "*my waters were fresh and limpid. They sparkled in the sunlight and circled in crystal eddies in pools dear to trout or glancing minnows"*. *"But now behold me desecrated and defiled; my waters penned and pounded, not returned to me unstained as from the old mill-wheels I was glad to turn, but made poisonous by acids and refuse, and bringing an unwholesome leaven into my whole stream. And this is not the worst, for as I pass your towns and villages – faugh!"* (Sheffield Telegraph: 28th May 1872). Although the newspaper articles did not mention these acts it is likely that the Public Health Act (1875) and the Rivers Pollution Prevention Act (1876) were important factors in driving these early actions to reduce the amount of pollution entering the River Don (Johnstone and Horan, 1996; Woods, 2006). The former assigned legal responsibilities regarding the treatment and disposal of sewage and the latter prohibited the disposal of solid matter and the discharge of untreated sewage into rivers.

Further action was taken in the 20th century to reduce the quantity of pollutants which entered the River Don. In 1965 it was reported that the Yorkshire Ouse and Hull River Authority had dealt with more than 7,000 discharge applications, mostly approving them initially to avoid disrupting the industry or sewage disposal systems of offending towns but also agreeing on five year plans for applicants to reduce their emissions (The Guardian: 8th October 1965). Such agreements were made under the Rivers (Prevention of Pollution) Act, which came into force in 1963. Given that the Rivers (Prevention of Pollution) Act 1961 stated that it would be enforced only after the date appointed by the Minister at least 14 months after the Act was passed it is clear that this is the Act to which they are referring (Rivers (Prevention of Pollution) Act, 1961). The National Rivers Authority was confident that substantial improvements would be seen by 1970 (The Guardian: 8th October 1965). The Rivers (Prevention of Pollution Act) 1961 was viewed by Langford *et al*. (2009) as the earliest legislation which "*imposed strict and enforceable controls on all identified existing point-source discharges*" and according to the newspaper articles had great impact on the amount of industrial effluents entering the River Don. In 1979 it was reported that the Yorkshire Water Authority had launched a five year programme to divert industrial waste into public sewers and persuade organisations in the manufacturing sector to improve their own waste treatment processes (Sheffield Telegraph: 7th August 1979). The same article reported that construction of the Don Valley sewer had commenced. In 1984 it was reported that "*The Yorkshire Water Authority has spent millions of pounds on sewerage and sewage treatment, and the industrialists on waste water treatment*" (Unknown publication available from Sheffield Star Archives: 14th September 1984).

The only article which empathised with the reliance of industry and sewage treatment companies on the River Don for waste removal was published in The Guardian on 8th October 1965. In this article legislation which came into force in 1963 is said to have broadly given river authorities the "r*ight to demand improved standards from thousands of firms and authorities who had been polluting rivers until then virtually at will.*" Although not explicitly stated the legislation referred to is most likely the Water Resources Act (1963) (Johnstone and Horan, 1996). The Yorkshire Ouse and Hull River Authority had already received 7,000 applications to discharge their effluents and the article states "*Most have been approved, simply because not to do so would seriously disrupt industry or the sewage disposal system of some of the offending towns"*. However, offenders were not permitted to continue the status quo. Instead they were given a time limit, usually of five years, to meet requirements regarding the quality of their effluents. The need to give companies sufficient time to adapt their infrastructure and processes to comply with new environmental controls with minimal adverse social and economic impact is also recognised by Johnstone and Horan (1996).

Despite the earliest legal action against polluters being first reported in the newspaper articles in the 19th century and new legislation to restrict pollution discharges further being reported in the 1960s only two articles which were published in the 20th century reported legal action against polluters and they were published in the 1980s and 1990s (Unknown publication available from Sheffield Star Archives: 14th December 1984, 27th February 1990). They both concerned industrial liquid pollution specifically petrol (Unknown publication available from Sheffield Star Archives: 14th December 1984) and oil (Unknown publication available from Sheffield Star Archives: 27th February 1990). The first article simply stated that the company would be held to account but also praised it for quickly implementing emergency procedures, minimising the impact of the incident. The second article stated that a steel forging company had been fined. Only one article, published in 1990, encouraged members of the public to report evidence of pollution incidents to the National Rivers Authority (Unspecified publication available from Sheffield Star Archives: 6th January 1990). According to Amisah and Cowx (2000) episodic pollution events and illegal tipping of domestic and industrial waste greatly reduced the extent to which fish populations in the River Don had recovered by the 1990s in response to reduced discharge of effluents so more effective action against polluters could potentially have made substantial difference.

The low number of reports of legal action may reflect the ineffectiveness of the legislation. In 1974 the Sheffield Area Branch of the Conservation Society raised concerns about Yorkshire Water Authority taking responsibility for managing pollution as they would be in charge of both sewage treatment, making them one of the greatest polluters and inspectors employed to reduce pollution (Sheffield Star: 19th March 1974). Similarly, concerns that legislation which privatised sewage treatment and the provisioning of drinking water could be environmentally harmful if the national rivers authority was not given enough control were raised in 1989 (The Guardian: 27th February 1989). On a national scale Johnson and Handmer (2002) recognised that the Water Authorities failed to self-regulate and water quality actually decreased through the 1980s until the regulation responsibilities were transferred to the newly created National Rivers Authority in 1989. They also recognised the role of stricter European standards in driving more effective water regulation practices. None of the conservation articles published in the 21st century concerned legal action against polluters. The focus on reducing the amount of point source pollution which entered the river over addressing diffuse pollution or removing pollutants which were already in the river reflected the national approach to reducing pollution from the 19th century through to the 21st century (Langford *et al*., 2009).

Action to remove pollution from the river was limited to rubbish and fly tipping and only discussed within newspaper articles from the 1980s onwards (Unknown publication available from Sheffield Star Archives: 30th July 1982; 1st June 1983, 14th September 1984, 9th August 2012). Such projects were generally community led and some were very labour intensive. For example, on 5th May 1970 it was reported in the Sheffield Star that nearly 200 people had been involved in a recent clean-up organised by the Sheffield Junior Chamber of Commerce. Recognition of the benefits achieved through the previous actions of others is likely to encourage others to perform similar actions in the future through vicarious learning (Bandura, 1971 cited in Masia and Chase, 1997).

Although there was much discussion of the effects of iron ochre pollution from disused mines these mostly discussed researching, funding and assigning responsibility for the issue (The Guardian: 26th May 1970; Unknown publication available from Sheffield Star Archives: 24th August 1984; Unknown publication available from Sheffield Star Archives: 26th May 1995). Clearly this pollution severely impacted fish communities as one article stated that the river section immediately above the point where discharges from a mine entered the river supported a high quality gaming fishery (Unknown publication available from Sheffield Star Archives: 24th August 1984) and that this pollution was so visible that the shadow environment spokeswoman was to be filmed there when criticising the Labour party over water privatisation legislation (The Guardian: 27th February 1989). In 1998, 28 years after the issue had first been reported in the newspaper articles, it was finally reported that a section polluted with iron ochre pollution was to be cleaned (The Guardian: 18th September 1998). Ofcourse additional actions to reduce mining pollution may well have been discussed in newspaper articles which were not included in the sample. However, it is still clear from the analysed articles that diffuse pollution received far less attention in the newspapers than point source pollutin and many of the articles which reported diffuse pollution discussed proposals for action rather than tangible achievements with regards to managing this problem. Furthermore, Amisah and Cowx (2000) recognised diffuse pollution from mines as a key factor which prevented the River Don's fish communities recovering in the 1990s despite greatly reduced point source pollution.

Despite efforts to reduce the pollution in the River Don being discussed from 1864 onwards (Sheffield Telegraph: 29th October 1864) with polluters having been threatened with legal action since 1870 (Sheffield Telegraph: 22nd July 1870) and substantial practical action having been taken to notably reduce the amount of sewage entering the River Don by 1875 (The Times: 23rd July 1875), in 1965 it was reported that *"The River Don between Doncaster and Sheffield, has a normal flow of 90 m.g.d.* [approximately 0.4 million m^3d^{-1}] *of which 50 per cent is sewage effluent and 25 per cent industrial effluent"* (The Guardian: 8th October 1965). Between 1972 and 1975 surveys conducted by the Department of the Environment found that whilst on a national scale several stretches of river which had previously been severely polluted were now clean enough to enable fish and other wildlife to "*flourish"*, the River Don was classed as "*grossly polluted"* (The Guardian: 22nd March 1978). The River was described as "*lifeless from its source in the south Pennines to its junction with the equally polluted Ouse"*. The first evidence that pollution in the River Don had actually decreased was reported in 1976, more than a century after the first action had been taken. The section of the river which flows into Sheffield was described as being "*on the threshold of being a fishery, supporting coarse fish and some trout"* (Sheffield Star: 30th June 1976). Although earlier evidence of reduced pollution may have been reported in an article which was not analysed this date is in keeping with Firth's (1997) interpretation of the largely successful petitioning against an abstraction licence due to the presence of trout upstream of Penistone in 1975 as the start of concerted efforts to substantially improve the river's water quality and the fact that until 1965 industries had been able to pollute the River Don virtually at will and these industries were given five years to adopt less pollutive practices. This suggest that little evidence if any would have been published in the newspapers before this time. Two other articles reported fish returning to the River Don as a result of reduced pollution in the 1970s. These were published in the Sheffield Star on 1st March 1978 and the Sheffield Telegraph on 7th August 1979. These improvements were largely attributed to the efforts of industry to reduce the input of industrial effluents into the river. However, it was still recognised that there was "*a long way to go*" with regards to the reduction of pollution and the recovery of fish (Daily Telegraph: 7th August 1979). Improvements in the quality of the River Don in the second half of the 1970s were concurrent with improvements in other grossly polluted rivers in other parts of England which previously supported extensive heavy manufacturing (National Water Council, 1980).

Through the 1980s and the first half of the 1990s some articles evidenced decreased pollution whilst others evidenced that the river was still severely polluted. Evidence that pollution had decreased was reported in six articles between 1980 and 1995 (Unspecified publication available from Sheffield Star Archives: 5th September 1980, 23rd June 1983, 14th September 1984, 9th September 1987, 5th December 1995, 5th July 1995). 1980 was the first time that fish were found in large numbers in the Sheffield city centre section of the River Don which was seen as a result of reduced pollution (Unknown publication available from Sheffield Star Archives: 5th September 1980). In 1984 it was reported that although the Don had been "*nearly at the bottom of the country's water quality league table*" 20 years previously, due to better treatment of domestic sewage and industrial effluents it now "*supports an increasing variety of wildlife"* (Unknown publication available from Sheffield Star Archives: 14th September 1984).

Conversely, in the 1980s and first half of the 1990s six articles reported that the River Don was still severely polluted (The Times: 8th June 1983; Unspecified publication available from Sheffield Star Archives: 2nd July 1980; 12th March 1987, 29th September 1989, 25th February 1992, 6th May 1994). In 1980 council officials stated that "*Despite the clean-up campaigns of the 1970s, pollution is pouring into the county's rivers and streams in greater quantities than ever"* and that over the last decade the Don downstream of Sprotbrough had deteriorated from *"poor quality"* to "*grossly polluted"* (Unknown publication available from Sheffield Star Archives: 2nd July 1980). In 1983 it was reported that "*the water is so badly polluted it is like an open sewer*" (The Times: 8th June 1983). In 1985 it was reported that "*Nowadays anglers tend to avoid the Don – one of Britain's most polluted rivers*". In 1987 it was reported that "*In parts of the Don more than half the flow is made up of industrial waste."* (Unknown publication available from Sheffield Star Archives: 12th March 1987). In 1989 a local MP said "*The pollution by sewage works and industry is on such a scale and consequently so serious that improvement will only come in the 1990s and probably not sooner than the middle of the decade"* (Unknown publication available from Sheffield Star Archives: 29th September 1989). In 1992 an environmental consultant stated "*Not many people get to see the Don close up… They would not be impressed with what they saw – islands of bricks and tyres, trees with plastic bags hanging off the lower branches, scrap metal and timber*" (Unknown publication available from Sheffield Star Archives: 25th February 1992). In 1994 an article on restocking stated "*They were born and bred in the pure waters of the North Yorkshire dales… but from today they must swim in Sheffield's polluted rivers"* (Unknown publication available from Sheffield Star Archives: 6th May 1994). In the same year the River Don was described as "*among the most polluted in Britain"*.

In addition to compliance with legislation and the desire to restore nature as discussed within this section above from the 1960s to 1995 the main motives for reducing pollution were: improving the River Don from a visual and olfactory aesthetic perspective (Sheffield Telegraph: 10th September 1980; Unspecified publication available from Sheffield Star Archives: 24th August 1984; 14th September 1984; 12th March 1987) and providing good recreational opportunities (Sheffield Star:

17th March 1975). In the mid-1980s it was reported that "*in the wake of the depression in the steel and cutlery industries, the city and county councils have become more involved in improving the image of the Don."* (Unspecified publication available from Sheffield Star Archives: 14th September 1984). This was the only article which recognised that loss of industry stimulated conservation action. On 17th March 1975 the vision that the "*polluted*" River Don was "*to be turned into a people's playground that could be the pride of the city*" was reported in the Sheffield Star. This article reasoned that the management of the River Don depended on industry thriving to raise the funds to cover its costs (Sheffield Telegraph: 18th September 1973). However, the river was largely restored following the demise of industry which began in the late 1970s (Firth 1997; Watts 2004) and the extent to which the desire to create an attractive environment for recreation had results over and above the effects of national legislation and deindustrialisation are unclear. Public opposition may have also discouraged some of the most polluting industries from opening premises nearby. For example, in 1989 readers were encouraged to oppose a large waste disposal company moving to the area (The Guardian: 27th April 1989).

Collectively conservation articles published in the latter half of the 1990s portrayed pollution largely as a historical rather than a current problem. Five of the seven recognised reduced pollution (Unspecified publication available from Sheffield Star Archives: 11th September 1997, 2nd September 1998, 4th February 1999, 3rd September 1999 and 1st November 1999). The remaining two were concerned about iron ochre pollution (Unspecified publication available from Sheffield Star Archives: 13th March 1997; 18th September 1998). By 1997 reduced pollution had enabled fish populations to recover to the extent that the river was able to support some of the "*premier match fisheries in the North of England, if not the whole country"* (Sheffield Star Archives: 2nd July 1997). In 1999 the EA (Environment Agency) reported that "*The River Don – once dubbed one of the dirtiest rivers in Europe is one of the region's success stories*" (Unspecified publication available from Sheffield Star Archives: 3rd September 1999). In addition to background pollution levels the frequency of pollution incidents was also reported to have fallen from 78 in 1990 to 22 in 1998 (Unknown publication available from Sheffield Star Archives: 3rd September 1999). Using old newspaper articles to educate the public about how polluted the River Don used to be relative to its current state could increase their appreciation for its current state with accordance to the contrast principle (Cialdini, 2007). This principle recognises that people tend to exaggerate the difference between two different states.

Obstacles to managing pollution in the River Don in the 20th century received relatively little attention but were mostly due to the costs incurred. In 1965 the Yorkshire Ouse and Hull River Authority had to allow organisations time to implement changes to reduce their discharges because "*not to do so would seriously disrupt industry or the sewage disposal system of some of the offending towns"* (The Guardian: 8th October 1965). A large project to give the unemployed work experience by cleaning up the river had to be "*tuned-down*" because its funding application was unsuccessful (Unspecified publication available from Sheffield Star Archives: 30th July 1982). In 1984 it was reported that "*The NCB* [National Coal Board] *has devised several successful solutions for treating the ochre but neither it nor the local authority was responsible for dealing with it"* so a local MP wrote to the Environment Secretary to request help (Unspecified publication available from Sheffield Star Archives: 24th August 1984).

Pollution was only mentioned in two articles in the 21st century. One focused on community action to remove rubbish (Unknown publication available from Sheffield Star Archives: 9th August 2012). The other reported a woodchip fire which caused polluted run-off to enter a tributary of the River Don (Unknown publication available from Sheffield Star Archives: 6th June 2014). The EA responded to this incident by working to contain the pollution.

3.3.5.1.2 Physical degradation

Physical degradation was only recognised in a total of four analysed conservation articles. Whilst it is likely that it was also mentioned in newspaper articles which were not included in the sample, it is clear that it received far less attention in the newspapers than pollution did. The first of the four articles was published in the 1970s. It simply expressed the need to restore the river's "*physical, chemical and biological purity"* but focused on sewage pollution and did not discuss how the river would be restored from a physical perspective (Sheffield Star: 9th January 1970). The remaining three were all published in the 21st century. These late dates reflect that it was not until the 1990s and 2000s that the European Commission Habitats Directive (1992) and Water Frameworks Directive (2000) fostered a more holistic approach to conservation rather than one which focused almost entirely on pollution (Langford *et al*., 2009). Under this directive the EA produced River Basin Management Plans for all river basins in England (EA, 2015). However, it does not acknowledge the work which has been done to restore wetlands along the banks of the River Don since the 1950s (Firth, 1997). Although a heavy focus on reducing pollution has facilitated the ecological recovery of the River Don to a large extent as discussed in section 3.3.5.1.1 further restoration including the restoration of salmonid and mammalian populations will be more dependent on improved physical habitat including the installation of fish passes and the restoration of river banks (EA, 2009). Physical degradation caused by anthropogenic disturbances is unlikely to be reversed by natural processes within a reasonable time scale and thus requires active management (Milner, 1996).

Despite the strong need to reverse the river's legacy of physical degradation lack of attention given to such issues in the media suggests that the physical restoration of the River Don is not being achieved to a great extent. This suggestion is supported by this quotation from the Canal and River Trust (2016): *"Whilst the chemical condition of the river was vastly improved, there remained features of the physical damage which continue to affect the long term sustainability of fish stocks."* If such projects are to receive the public support on which their success depends it is important that their aims and plans to achieve these aims are communicated to local people (Wohl *et al*., 2005). The American River Conservancy in California (1998 cited in Paretchan, 2002) reasoned that "*without a community-based understanding of the necessity and means of pursuing* [ecological health], *mere protection must ultimately prove insufficient*". Press coverage of the benefits of such actions can also increase the number of similar projects on a national scale (Crane, 2009). However, the ecological impacts of weirs were not discussed in any of the analysed newspaper articles despite the Canal and River Trust (2016) recognising them as *"By far the most serious"* feature of the River Don's legacy of physical degradation in terms of its effects on the sustainability of the river's fish populations. The severe ecological impacts of weirs were discussed in more detail in Section 3.3.2.1. Whilst these were not mentioned in any of the analysed articles, only a relatively small proportion of articles were analysed so there is a relatively high possibility that they were discussed in other articles. The fact that they were not discussed in any of the analysed articles strongly suggests that they received much less attention than pollution did though. Despite the lack of media attention, other sources document that substantial action has been taken to address the environmental constraints imposed by weirs as fish passes have been installed at seven sites along the River Don (Canal and River Trust, 2016). Furthermore, there are plans to install many more fish passes in the near future (The Don Network, 2016).

Analysed Theme D subtheme physical degradation articles focused instead on the restoration and preservation of wetland habitats and the restoration of the River's old course. However, given the small number of Theme D articles which mentioned physical degradation it is not clear whether their occurrence in the sample articles reflects the frequency of their occurrence relative to other examples of physical degradation in the newspapers which were published in this time period overall. The limited coverage of wetland habitat restoration in the sample articles suggests that it was restored in large part to reduce the flood risk but also to create "*a combined wetland/wildlife corridor to serve local communities*" (Telegraph: 2008 specific date unspecified). The ecological benefits of such projects are discussed in section 3.3.2.5. When plans to construct HS2, a high speed railway, threatened wetland the chief executive of the Sheffield and Rotherham Wildlife Trust strove to generate public concern by stating "*With so many areas potentially destroyed or damaged, our vision for a connected network for nature and all the work we've done over the last few decades towards this will be under threat."* (Sheffield Telegraph: 31st January 2013). De Santo and Smith (1993) also recognised that habitat loss and fragmentation were key ecological threats posed by the construction of high speed rail. They suggested that relatively small adjustments could be made to minimise these impacts thus optimally balancing the needs of people and wildlife. Local newspapers can play an important role in effective campaigning to minimise the effects of proposed developments on the natural environment by increasing public opposition and sensitising local councillors to this opposition thus putting pressure on developers not to implement their plans or to modify them to minimise their net environmental harm (Short *et al*., 1987). Greater use of local newspaper articles to explain the potential negative impacts of proposed developments including HS2 on the River Don and its wildlife could thus be instrumental in preventing further environmental degradation.

In 2015 an article reported the restoration of a short section of the old course of a section of the River Don (Unspecified publication available from Sheffield Star Archives: 31st January 2015). Remeandering rivers can increase habitat heterogeneity, increase total fish abundances, increase the proportion of lotic fish within fish communities, reduce the risk of flooding and increase the aesthetic value of riparian landscapes (Kaguchi *et al*. 2005 cited in Nagayama *et al*. 2008; Eden and Tunstall, 2006). Both the River Don's ecological quality and local people are thus likely to benefit from such projects and greater press coverage could increase public support for them which may ultimately increase the extent to which the River Don is remeandered (Paretchan, 2002).

3.3.5.2 Taxa

The only taxa which were specifically mentioned in the analysed Theme D newspaper articles were: fish, mammals, birds and plants. Whist other taxa may well have been mentioned in newspaper articles which were not analysed it is likely that these taxa were mentioned in the greatest number of articles as their relatively large size attracts public attention. None of the analysed Theme D newspaper articles mentioned invertebrate species either in general or with regards to specific species despite Sheffield Local Biodiversity Action Partnership (n.d.) recognising that the post-industrial landscape on what was naturally floodplains supports "*many nationally rare species, particularly invertebrates and plants"* and discussing the role of elm trees (species unspecified) on the banks of the River Don in supporting white letter hairstreak butterflies (*Satyrium w-album*), a UK BAP (Biodiversity Action Plan) priority species. This reflects that invertebrates generally receive less media attention, less public concern and less conservation funding than vertebrates (New, 1993; Nash, 2004). However, as the European Water Framework Directive requires all restoration projects to assess benthic macroinvertebrate community composition in order to receive funding it can be expected that conservation practitioners will put more emphasis on invertebrate conservation in future (Haase *et al*., 2013).

Overall the most frequently mentioned taxon in the Theme D articles was fish (Figure 6a). They were mentioned in 26 articles whilst the second most frequently mentioned taxon, mammals was only mentioned in six articles (46% and 11% of all conservation articles respectively). Wildlife in general was mentioned without being more specific in 13 articles (23% of all Theme D articles). Fish were the most frequently mentioned taxon in the 19th and 20th century but plants and unspecified wildlife were both mentioned in a greater proportion of analysed articles than fish in the 21st century. Overall from the 1960s onwards fish were the most frequently mentioned taxon as they were mentioned in 24 articles (50% of conservation articles). Mammals were the second most frequently mentioned as they were mentioned in six articles (13% of conservation articles). Fish were the most frequently mentioned taxon each decade from the 1970s to the 1990s. These were the only decades in which at least ten articles mentioned Theme D (54%, 38% and 69% of Theme D articles respectively). They were also the only taxon which was mentioned in the only Theme D article published in the 1960s. Only one Theme D article was published in the 2000s and it mentioned both plants and unspecified wildlife. Plants and fish were each mentioned in one of the four Theme D articles published in the 2010s and unspecified wildlife was mentioned in two. The proportion of conservation articles which mentioned wildlife without being more specific each century increased from the 19th century to the 21st (0%, 23% and 60% respectively).

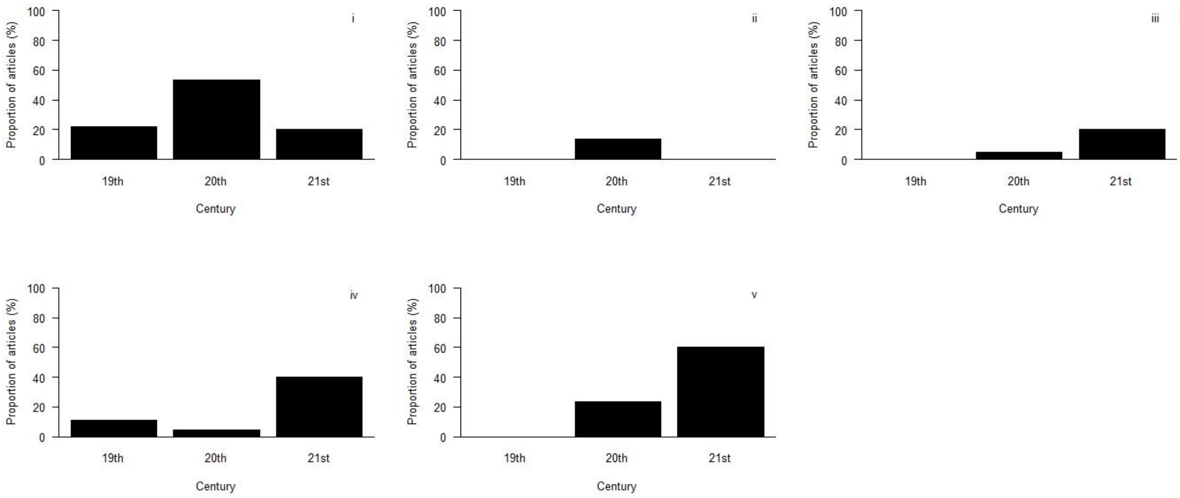


Figure 6a. Proportion of conservation articles that mention each taxon by century (i= Fish, ii=Mammals, iii=Birds, iv=Plants and v=Unspecified wildlife) (n=9, 43 and 5 conservation articles from the 19th 20th and 21st centuries respectively).

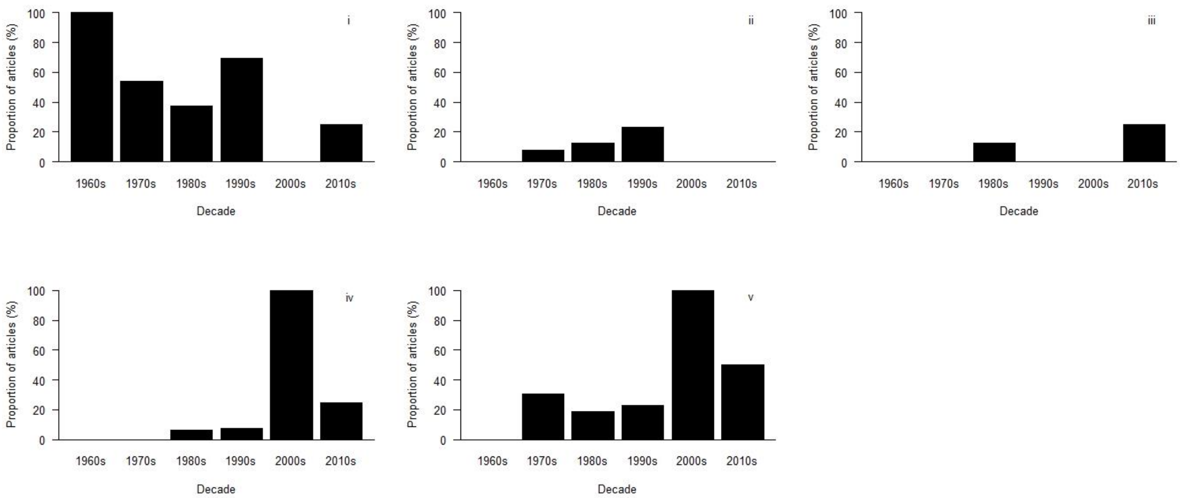


Figure 6b: Proportion of conservation articles that mention each taxon by century (i= Fish, ii=Mammals, iii=Birds, iv=Plants and v=Unspecified wildlife) (n=1, 13, 16, 13, 1 and 4 conservation articles from the 1960s, 1970s, 1980s, 1990s, 2000s and 2010s respectively) .

3.3.5.2.1 Fish

The high proportion of Theme D articles which mentioned fish reflects their historical and current social and ecological importance. The public excitement generated by sightings of charismatic fish species, particularly salmon is discussed in section 3.3.3.4. From a more utilitarian perspective people have been interested in fisheries for thousands of years (Burnett, 2003) and according to Giller and Malmqvist (1998) fish are the "*best-known inhabitants in freshwater systems*". The importance of interest to anglers in increasing the publicity of fish conservation is reflected in the fact that angling was mentioned in a total of 11 out of the 26 Theme D articles which mentioned fish (42%). The earliest article which mentioned anglers expressed optimism that pollution would be noticeably reduced by 1970 due to new legislation described in section 3.3.5.1.1 (The Guardian: 8th October, 1965). It stated "*Angling associations, which have already claimed fishing rights on some of the most grossly polluted rivers, are perhaps showing a degree of optimism which is not yet justified, but the future of the rivers of the North appears to be brighter in every sense than it has done for a hundred years or so.*" In 1987 it was reported that "*The Don, which has seen a major clean-up is being projected as a home for wildlife and a base for fishermen* (Unspecified publication available from Sheffield Star Archives: 9th September 1987).

Anglers played an active role in the restoration of fish communities and the river more broadly by removing rubbish from the river (The Guardian: 26th May 1970), restocking trout (Sheffield Telegraph: 29th March 1971; Unspecified publication available from Sheffield Star Archives: 6th May 1994) and even holding a fishing match when there was very little chance of catching anything to raise public awareness of the extent to which the river was polluted and the consequences of this (Sheffield Star: 4th June 1973; Unspecified publication available from Sheffield Star Archives: 23rd August 1985). By 1976 the section of the River Don flowing into Sheffield was "*on the threshold of being a fishery, supporting coarse fish and some trout"* (Sheffield Star: 30th June 1976) and by 1984 an upstream section of the River Don was able to support a "*high quality gaming fishery"* (Unspecified publication available from Sheffield Star Archives: 24th August 1984). In 1998 it was reported that "*The quality of the Don has improved so much that one angler recently caught a 12lb salmon"* (Unspecified publication available from Sheffield Star Archives: 2nd September 1998). Although the newspaper articles did not mention that anglers had contributed towards the restoration of the River Don in the 21st century it is clear from the SPRITE website that they continue to do so (SPRITE, n.d.a; SPRITE, n.d.b; The Wild Trout Trust, n.d.). Their current activities include: removing litter; controlling overgrowing vegetation; removing non-indigenous species; planting native species; enhancing habitat for fish, plants, birds, mammals and invertebrates; monitoring river health using invertebrate surveys; and educating local schools and community groups on the value of rivers of high ecological quality. Anglers have also played an important role in the restoration of other rivers. According to Clapp (1994) anglers and fishermen were the most vociferous objectors against the pollution of British rivers in the 19th century and the role of anglers in raising awareness of UK water quality issues through most of the 20th century is recognised by Davies *et al*. (2004).

The benefits of learning of the positive outcomes of actions of others in terms of vicarious learning are recognised in section 3.3.5.1.1 (Bandura, 1971 cited in Masia and Chase, 1997). However, they may be even stronger in the case of anglers as according to social learning theory individuals are generally more influenced by the behaviour of others who are more similar to them and in this case all anglers share a similar interest although their particular preferences may differ (Phillips, 1980; Phillips and Cartensen, 1986; Bandura, 1986 all cited in Rimal and Real, 2005). In 2009 the River Basin Management Plan for the Humber River Basin District recognised that anglers had a large role to play in the conservation of the River Don (EA, 2009). In addition to continuing past work there is the potential for anglers to contribute towards the restoration of the River Don in more ways than they are currently as elsewhere anglers have been reported to: raise funds and build public support for the installation of fish passes, restrict the spread of NISs and restrict environmentally harmful development through lobbying and media campaigning (Granek *et al.*, 2008).

Umbrella species can be defined as those *"whose conservation confers protection to a large number of naturally co-occurring species"* (Roberge and Angelstam, 2004). The fact that some fish, particularly large migratory species such as salmon can be viewed as umbrella species due to their dependence on good quality habitats suggests that conservation of the River Don for the benefit of fish will benefit a broad range of species (Abell, 2002). However, Haase *et al*. (2013) conducted a meta-analysis of 24 large river hydromorphological restoration projects in Germany and found that they benefited fish to a substantially greater extent than they benefited benthic invertebrates or plants suggesting that conserving the River Don for the benefit of fish may not yield expected benefits for other species. If Theme D articles continue to be dominated by fish in future this could reduce their value in generating public conservation for the River Don as a whole particularly given the extent to which fish communities have already been restored due to diminishing returns on investment (Murdoch *et al.*, 2007). The frequency with which the assumption that conserving ecosystems for umbrella species yields benefits for many other species is broken and the consequences of this was discussed by Roberge and Angelstam (2004). The only other species which were explicitly recognised to have benefited from the recovery of fish communities were charismatic mammal species such as seals and porpoises (The Guardian: 27th April 1989; Unspecified publication available from Sheffield Star Archives: 5th July 1995; 4th February 1999). Surprisingly fish were not explicitly recognised as a food source for freshwater mammals or birds. The role of anadromous fish as prey for both aquatic and terrestrial vertebrates is of such ecological importance that Willson and Halupka (1994) have classified them as keystone species. A keystone species is most commonly defined as one "*whose impact on its community or ecosystem is large, and disproportionately large relative to its abundance"* (Power *et al.*, 1996 cited in Cury *et al*., 2003).

All but three of the 26 Theme D articles which mentioned fish stated that fish communities were currently depleted or had recently recovered having been depleted or expressed concern that new threats would lead to their future depletion. The earliest article which recognised that fish populations were depleted was published in the late 19th century. It was written very poetically from the perspective of a hypothetical nymph which ruled the River Don. It stated: "*They* [the River Don's waters] *sparkled in the sunlight and circled in crystal eddies in pools dear to speckled trout or glancing minnows.*" (Sheffield Telegraph: 28th May 1872). By comparing the River Don in its reference conditions and current conditions it stressed the need for action to be taken to reduce the amount of sewage which was discharged into it. The first article to evidence the recovery of fish populations was published in 1976. It stated that the stretch of river from Deepcar to Hillsborough was "*on the threshold of being a fishery, supporting coarse fish and some trout"* (Sheffield Star: 30th June 1976). However, there was plenty of evidence in subsequent articles to evidence that the fish community was still very much depleted. In the 1980s four articles spoke positively about the fish communities whilst another said "*Nowadays anglers tend to avoid the Don – one of Britain's most polluted rivers"* (Unspecified publication available from Sheffield Star Archives: 23rd August 1985). The only two Theme D articles which reported that fish had died as a result of temporarily elevated pollutant concentrations were published in 1875 and 1984. The first incident involved sewage being flushed downstream by a flood (The Times: 23rd July 1875). The second reported a petrol spill (Unspecified publication available from Sheffield Star Archives: 14th December 1984). The response of fish communities to changes in the concentration of pollutants reflects their role as indicator species. The presence or absence of fish has been used to assess river quality in the UK since at least 1958 when the first river water quality survey was undertaken by the former Ministry of Housing and Local Government and since 1980 the quality of fisheries has been broadly considered in these assessments (National Water Council, 1980).

3.3.5.2.2 Mammals

Only two of the six Theme D articles which mentioned mammals mentioned freshwater mammals both of which were concerned about depleted otter populations, the remaining four mentioned marine mammals. Although the only freshwater mammals which were mentioned were otters it is possible that other freshwater mammals, particularly water vole, were mentioned in articles which were not included in the sample. An interview participant recognised that the River Don's water vole population had declined (Chapter Four). Furthermore, bats were mentioned in an article discussed in section 3.3.3.2 but as no efforts to manage the river's environmental quality were discussed in this article it was not a Theme D article. One of the Theme D articles reported that in a debate about otter hunting in parliament in the 1970s a local MP said "*But I would hope that we shall clean up the rivers and see more wildlife in them, but the otter will not be in them in this century or the next unless it is protected in the very near future"* (Sheffield Star: 10th July 1970). An angler who spotted an otter in the River Don in the 1990s said that he "*couldn't believe his eyes when an otter turned up in the River Don – once considered one of the most polluted rivers in the country"* thus providing anecdotal evidence of reduced pollution (1st November 1999). This was the only article which reasoned that the River Don should be conserved for the benefit of mammals. It is surprising that such little desire to conserve the River Don for the benefit of mammals was expressed in the newspaper articles, particularly as they were clearly perceived to be charismatic by the local people who were excited by their presence. The national plight of otter in the 1970s even made the front cover of the Daily Mirror (Purseglove, 1988)! Yamanoto and Ando (2011) expressed concern that otters being mentioned in fewer articles in Japan since their extirpation may reduce support for their restoration. Similarly the restoration of the River Don may benefit in future from greater media attention on charismatic mammals such as otter and water voles (*Arvicola amphibious*) which were previously abundant but are now depleted due to environmental degradation and the presence of non-indigenous species such as mink (*Neovision vision*) (Sheffield Local Biodiversity Action Partnership, n.d.). However, as discussed in section 3.3.3.4 caution should be taken when conserving ecosystems for the benefit of flagship species.

The marine mammals mentioned in the remaining articles were porpoises (The Guardian: 27th April 1989; The Times: 8th June 1983; Unspecified publication available from Sheffield Star Archives: 4th February, 1999) and seals, the species of which was not specified (The Guardian: 27th April 1989; Unspecified publication from Sheffield Star Archives: 5th July 1995; 4th February 1999). As an indication of the number of marine mammals which were observed in 1999 an article reported that "*In the past 10 years there have been a couple of porpoises and about 10 seals spotted around Doncaster"* (Unspecified publication available from Sheffield Star Archives: 4th February 1999). One porpoise was rescued and taken back to sea (Unspecified publication available from Sheffield Star Archives: 8th June, 1983). However, marine mammals were generally not the focus of conservation measures mentioned within the same articles though they did cause much excitement amongst those who saw them. For example, an angler who saw a seal said "*It was amazing and we couldn't believe our eyes, the seal came so close"* (Unspecified publication available from Sheffield Star Archives: 4th February, 1999). The article was classified as a Theme D article as it also discussed the benefits of reduced pollution for salmon.

3.3.5.2.3 Birds

In total only three Theme D articles mentioned birds. Two of these were published in the 1980s and one was published in the 2010s. They each had very different reasons for mentioning birds. The earliest simply reported that volunteers had been unable to undertake the practical conservation which they had planned as they found a duck (unspecified species) hatching five eggs (Unspecified publication available from Sheffield Star Archives: 1st June 1983).

The second reported a petrol spill which had killed birds (Unspecified publication available from Sheffield Star Archives: 14th December 1984). Images of birds dying as a result of such pollution incidents have the potential to foster opposition towards polluters thus adversely affecting their reputations which may ultimately affect their financial success (Lundgren and Olsson 2010; Morse, 2012). If historical information regarding a previous organisation's environmental violation is combined with information regarding its most recent environmental violation which is being reported this may increase the extent to which the organisation's reputation is damaged by the most recent event (Zou *et al*., 2015). Analysis of old newspaper articles is one way in which previous similar events may be identified for this purpose. They also have the potential to motivate people to volunteer to address the immediate problem. However, I have found no evidence to suggest that volunteers have been involved in addressing environmental pollution incidents on the River Don either through the newspaper articles or on websites of local voluntary groups which conserve the River Don such as DCRT (n.d.d), SPRITE (n.d.) and Friends of the Blue Loop (River Stewardship Company, n.d.). Their efforts are generally focused towards addressing long term problems. It is likely that individual pollution incidents have generally been small enough to be managed effectively by the polluters and the authorities and that volunteer contributions were unnecessary and would have put volunteers at unnecessary risk of harm due to the toxicity of the pollutants.

The most recent article reported that a local conservation volunteer group had received funding to restore the old course of the River Don and create an adjacent woodland area which they hoped would support reed warblers (*Acrocephalus scirpaceus*), kingfishers (*Alcedo atthis*), marsh harriers (*Circus aeruginosus*) and bearded tits (*Panurus biarmicus*) in the Fishlake area downstream of Doncaster (Unspecified publication available from Sheffield Star Archives: 15th March 2015). Golet *et al*., 2003 cited in Gardali *et al*., 2006) also recognised habitat creation for birds was an important motive for restoring riparian woodland. The potential benefits and problems with planning conservation to benefit flagship species are discussed in section 3.3.3.4. These species are frequently found in freshwater habitats (RSPB, 2016a; RSPB 2016b; RSPB 2016c; RSPB 2016d). This was the only article which was concerned about the depletion of bird populations. It is quite surprising that efforts to restore habitat for birds were not discussed in earlier articles as Vuorisalo *et al*. (2001) reported that great interest in feeding birds and constructing nest boxes was expressed in Finnish newspapers from the late 19th century onwards. Furthermore, by 1960 RSPB had 10,000 members, demonstrating that the British public valued the conservation of birds (RSPB 2016e). The Sheffield Local Biodiversity Action Partnership (n.d.) recognise that the River Don already provides valuable habitat for birds including some which are severely threatened on a national scale such as starlings (*Sturnus vulgaris*), song thrushes (*Turdus philomelos*) and house sparrows (*Passer domesticus*). However, they call for wildlife-friendly planting and bird boxes to help mitigate against the effects of flood damage and construction works (Sheffield Local Biodiversity Action Partnership n.d.). Greater media attention on depleted bird populations along the River Don could potentially play an important role in generating support for its restoration.

3.3.5.2.4 Plants

In total only five Theme D articles mentioned plants. None of them mentioned specific plant species (Sheffield Telegraph: 28th May 1872; unspecified date in 2008; Unspecified publication available from Sheffield Star Archives: 1st June 1983, 27th February 1990, 15th March 2015). Although it is possible that plants species were mentioned by name in other articles, it is clear that the majority of conservation articles were more concerned about animals and even those which mentioned plants were mostly concerned about the benefits which they provide to animals. A lack of public interest was evidenced by the expression of apathetic views in addition to the low number of articles in which plants were mentioned. One article reported that there was "*no evidence that wildlife other than vegetation was harmed*" by an oil spill (Unspecified publication available from Sheffield Star Archives: 27th February 1990). The lack of attention given to plants in the newspaper articles can be attributed to *plant-blindness*, a term coined by Wandersee and Schussler (1998 cited in Allen, 2003) which recognises that generally plants receive less attention from the public than animals. Though the difference in the proportion of articles which mention animals and plants may be exaggerated by the small sample size it is probable that fish were mentioned in a larger proportion of Theme D articles including those that weren't analysed than plants as this expectation is supported by both the sampled articles and theory. Allen (2003) recognised the role of plant blindness in reducing support for plant conservation and Wandersee and Schussler (1998 cited in Allen, 2003) recognised the role of environmental education which may include media attention in mitigating against this.

Negativistic attitudes were also expressed towards plants in conservation articles. Another article reported that "*a large amount of slurry and vegetation*" had been "*excavated*" as part of "*a massive clean-up of the River Don*" (Unspecified publication available from Sheffield Star Archives: 1st June 1983). People generally find ecologically valuable landscapes which look actively cared for more aesthetically pleasing than those that do not which can foster public support for their maintenance (Nassuaer, 1995). One way to make landscapes looked cared for is to prevent vegetation from overgrowing. This may be beneficial for the natural environment overall if it encourages more people to visit it and thus fosters support for its conservation (Haslam, 1997). As discussed in section 3.3.2.5 it may also reduce the risk of flooding thus reducing the need for environmentally harmful technocentric approaches to flood management. Despite the negative view towards plants no non-indigenous invasive plant species were mentioned in any of the conservation articles.

Despite the expression of apathetic and negativistic attitudes towards plants in some articles, their aesthetic and ecological value was recognised in others. The earliest article which mentioned plants conveyed the belief that they contributed to the beauty of the River Don's reference conditions. The poem within the article which was written from the perspective of a fictitious nymph which ruled the River Don stated "*The trees stooped down to kiss me*" (Sheffield Telegraph, 28th May 1872). However, it did not state whether or not they were still present or express any concern for their restoration explicitly. In the 1870s individual trees were viewed as an aesthetically pleasing aspect of the landscape by the upper class in Victorian England and thus helped to evoke a sense of nostalgia amongst the poem's readers (Lowenthal and Prince 1965). A sense of loss has the potential to foster support for restoration (Higgs, 2003; Hagerman, 2007; Higgs *et al*., 2014). Two recent articles recognised the ecological value of plants. One reported the aim to create a wetland/wildlife corridor (Sheffield Telegraph: unspecified date in 2008), the other woodland adjacent to the River Don which would provide habitat for many bird species as discussed in section 3.3.5.2.3 (Unspecified publication available from Sheffield Star Archives: 15th March 2015). The view that riparian plant communities should be restored for the benefit of a range of animal taxa including water voles (Barreto *et al*., 1998), fish (Lyons and Courtney, 1990; Hunter, 1991; Hunt, 1993 all cited in Lyons *et al*., 2000) and birds (Kus 1998; Loomis *et al*., 2000) has been expressed in many scientific papers. There was no clear evidence in these newspaper articles that plant communities had actually changed through time with the exception of the loss of adjacent woodland although recognition that wetland had been created strongly indicated that the plant community composition in the affected area would have changed substantially. Despite the relatively low levels of interest shown in the conservation of plants historically it is likely that conservation practitioners will put more emphasis on plant conservation in future as the European Water Framework Directive requires all restoration projects to assess plant community composition in order to receive funding (Haase *et al*., 2013). Furthermore, according to Sheffield Local Biodiversity Action Partnership (n.d.) there are already many patches of UK BAP priority habitat in the post-industrial landscape through which the River Don flows which support "*many nationally rare species, particularly invertebrates and plants, as well as several scarce and threatened open vegetation communities"*.

3.3.5.2.5 Other Wildlife

In total 13 Theme D articles mentioned wildlife without being more specific. None was published before the 1970s but they were published every decade from the 1970s onwards. Like the articles which described efforts to mitigate the effects of past and present human activities on fish, the majority of articles focused on the effects of pollution. Three articles expressed concern over the effects which general pollution was having on wildlife (Sheffield Star: 9th January 1970, 10th July 1970; The Guardian: 22nd March 1978). They were all published in the 1970s. This quote demonstrates how severely wildlife was portrayed by the media to have been affected by pollution: "*lifeless from its source in the South Pennines to its junction with the equally polluted Ouse"* (The Guardian: 22nd March 1978). None of these articles proposed physical action to address the issue though one proposed research was undertaken to inform the river's restoration (Sheffield Star: 9th January 1970).

The first evidence within the analysed Theme D articles that wildlife in general had benefited from reduced pollution was published in 1984, eight years after the first article which recognised that fish had benefited from reduced pollution, discussed in section 3.3.5.1.1 (Unspecified publication available from Sheffield Star Archives: 14th September 1984). The time lag may have simply been due to the relatively small proportion of published articles which were analysed. Three other articles which were published in the 1980s and 1990s recognised the extent to which the pollution had been abated and wildlife in general had benefited (Unspecified publication available from Sheffield Star Archives: 9th September 1987; 11th September 1997). One stated "*FIFTEEN to 20 years ago, the Don was nearly at the bottom of the country's water league table. Today the river is improving and supports an increasing variety of wildlife"* (Unspecified publication available from Sheffield Star Archives: 12th March 1987). Two articles, published in 1970 and 1997, specifically reported the effects of pollution from abandoned mines on general wildlife and discussed ways they planned to abate the pollution as discussed in section 3.3.5.1.1 (Unspecified publication available from Sheffield Star Archives: 26th May 1970; 13th March 1997). The only article which mentioned general wildlife in the context of a pollution incident simply stated that no wildlife other than plants was affected (Unspecified publication available from Sheffield Star Archives: 27th February 1990). Although it is relatively likely that articles which were not analysed mentioned the effects of pollution incidents on wildlife in general this conveys that the effects of persistent pollution received more media attention than the effects of individual incidents.

Only two analysed Theme D articles stated that general wildlife had been harmed by physical habitat degradation. Although it is relatively likely that some of the articles which were not analysed mentioned the effects of physical degradation on wildlife in general it is clear that the proportion of such articles is low relative to the proportion which mentioned the effects of pollution. The one which was published in 1970 simply recognised the need to restore the river's "*physical, chemical and biological purity"* (Sheffield Star: 9th January 1970). The other described the creation of a wetland as "*a combined wetland/wildlife corridor to serve local communities"*. There was very little recognition that people may benefit from seeing wildlife other than fish, mammals, birds and plants along the River Don. The only other article which suggested that local people would benefit from its presence was one which concerned the construction of the Five Weirs walk and stated "*The Don, which has seen a major clean-up is being projected as a home for wildlife and a base for fishermen"* (Unknown publication available from Sheffield Star Archives: 9th September 1987). The most recent Theme D article which mentioned general wildlife was published in 2013 and concerned the potential effects of HS2, a proposed high speed railway, with regards to habitat loss and fragmentation (Sheffield Telegraph: 31st January 2013). This project is discussed in section 3.3.5.2.4.

3.4 SUMMARY AND CONCLUSION

Previous environmental history studies which have analysed historical newspaper studies have focused largely on interactions between people and animals over relatively large geographical areas, ranging from cities to whole countries, and the pollution of rivers and mitigation against this. They have found that interactions between people and the natural environment have changed greatly through time particularly with regards to decreased persecution of animals and increased followed by decreased pollution of rivers, lakes and estuaries. This study took a more holistic approach to describe interactions between people and both the biological and abiotic components of a single river through time, as reported in historical newspaper articles. Such interactions included the way in which people derive benefits from the river or are adversely affected by it and the ways in which they act to preserve or enhance the river environment to maximise these benefits and minimise harm to local people and the local economy in addition to wildlife.

This study found that the ways in which the River Don was used and managed changed greatly in response to the interrelated effects of technological advancements, social and economic changes and legislation. The first social and economic benefits derived from the River Don were reported in newspaper articles published in the 19th century. This is a consequence of the lack of availability of earlier newspaper articles as the River Don has been used for defence and almost certainly other purposes since ancient times and the River Don has been used for hydropower at least since the 12th century (Walton, 1952; Hey, 1979). The newspaper articles provided evidence that in the 19th century industry benefited from the River Don in terms of: hydropower; water abstraction for steam power, cooling and other industrial processes; the removal of waste; and navigation. Industry's use of the River Don for these purposes decreased long before the deindustrialisation of South Yorkshire largely due to improvements in technology such as alternative power sources and the development of rail and road transport. This was demonstrated in the newspaper articles through reduced reporting of such uses of the river, increased reporting of the use of water from the river for the production of steam power and conflict between the navigation and the construction of railways. Efforts to reduce the extent to which the River Don was used for waste removal through legal action against polluters were first mentioned in an article published in 1870 but the first evidence that they had been successful was reported in 1976 and most likely to have been a result of the Rivers (Prevention of Pollution Act) 1961. It is relatively likely that the date of the earliest attempts to reduce pollution in the River Don were even earlier as only a relatively small proportion of newspaper articles were analysed. However, the 1870 article together with Firth's (1997) book make it clear that at least a century passed between the earliest attempts to reduce pollution in the River Don and a notable reduction in the extent of its pollution.

The newspaper articles also showed that the River Don has been used for recreation at least since 1839 and that its use for recreation increased greatly through time with the exception of its use for swimming, which showed a marked decrease. The quality of the recreational opportunities which the river affords improved greatly as the extent to which it was polluted decreased in recent decades and more effort has been made to manage the river for recreation, for example through the construction of the Five Weirs Walk in 2007 (BBC News, 2007). Although the River Don was valued for its heritage from the 19th century onwards its industrial heritage with the exception of demonstrating prestige of businesses which were currently trading has only been substantially valued from the 1980s onwards following the deindustrialisation of South Yorkshire which began in the late 1970s (Watts, 2004). Wildlife sightings were only viewed positively from the 1970s onwards as the extent to which the river was polluted began to decrease and wildlife began to return.

The newspaper articles also showed that the River Don has affected people and property adversely since the 18th century. It has directly affected people and property largely through flooding and accidental drowning. Surprisingly little damage was reported to have been caused by the species which lived in, on or by it. In addition to damage caused directly by the River Don it provided escape routes and a place to dispose of bodies for criminals. The number of deaths associated with the River Don decreased through time reflecting national trends in fatalities resulting from accidents and crime and improved flood warnings. Damage caused to property and infrastructure by severe floods showed no clear trend through time but no damage associated with the River Don when it was not in flood has been reported since the first half of the 20th century.

A further pattern that was evident in the newspaper articles was that much more effort has been made historically to reduce pollution than to reverse or mitigate against physical degradation. This seems to reflect historical conservation priorities which were greatly influenced by national policy and the extent to which ecological improvements in terms of the return and recovery of species could be achieved through reducing pollution despite the extent to which the river remained physically degraded. There was also evidence of taxonomic bias towards fish and to a much lesser extent birds and mammals. Several other studies have found that these taxonomic biases are prevalent in society. The lack of attention given to many taxa in recent newspaper articles suggests that environmental managers may increase support for their work in future by raising awareness of the need to reverse the River Don's legacy of environmental degradation for the benefit of these taxa.

Despite their biases this study found newspaper articles to be a valuable resource for describing interactions between people and the natural environment, with regards to the River Don, from the 19th century onwards. This includes historical changes in the ways in which people have: benefited from and been adversely affected by the river; degraded the river; and restored the river. Currently newspaper articles are an underutilised resource for this purpose. Environmental historians could thus benefit from taking a more holistic approach when using newspaper articles to describe historical interactions between people and the natural world than they have previously.

Useful inferences can be drawn from both identifying the themes which are reported frequently in the newspaper articles and the issues which received little attention. For example, it is interesting that the discharge of pollutants into the River Don received relatively little attention before the 1960s despite the severity of the social and environmental consequences and the extent of the economic benefits. It reflects the extent to which the problem was ignored by those with power in society. Furthermore, the decision not to market the waste removal opportunities provided by the river suggests that the factory owners were somewhat ashamed that they used the river in this way. When future studies identify important issues which have received little attention in sampled articles from particular time periods they are likely to benefit from conducting additional complementary research which focuses on the limited number of articles in which the issue has been mentioned. This would enable them to quantify the amount of media attention which they have received, describe how this has changed through time and qualitatively describe how the aspects of the issue and attitudes towards the issue have changed through time. The qualitative analysis may also help to explain why the topics received little attention in the newspaper articles.

This study also found that adverts published in old newspapers as well as newspaper articles convey useful information regarding how people benefited from aspects of the natural world in the past and how they perceived the natural world. In addition to describing the environmental history of different ecosystems and geographical areas it would be interesting to compare and contrast the ways in which the history of these different case studies has been conveyed in newspapers. This could help generate a greater understanding of the factors which drive the interactions between people and their local natural environment.

4 LOCAL PEOPLE'S HISTORICAL KNOWLEDGE OF THE RIVER DON AND IMPLICATIONS FOR THEIR CURRENT PERCEPTIONS, FUTURE PREDICTIONS AND SUPPORT FOR ITS RESTORATION

4.1 INTRODUCTION

4.1.1 The Importance of Public Perceptions in Environmental Management

Public perceptions of environmental management are key to its success. Wohl *et al*. (2005) stated that "*Societal perceptions and expectations of ecosystem performance ultimately determine whether restoration is a viable management option*." Many restoration projects depend on the support of local communities in terms of financial contributions and voluntary labour (Holl and Howarth, 2000; Gooch 2003; Fisher *et al*., 2012). However, projects with the aim of minimising human impacts on the natural environment can also be hindered or even stopped entirely by the opposition of local communities expressed through legal challenges, deliberate damage to restoration sites and even violence towards conservation practitioners (Born *et al*., 1998; Stoll-Kleemann, 2001; Stern 2008). Opposition towards restoration generally arises when the public prefer the *status quo* to the outcomes which environmental managers are working towards. For example, Stoll-Kleemann (2001) found that the desire to maintain landscapes which local people were accustomed to and valued fostered opposition against the creation of protected areas. Public sector projects often require trade-offs regarding the extent to which ecosystems are managed for the provision of different benefits to be balanced to maximise the extent to which the interests of those who use and value ecosystems for different often conflicting purposes and reasons are met (Coakes and Fenton, 1999). For example, the Bureau of Land Management resolved conflict over the effects of cyclists causing environmental degradation by camping over a large area in order to use a popular trail. First by increasing their understanding of the needs of cyclists and local people through public consultation; and secondly by charging cyclists to use the trail to generate funds for environmental conservation and creating a campsite near the trail and limiting camping to ecologically tolerant areas (Van de Wetering, 1996 and Reiter and Blahna, 2002 both cited in Keough and Blahna, 2006; Keough and Blahna, 2006).

4.1.2 Empirical Evidence of the Relationship between Historical Knowledge and Support for Restoration from Previous Studies

Knowledge of an ecosystem's previous less degraded state has been found to foster support for restoration projects, for example by motivating volunteers to provide the voluntary work on which many projects depend (Gooch, 2003; Drenthen, 2009; Cuerrier *et al*., 2015). The role of historical knowledge passed down through the generations is particularly important in fostering public action in support of restoring the natural environment in cultural keystone places (Cuerrier *et al*., 2015). Cuerrier *et al*. (2015) define these as "*A given site or location with high cultural salience for one or more groups of people and which plays, or has played in the past, an exceptional role in a people's cultural identity, as reflected in their day to day living, food production and other resource-based activities, land and resource management, language, stories, history, and social and ceremonial practices.*"

However, it is also recognised that substantial prior positive experience of degraded ecosystems, can lead local residents to develop a strong affinity with them and thus oppose restoration efforts. A sense of place is not acquired immediately when new residents move into an area, rather it is cultivated over time (Carr, 2002). Those who have established a stronger sense of place with a degraded but aesthetically pleasing landscape through time may be more resistant to change even if these changes restore it to a state more akin to its previous less degraded state (Drenthen, 2009).

According to Drenthen (2009) Dutch citizens opposed restoration measures to convert agricultural land into wetlands because they valued the old traditional agricultural landscape for which Holland is famous. Furthermore, Ostergen *et al*. (2008) concluded that rural residents were less supportive of forest thinning in America than urban residents because they were more familiar with dense forest, which they deemed to be aesthetically pleasing. Single incidents of poor applications of restoration techniques can influence public perceptions long after the event. This can prevent managers from implementing the technique with substantial environmental consequences. For example, following the severe 1988 wildfires in Yellowstone National Park public opposition greatly reduced the extent to which conservation practitioners were able to use prescribed fire as a restoration technique (Ostergen *et al*., 2008).

There has also been much study of the effects of a lack of historical knowledge on the public's perceptions of local environments. This has largely focused on the "*shifting baseline*" phenomenon which was coined by Pauly (1995). This phenomenon has been observed in a wide range of environments including: forest (Kai *et al*., 2014), a river catchment (Turvey *et al*., 2010) and a village (Papworth, 2007). It recognises that subsequent generations take their earliest experiences of the environment to be the baseline and evaluate the extent to which either the same or similar ecosystems which they experience later in life are degraded by comparing it to this (Papworth *et al*., 2009). In an ecosystem which has been increasingly degraded over a number of generations, each subsequent generation will consider an ecosystem in its current state to be less degraded and more natural than the previous generation would if they experienced the ecosystem in the same state. Although this information may partly be overcome through second hand information describing how the local environment was prior to their first experiences, this information is likely to be incomplete and include inaccuracies (Kahn, 2007).

As the shifting baselines phenomenon prevents communities from appreciating how degraded their local ecosystems are we may expect a loss of historical knowledge to reduce support for restoration (Pauly, 1995; Miller, 2005; Papworth *et al*., 2009). This is demonstrated well in the case of people's attitudes against the eradication of non-indigenous species which have been present for as long as they can remember. For example, Schüttler *et al.* (2011) reported that some Chilean residents who remembered beavers from childhood regarded them as belonging to them and were thus against their eradication. Schama (1995) observed that descriptions of landscapes passed down from generation to generation may lose accuracy over time to the extent that restoration goals are shaped by myths and stories of how a place used to be rather than factual information. This can greatly reduce the effectiveness of restoration projects. For example, local residents in Colorado aimed to return the Fork Gunnison River from a braided channel to a meandering single-thread channel as they believed this to be the river's natural state (Jaquette *et al*., 2005). However, geomorphological research later indicated that the river's natural state was most likely a braided channel. A consequence of the work was reduced bank stability which may be hazardous to local communities.

4.1.3 Likely Implications of the Broader Relationship between Historical Knowledge and Perceptions of Ecosystems for Fostering Support for Restoration

A strong sense of place can increase the extent to which individuals value their local landscapes (Gooch, 2003). This could potentially influence support for restoration in both directions as Kaltenborn (1998) found that those with a stronger sense of place were more willing to contribute towards the reversal and prevention of environmental degradation whilst Ostergen *et al.* (2008) and Drenthen (2009) found that those who had a strong sense of place for anthropogenically modified aesthetically pleasing landscapes were against ecological restoration towards their reference conditions. Here I use the term reference conditions to refer to an ecosystem's "*non-degraded natural baseline"* (Bennion *et al*., 2011). Williams and Stewart (1998) explicitly recognised that the historical context within which landscape users form meanings and values is a key dimension of sense of place. Furthermore, Hay (1998) found that feelings of place attachment increase with age but place attachments formed from childhood experiences are generally stronger than those formed later in life. The role of historical knowledge in strengthening a sense of place is not limited to personal experience of the landscape but can also be strengthened by historical information from books and oral histories including ancient history (Gooch 2003; Drenthen, 2009). To increase sense of place towards a particular landscape the historical information does not need to pertain to the particular landscape as it can also be strengthened by earlier experiences of similar landscapes in different geographical localities (Feldman, 1990).

Closely related to the concept of sense of place is the concept of nostalgia. Nostalgia is a sense of loss derived from viewing aspects of a historical landscape which are not held to the same extent by the present landscape favourably (Hagerman 2007; Higgs *et al.*, 2014). This can strengthen the desire to restore the landscape for which the individual has historical knowledge or similar landscapes in different geographical localities. Higgs (2003) recognises that restoration is underpinned by the belief that at least some aspects of a landscape were better in a previous state than they are now and thus worth re-establishing. This quote from McQuoid, one of Greening Australia's Bushcare Support coordinators, in Robertson *et al.* (2000) explicitly recognises the importance of nostalgia in fostering support for conservation "*Only the local people can really feel the loss because it's their place, and they want to get back something they have lost*". Gooch (2003) and Gomes (2012) both reported that local people were motivated to restore landscapes in part due to a sense of loss when they compared previous generations' experiences of landscapes with their own. Petts (2006) found that an older resident who had experiences of paddling in a brook in the West Midlands of England which had since been culverted would probably appreciate the section being de-culverted so that future generations could enjoy the same experience. Although not ecologically driven such a management action would have great environmental benefits (Wild *et al.*, 2011).

A wide range of landscapes are valued for their heritage including: agricultural landscapes (Lowenthal, 1991), industrial landscapes (Rudd and Davis, 1998) and waterways (Stewart *et al*., 2004). Historical knowledge of heritage landscapes increases the place attachment which local communities feel towards landscapes as well as their perceived educational value (Stewart *et al*. 2004; Drenthen, 2009). Increasing the extent to which landscapes are valued can increase the extent to which they are visited and ultimately the support for their restoration especially if some anthropogenic modifications are perceived negatively (Haslam 1997; Zedler and Leach, 1998). However, when communities value aspects of greatly anthropogenically modified landscapes for their heritage and conservation practitioners wish to restore the landscape to its more natural state, conflict can arise reducing support for restoration (Drenthen, 2009).

Furthermore, the effects of historical knowledge whether gained through personal experience or from secondary sources are not limited to their positive attributes. According to availability heuristics theory the perceived likelihood of future natural hazard events is positively influenced by the ease with which individuals can bring to mind examples of similar events (Tversky and Kahneman, 1982 cited in Keller *et al*., 2006). This has been empirically demonstrated to influence the perceived likelihood of future flooding (Siegrist and Gutscher, 2006; Botzen *et al*., 2009). The belief that a river is more likely to flood in future could potentially increase demand for the maintenance and enhancement of structural flood defences and dredging which destroy habitats, reduce habitat heterogeneity and reduce diversity and thus reduce the effectiveness of any actions which are undertaken with the aim of restoration (Hey, 1987 and Hey *et al*., 1990 both cited in Hey, 1994; Harvey and Wallerstein, 2009).

4.1.4 Education

Given the positive effects which historical knowledge can have in terms of engaging local communities in restoration, restoration projects may benefit from the dissemination of such information through environmental education. Grossinger (2001) advocated a collaborative approach between local citizens and experts in a variety of disciplines including local historians, scientists and archivists for the aggregation, interpretation and communication of local environmental history. From such a project in the San Francisco Bay area he concluded "*It may well be that you can only look ahead as far as you can look back. As citizens, resource managers, and policy makers become more comfortable with well-validated, locally grown pictures of landscape history, a shared understanding of present conditions and potential future scenarios becomes more possible, and a common vision of the future can emerge*."

Gomes (2012) reported on the success of an environmental restoration project on the Tl'chés Archipelago off South West Canada. The project involved the transmission of traditional ecological knowledge and wisdom from elderly community members to local young people and fostered a sense of environmental stewardship amongst the young who volunteered their time to various practical aspects of the project such as the eradication of NISs. Hanley *et al*. (2009) found that using text from primary accounts describing visitors' experiences of the Lake District National Park in England in the 18th century and maps describing vegetation land cover produced in the 18th and 19th centuries enabled participants to understand that the landscape had changed substantially in the past and thereby increased the extent to which they were open to the possibility of environmental managers making substantial differences to forest cover in the future. Furthermore, a social experiment conducted by Taylor and Daniel (1984) found that the provision of education materials regarding the long term effects of the use of prescribed fire as a restoration technique, increased support for its use in Arizona in the South West of America. Although Taylor and Daniel (1984) did not explain where they got the information from which they shared with the study participants, evidence from long term natural experiments has influenced public perceptions in this direction and scientists have used historical data to evaluate the long term effectiveness of prescribed fire as a restoration technique (Ostergen *et al*., 2008; Boer *et al.*, 2009).

A greater understanding of current public perceptions and the factors which shape them could help inform environmental education programmes which aim to influence the extent to which local communities support restoration projects (Carpenter *et al*., 1986). Public perceptions of urban river restoration are particularly important as rivers provide havens for wildlife within cities and thus give urban residents, many of whom lack first-hand experience of wildlife to experience it (Tapsell, 1995; Turner *et al*., 2004). Furthermore, because they provide such a wide range of ecosystem services it is important that the diverse needs of different stakeholder groups are taken into consideration when planning restoration projects (De Groot *et al*., 2010). The relationships between historical knowledge and support for conservation are likely to be complex and differ between stakeholder groups so it is important that education materials are tailored to their audience (Lodge and Matus, 2014).

4.1.5 Aims of this study

This study aims to assess the extent to which members of local walking groups are knowledgeable about the history of the River Don in South Yorkshire, establish how they acquire such historical knowledge and describe how their perceptions of its current state as a recreational resource and predictions about its future state are influenced by their historical knowledge. It encourages the participants to think about the history of the River Don very broadly including social, economic and environmental aspects from ancient times right through to deindustrialisation from both a positive and a negative perspective. Walking group participants were chosen because they have in common an interest in using outdoor spaces for walking, a key recreational activity for which the River Don is currently managed (The Five Weirs Walk Trust, 2015). This shared interest was hoped to narrow to an extent the range of other factors which are likely to influence participants' answers although I recognised that this would limit the extent to which the results could be generalised to the local population as a whole. They were also expected to differ substantially in a number of aspects which were likely to influence their historical knowledge and the ways in which they perceived the river. For example, it was expected that some would be much more interested in heritage and some would be much more interested in wildlife. They were also expected to have a wide range of levels of experience of the River Don. It was important that the knowledge and views of a wide range of participants were collected as this was likely to maximise the number of views held in the population which were recorded (Bryman, 2008).

This study took a grounded theory approach, setting out to answer broad questions rather than test specific hypotheses (Price, 1999 cited in Stoll-Kleemann , 2001; Stoll-Kleemann, 2001; Bryman, 2008). This approach minimises the effects of interviewers' preconceptions on the information which is collected from participants. More specifically it aimed to establish how knowledge of the history of the River Don in terms of how it benefited and harmed local people, the local economy and the natural environment from prehistoric times onwards, influenced their perceptions of it in its current state and predictions for its future. It also aimed to establish how the interview participants had learned about the history of the River Don. It was expected that answering these questions would have practical applications in terms of informing future environmental education efforts to foster support for and minimise opposition to the River Don's environmental management, and that broad conclusions may also similarly influence public environmental education with regards to other ecosystems. Semi-structured interviews were used to ensure that all of the broad points listed above were covered but interview participants also had the opportunity to share any knowledge and opinions they felt were relevant to each of the main points. Furthermore, the interviewer had the opportunity to use follow-on questions to maximise the likelihood that all points were addressed fully. The findings of this study will be discussed with regards to how historical information may be used to inform communications to foster support for and minimise opposition to the river's conservation.

The River Don was chosen as a case study as it has a long history of degradation, much work has been done on it recently to restore it for the benefit of people and wildlife, including the opening of the Five Weirs Walk in 2008, but it is still degraded and forms an important part of local heritage as evidenced by books, information boards and recent newspaper articles (The Five Weirs Walk Trust, 2015). It is particularly important to develop our understanding of how the perceptions of local landscapes of urban residents in developed countries are shaped by historical knowledge as more than 80% of residents in North and West Europe live in urban areas and the proportion is expected to continue to rise (United Nations Center for Human Settlement (HABITAT), 1996 and 2001 cited in Antrop, 2004; Antrop, 2004). Despite this, very limited anecdotal evidence describing the relationship between historical knowledge and perceptions of local residents on urban landscapes has been published in academic papers. Examples of such evidence are that: Petts (2006) reported that older residents had recalled paddling in a river section which could no longer be used for such purposes due to culverting as part of a discussion group to inform the restoration of the Upper Tame catchment in the West Midlands of the UK; and Mah (2010) reported that two residents remembered the smell emitted from a boneyard on the River Tyne in Newcastle. However, the vast majority of studies in which people have been interviewed about past landscapes have recruited participants with strong relationships with the land such as indigenous peoples (Showers and Malahleha, 1992; Stewart *et al.*, 2000) farmers (Riley and Harvey, 2007), conservation practitioners (Robertson and McGee, 2003) and conservation volunteers (Gill, 2005). Professionals who do not work on the land are likely to have less detailed knowledge of the historical landscapes but the implications of their limited knowledge on their support is still likely to have an important influence on the success of conservation projects (Robertson and McGee, 2003). The historical knowledge collected in these studies was also predominately about the ecosystems in their previous less degraded states. It can therefore be concluded that the role of historical knowledge in influencing urban residents' perceptions of the current and future states of local degraded ecosystems which have been partially restored has received very little attention. It is important that this knowledge gap is addressed because there are so many ecosystems which meet these criteria and their proximity to densely populated areas means that local people will play a huge role in shaping their future whether this is positive or negative (Bothmann *et al.*, 2006).

Local walkers' perceptions of the River Don are particularly likely to be influenced by their historical knowledge in a variety of ways as: it played an essential role in the development of Sheffield, particularly by powering heavy manufacturing industries, thus facilitating the growth of the city's famous steel industry; it has been extremely degraded chemically, biologically and physically but has been restored greatly over recent decades; a long history of flooding including the Great Sheffield Flood described by Sheffield Council as "*the greatest civilian disaster of Victorian Britain"* (Sheffield City Council, 2009); it is currently valued for its heritage; and much historical information is readily available to the public. For a more detailed description of the history of the River Don please see Chapter One of this thesis.

4.2 METHOD

4.2.1 Pilot interviews

Prior to conducting the interviews I conducted a series of five pilot interviews with personal friends and members of Friends of the Blue Loop, a community organisation which conserves a Sheffield centre section of the River Don (River Stewardship Company, 2016). This enabled me to test the effectiveness of the interview guide in eliciting the information which I aimed to collect, familiarise myself with the audio recording equipment and ensure that the audio recordings were audible over the background noise in a café environment.

4.2.2 Participant recruitment

The majority of participants were recruited by emails which were circulated by the leaders of local walking groups (Appendix B: B1). At the recruitment stage participants were simply told that I was interested in public perceptions of rivers in Sheffield as I did not want to risk the possibility that they would think too much or even research the history of the River Don in advance as this had the potential to modify their perceptions before the interview. However, as those who replied to the emails were mostly over 40 years old I recruited further participants at a social event which was organised by Sheffield 20s and 30s Walking Group, a walking group aimed at those between the ages of 20 and 40. In my quest to ensure that I collected responses from people who varied substantially in a range of relevant ways it was particularly important to interview people of a wide range of ages, as younger participants were expected to differ substantially from older participant in terms of: the extent to which they had experience of Britain prior to deindustrialisation; the way they perceive landscapes (Jorgensen and Anthopoulo, 2007) and how their worldviews influence the relative values which they assign to the economy and the natural environment (Abramson and Inglehart, 1992). I interviewed all those who volunteered to participate unless they later dropped out of the study. In total five of the recruited participants dropped out giving a total sample size of 23 interview participants. Four because they did not have enough time, and one due to difficult personal circumstances.

4.2.3 Interviews

All participants were given the choice of having their interviews conducted in a quiet local café of their choice or on University premises. On arrival participants were welcomed and asked to read a participant information sheet, and view a map of the Sheffield section of the River Don and complete and sign a consent form (Appendix B: B2 and B3 respectively).

Participants were asked a series of open questions. In consecutive order they were asked: 1) why they visit the river, the ways in which they use the River, who they visit it with and the frequency with which they visit it; 2) to describe the history of their use of the River Don including their first experience of it and when this was; 3) how they perceived the River Don today as a recreational resource; 4) how they perceived the River Don today from a positive and negative social, economic and environmental perspective; 5) how they expected the river to change over the next 25 years both positively and negatively; 6) to summarise their historical knowledge of the River Don from a positive and negative social, economic and environmental perspective; 7) where they got their historical information from; 8) how they thought their historical knowledge of the River Don affected their perceptions of its current state and predictions for its future. The skeletal interview structure which was used as a guide in all interviews is given in Appendix B: B4. All themes and subthemes were addressed in each question and follow-up questions were used to ensure that all participants were answering all questions as fully as possible.

Interspersed with these questions were Likert scale questions which asked participants to: rate the River Don as a recreational resource on a scale of one to ten (*current state rating*) (one being the worst possible rating); predict how the River Don would change over the next 25 years on a scale of one to ten (*future state rating*) (one being greatly deteriorate and ten being greatly improve); the extent to which they believed their current perceptions and future predictions regarding the River Don were influenced by their historical knowledge of it on a scale of one to ten, ten being the greatest extent; and to rate the extent to which they were confident in making each of these three judgements on a scale of one to five. At the end of the interview participants were asked to: rate their interest in environmental issues and local history on Likert scales from one to five, five being the most interested; state how long they had lived in the local area which was defined as South Yorkshire, Chesterfield and the Goole area; state their age category (<25, 25-39, 40-60 and 60+); and state their career or previous career if they were now retired. Interviews were transcribed by an independent transcription service (*Way With Words* http://waywithwords.net/) in standard format meaning that all words were transcribed but other aspects of speech such as hesitations were not.

4.2.4 Data analysis

Thematic analysis using a matrix-based framework strategy was used to qualitatively analyse the interview transcripts (Bryman, 2008). A spreadsheet was created for each of the following main topics: past, present, future, worst possible scenario, best possible scenario and use of historical knowledge. The first three spreadsheets were separated into the following subthemes: social positive, social negative, economic positive, economic negative, environmental positive, environmental negative and management. The same subthemes were used for the best and worst possible scenario spreadsheets with the exception of management. These subthemes were divided into smaller subthemes which were mentioned by several participants and *other*, for example: specific benefits derived from the river; types of environmental degradation; and management successes, failures and limitations. Table 1 shows how the use of historical knowledge spreadsheet was divided into subthemes and smaller subthemes.

Table 1: Subthemes and smaller subthemes for the historical knowledge spreadsheet.

Future predictions	Present views	Sources of historical knowledge
Trends	Heritage/Legacy	Books/written media
Reference conditions	Comparisons	Remnants
Constraints	Management Drivers	Information boards
Values	Constraints	People
Lessons from past management	Philosophical beliefs	Own experience
Other	Hypothesise about present	Place names
		Other ecosystems
		Other
		Comments against historical knowledge

Historical knowledge was measured by counting how many key issues each participant mentioned with regards to the history of the River Don (Historical knowledge score). The key issues were not predetermined and were derived from the interview transcripts. They were: stone age, preindustrial water usage, food, power, recreation pre-restoration, abstraction for industry or agriculture, street cleaning, fertile land due to river deposits, navigation, landmark for explorers, job creation, pollution, illness, segregated human communities, flooding, loss of wildlife, physical degradation, greatly altered course, risk of death or injury when not in flood, infrastructure costs, non-indigenous species, political activity and recent improvements. I believed this approach of counting issues to be less subjective than rating the extent of each participant's historical knowledge based on my overall impression following the interview.

All statistical analyses were performed in R v3.2.3 (R Core Team, 2015). Spearman rank correlations were used to assess the significance of relationships between historical knowledge, interest in local history and interest in environmental issues. They were also used to test the relationships between: historical knowledge, interest in local history, the extent to which participants believed their historical knowledge affected their current perceptions and future predictions regarding the state of the River Don and their confidence in making this judgement; historical knowledge, interest in local history and current and future state ratings and confidence in these ratings. ANOVA tests were used to assess differences in the knowledge and interests of participant of different ages and who had lived in the local area for different time periods (Table 2).

Table 2: ANOVAs regarding the effects of historical knowledge on participant's current perceptions and future predictions of the state of the River Don.

Explanatory variable	Response variable
Age	Historical knowledge score
	Interest in local history
	Interest in environmental issues
Time lived locally	Historical knowledge score
	Interest in local history
	Interest in environmental issues

4.3 RESULTS

4.3.1 Participants and their Use of the River Don

Twelve participants were over 65, six were between 40 and 65, five participants were under 40 and no participants were below 25 years old. Five of the participants had moved away from the area and returned later. Of those participants who had lived in the local area for a single block of time, five had lived there for more than 65 years, four for 40-65 years, five for 20 to 40 years and four for less than 20 years. The majority of participants held or had retired from professional careers. One had worked directly with the River Don as an ecologist for the EA, another had worked in a steel factory which used the River Don for waste disposal and cooling and another for a brewery which discharged warm water into the river.

Participants had undertaken a diverse range of activities on or by the river but by far, as would be expected given that they were all members of local walking groups, the most popular activity was walking. All 23 interview participants said that they had walked along the River Don. Ten of these had not participated in any other activities within the River Don corridor. Only two participants had been angling on the River Don. Some participants visited the River Don explicitly to engage with its natural environment. One visited for each of the following purposes: to learn about mycology on an informal course; investigate pollution as part of an informal course; investigate the 2007 flood out of interest; and to performing ecological surveys as an employee of the EA (Environment Agency). Two participants mentioned that they had driven past and one participant said that she used to look at the river from the balcony of her old apartment.

All participants had visited the River Don previously but there was great variation in the frequency with which they had. One had last visited several years ago whilst another visited it at least three times a week. However, 16 of the 23 interview participants stated that on average they visited the river between one and seven times per year. Participants visited the river with people who they were connected to in a diverse range of ways. 19 of the 23 participants stated that they had walked along the River Don as part of a walk organised by a walking group or other community organisation aiming to improve public health. One visited with a cycling group and one with a local history group. 11 of the 23 participants stated that they had visited the River Don alone and 11 stated that they had visited with friends whilst only six stated that they had visited with family members.

Participants chose to visit the River Don rather than other local green spaces to partake in such activities partly because it was easily accessible, flat and provided access to the countryside but also because of the opportunities it provided to engage with cultural heritage and wildlife. Those participants who were attracted to the River Don by its cultural heritage were largely attracted by its industrial archaeology, particularly its weirs and disused factory buildings. However, one participant was very interested in the river's Mesolithic history. Thirteen of the 23 participants were attracted by the aesthetic qualities of the environment including water, wildlife and variation within the landscape.

Ten of the 23 participants first visited the River Don during or before the 1980s and six had only visited since the Five Weirs walk had been opened in 2008. Six of the participants first visited the River Don as children. Four participants stated that they first visited the river when they moved to the area. One of these participants had moved within Sheffield and had previously been largely unaware of the River Don.

4.3.2 Participants' Historical Knowledge

The first aim of this study was to describe participants' knowledge of the River Don. All 23 participants communicated awareness that the River Don had been severely polluted and that its environment has improved recently (Figure 1). Between 18 and 20 participants communicated awareness of: the loss of wildlife due to the river's degradation; the previous use of the river to generate power; industrial abstraction; pre-industrial water usage; and the 2007 floods. Fewer than 18 but more than half of the participants communicated awareness of: the previous use of the River Don for navigation; the River Don as a food source; the use of the River Don for recreation prior to its restoration; and the potential of the River to have made people ill. Physical degradation was recognised by 11 of the 23 participants. Only four people recognised that the River Don had posed a threat to people in terms of injury or death when it was not in flood. Other ecosystem services and other ecosystem disservices were recognised by six and seven participants respectively. These categories are described in Table 3.

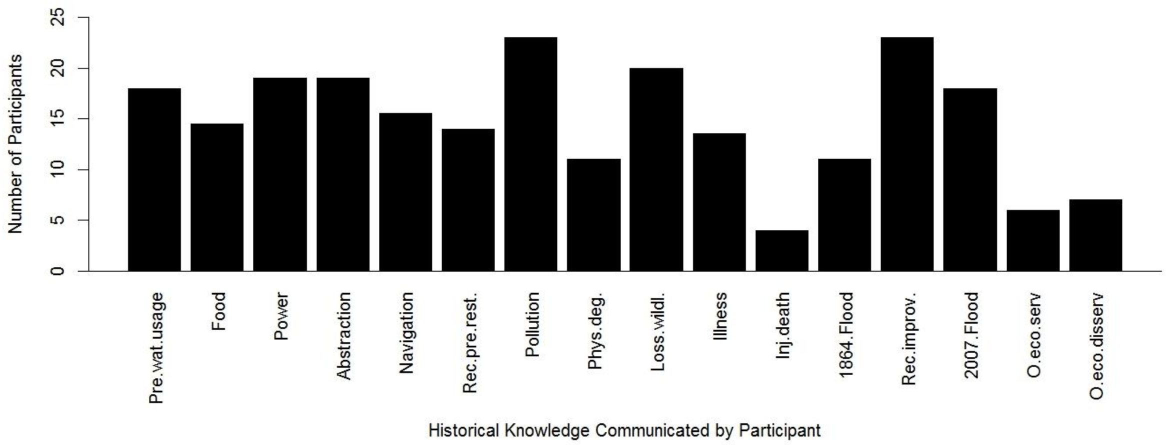


Figure 1. Content of historical knowledge communicated by participant. For more information on the information categories please see Table 3 below. Participants who stated that the River may have provided rather than did provide a particular ecosystem service or subjected people to a particular ecosystem disservice were counted as half a participant.

Table 3. Categories of participants' historical knowledge.

Category name abbreviation used in Figure 1	Category name	Description
Pre.wat.usage	Preindustrial water usage	All direct uses of water either in or abstracted from the River Don for domestic, agricultural and early industrial purposes prior to the industrial revolution.
Food	Food	Animals associated with the River Don which were consumed by people.
Power	Power	The use of the River Don to generate hydropower.
Abstraction	Abstraction	Water abstracted from the River Don for agricultural and industrial

		purposes since the industrial revolution.
Navigation	Navigation	The use of the River Don for the transport of resources, goods and people and explicit recognition that water from the River Don filled the canals.
Rec.pre.rest	Recreation prior to restoration	The use of the River Don and its banks for recreational activities before it was restored.
Pollution	Pollution	Awareness of the historical input of chemicals or energy into the river as a result of human actions which had adverse ecological effects.
Phys.degr	Physical degradation	Anthropogenic modifications to the river's physical environment which had adverse ecological effects.
Illness	Illness	Recognition that the river made people ill or had the potential to do so.
Inj.death	Injury or death	Recognition that people were at risk of or experienced injury or death as a result of the river when it was not in flood.
1864.Flood	1864 Flood	The Great Sheffield Flood which was caused by the bursting of the dam at Dale Dyke Reservoir.
Rec.improv	Recent improvements	Improvement of the River Don's environment and ability to provide ecosystem services.
2007.Flood	2007 Flood	The most recent time the river flooded with severe consequences.
O.eco.serv	Other ecosystem services	Any other benefits associated with the river historically. Included: use as a landmark by explorers, fertilisation of agricultural land, street cleaning, jobs and income derived from bridge crossings and its role in a Right to Roam protest.
O.eco.disserv	Other ecosystem disservices	Any other problems associated with the river historically. These included the river's role as a physical barrier which led to the segregation of communities and costs associated with bridge construction and maintenance; the role of world trade in the introduction of invasive species and degradation following the loss of industry. Although the historical presence of fig trees (*Ficus carica*) was not viewed negatively in itself

	such knowledge was included in this category because it was perceived to result from the river's pollution.

4.3.2.1 Pre-industrial period

Eighteen of the 23 participants identified ways in which water from the River Don was used prior to the development of heavy manufacturing industries (Figure 1). Such uses included: drinking, washing, bathing, agricultural irrigation, water for livestock and brewing. Demonstrating the perceived importance of these ecosystem services, one participant expressed the belief that a settlement had initially developed in the location now occupied by Sheffield as the River Don provided a water supply for drinking.

Fourteen participants stated that food had been obtained from the River Don in the past and an additional participant stated that they may have used salmon (*salmo salar*) from the river as a food source in the past. The place name Salmon Pastures and the well-known historical narrative of the apprentices complaining that they were fed too much salmon meant that participants knew more about the consumption of salmon than they did about other food sources. However, one participant stated that although she had heard that there used to be salmon in the river she found it hard to believe. Other foods which were believed to have been sourced from the River Don included: ducks, geese and unspecified fish, bird and animal species. One participant believed that the wetlands associated with the River Don had been used for hunting in the Stone Age.

One participant mentioned a Bronze Age canoe which he said was now in a museum which proved that it had been used for transport since ancient times. Another believed that it would have been a useful landmark for early explorers.

4.3.2.2 Industrial period

Whilst this section focuses on the use of the River from the start of the industrial revolution through to the deindustrialisation of Sheffield it also includes earlier industrial uses such as grinding corn which dates back to the early 13th century (Firth, 1997). Many recognised the historical social and economic importance of the river's contribution to industry. For example, one participant said:

"*it was very, very important to the rise of Sheffield and to the rise of a lot of steel processing."*

However, the social benefits derived from the River Don through its use in industry were questioned. For example, one participant said:

"*Well some people became very rich. Other people, the poorer people who were brought in to work on it, whether they actually benefited from working in industrial cities as opposed to labouring in the fields, I don't know*"

The most widely recognised industrial ecosystem service was abstraction. Nineteen of the 23 participants stated that water abstracted from the river had been historically used in manufacturing and/or agriculture (Figure 1). Participants identified a range of industrial processes which it was used for including: treating steel, cooling, cleaning machines, cleaning products, brewing and generating steam power. Within the agricultural sector water was identified as a resource both for irrigating crops and watering livestock. Eighteen of the 23 participants recognised that the River Don had powered industry in the past and an additional two participants stated that power may have been generated from it. Whilst participants mainly identified the role of power generated from the river in the steel and cutlery industries, they also identified its role in grinding corn and powering the textiles, paper, button, tobacco and soap manufacturing industries. Fourteen of the 23 participants state that the River Don had been used for navigation historically and a further three participants thought that the River Don may have been. Participants mainly recognised the river's role in transporting goods and resources for heavy manufacturing industries but some recognised that it was also used for transporting people and supplying water for the canal. However, one participant doubted that the River Don had been used for navigation due to the impoundments.

Fourteen of the 23 participants mentioned the River Don's use for recreation prior to its restoration following deindustrialisation (Figure 1). However, one participant explicitly stated that she did not think that the River had been used for recreation before the last ten years. Pollution was widely believed to have discouraged people from using it for recreation. Knowledge of the River Don's use for recreation during this time period generally came from personal experience and informal conversations with those who had had personal experience. Pre-restoration recreational activities which were mentioned included: swimming, raft races, angling, walking and boating. Whilst the pleasure experienced from engaging in such activities was recalled, participants' accounts whether first or second hand generally gave a negative impression of the river at the time, particularly with regards to pollution. For example, those who swam in the river and participated in raft races were perceived to have made somewhat foolish and risky decisions. However, the extent to which the pollution from industry would have impacted the recreational fishery was generally not explicitly recognised. One participant who had waded across the river as a child recognised the risk of drowning and injury due to submerged manmade objects. Legislation was also recognised by one participant whose march for the right to roam movement had included a section of the River Don. Few participants considered uses of the River Don for recreation prior to living memory. One participant believed that the land surrounding the lower section of the River Don had been drained to provide hunting grounds for aristocracy. Another thought that people would probably have bathed in the river in ancient times.

All 23 participants referred to the historical chemical pollution of the River Don in their interviews and most attributed this to the industrial revolution (Figure 1). Chemical pollution was largely blamed for the loss of wildlife and recreational opportunities. Industrial chemical pollution was recognised to a greater extent than domestic chemical pollution. It was recognised that the River Don was polluted long before the industrial revolution and one participant said that it had been an "*open sewer*" since the 1300s. Only those who had either worked within the organisations which were responsible for it or had done qualifications in environmental subjects mentioned heat pollution. The presence of fig trees was attributed to both domestic sewage and heat pollution. Some had experienced the pollution themselves and others had been told about first hand experiences of the pollution by older family members. Contemporary paintings were believed to give the impression that the industrial landscape was less polluted than it was. Participants had mixed views concerning whether or not the pollution was justified by the social and economic benefits the industrial revolution brought. Some believed that the environmental consequences of the growth of heavy manufacturing industries were justified because many were lifted out of poverty, others believed that the environmental degradation was not justified. One participant believed that such severe environmental degradation had only been allowed due to a lack of awareness which they attributed to a lack of scientific knowledge and equipment used to monitor environmental degradation such as microscopes and chromatography tools. Thirteen of the 23 participants believed that the polluted River Don would have historically made people ill. Another participant said that it may have done. Illness was attributed to pollution, water-borne diseases and vermin.

Only 11 participants recognised that the River Don had been physically degraded by people in the past (Figure 1). This did not include participants who were aware that weirs had been constructed on the river but did not consider their environmental impacts. A few participants believed impoundments blocked migratory pathways and fewer recognised that it reduced flow which may have caused sedimentation and fish to suffocate but also provided habitat for trout in reservoirs. Participants also considered the alteration of the river's course in terms of channelisation and culverting. One participant dated channelisation back to Saxon times. Some participants were aware of the work which Vermuyden had undertaken under the instruction of Charles I. However, their accounts differed from those obtained from more credible sources. Two participants expressed the belief that the lower section of the River Don, called the Dutch Canal was straight because it was used for navigation. One said that the land drainage had been commissioned by the king to provide better hunting opportunities and another believed it had been diverted from the Ouse to the Trent. Conversely Thirsk (1953) stated that the land was drained so it could be used to grow crops and (Firth 1997) stated that the river initially flowed into the Aire and Trent but since the work of Vermuyden flows into the River Ouse. Participants generally had little knowledge of the consequences of these changes for wildlife. However, one participant said "*A natural state, it wouldn't have any engineering and you'd have your oxbows you'd have your natural flood areas as well with beautiful meadows, teeming with dragonflies"* and *"The extreme engineering destroys available habitat. For example, water vole* [*Arvicola amphibius*] *like to burrow, birds like to nest in river banks. Trees can't take root in river banks if they've been engineered and straightened."*

Twenty of the 23 participants recognised that wildlife had been depleted in the past (Figure 1). Some recognised that salmon and otters (*Lutra lutra*) had been extirpated. They also stated that as the river became increasingly degraded populations of birds, chub (*Squalius cephalus*), barbel (*Barbus barbus*), trout (*Salmo trutta*), roach (*Rutilus rutilus*) and perch (*Perca fluviatis*) and dragonflies had declined in abundance, that plant and bird diversity had decreased and that there would have been less insect life. Some believed that in its worst state there were no fish in the River Don and one believed there was no wildlife at all in the 1950s and 1960s. Some participants believed that the animals which are viewed negatively such as rats (species unspecified) and pigeons (*Columba palumbus*) would have remained present. Other taxa believed to have survived when the river was most degraded included gulls (unspecified species), ducks (unspecified species), algae and insects. The latter two were believed to have been more resistant due to their lower trophic levels.

Although the Don Catchment has a long history of flooding and frequent flooding was recorded throughout the 19th century and first half of the 20th century (Chapter Three), flooding was not thought by participants to have been a serious problem during the industrial period (Firth, 1997; EA, 2010). Whilst a few participants recognised that the River Don was likely to have flooded during the height of industry other than in 1864 only one participant was aware that it had. He had worked at steel works adjacent to the river and had personal memories of regular floods. Participants also had relatively little knowledge of the history of flood management on the River Don. This is described in Chapter Three.

Participants were considered to be aware of the 1864 flood if they referred to a flood which had occurred around that time period or elucidated to its causes i.e. a dam burst. 11 of the 23 participants met these criteria (Figure 1). Identified social and economic costs included: human deaths, destruction of residential properties, damage to industrial premises and pubs and loss of livestock. The flood was also thought to have adversely affected wildlife in the short term through drowning and habitat destruction. Participants were aware of these floods from memorials, information boards and talks.

Only four of the 23 participants believed that the River Don posed a risk to local people historically in terms of injury or death not associated with flooding (Figure 1). These risks included drowning and injury from submerged objects due to fly tipping. Participants discussed this risk in a hypothetical sense. They were not aware of any specific incidents.

4.3.2.3 Post-industrial period

All 23 participants stated that the River Don had been improved since Sheffield's deindustrialisation (Figure 1). Participants recognised that pollution had greatly decreased, flooding had been better managed since the 2007 floods, bridges and footpaths had been constructed, a park had been created, vegetation was now actively managed and physical habitat heterogeneity had been increased through the installation of boulders. Reflecting the scale of the changes one participant said "*it has become a different river*". Participants recognised that wildlife was returning, recreational usage of the river had increased and the risk of future flooding had been reduced as a result of these improvements. One participant said that before the Five Weirs Walk was constructed access was so poor that "*it was very much a matter of seeing little sections going over bridges*" but now they can walk along long sections. However, participants still believed that additional work was needed and that the Five Weirs Walk had not been maintained as well as they would have hoped and had become vandalised. One participant recognised a period between deindustrialisation and restoration for which she described the River Don's landscape as "*depressing*". Another participant believed that the River Don had been better managed with regards to keeping it flowing for the benefit of industry before deindustrialisation but since deindustrialisation rubbish aggregated and increased the flood risk.

Despite records of the River Don flooding in Sheffield in 1990 (Chapter Three), the only flood since the loss of industry which was mentioned by participants was the 2007 flood. 18 of the 23 participants, including two who had moved to the area since 2007 were aware of this flood (Figure 1). Many participants had experienced the floods themselves and others shared accounts from friends, family and colleagues who had been affected. However, effects on participants and those they had spoken to were minimal. They had learned about the severity of the floods from third hand information which they described through terms such as "*unbelievable*", "*absolute mayhem*" and "*devastating*". Damage recognised by participants included: lost lives, damaged homes, damaged industrial premises, disruption to infrastructure including electricity, roads and bridges and damage to historical artefacts in Kelham Island museum. However, the floods were not viewed entirely negatively. One participant recalled his experiences of witnessing the floods with excitement. Several believed that the risk of flooding had been substantially decreased since 2007 through dredging and vegetation clearance. One argued that the only long term effects of the flood had been that the river had been cleared out a lot. Some were sad that trees had been lost as a result but believed that this was a necessary consequence of managing the flood risk.

4.3.2.4 Unspecified time period

Six participants shared historical knowledge on ecosystem services which could not clearly be placed into one of the time periods covered by sections 4.3.2.1 to 4.3.2.3 included: fertilising agricultural soils and street cleaning (Figure 1). Seven participants discussed ecosystem disservices without specifying a historical period. Two participants highlighted the risk of drowning when the river was not in flood. The river was also recognised as a physical barrier which segregated communities and necessitated the costly construction and maintenance of bridges. However, two participants expressed the belief that collecting tolls for their use would have also created jobs and generated income for some. Only one participant considered invasive species in a historical context. She attributed their increase to the growth of global trade.

4.3.2.5 Lack of historical knowledge

Participants generally knew relatively little about the River Don's reference conditions. Although many knew that salmon had been previously present and the river and its surrounding landscape were generally believed to be aesthetically pleasing, participants were unable to identify differences between the River Don and other rivers. This is likely to be largely due to a lack of knowledge amongst experts on the environmental history of the River Don. For example, although the historical presence of salmon in the River Don is culturally locally important and Firth (1997) described the river as "*once one of the country's finest salmon rivers*" this statement is ambiguous. Whilst there is plenty of evidence that salmon were once abundant in the River Don, Hendry and Cragg-Hine (2000) stated that "*Historically, the species was widely distributed in all countries whose rivers enter the North Atlantic"* and I was unable to find any evidence that salmon was more abundant on the River Don than it was in other rivers prior to their degradation (Mander, 1973; Firth, 1997). The presence of burbot (*Lota lota*) was more likely to be a feature of the River Don's reference conditions not shared with the majority of British rivers but this species was not mentioned by any of the participants (Firth, 1997; Davies *et al*., 2004).

Although eight participants were aware of the invasive non-indigenous species which are now present only one participant considered them in a historical context. She thought that Japanese Knotweed (*Fallopia Japonica*) may have been introduced to the UK in Victorian times. None was aware of the creation of floodplains or wetlands to attenuate flood waters although these are estimated to have reduced the risk of flooding in Doncaster from one every 40 years to one every 150 years (Firth, 1997). Though several participants referred to Sheffield Castle or associated place names such as Castlegate and Castle Market and one participant mentioned a Roman fort which overlooked the River Don no participants explicitly recognised the role of the River Don in affording defence.

4.3.3 Participants' Sources of Historical Information

Many participants expressed interest in seeing remnants in situ, particularly those associated with heavy manufacturing industries such as weirs and factory buildings (Table 4). Whilst many participants appreciated expert interpretations of these, one gained pleasure from interpreting them for herself. These stimulated the sharing of historical knowledge including personal experiences of working in the steel industry through informal conversations and were a focal point for tour guides, leaflets and information boards.

Many participants had acquired a substantial proportion of their historical knowledge from other people including friends, family and tour guides (Table 4). Many people had learned about the history of the industry along the banks of the River Don from other people but this information tended to be quite dry focusing on the purposes of the disused factory buildings rather than personal experiences of working there. To a lesser extent they had learned about the experiences which previous generations had had of the polluted river. This enabled them to describe it vividly. For example, one participant stated:

"*my Mum and Dad were at university in Sheffield and they did a Sheffield RAG race* [raft race to raise money for charity] *in the River Don and my Mum said it was the most disgusting thing. She was really ill afterwards and there were loads of dead cats because all the factories along the River Don used to have factory cats to help keep the mice populations down."*

Guided tours were also perceived as a relatively effortless way for adults to gain historical knowledge. The main limitations of verbal communications recognised by participants were: inaccuracies, boredom if tour guides tried to share too much information and only people from relatively small geographical areas i.e. regions within Sheffield spoke much informally about the history of the river. Much less emphasis was put on verbal communications out of situ but one participant recognised that recent developments in technology such as the digitalisation of old photographs may facilitate the communication of historical knowledge through presentations (Table 4).

Many participants were able to describe the River Don in its most degraded state using their own experience. For example, one participant said:

"*I can see it, what it used to be like in the 1950s, 1960s, and there'd be oil slicks on River Don. It were brown completely. Lifeless."*

Many participants learned about the history of the River Don from written information sources. On site information boards were also generally valued by participants because they gave participants the opportunity to learn about the history of the river during their visit without having done prior research (Table 4). However, there were also complaints that the information boards had been vandalised and one participant said that she would rather have a number system together with leaflets than too much street furniture. Leaflets were generally a tool which participants felt that they would value but several complained that they had been out of print for a long time and thus were very difficult to acquire. Participants appreciated both contemporary and recently published books. However, one participant complained that recent publications by historians are often too similar in content. Information on websites had the advantage of being easily accessible for participants. Place names, particularly Salmon Pastures were contextualised with the river's history, perhaps increasing the salience of relevant information held by participants.

Paintings may play an important role in promoting positive images of the River Don's reference conditions as they predate other publically available contemporary sources. For example, participants mentioned landscape paintings including pastoral scenes dating back to the 18th century. However, their reliability was questioned as they felt that artists had portrayed both pastoral and industrial landscapes to look better than they had in reality. Furthermore, only five out of 23 participants mentioned paintings in their interviews (Table 4). Ten participants had learned about the history of the River Don from museums and those who had visited with children believed that the exhibitions were enjoyed by both adults and children. However, the historical information which participants recalled was all quite dry, for example it described the uses of hydropower technology rather than the lives of the workers.

Table 4. Sources of historical information from which participants stated that they learned about the history of the River Don. Numbers in brackets indicate the total number of people who stated that they had learned from an information source in each category.

Category	**Source**	**Number of participants**	**Themes**
Remnants (20)	Buildings (mostly industrial buildings such as factories and mills but also a large house and a farmhouse)	18	Water power, domestic and agricultural land use
	Water power infrastructure (weirs, dams and waterwheels)	16	Water power
	Landscape modifications (e.g. the construction of reservoirs, the canal,	12	Ancient history, quarrying, defence, water power,

	goits, millraces and millponds; channelisation including great modifications in the lower section of the river; industrial land use; and an Iron Age fort and evidence of pre-Roman quarrying in the vicinity)		navigation and downstream channel modifications
	Bridges	3	Barrier
	Small objects (both in situ and in museums - grindstones, millstones, iron slag, tractors, bottles, Stone Age Flints and a Bronze age canoe).	3	Ancient history, navigation, water power and agricultural land use
	Living things (Fig tree, fossils and fragments of dry oakland)	2	Pollution and changes in land use
	Other (mine discharges, drainage pipes, ironwork that used to control the flow in the dams and a Victorian cemetery)	4	Pollution, water power and cultural land use
People (20)	Friends (note that they shared secondary information as well as personal experiences)	7	Industry, cooling, pollution and 2007 floods
	Walking group members (note that they shared secondary information as well as personal experiences)	7	Industry, recreation and pollution
	Tours	5	Industry, water power, pollution and fig trees
	Family (note that they shared secondary information as well as personal experiences)	4	Industry, pollution, low flow, waste removal, illness, cooling, recreation, industrial harm to wildlife and roman defence
	Talks	4	Industry, 1864 flood, breweries and street cleaning
	Colleagues (note that they shared secondary information as well as personal experiences)	2	Industry
	School	2	Industry, water

			power, steam power
	Other ("*People I know*", "*people who have worked in industry*", neighbours)	5	Industry
Own experience (18)	Participant's previous experiences	18	Recreation, industry, steam power, cooling, breweries, pollution, figs, flooding including 2007, restoration
	Employment (both in industry and the environmental sector)	3	Industry, cooling, steam power, pollution, flooding, restoration, wildlife, breweries, invasive NISs
	Recreation (Walking, angling, swimming, wading, raft race)	6	Recreation, pollution, loss of wildlife, restoration, flooding, illness, fly-tipping and vandalism
	Voluntary work	1	Restoration
Written publication (15)	Books (obtained from libraries and shops)	13	Industry, wildlife histories, 1864 flood and the formation of the river during the Ice Age.
	Leaflets (These have been out of print for a couple of years (Personal communication with Visitor Information Centre, 1st December 2015))	5	Industry
	Newspapers (Including articles available in the library)	4	River restoration
	Websites (Including Wikipedia but also online press)	4	General history. The current Wikipedia article includes: modification of the river's lower course, navigation, 1864 and 2007

			floods, water power, bridge construction, pollution and fig trees (Wikipedia, 2015).
	Contemporary (Tour of the Don by Holland 1837a and Holland 1837b), a George Orwell book, newspaper articles and natural history society journals, advertisement to communicate legislation)	4	Historical community composition, pollution, legislation on feeding too much salmon (*Salmo salar*) to apprentices.
	Other	1	One participant said: *the only documentation of any major flood is, you know, the 1865 flood*. It is not clear what type of document she was referring to.
On site written interpretation (12)	Information boards	12	Industry, water power and 1864 flood
Museums (10)	Kelham Island Museum	8	Industry and water power
	Abbeydale Industrial Hamlet	1	Industry
	Weston Park Museum	2	Not specified
	Not specified	1	Environmental degradation and restoration Ancient history and navigation
Place names (7)	Salmon pastures	5	Salmon fishery, loss of wildlife, pollution
	Attercliffe	1	Industry, channelisation,
	River Don Works	1	Industry
	Wharncliffe Crags	1	Pre-Roman corn grinding
	Other River Dons	1	Ancient history
Visual media (7)	Pictures including paintings (Art galleries, museum and library)	5	Industry, water power, pollution and agriculture
	Photographs (Online, books and talks)	3	Industry, 1864 flood and

			navigation
	Monument (1864 flood monument and cholera monument)	2	1864 flood and illness
	Maps (Online and in possession)	2	Industry, water power
	Sculpture (In situ)	1	Industry, salmon
	Flood markers	1	1864 flood
Other (3)	Radio	2	Not specified
	Television	2	Not specified

4.3.4 Historical Knowledge, Current Perceptions and Future Predictions: Quantitative Analysis

4.3.4.1 Historical knowledge, interest in local history and interest in environmental issues

This section aimed to describe the relationship between interest in local history, knowledge of the River Don's history and interest in environmental issues as positive relationships would suggest that interest in and knowledge of history fosters support for conservation to a greater extent than it fosters opposition against restoration and a negative relationship would suggest the reverse. On a scale of one to five 16 of the 23 participants rated their interest in local history as four or five, whilst only two participants ranked it as one or two (Figure 2). All participants had some knowledge of the history of the River Don, with the lowest historical knowledge score being six but there was much variation in the extent of historical knowledge held by participants with the highest score being 13. However, those who were more interested in local history were statistically significantly no more knowledgeable about the history of the River Don (Spearman's rank correlation: n=23, r_s=0.406 and p=0.055).

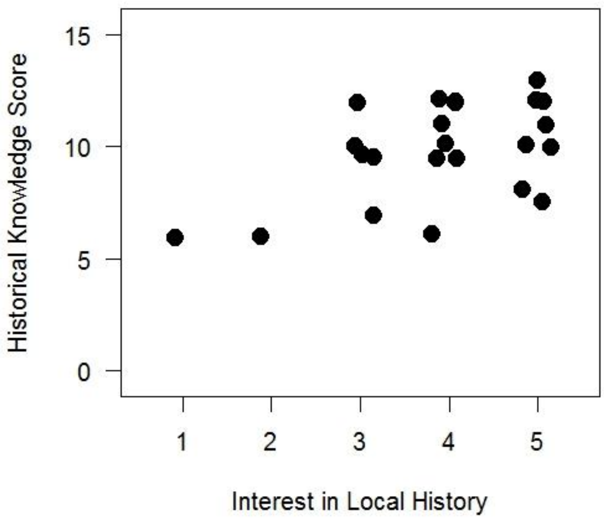


Figure 2. Interest in local history and extent of historical knowledge (n=23).

Conversely, participants who were more interested in local history were significantly more interested in environmental issues (Figure 3; Spearman's rank correlation: n=23, r_s=0.429 and p=0.041). However, the relationship was very weak with those who rated their interest in environmental issues as five on a scale of one to five rating their interest in local history from two to five.

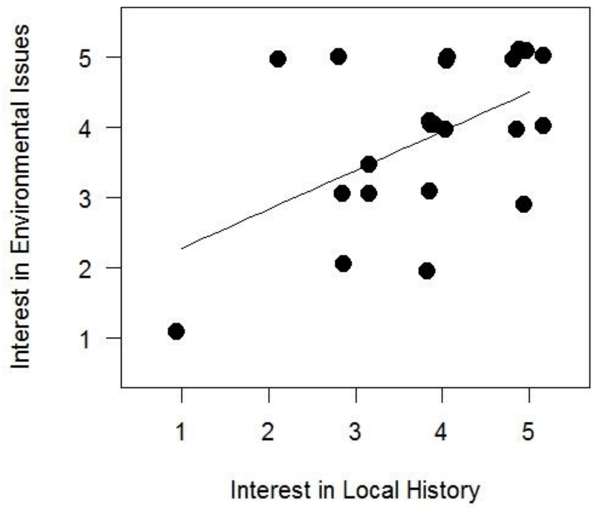


Figure 3. Participant interest in environmental issues and local history (n=23)

Despite this positive relationship no significant relationship was found between participant historical knowledge and interest in environmental issues (Figure 4; Spearman's rank correlation: n=23, r_s=0.120 and p=0.584).

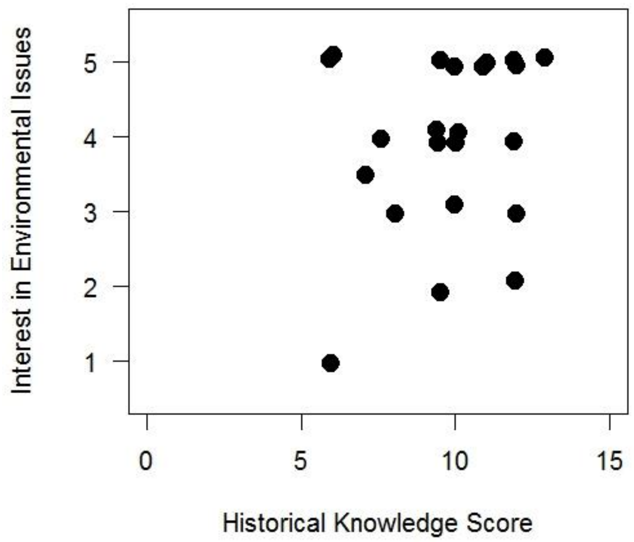


Figure 4. Participant historical knowledge and interest in environmental issues (n=23).

Given that older people have earlier personal experiences and those that have lived in the area longer have earlier local experiences I was concerned that any relationship between participants' historical knowledge, interest in local history and interest in environmental issues could be a spurious outcome of relationships between age, time lived locally and interest in environmental issues. However, participants of different ages did not differ significantly in terms of the extent of their historical knowledge on the River Don, their interest in local history or their interest in environmental issues (Figure 5; Table 5).

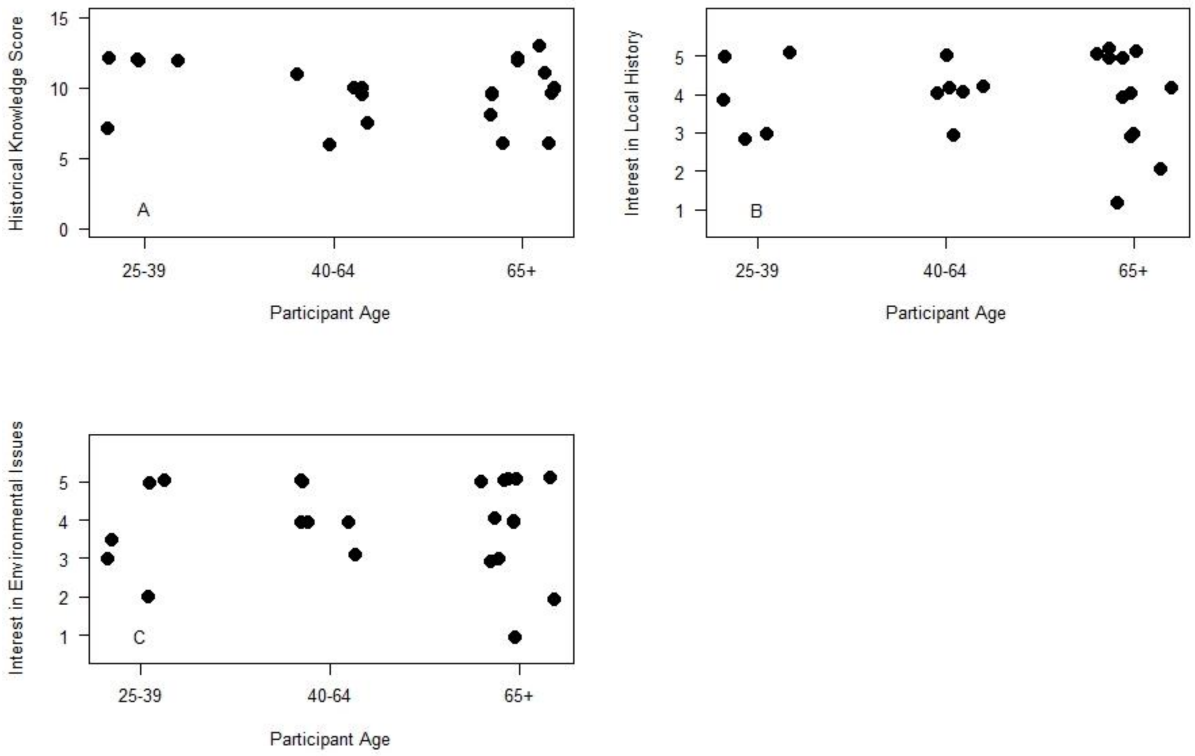


Figure 5. Extent of historical knowledge (A), interest in local history (B) and interest in environmental issues (C) by participant age (n=23: five 25-39, six 40-64 and twelve 65+ years old).

Table 5. Differences between participants of different ages in terms of their interests and knowledge (ANOVAs) (n=23: five 25-39, six 40-64 and twelve 65+ years old).

Variable	**DF**	**F**	**P**
Extent of historical knowledge on the River Don	2, 20	1.221	0.316
Interest in local history	2, 20	0.062	0.94
Interest in environmental issues	2, 20	0.231	0.795

There were no significant differences between participants who had lived in the local area for different time periods in terms of the extent of their historical knowledge on the River Don or their interests in local history or environmental issues (Figure 6, Table 6). Those who had moved away from the area then returned did not differ from those who had remained in the area with regards to these interests and the extent of their historical knowledge.

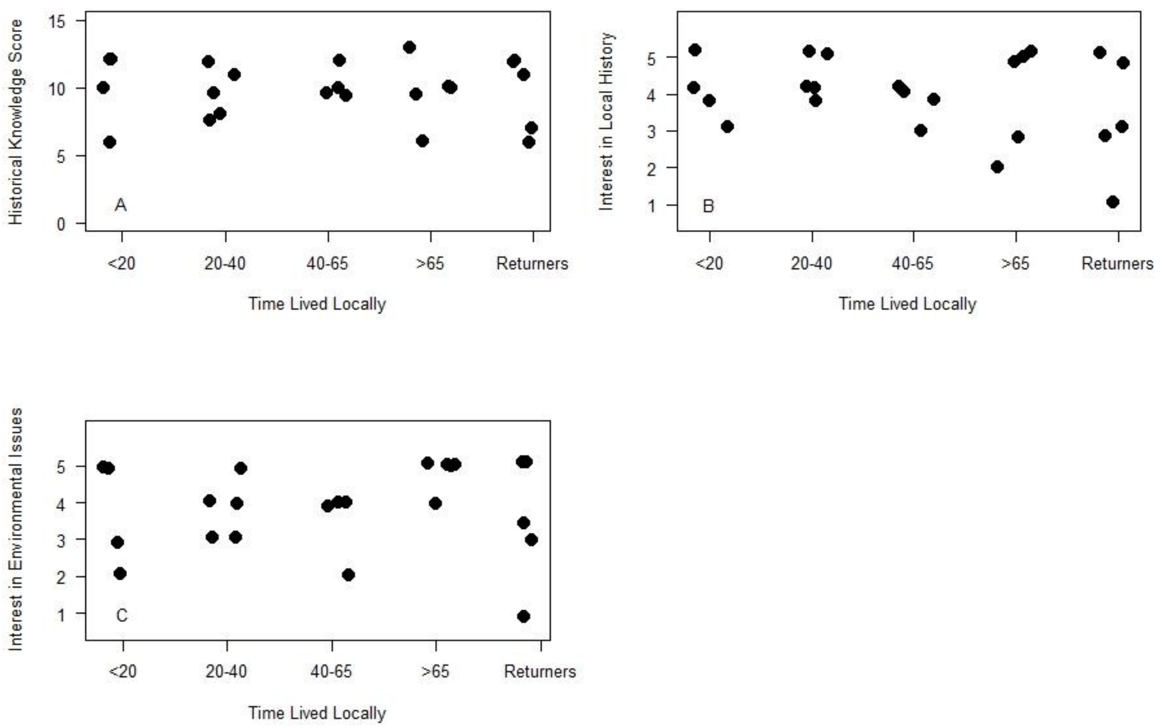


Figure 6. Interest in local history (A), extent of historical knowledge (B) and interest in environmental issues (C) by time lived locally (n=23: four <20, five 20-40, four 40-65 years, five >65 years and returners=five). The local area included the whole of South Yorkshire, the Goole area and Chesterfield. Returners were those who had lived in the area, moved away for a year or more and now currently reside in the area again.

Table 6. Differences between participants who had lived locally for different time periods in terms of their interests and knowledge (ANOVAs) (n=23: four <20, five 20-40, four 40-65 years, five >65 years and returners=five).

Variable	DF	F	P
Interest in local history	5, 17	0.407	0.837
Extent of historical knowledge on the River Don	5, 17	0.051	0.998
Interest in environmental issues	21,22	0.844	0.537

4.3.4.2 Participant perceptions of the effects of their historical knowledge on their current perceptions and future expectations of the River Don

Participants generally believed that their historical knowledge substantially affected their perceptions of the River Don as it is today and their expectations for its future (Figure 7). 17 of the 22 participants who answered the question rated the extent of the effect as seven or higher on a scale of one to ten. Participants were also generally confident in their ability to make such judgements with 17 out of 22 ranking their confidence at four or five on a scale of one to five. Participants who were more knowledgeable about the history of the River Don believed that their historical knowledge influenced their perception of its current state and predictions of its future state to a significantly greater extent (Spearman's rank correlation: n=22, r_s=0.534 and p=0.011; Figure 7A). However, interest in local history was not significantly related to the extent to which participants believed that their historical knowledge affected their perceptions of the River Don as it is today or as they expect it will be in the future (Spearman's rank correlation: n=22, r_s=0.306 and p=0.166; Figure 7B). Those participants who believed that historical knowledge had greater impact on their current perceptions and future expectations were highly significantly more confident in judging the extent of this relationship (Spearman's rank correlation: n=22, r_s=0.588 and p=0.004; Figure 7C).

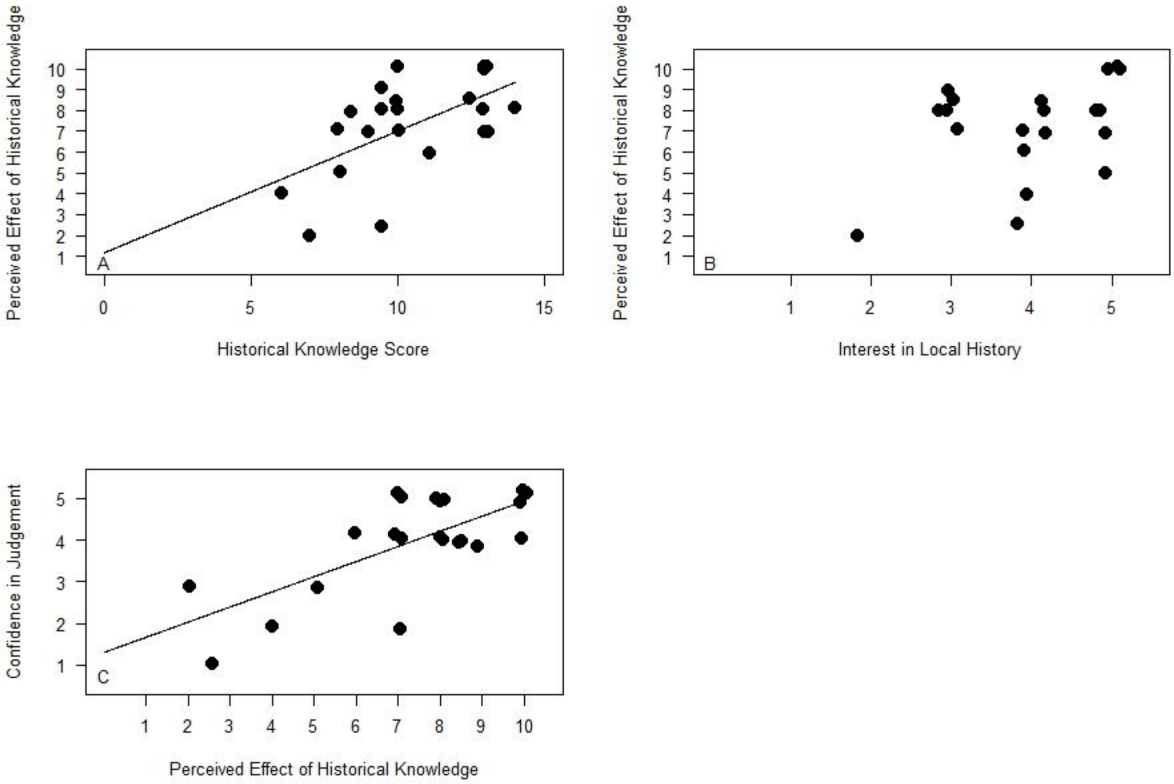


Figure 7. Extent to which participants perceived that their historical knowledge affects their current perceptions of the River Don as it is today by Historical Knowledge Score (A) and Interest in Local History (B). The extent to which participants believe that their perceptions of the River Don as it is today and expectations regarding its future are related and the extent to which they are confident in making this judgement (C).

4.3.4.3 Historical knowledge, interest in local history, current perceptions and future expectations of the River Don

Despite the extent to which participants believed that their current perceptions of and future predictions regarding the state of the River Don were influenced by their historical knowledge it was found that neither knowledge of the River Don's history nor interest in local history affected the extent to which people valued the River Don as a recreational resource or the extent and direction in which they expected it to change in the next 25 years (Figure 8 and Table 7). Historical knowledge and interest in local history also had no effect on the extent to which participants felt confident to make judgements about the River Don in its current state or predictions about its future state.

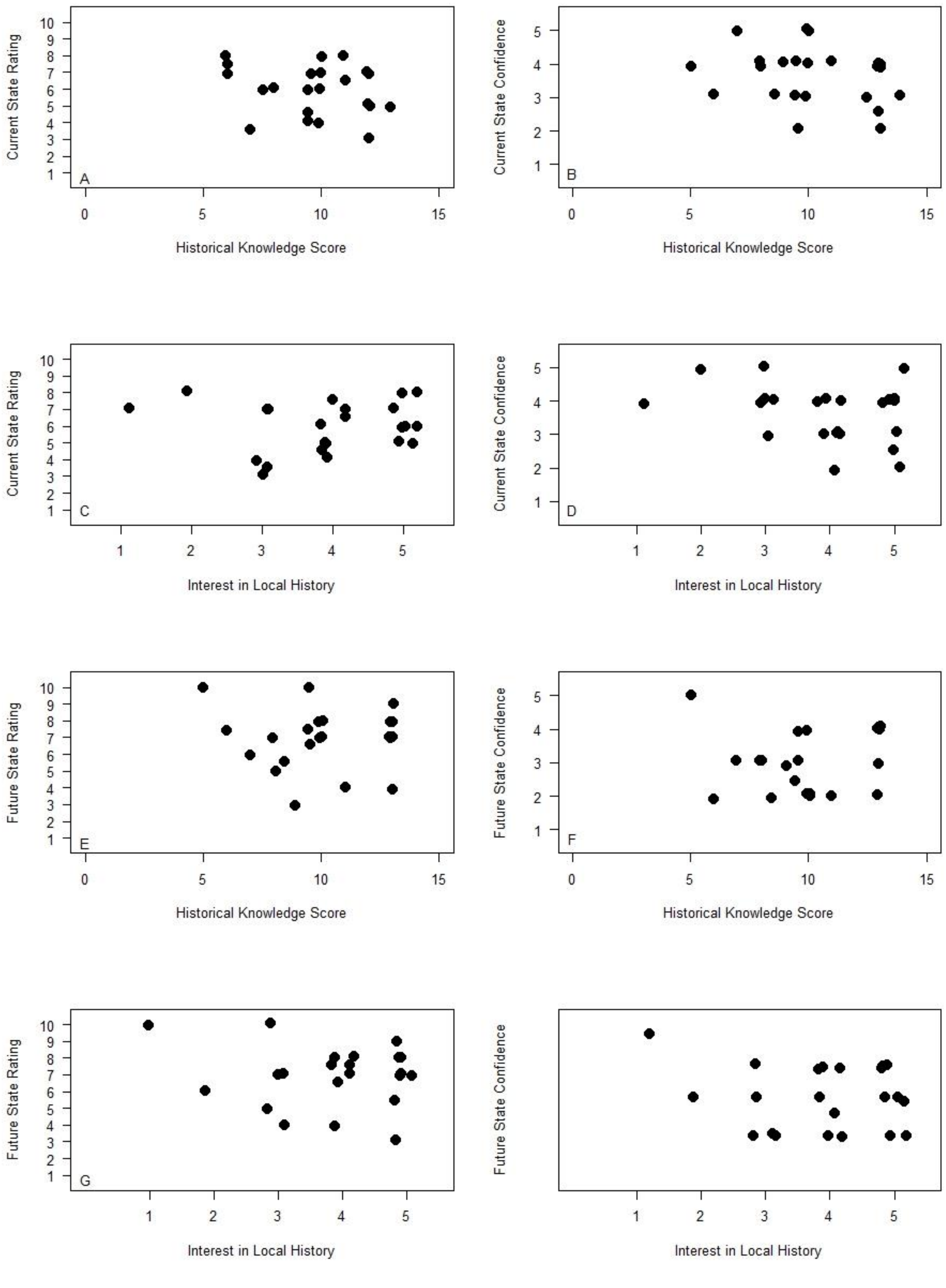


Figure 8. Current state rating and confidence in current state rating by historical knowledge score (AandB respectively) and interest in local history (CandD respectively). Future state rating and confidence in future state rating by historical knowledge score (EandF respectively) and interest in local history (GandH respectively).

Table 7. Spearman's rank correlations of relationships between participants' historical knowledge of the River Don and interest in local history and their perceptions of the River Don as it is today and their expectations for its future.

Variables	N	r_s	P
Current state rating and historical knowledge score	23	-0.207	0.343
Confidence in current state rating and historical knowledge	23	-0.233	0.285
Current state rating and interest in local history	23	0.100	0.650
Confidence in current state rating and interest in local history	23	-0.306	0.156
Future state rating and historical knowledge score	22	0.048	0.833
Confidence in future state rating and historical knowledge	22	0.169	0.454
Future state rating and interest in local history	22	0.005	0.982
Confidence in future state rating and interest in local history	22	0.031	0.893

4.3.5 Historical Knowledge, Current Perceptions and Future Predictions: Qualitative Analysis

4.3.5.1 Reference conditions as restoration goals

Generally knowledge of the River Don's reference conditions lacked any detail although it was well known that the river would have been less polluted and more diverse and that salmon would have been more abundant. Aesthetically it was thought to have been very attractive. Some participants believed that it had been highly valued in its reference conditions and thus expected that it would be valued more in the future as it became more similar to its reference conditions. Several participants expressed the belief that the River Don was becoming more similar to its reference conditions which they viewed positively. Some considered the landscape as a whole and believed that it was becoming more attractive and as the place name Salmon Pastures indicates that it "*should*" be. Others focused on the recovery of wildlife generally and more specifically: fish including salmon, trout, grayling (*Thymallus thymallus*), perch, pike (*Esox Lucius*), carp (*Cyprinus carpio*), roach, dace (*Leuciscus leuciscus*), chub and barbel (*Barbus barbus*); mammals especially otters; trees; waterfowl including kingfishers (*Alcedo atthis*), herons (*Ardea cinerea*) and unspecified species of ducks and geese.

Two additional participants expressed the hope that the river would become more like its previous less degraded state, without recognising that it had already changed in this direction. One was keen to see trout and salmon return and bird species including kingfishers (*Alcedo atthis*) and herons (*Ardea cinerea*) to increase in abundance. The other simply focused on the aesthetics of the landscape and the reduction of pollution.

Three participants expressed the belief that the river would regenerate itself naturally and thus require little active management. One said:

"*At the moment, I expect it would be really like nature would explore, so let the trees grow, you know. There wouldn't necessarily be much to improve if they let it return to how it should be.*"

Two participants expressed the view that even if taking certain management actions would improve ecosystem service provisioning, they would not want to see such actions taken if they changed it further from its natural state. For example, one participant suggested that dredging the river would be beneficial for boating but did not want it to be dredged if it was naturally shallow. Another participant said that she would like to see sea otters (*Enhydra lutis*) on the River Don but only if they had naturally been there historically. Overall there was a strong view that the River Don should be returned to its reference conditions. Only one participant expressed the concern that reversing past decisions to alter the course of the river may have detrimental consequences.

4.3.5.2 Appreciation and extrapolation of improvements

Participants used comparisons between the River Don as it is now and the River Don as it was prior to deindustrialisation to stress the importance of good management. They believed the comparison showed the effectiveness of good management whilst the previous severely degraded state showed the consequences of poor management. Evidence of good recent management fostered trust in future management. The contrast between the River Don's current state and its previous severely degraded state led some participants to value the river's current state more. For example, one participant said:

"*I can't possibly have any negative* [views] *about the Don because I grew up when it was heavily polluted and it's not anymore."*

Another participant expressed surprise at the aesthetic value of the River Don as her recent experiences contrasted with her preconceptions based on her historical knowledge. Another participant exaggerated the scale of the improvements by stating that the River Don was "*an old sewer"* but is now "*very, very clean"*. Conversely, another participant recognised that the state of the river may have improved more than she had realised as she did not know whether or not the water was still polluted. No participants expressed the belief that they expected the River Don in the future to be similar to how it was in its most degraded industrial state. One participant explicitly expressed the belief that as a society we had learned from our mistakes.

Eight participants expressed the hope that improvements which had already taken place would continue into the future. Such trends included: less pollution; the return of more wildlife including additional fish species such as salmon and coarse fish species which are not currently present; and greater accessibility including more path construction. Some participants recognised that the River Don had become increasingly valued in recent years particularly by grass roots organisations involved in its conservation which increased their optimism for its future management. Other participants expressed the hope that greater awareness would increase environmental stewardship.

Participants also recognised past drivers of management and expected that these would be important in driving future action. Historical information could also be used to predict under what circumstances management would take action. For example, one participant highlighted the role of the 2007 floods in driving recent improvements to the River Don and reasoned that future funding would only increase substantially if another flood occurred.

4.3.5.3 Constraints from past environmental degradation

Seven participants reasoned that the past usage of the River Don reduced its ability to provide ecosystem services today. These included the impact of pollution and submerged objects on recreation such as boating and swimming; the weirs on boating; buildings on access; the establishment of Japanese knotweed on property development; and the removal of industrial remnants on heritage.

Reversing some of these changes was perceived to be feasible but expensive and time consuming. For example, one participant believed that it may be too expensive to replace derelict sites with green spaces. Some changes were valued despite their adverse effects on ecosystem service provisioning. For example, one participant recognised the effects of the weirs on boating but believed that they should be maintained for their heritage value. Fully restoring the River Don was not perceived to be possible. For example, one participant reasoned:

"You'll never get back to how it was because the building that's going on and the size of the city from a few thousand to half a million so that in itself and the whole gambit of South Yorkshire right through to the confluence of Goole would be that the River will never be the same as it used to be"

Another participant more specifically believed that it would not be possible to reverse engineer the river back to its original meandering channel.

Other participants did not recognise that the river's past usage was likely to affect its future. One participant made this point generally and another believed that the weirs had eroded to an extent that they are no longer a barrier to migratory species.

4.3.5.4 Recognition of what has been lost and extrapolation of recent degradation into the future

Although generally changes on the River Don over the last few decades were viewed positively some participants lamented the loss of industry and recent loss of particular charismatic species and were concerned that in some ways the River Don's natural environment had become more degraded in recent years. The loss of industrial remnants such as water wheels was lamented. Participants were also sad to see the more recent loss of grandeur as industrial buildings were abandoned and became derelict and vandalised. However, others recognised that the River Don had always been valued historically albeit for very different reasons and thus expected it to be valued highly in the future. One participant recognised that society could benefit from harnessing the river's energy in the future as industry had in the past. He saw this as a way to reduce society's dependence on fossil fuels.

Recent changes to the River Don's environment or management which participants viewed negatively led three to predict that certain aspects of the environment would deteriorate in future. One participant saw that the Five Weirs Walk which had been vandalised was on a trajectory of degradation. Concerns over invasive species such as Japanese knotweed and Himalayan balsam (*Impatiens glandulifera*) having increasingly severe ecological impacts were also voiced. One was concerned about the loss of many plants as a result of the increased abundance of Japanese knotweed. Another identified a decline in certain charismatic species such as dippers (*Cinclus cinclus*) and water voles (*Arvicola amphibius*) on the River Don since her childhood. There was also a general concern that improvements had slowed and would remain slow in the future. However, participants were also able to appreciate that losses could be compensated. For example, one participant accepted that although the islands which he had valued had been lost this was necessary to manage the flood risk and other features had been created to maximise biodiversity.

Overall a lack of recent management was viewed as evidence that the River Don had not been valued highly enough in the very recent past, increasing concerns that it would not be managed well in the future especially as financial resources were increasingly limited. A lack of action to manage the River Don since the construction of the Five Weirs Walk has reduced participants' faith that action to improve or even just maintain the current landscape will be taken in future. Similarly discrepancies between publicised management plans and recent changes which have been seen have also reduced the extent to which some participants trust management. Past management decisions which participants believed to have been unwise also left a legacy of mistrust. For example, one participant expressed the belief that if the council had a lot of money they would waste it as they believed that decorative infrastructure on the Five Weirs Walk had been a waste of money. For example, one participant said that some plans which had been announced at least ten years ago had still not been implemented. It was expected that the river and adjacent land would deteriorate in terms of: overgrowing vegetation, degradation of man-made structures such as paths and bridges and reduced accessibility.

4.3.5.5 Historical knowledge and heritage value

18 participants stated that they valued the River's heritage and an additional three participants, whilst not valuing the heritage highly themselves recognised that it was of value to others. Of the 18 participants who valued the River's heritage ten expressed how they believed that it had an important role in Sheffield's identity. This was mainly attributed to its role in the development of Sheffield's heavy manufacturing industries. One explained that this was important to him because he had grown up in Sheffield. However, a participant who had moved to the area welcomed the opportunity to learn about Sheffield's history and the river's role within that. Another participant was particularly interested in the River Don's heritage because he could see similarities with the river in a city in Germany with a history of steel manufacturing in which he had grown up. One participant believed that because the river is valued by local people for its heritage it will continue to be valued and actively managed in future.

Whilst the majority considered industrial heritage some considered earlier heritage. Only one participant considered the River Don from the perspective of his ancestors. He reasoned that very few people who live in Sheffield now had ancestors in the area before the rapid population growth facilitated by the industrial revolution. Whilst the majority of participants limited their considerations of the river's industrial heritage, three referred to old bridges. Two appreciated them for their aesthetic value whilst one simply saw the presence of an old bridge as evidence of past human contact with the river arguing that it is impossible to miss remnants of the river's history. Another participant believed that even modern bridges should reflect the river's heritage suggesting that they should be made out of steel. He believed a wooden medieval style bridge would look out of place.

Only four participants highlighted the need for managers to preserve the River Don's heritage. One was concerned that too much heritage, particularly waterwheels, had already been lost in the past and another was concerned that enough was not being done to preserve the existing historical remnants. Two accepted that there would be a trade-off between managing the river for its heritage value and managing the river for wildlife and believed that it was worth compromising nature conservation for heritage conservation. One considered the option of completely re-naturalising it and reasoned:

"*I think that would be a mistake because then this really important, yes it's really important meaning for history and identity would get lost. And I think that would be wrong"*

There was also a clear demand for the River Don's heritage to be interpreted for the benefit of the public. This is reflected in the extent to which participants had engaged with a wide range of information sources to further their understanding of the River Don but also in the extent to which people recognised the need for others to learn from information regarding the history of the river. Nine participants highlighted the importance of communicating the river's heritage to others. Of these six commented positively on what managers were already doing, particularly with regards to information boards, whilst three highlighted the need for more to be done. Many participants wanted to improve their own knowledge of the river's history. Another stressed the need to go into schools to teach children about the river's heritage and wildlife.

4.3.5.6 Historical flooding and future risk

Participants expressed the attitude that if it has happened before it could happen again. For example, one participant was only aware of the 1864 and 2007 floods but believed they collectively indicated that the river could flood again with grave consequences. Another viewed the 2007 floods as evidence that the river is not as well tamed as is often believed. However, the extent of past flooding was not always viewed as a predictor of future flooding. Three participants reasoned that the River Don had flooded in 2007 because it had not been adequately managed but were confident that it was now much better managed as a result and thus posed a low level of threat. One participant who recognised that flooding was quite frequent in the past believed it to be worse then than it is now, whilst another participant who believed that it had not flooded much in the past believed that it was more likely to flood in the future due to climate change.

4.3.5.7 Use of historical knowledge not specific to the River Don for understanding its current state and predicting its future

Participants generally believed that the river's reference conditions were similar to those of other rivers to the extent that they struggled to identify any ways in which the River Don would have been different to other British rivers before it was degraded. Some participants believed that the pollution of the River Don at the height of industry was similar to that of other rivers. One explicitly said:

"*Everybody tipped their effluence into the river, but that's what everybody did everywhere, there wasn't anything unique about the Don in that respect, I don't think."*

Similarly, others recognised the decline of water vole and hedgehog (*Erinaceus europaeus*) populations as a national rather than a local phenomenon.

When participants did contrast the history of the River Don to that of other rivers their comparisons were largely negative. For example, one said that there were fish in other rivers but not in the River Don. Another said:

"*I think George Orwell wrote about [inaudible] in the 19th century, or was it 19th century? I think so, when industry was full on and he described Sheffield and the rivers as the most polluted, most toxic rivers in the world."*

When participants lacked historical knowledge specific to the River Don they used their knowledge of other rivers to inform their speculations on the history of the River Don. For example, one participant explicitly stated that his understanding of the history of the River Don was drawn from his knowledge of the history of industrial rivers in general rather than historical knowledge specific to the River Don. Another said that she knew that some of the five rivers in Sheffield had powered industry but she was not sure whether or not the River Don had done. Another was aware that an acquaintance's father had been fishing on a different river decades ago and thus suggested that the River Don may have been used for this purpose. Another reflected on her experiences of living in London where communities were greatly segregated by the River Thames and suggested that this may have applied to the River Don.

Without knowledge of the history of the fauna and flora within the UK as a whole it would not be possible to identify non-indigenous species. Participants who discussed the fig trees generally expressed a positive interest although they knew that they were indicative of previous pollution. However, some participants were particularly concerned about the adverse environmental impacts of invasive species particularly Himalayan Balsam and Japanese Knotweed and believed that they would be greater in future.

Another environmental threat to the River Don which required historical knowledge to identify is climate change. Participants expected that due to climate change there would be: an increase in the risk of flooding; an increase in the number of invasive species living on the River Don; an increase in the abundance of algae; and a decrease in the abundances of some species. Another participant recognised that climate change may increase the likelihood of the River Don being used to generate energy in the future. One participant indicated that perceptions of environmental impacts on a local scale may have been less concerning to local people at the time as they did not have the context of today's global environmental problems.

Industrialisation and deindustrialisation were seen generally by participants to be the greatest socio-economic drivers of environmental change both on the River Don and on a national scale. Industrialisation was believed to have been driven by the desire to make money and participants believed that environmental impacts were not considered. Participants believed that active management of the River Don's natural environment was a response to deindustrialisation and national legislation. One believed there was not really any legislation preventing the discharge of industrial effluents into the river before the 1980s. Participants also attributed changing attitudes towards the management of the River Don to greater scientific knowledge, greater awareness of the importance of managing the natural environment for ecosystem service provisioning and what they saw as the global environmental crisis. One participant also recognised the role of shareholders in incentivising companies to act in a more environmentally responsible manner. Overall it was recognised that both on a local and national scale society cared for the natural environment much more than they had when heavy manufacturing was at its peak both in terms of attitudes and practical actions and participants strongly believed that the River Don would never be as degraded in the future as it had been prior to the deindustrialisation of Britain.

However, several participants were concerned that the trend towards greater care for the natural environment had reversed in recent years. They extrapolated this trend into the future and expressed concern that the economic recession coupled with the reduced extent they believed society and politicians to value the natural environment would reduce the extent to which the river was managed in the future. One explicitly stated that it was not the organisations which manage the environment such as Natural England which were to blame for reduced management but the government which funded their work. Another stated that previously organisations had been incentivised by consumers and shareholders to do more for the natural environment than was legislatively required but that the economic recession had increased demand for bargains at the expense of the natural environment.

Although the River Don's recent lack of management was largely attributed to the economic recession, looking 25 years into the future participants were generally not confident that financial investment into the River Don's management would improve. One explicitly viewed the costs of an aging population as a factor which would substantially reduce the amount of funding available for environmental management. One believed that because Sheffield had never promoted itself well to tourists and because it benefits from having the Peak District so close the council would not be incentivised to manage the River Don as a tourist attraction in future. However, another participant anticipated that in future more power would be devolved to local councils and Sheffield council would view management of the natural environment as a high priority. One participant argued that local people would not have much say in the future management of the River Don because he believed most decisions were made at EU level. Conversely, one participant explained that they did not trust the council to implement its plans to improve access to the area surrounding the site of Sheffield Castle which would increase usage of the River Don because they had a reputation of not meeting their promises. They used a completely unrelated example of a shopping centre which had been discussed years ago but had never opened to support their point.

4.4 DISCUSSION

4.4.1 How Can Historical Knowledge Foster Support for Environmental Management?

This study found a significant positive relationship between interest in local history and interest in environmental issues. However, this relationship was very weak and it was not clear whether interest in local history fosters interest in environmental issues or whether they are both simply correlates of a third variable. For example, people who score highly on the openness personality trait are likely to be interested in many aspects of the world around them which may include both local history and environmental issues (McCrae, 1996). This study found no significant relationship between historical knowledge of the River Don and interest in environmental issues. However, it found a large amount of qualitative evidence to suggest that historical knowledge affected perceptions of the River Don as it is today and expectations of how it will change over the next 25 years mostly in ways which are likely to foster support for environmental management but to a much lesser extent in ways which are likely to reduce support for conservation. The lack of a significant relationship between historical knowledge and interest in environmental issues may be due to asking participants broadly about their interest in environmental issues rather than specifically about their concern for the River Don's future from an environmental perspective.

The majority of participants strongly believed that their historical knowledge influenced the way they viewed the River Don as it is today and their expectations regarding its future state. Those who believed that their historical knowledge had a greater effect were significantly more confident in their ability to make this judgement accurately. However, neither historical knowledge of the River Don nor interest in local history were significantly related to either participants' current perceptions of the River Don as a recreational resource or the extent to which they expected the River Don to improve or deteriorate over the next 25 years or their confidence in making these judgements. This suggests that the effects of historical knowledge on overall perceptions of the River Don as a recreational resource and predictions for its future were relatively weak. Furthermore positive and negative effects may have cancelled each other out to an extent. The lack of significant relationships in general may also be due to small sample size.

Outcome desires and perceived efficacy are widely recognised to motivate behaviours including pro-environmental behaviours (Axelrod and Darrin, 1993). This study found that outcome desires can be influenced by knowledge of and informed assumptions about an ecosystem's reference conditions. Participants viewed the River Don in its pre-degraded state very positively particularly with regards to its aesthetics and the presence of charismatic species such as salmon, kingfishers, herons, otters and trout and had a strong desire to restore it. Gooch (2003) also recognised the role of aesthetic aspects of an ecosystem in its pre-degraded state in fostering support for restoration in the form of voluntary practical conservation labour in Australia. Some explicitly stated that they believed that the River Don would have been highly valued by local people in its reference conditions. This suggests that educating a larger proportion of local people about the natural aesthetic beauty of the River Don and the charismatic species which are now less abundant than they naturally were will increase support for its restoration. However, care must be taken with this approach given that managing ecosystems to maximise their aesthetic appeal and ability to support flagship species may not restore the ecological processes on which the sustainability of ecosystems depends (Simberloff, 1998; Gobster *et al*., 2007). Knowledge of reference conditions may also increase opposition towards management options which have the potential to bring social benefits but will alter the River Don's ecology away from its natural state. One participant stated that although it would be nice to see sea otters on the River Don she did not want them to be introduced if they were not naturally present there and another said that although deepening the water would be beneficial for recreational boating she did not want it to be deepened if it was not naturally deeper.

Furthermore, those who assumed that the River Don had been highly valued by local people when it was in its reference conditions also believed that it would be highly valued in future. Unfortunately as the River Don was degraded so long ago it is unlikely that it will be possible to evidence these attitudes though this assumption may be strengthened by positive descriptions and images of how the river's landscape was thought to have been based on palaeoecological records (Birks, 2012) and accounts of abundant salmon (Firth, 1997). However, information on the River Don's reference conditions may be more effective in fostering support for restoration if it is complemented with information explaining why practical action is needed as participants explicitly stated the belief that the River Don needed little active management as it would naturally restore itself. In particular participants will need to be made aware of the importance of reversing the impacts of physical degradation and the control of non-indigenous species.

However, a greater understanding of what was special about the River Don relative to other UK rivers before it was degraded may foster further support for their restoration. Unfortunately there is relatively little evidence to indicate how the River Don's reference conditions differed from those of other rivers. However, according to Firth (1997) burbot were previously present on the River Don whilst Davies *et al.* (2004) stated that their natural distribution was limited to rivers connected to the East Coast of England from Durham to East Anglia. Recognising that if all British rivers were restored as far as is practicable burbot would be likely to be present in the River Don and few other rivers is likely to increase the desire to restore the River Don for its benefit. Kellert (1986) recognised that rarity could increase a species' value from the perspective of naturalists and recreationalists. The reintroduction of burbot is generally supported by the British public and to an even greater extent by anglers (Worthington *et al.*, 2010b). Furthermore, increased knowledge of the species has been found to increase support for its reintroduction, suggesting that there is strong potential for environmental education to foster support for their reintroduction. Restoring the River Don for the benefit of burbot is likely to require the restoration of wetlands, increased physical habitat heterogeneity and the installation of fish passes and thus benefit many other species if these changes to the abiotic environment are feasible (Slavík and Bartoš, 2002; Aarts *et al.*, 2004 and Stapanian *et al.* 2010 both cited in Worthington *et al.*, 2012). A desire to restore burbot populations on the River Don may be particularly effective in fostering support for further improvements once salmon, which plays a major role as a flagship species on the River Don becomes more abundant (DCRT (Don Catchment Rivers Trust), n.d.a).

Knowledge of historical environmental degradation is essential to understand what managers have achieved to date and the potential for further future improvements. All participants were aware that the River Don had been historically severely polluted and most were aware that wildlife had been depleted but fewer than half were aware that the River Don had been physically degraded and adversely affected by the presence of invasive species. In addition to a lack of knowledge of the historical physical degradation of the River Don, surprisingly knowledge that the weirs had adversely affected wildlife in the past did not always lead to an appreciation of the ways in which they currently prevented wildlife from fully recovering. One participant even reasoned that they had naturally been degraded to the extent that they were no longer a barrier. Public awareness of the historical and current impacts of weirs and channelisation thus need to be increased in order to gain support for their reversal. Given that the community composition of the River Don is likely to have changed greatly as a result of the installation of the weirs and that the presence of the weirs is still preventing these changes from being reversed it is important that the public are aware of both the historical and current environmental effects of the weirs and other ways in which the channel has been modified. However, such knowledge did not foster support for the river's physical degradation to be reversed when participants believed that this would have severe social consequences. For example, those participants who considered the social consequences of remeandering the river were ready to accept that they were too great for such action to be feasible. This view is supported by Bernhardt and Palmer (2007). Some participants also said that they valued the River Don as it is today more highly because they are aware of how degraded its previous state was. This is illustrative of the contrast principle which identifies a psychological tendency to exaggerate the differences between two different things (Cialdini, 2007). Valuing the river more highly may increase the extent to which people visit it for recreational purposes and ultimately increase support for its restoration (Haslam, 1997; Zedler and Leach, 1998).

However, the failure of a few participants to recognise that the River Don was historically degraded far more than other rivers may reduce support for its conservation by preventing them from recognising that to achieve the same ecological status the River Don is likely to require more environmental management input than other rivers. One participant explicitly stated that whilst industrial effluents had been discharged into the River Don this was not unique to the River Don without recognising the relative severity of the pollution of the River Don which was widely recognised to be one of the most polluted rivers in Europe (Firth, 1997). Bottrill *et al.* (2008) argued that using a triage system to prioritise conservation efforts which take into consideration extent of degradation will potentially increase public confidence in decision makers and increase support for restoration, suggesting that the public would be more likely to support an environmental restoration project if they knew that the ecosystem was more degraded.

All participants were aware that the River Don had been improved over recent decades. They were particularly aware of reduced pollution, the return of wildlife including salmonids and aquatic mammals and increased accessibility including the construction of footpaths and bridges and the management of vegetation to prevent it from overgrowing. However, participants largely lacked knowledge of efforts to reverse physical habitat degradation. Only one mentioned the boulders which had been installed to increase habitat heterogeneity and one thought that a culvert may have been opened. No participants mentioned the installation of fish passes, active restocking, the creation of wetlands or any successes with regards to the management of non-indigenous species. Knowledge of past management successes are likely to increase public perceived efficacy and trust in management by evidencing the ability of managers to achieve outcome desires when given appropriate support (Axelrod and Darrin, 1993; Van de Walle and Geert, 2007). Participants also viewed these improvements as evidence that as a society we have learned from our past mistakes and increased the desire to avoid them in future. With accordance to expectance-value theories if people do not understand why supporting particular projects will increase the likelihood of outcome desires being realised they are unlikely to support them (Axelrod and Darrin, 1993). Greater appreciation of the benefits brought from reversal of the physical degradation of the River Don such as the installation of fish passes, increased habitat heterogeneity and the creation of washlands is therefore likely to foster greater support for such actions in future (Firth, 1997; Canal and River Trust, 2016; DCRT, n.d.a).

Counter to the overall narrative of the River Don over the last few hundred years being one of environmental degradation followed by environmental restoration some participants recognised that in recent years certain negative environmental changes had occurred and believed that if no action was taken such trends would continue into the future. Such changes included decreased abundances of certain charismatic species such as water voles and hedgehogs and increased abundances of invasive species such as Himalayan balsam and Japanese knotweed. Recognition that populations of some charismatic species such as water voles and hedgehogs are declining on a national rather than just a local scale may strengthen the perceived need for action to halt this decline and thus foster public support for restoration. Several participants recognised that the River Don had been actively managed to a lesser extent since 2008 when the Five Weirs Walk was opened and Britain was plunged into an economic recession (Astell-Burt and Feng, 2013; The Five Weirs Walk Trust, 2015; Osman, 2016). Realisation of the capabilities of environmental managers as proven through their previous successes together with recognition of the limitations imposed by government cuts may increase public willingness to actively support environmental managers through the donation of financial resources or labour.

Many participants valued the opportunity to see industrial heritage remnants and learn about the River Don's heritage in situ. This is likely to increase support for environmental restoration by increasing the extent to which the river is visited and valued by local people (Haslam, 1997; Zedler and Leach, 1998). However, conflict may also arise when preserving the River Don's industrial heritage prevents its ability to support wildlife from being maximised. In this study one participant explicitly stated that they were keen for remnants to be preserved even if it reduced the extent to which the River Don could be managed for the benefit of wildlife. Others lamented the industrial heritage which had already been lost in terms of the infrastructure associated with the harnessing of the river's energy and the grandeur of the factory buildings. The loss of landscape features which local people and communities have appreciated for generations has been found to increase opposition towards restoration in other projects (Ostergen *et al.*, 2008; Drenthen, 2009). However, this study also found that those who were more interested in local history were generally more interested in environmental issues suggesting that generally there will be greater support for management programmes which balance outcome desires concerning the preservation of industrial heritage and ecological restoration. Furthermore, DCRT have undertaken extensive public consultation with regards to their plans to install fish passes on the River Don and have not found any opposition on heritage grounds (personal communications with Edward Shaw, Trustee of DCRT, January 2016). Conversely, the desire to conserve industrial heritage may reduce the severity of future environmental degradation. For example, the continued presence of valued industrial buildings will prevent the occupied land from being further developed which in itself can be environmentally destructive (Cole, 2000). The desire to restore ecosystem services for which the river was previously managed such as the generation of power may also adversely affect it from an ecological perspective (Abbasi and Abbasi, 2011).

4.4.2 How Can Historical Knowledge Reduce Support for Environmental Management?

Awareness of the River Don's degraded state without awareness of its much improved current state is likely to decrease support for its restoration. Some participants were surprised how nice it was when they visited as they expected it to be much more similar to its severely degraded state. This suggests that other members of the local community still value it less as they have not realised the extent to which it has improved. This could potentially reduce support for its restoration by discouraging them from visiting it and thus forming an attachment to it. Time lags between restoration and public recognition of restoration were also recognised by Gobster and Westphal (2004) and Pendleton *et al*. (2001).

In accordance with the micro-performance hypothesis participants cited actions of those responsible for the management of the River Don particularly the local council to explain why they did not trust them to use resources wisely to deliver environmental improvements in future (Van de Walle and Geert, 2007). One participant complained that the council had wasted too much money on decorative aspects of the Five Weirs Walk infrastructure and another stated that they did not trust the council because they had not delivered on promises in the past unrelated to the River Don and even environmental management more broadly.

In line with previous studies and availability heuristics theory this study found that knowledge of previous floods increased the perceived risk of future flooding for some participants (Tversky and Kahneman, 1982 cited in Siegrist and Gutscher, 2006; Siegrist and Gutscher, 2006; Botzen *et al*., 2009). Increased fear of flooding can increase support for action to minimise the flood risk. This could potentially either: increase support for environmentally degrading actions such as the construction and maintenance of heavily engineered flood defences and dredging (Hey, 1987 and Hey *et al*., 1990 both cited in Hey, 1994; Harvey and Wallerstein, 2009); or increase support for projects which aim to reduce flood risk and restore habitat simultaneously for example through the creation of washlands in previously drained areas (Morris *et al*., 2005). The interview participants were mostly aware of and supportive of dredging and vegetation clearance which they believed to be effective in reducing the flood risk and deemed the resulting environmental degradation as a necessary consequence of managing the flood risk even though some were sad to see the loss of trees. None mentioned the creation of controlled washlands to attenuate flood waters some of which have benefited wildlife to the extent that they have been designated SSSIs; or the great extent to which the channel had been modified historically to mitigate against the flood risk with limited success. According to Firth (1997) levees have been constructed and raised since the 19th century but the increased volume of peak flows due to land development made such strategies economically unviable by the 1950s. The dissemination of such knowledge is likely to help reduce support for environmentally degrading flood management and increase support for environmentally beneficial flood management as the realisation of the ineffectiveness of heavy engineering strategies to manage flood risk increased interest in more holistic approaches on a national scale (Johnson *et al.*, 2005). However, most participants were only aware of the 1864 and/or 2007 floods and believed that the river had rarely flooded historically. This belief is likely to reduce support for both environmentally beneficial and environmentally harmful flood defence projects.

4.4.3 How Should Historical Knowledge be Disseminated to Foster Support for Restoration?

This study found that knowledge of the river's reference conditions, historical degradation, environmental management successes, constraints on recent environmental management had the potential to influence participants' perceptions of the River Don as it is now and as they expect it to be in the future in ways which are likely to foster support for environmental management by: enabling participants to describe outcome desires and understand how these could be realised; increasing trust in environmental management organisations based on their past successes; and enabling participants to realise that future successes will be constrained by a lack of funding and resources which local communities may be able to mitigate against at least to an extent. However, participants had substantial knowledge gaps which may reduce the extent to which they value the river's reference conditions and understand what needs to be done to restore them as far as is feasible. In particular participants lacked knowledge of: how the reference conditions of the River Don may have differed from those of other rivers in ways which could potentially foster support for the restoration of the River Don over the restoration of other rivers, for example no participants were aware that burbot had previously been present on the River Don; all participants were aware that the River Don had been severely polluted in the past but some did not realise that it had been polluted to a much greater extent than other British rivers; and awareness of other anthropogenic threats to the river's ecology including impoundments, channelisation and the presence of invasive species was generally poor. Furthermore, this study found that historical knowledge had the potential to foster opposition toward restoration for example by reducing trust in the local council and increasing support for potentially environmentally harmful flood defences thus highlighting the need for care to be taken when using environmental history as a tool to foster support for conservation.

Although participants had learned about the history of the River Don from many different sources, collectively they identified many more sources which described the ways in which the river had benefited industry than described the river's environmental history. In the knowledge that several sources of information on the industrial history of the River Don especially information boards, leaflets, museum exhibitions and books attract large audiences of people who wish to learn about the history of the river environmental educators may benefit from working collaboratively with industrial historians to create such sources which describe the industrial heritage of the river, its environmental legacy, how its environmental legacy has been reversed to date and proposed future actions. It is important that those who are informed about the river's environmental degradation are informed about how this has been reversed to an extent as they may otherwise be put off from visiting which could reduce support for future environmental management. Knowledge of future proposed actions may help local people to understand how they can actively support the future management of the River Don once their interest has been sparked.

Environmental educators could also benefit from signposting people to several texts which are freely available online but none of the participants mentioned, suggesting a low level of awareness of their existence. These include information on the River's reference conditions including: *900 years of the Don Fishery: Domesday to the dawn of the new millennium* by Firth (1997), a book which is freely available to read online on the DCRT website (DCRT, n.d.e); the River Don's *Biodiversity Action Plan* (Sheffield Local Biodiversity Action Partnership n.d.) and *Our plan for the River Don* (DCRT n.d.b) which were not mentioned by any of the participants. The only websites which participants stated that they had learned about the history of the River Don from were Wikipedia and those belonging to the local press. Given that anyone can edit Wikipedia entries and submit press releases to the local press these may provide good opportunities to raise awareness of the historical physical degradation of the River Don and the impacts of invasive species and signpost those who are interested to the websites listed above (Wikipedia, 2016). Although participants were not asked if they would welcome the opportunity to learn more about the environmental history of the River Don two explicitly stated that they would like to know more about the history of the river in order to inform what changes they wanted to be made to it in future in order to ensure that these changes would not increase the difference between the River Don's current state and its reference conditions.

In order for any environmental education initiative to maximise its influence on attitudes and behaviours it is essential that the content and dissemination methods of information are tailored to their audience (Maibach, 1993). However, as discussed in section 4.1.4 and 4.1.5 the effects of different types of historical information on the attitudes and behaviours of different sectors of urban communities with regards to their local natural environment are poorly understood. This study assessed the effects of age and residence period on interest in local history and historical knowledge. Although participants differed greatly in terms of age and the time period for which they had lived in the local area contrary to the shifting baselines phenomenon which is supported by much empirical evidence these variables were not found to be significantly related to interest in local history or extent of historical knowledge on the River Don (Pauly, 1995; Papworth *et al.*, 2009; Turvey *et al.*, 2010; Gomes, 2012; Kai *et al.*, 2014). This may be partly due to small sample size particularly with regards to those under 40 years old and those who had lived in the area for a short time period but also suggests that some people of all ages are knowledgeable about and interested in the history of the River Don and that people of a wide range of ages have substantial knowledge gaps. The similarities between participants of different ages with regards to knowledge and interests suggests that environmental education campaigns may need to be adapted to meet the needs of different sectors of society to a lesser extent than initially expected although it should be noted that all participants had in common that they were members of walking groups so the extent to which environmental education efforts would need to be adapted for non-members cannot be gleaned from this research. Societies may also benefit from environmental historical knowledge being held by people of different ages rather than being predominately held by older members of a community because it reduces the risk of historical information being lost as the oldest members of a community die and increases the likelihood that people of all ages will receive messages from their peers including historical knowledge and environmental attitudes based on historical knowledge. People's attitudes are generally more influenced by communications from their peers than communications from those of different ages (Katz, 1963, cited in Simons *et al.*, 1970; Sinan and

Walker 2012). Surprisingly those participants who were more interested in local history were not more knowledgeable about the history of the River Don. This suggests that interest in local history is not a prerequisite for the impartation of historical knowledge which may foster support for environmental management.

Although the relationship between profession, historical knowledge and attitudes towards environmental management were not analysed quantitatively due to the low sample size of people with similar professions anecdotal evidence suggested that professional experience does influence the way local people view the history of the river and the ways in which it should be used as an environmental educational tool. For example, though most participants were unaware of any flood with the exception of the 1864 and 2007 floods a retired steelworker recalled how the steelworks at which he had formerly worked had regularly flooded. Furthermore, a former employee of the EA was particularly concerned about the role of non-indigenous species in reducing biodiversity. Those who had worked in education were particularly concerned that more opportunities for children to learn about the history and biota of the river were created.

4.5 CONCLUSION

This study found that knowledge of the history of the River Don had the potential to influence walkers' perceptions of the River Don as it is today and as they expect it will be in the future in ways which are likely to foster both support for and opposition against its restoration. Participants who were aware of the river's reference conditions generally showed strong desire to restore them; knowledge of historical environmental degradation increased their understanding of how this could be achieved; knowledge of past management successes increased trust in the organisations responsible; recognition that financial constraints had recently reduced the extent to which the River Don was actively managed resulting in the River Don's environment improving at a slower rate and the reversal of some recent successes increased the desire for management organisations to be funded adequately. However, knowledge of the river's environmental degradation was found to have the potential to reduce the desire which people had to visit and thus care about the River Don; knowledge of poor management decisions in the past and broken promises unrelated to the River Don reduced the extent to which the local council were trusted to manage the River Don in future; and knowledge of historical flooding and management through vegetation clearance and dredging increased support for such actions. It found that people learned about the history of the River Don from a broad range of sources but these mostly focused on the industrial history of the river and knowledge of: differences between the river's reference conditions and that of other rivers; the river's physical environmental degradation and the presence of NISs was poor.

5 HOW DOES HISTORICAL INFORMATION INFLUENCE PEOPLE'S PERCEPTIONS OF THE RIVER DON AS IT IS TODAY AND AS THEY EXPECT IT WILL BE IN THE FUTURE? AN EXPERIMENTAL APPROACH.

5.1 INTRODUCTION

For reasons discussed in detail in Chapter 4 historical knowledge has the potential to influence public perceptions of ecosystems in ways which are likely to both foster support for and increase opposition against their environmental management. For example, knowing that an ecosystem used to be more aesthetically pleasing and support charismatic species is likely to increase support for its restoration (Gooch, 2003; Chapter 4). Conversely, when people form attachments to aesthetically pleasing highly modified landscapes over time or highly modified landscapes are valued for heritage purposes this can increase opposition towards their restoration (Ostergen *et al.*, 2008; Drenthen, 2009; Chapter 4). Furthermore, the extent to which organisations responsible for environmental management are trusted by the public is strongly related to their past performance and trusted organisations are more likely to gain public support for further environmental management efforts (Van de Walle and Geert, 2007; Chapter 4).

However, the relationship between historical knowledge and public perceptions of local environments is relatively poorly understood, particularly with regards to recently restored urban ecosystems. Experiments are the only way in which true cause and effect relationships can be identified as when all other variables are controlled investigators can be certain that the apparent relationship is not due to the variables of interest being related to a third variable such as the extent to which an individual is broadly interested in the focal ecosystem or landscapes more generally (Arceneaux, 2010). By changing only one independent variable the direction of the cause and effect relationship can also be determined. In this case we would naturally expect historical knowledge and current perception to both affect each other as those who perceive the River Don more positively are more likely to have seen the archaeological remnants and read the information boards alongside it. These were both identified as important sources of historical knowledge by the interview participants in Chapter 4. Despite the benefits of the experimental approach I was only able to find one previous study which had experimentally tested the effects of the provisioning of historical information regarding an ecosystem on public perceptions of that ecosystem (Hanley *et al.*, 2009). Hanley's *et al.* (2009) experiment differed greatly from this experiment. Hanley *et al.* (2009) studied the effects of primary historical sources some of which conveyed the authors' strong opinions on visitor support for afforestation and deforestation. This experiment will provide university student participants, many of whom are expected to have very little prior experience or knowledge of the River Don with texts written for the purpose of the experiment with the aim of minimising bias before asking them to answer questions about the River Don in its current state and how they expect it to change over the next 25 years from an environmental, social and economic perspective. The relationship between the frequency with which participants visit the River Don and the effects of the experimental treatment on their perceptions of the river in its current state and how they expect it to change, will be assessed. Finally the effects of reading past or present text on the extent to which participants expect to visit the river in future will be assessed.

This chapter aims to use a quantitative experimental approach to describe the effects of providing university students with sources of information on the River Don as it was approximately one century ago on their perceptions of it from an environmental, social and economic perspective. Changed perceptions will be measured using Likert scales to assess the extent to which participants agree or disagree with different statements regarding the River Don and the extent to and direction in which they expect to change the frequency with which they visit the river having read the text (Black, 1999).

The River Don was chosen as a case study as its severe degradation means that it is in great need for effective environmental management and the fact that it flows through several highly urban areas means that public support is even more essential for effective management than it is for ecosytems in more remote areas (Firth, 1997; Wohl *et al*., 2005). Furthermore, our understanding of the effects of historical knowledge on public perceptions is particularly poor with regards to urban populations and ecosystems which have been restored to a large extent over recent decades. As there are many rivers in the developed world which were severely degraded, have been restored to a large extent but still need a lot more work to reverse their environmental degradation legacies as far as is feasible, the outcomes of this research are likely to be broadly applicable to several other rivers (Bothmann *et al*., 2006; Yin, 2012 cited in Wickfeldt, 2016; Wickfeldt, 2016).

Undergraduate and postgraduate students were recruited to participate in the study due to the ease with which they could be recruited and because as a group they are highly diverse in terms of their interest in local history and environmental issues (Bryman, 2008). As a large number of students will have recently moved to Sheffield for their studies relatively few of the participants are expected to have much prior knowledge of the River Don. The majority of research on the effects of historical knowledge on public perceptions of ecosystems has recruited participants who have at least some if not extensive experience of the focal ecosystem so recruiting those who are largely unfamiliar with the focal ecosytem will help to fill a current gap in our knowledge and understanding of the relationship between historical knowledge and public perceptions (Crate, 2006; Ostergen *et al*., 2008; Drenthen, 2009; Hanley *et al*., 2009; Gomes, 2012). The loss of experience of the natural world means that increasingly key decision makers who are in part responsible for environmental management such as local councils and governments will be influenced by those with little experience of their local semi-natural environments (Miller, 2005). However, caution needs to be taken when generalising the conclusions to the wider population as they differ from the wider population as a group in terms of their young age and high education levels.

5.2 METHOD

5.2.1 Experimental Treatment

The experimental treatment used in this experiment was reading a text passage describing the River Don as it was approximately one century ago and the ways in which people interacted with it then. The control treatment was reading a text passage describing the River Don as it is today and ways in which people interact with it. For each of these treatments participants read one randomly selected text from six within the treatment (Appendix C: C.2). This was to reduce the possibility that differences between the texts, other than the time period which they described, influenced participants' perceptions. To create the text passages historic and current facts about the river were collected from newspaper articles (sources described within this section below) and sorted into the following categories: social positive, social negative, economic positive, economic negative, environmental positive and environmental negative. Facts which described the ways in which the River Don affected local people were classified as "*social*"; facts which described the ways in which the River Don affected businesses and the local economy were classified as "*economic"* and facts which described the River Don's wildlife and aesthetics were classified as "*environmental"*. Facts were assigned a number from one to six and these were used to randomly assign facts to individual texts. To ensure maximum variation between texts individual facts were assigned to as few paragraphs as possible whilst ensuring that each paragraph included a fact from each of the six categories to minimise bias (Table 1). The wording of the initial fact statements was then adjusted as necessary to ensure the text read as naturally as possible. This was challenging given the variety of facts which were included in each text.

Attitudinal markers such as "*unfortunately*", "*sadly*" and "*surprisingly*" were used to improve text cohesion and coherence. Attitudinal markers are also used in existing texts used to educate the public about the history of the River Don. For example, an exhibition board in Doncaster Museum states "***Ironically**, just as heavy industry collapsed the Don navigation was finally in a fit state to receive it*" [emphasis added] (Personal observation, 2017). Firth (1997) stated in his book on the history of the River Don which is freely available to the public online "**Unfortunately,** there were other impacts which were beginning to pose a threat by this time, including the construction of a navigation" [emphasis added]. As attitudinal markers are used in these existing texts their use in the experimental treatment also helped to increase the similarity between the texts which they read in the experiment and the texts which members of the public are likely to encounter in the real world. Attitudinal markers can be quite persuasive and thus may have influenced the participants' answers (Dafouz-milne, 2008). However, as they were used in a similar number of past and present texts (3 and 4 respectively) it is unlikely that they had a bias effect on the outcome of the experiment. The greatest difference with regards to the use of attitudinal markers in the past and present texts is that three present texts use attitudinal markers to introduce negative environmental facts, whilst only one past text does. However, this effect is likely to be largely outweighed by the severity of the environmental degradation described. Texts ranged from 238 to 244 words in length. All texts were then read independently by a writer in residence employed by the Department of Animal and Plant Sciences at the University of Sheffield to advise academics on writing to ensure that they flowed well and worked as standalone texts.

As far as possible information for the past treatment was limited to the 1910-1914 time period. This was to account for the increased probability of extreme events being reported over a longer time period which would be likely to influence responses to the experimental treatment. Expanding the time period from which information for the present treatment was collected may have meant that participants believe the older information within the time period not to reflect the River Don's current state. Historical information for the past paragraphs was largely collected from newspaper articles published between 1910 and 1914 and accessed through the British Newspaper Archive (2014) online database using the search term "*River Don*". Due to the paucity of information, particularly within the environmental positive and social positive categories this information was supplemented with information from newspaper articles from 1904-1910 found using the search terms "flood" and "bridge" in addition to "*River Don*", the fish records described in the second chapter of this thesis, a book called "*The River Don on old picture postcards. Reflections of a Bygone Age"* (Taylor 1995), Firth's (1997) book on the history of the River Don and an outline of the history of Goole available from Goole library. Information for the present paragraphs was collected from newspaper articles published between 2010 and 2014 using the Nexis online database (LexisNexis, 2014).

Table 1. Contents of each paragraph in the past (top) and present (bottom) treatment.

Text	Social positive	Social negative	Economic positive	Economic negative	Environmental positive	Environmental negative
1	Child play	Accidental child death	Steel	Bridge construction	Sewage treatment	Sewage
2	Boating	Housing	Navigation	Bank damage	Fish	Physical degradation
3	Bathing	Barrier	Fire	Bridge maintenance	Sewage treatment	Cooling
4	Housing	Accidental adult death	Paper	Inconvenienced farmers	Sewage treatment	Industrial pollution
5	Geology	Crime	Boilers	Fog	Fish	Vegetation clearance
6	Employment	Inaccessible	Corn	Bridge	Sewage	Impoundment

				construction	treatment	

Text	Social positive	Social negative	Economic positive	Economic negative	Environmental positive	Environmental negative
1	Boating	Metal steeling	Corporate employers	NISs	General	Industrial pollution
2	Flood management	Fly tipping	Corporate employers	Floods	Reserves/ SSSIs	Sewage
3	Heritage	Vandalism	Abstraction	Flood defence	Birds	Litter
4	Walking	Death	Corporate employers	Flood defence	Fish	Impoundments
5	Research	NISs	Corporate employers	Infrastructure	Mammals	NISs
6	Religion	Floods	Abstraction	Flood defence	Insects	Climate change

5.2.2 Experimental Design

An online survey was created using the Survey Monkey website (www.surveymonkey.com accessed 2014). A copy of this survey is provided in Appendix C: C.2. To reduce the risk of participants' answers being influenced by knowledge that the research was being undertaken within a particular department of the University (in this case the Department of Animal and Plant Sciences – suggesting an environmental focus to the study) participants were told *"In this study we are aiming to understand the effects of different information on people's perceptions of the area in which they live. You will be asked to read information on two different topics of local interest then complete a short questionnaire."* and given researcher names, but not the name of the department which was conducting the work.

In sequential order the experiment briefly consisted of: the presentation of text for a filler exercise, the presentation of the experimental treatment or control text on the River Don, the filler exercise, questions on the River Don as it is today, questions on the River Don as it will be in 25 years' time and questions on the frequency with which they currently visit the River Don and expect this to change in future having participated in the experiment (Appendix C: C.2). The idea to use a filler exercise came from Bless's *et al*. (1992) study in which a filler exercise was used to neutralise the mood of paticipants in an experiment which assessed the effect of mood on the effects of information on participant perceptions. However, I used a filler exercise as I believed that a distraction would enable me to measure participant views sometime after rather than immediately after reading the experimental treatment text which would be held for longer and thus have greater influence on their use of the River and their attitudes towards its management. The text initially presented to participants to prepare them for the filler exercise was 248 words about the role of football in Sheffield. This text was included so that participants could complete a filler exercise which consisted of nine Likert scale questions on their perspectives of the issue. The purpose of this filler exercise was to distract the participants so their answers would reflect their perceptions sometime after rather than immediately after reading the text (Bless *et al*., 1992). The topic was chosen as it was of high local relevance in keeping with the stated aim of the study, a complex enough issue to ask multiple questions regarding participants' perspectives and was unlikely to greatly influence their perceptions of the River Don. Participants were then asked to read the text on the River Don which had been assigned to them at random by Survey Monkey and view a map of the river which outlined its course and confluences with its tributaries and the position of the main settlements along and in close proximity to it: Sheffield, Rotherham, Doncaster and Barnsley (Appendix C: C.2). All participants were shown the same map.

Participants were then asked to express the extent to which they agreed with a total of 18 statements regarding the River Don as it is today using five point Likert scales which ranged from strongly agree to strongly disagree. Each category of statements: social, economic and environmental included one positive general statement, one negative general statement, two positive specific statements and two negative specific statements. For example, the environmental category included a general positive statement regarding habitat quality, a general negative statement regarding harm to wildlife, two positive specific statements regarding flagship species and aesthetics and two negative specific statements regarding pollution and physical degradation. They were then asked to express the extent to which they agreed with 18 statements regarding how they expected the River Don to be in 25 years' time. These statements were the same as those regarding the River Don as it is today but it was randomly determined whether the statement would express an improvement or deterioration with regards to each variable. For example, statements expressing positive and negative future changes with regards to the present statement "*Generally the quality of habitat which is provided by the River Don is good"* are *"The River Don will provide better quality habitats than it does today"* and *"The River Don will provide less good quality habitats than it does today"*. All statements which were used in this experiment are listed in Tables 2 and 3 in section 5.3.2 and 5.3.3 respectively. The order of statements within both the present and future questions was randomised by the survey software.

Finally participants were given two multiple choice questions which asked how frequently they visit the River Don and how they expect the frequency with which they visit the river to change now that they have read the text. The former gave the options: At least weekly, at least monthly, at least a few times a year, at least once in my lifetime and never. The whole survey took approximately 10 minutes to complete and participants were informed of this in advance. Participants were not permitted to return to previous pages of the survey. This prevented them from re-reading the text with the questions in mind. For ethical reasons participants were not obliged to answer any individual questions.

5.2.3 Participants

A recruitment email including a link to the survey was sent to all current undergraduate and postgraduate students at the University of Sheffield in June 2015 (Appendix C: C1). A total of 294 students participated in the survey of whom 157 completed it. Given that there are 23,309 students at the University of Sheffield (University of Sheffield, 2015) this gave a total response rate of 1.26% and a complete response rate of 0.67%. This low response rate is likely to give high self-selection bias (Robinson, 2014) but this seems likely to be with regards to interest in local information and general willingness to participate in online surveys rather than anything specific to the River Don or interest in nature. In all the following discussions "*participants*" refers to the 157 who completed the survey, unless otherwise stated.

5.2.4 Statistical Analysis

To test whether the extent to which participants agreed with each statement was associated with experimental treatment or the frequency with which participants visited the River Don cumulative link models (CLMs) were performed in the ordinal package in R version 3.2.3 (Christensen, 2015; R Core Team, 2015). These are regression models fitted by maximum likelihood for ordinal response variables. To find the optimal model a saturated model including an interaction term was produced then simplified through the stepwise removal of terms from the model starting with the higher order terms. Analysis of deviance tests were used to test whether the more detailed model was better able to explain the variation in the response variable to a significant extent.

5.2.5 Consideration of Bonferroni Method

To account for the increased likelihood of a type one error (i.e. falsely rejecting null hypotheses) due to the large number of statistical tests which were undertaken I considered using Peres-Neto's (1999) sequential Bonferroni method to establish the relationship between experimental treatment, frequency of visits to the River Don and perceptions of the River Don in its current state or predictions regarding its future state had when each clm had been performed and simplified as described in section 5.2.4. The main benefit of Peres-Neto's (1999) sequential Bonferroni method over the original Bonferroni method is that it is less prone to type two errors. However, this generated significance thresholds of 0.01 or less for 32 of the 36 variables which were tested (i.e. falsely accepting null hypotheses). I was therefore concerned that the risk of type two errors in this experiment would be too high if I used this method. Instead I accepted that it was unfortunately not possible to reduce the risk of type one errors without increasing the risk of type two errors and in line with the recommendations of other academics used the predefined significance threshold of 0.05 rather than those determined using Peres-Neto's (1999) sequential Bonferroni method (Rothman, 1990; Perneger, 1998; Armstrong, 2014). Peres-Neto's (1999) sequential Bonferroni method was not suitable for this experiment as I was interested in how the two groups differed in terms of each variable individually rather than whether or not they differed with regards to any one of the variables which were used; and the statements were chosen because I had sound rationale for expecting that they were likely to be affected by experimental treatment and/or related to frequency of visits to the River Don in that they all regarded attributes of the River Don which had changed substantially over the last century (Firth, 1997; Streiner and Norman, 2011 and Schulz and Grimes, 2005 both cited in Armstrong, 2014).

5.3 RESULTS

The full range of responses from strongly agree to strongly disagree was given by participants for every statement with the exception of those concerning: general benefits for the local economy, general benefits for local people, present heritage value and present physical environmental degradation. For each of these the full range of responses was given with the exception of "*strongly disagree"*. This results section will: first describe the frequency with which participants currently visit the River Don; then describe the relationship between the frequency with which they currently visit the river, experimental treatment and their perceptions of the river as it is at present; then describe the relationship between the frequency with which they visit the river, experimental treatment and their future predictions regarding the river; and finally establish whether or not experimental treatment affected the extent to which they intended to visit the River Don in future.

5.3.1 Frequency of Visits

The majority (65.0%) of the participants who fully completed the survey had visited the River Don at least once but only 39.5% visited it at least a few times a year and only 12% visited it at least monthly (Figure 1). Given that only one person who visited the River Don at least weekly had read the past text I amalgamated the "*At Least Monthly*" and "*At Least Weekly*" categories for the remainder of the analyses.

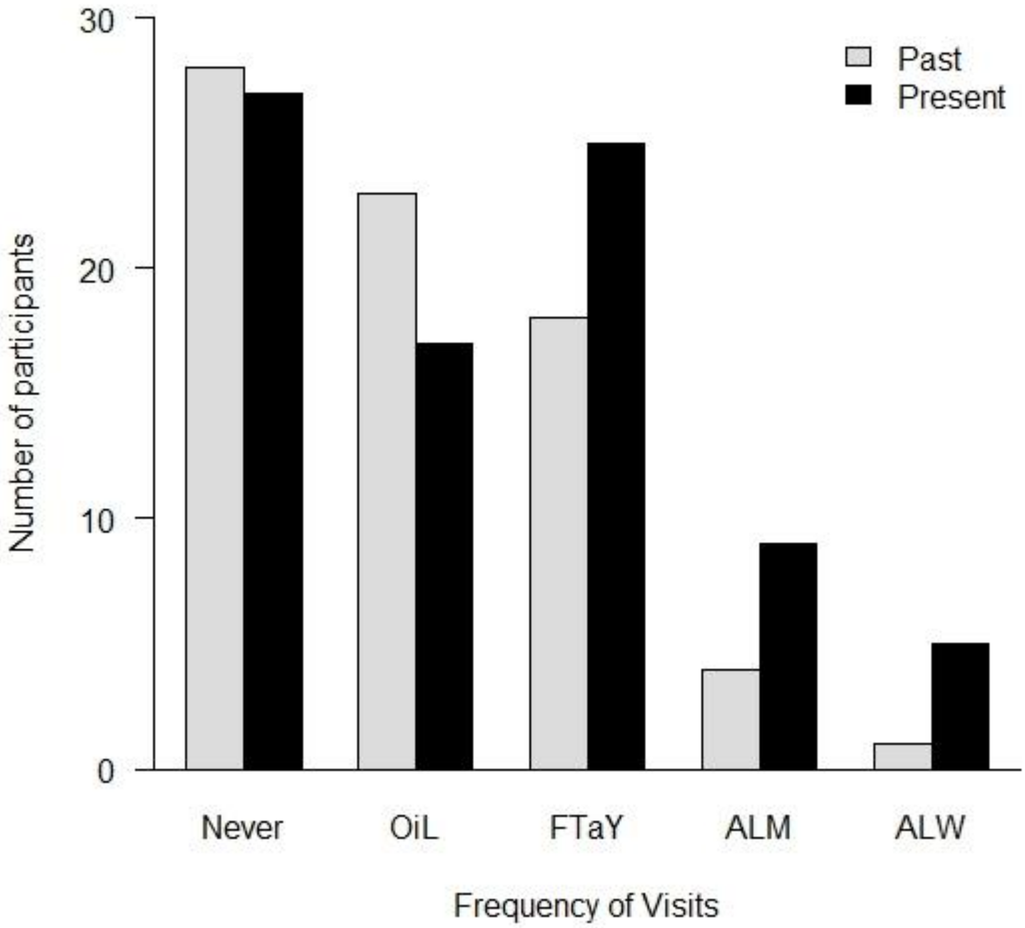


Figure 1. Number of participants by frequency of visits and experimental treatment (n=157, OiL=At least once in lifetime, FTaY=At least a few times a year, ALM=At least monthly, ALW=At least weekly).

5.3.2 Effects of Experimental Treatment and Frequency of Visits on Current Perceptions of the River Don

Participants were asked how they perceived the River Don as it is today from a social, economic and environmental perspective (Table 2). Experimental treatment alone was found to significantly affect the extent to which participants believed that: the River Don benefited the local economy; people had a good chance of seeing charismatic species when visiting the river; the River Don was harmful to wildlife. The interaction between experimental treatment and frequency of visits was significantly related to the extent to which participants believed that the costs of the maintenance of the River Don and its associated infrastructure were justified. Participants' beliefs regarding habitat quality were only significantly related to the frequency with which they visited the River Don. The extent to which participants agreed or disagreed with all other statements was not significantly related to experimental treatment or the frequency with which they visited the river.

Table 2. Results of participant agreement with statements regarding the current state of the River Don. Model selection began with an interaction between two explanatory variables: Response statement~River Don text period*Frequency of visits (n=154-157 participants). The explanatory variables were those which remained in each model when they had been simplified by removing any non-significant variables (p>0.05). The direction of the relationship with regards to any significant experimental treatment was described in terms of the effects of reading past text. Any models with no significant variables remaining are denoted by a dash in the explanatory variables column.

Response statement	**Explanatory variables**	**Direction of Relationship**
The River Don is an asset to local communities.	-	-
The River Don provides good opportunities for leisure and recreation.	-	-
The River Don provides good opportunities to engage with local heritage.	-	-
The River Don is a threat to local people and communities.	-	-
The River Don poses a threat to local people and their property through flooding.	-	-
Antisocial behaviour occurs frequently on the banks of the River Don.	-	-
The River Don benefits the local economy.	River Don Text Period	Negative
Workers who have a view of the River Don from their office windows are generally more productive.	-	-
The River Don attracts service sector businesses (e.g. those in the administrative, retail and, leisure, tourism and hospitality industries) to South Yorkshire.	-	-
The River Don harms the local economy.	-	-
The River Don poses a threat to local businesses through flooding.	-	-
The River Don and its immediate environment e.g. bridges and footpaths are more costly to maintain than they're worth.	River Don Text Period *Frequency of Visits	Negative for those who visited the River Don less than a few times a year but positive for those who visited more frequently.
Generally the quality of habitat which is provided by the River Don is high.	Frequency of Visits	Positive
People who walk along the banks of the River Don are likely to see some exciting wildlife.	River Don Text Period	Negative
The River Don is physically attractive.		
The River Don harms local wildlife.	River Don Text Period	Positive
Pollution prevents wildlife from thriving on, in or beside the River Don.	-	-
Physical degradation prevents wildlife from thriving on, in or beside the River Don.	-	-

5.3.2.1 Economic perspectives

Participants who read about the history of the River Don agreed with the statement "*The River Don benefits the local economy*" to a significantly lesser extent than those who read the present text as part of the experiment (Table 2, Figure 2). Those who read the present text were approximately 1.3

times more likely to agree or strongly agree with the statement than those who read the past text (64.5% and 49.3% respectively). Those who read the past text were more than three times more likely to disagree with the statement than those who read the present text (15.0% and 4.8% respectively).

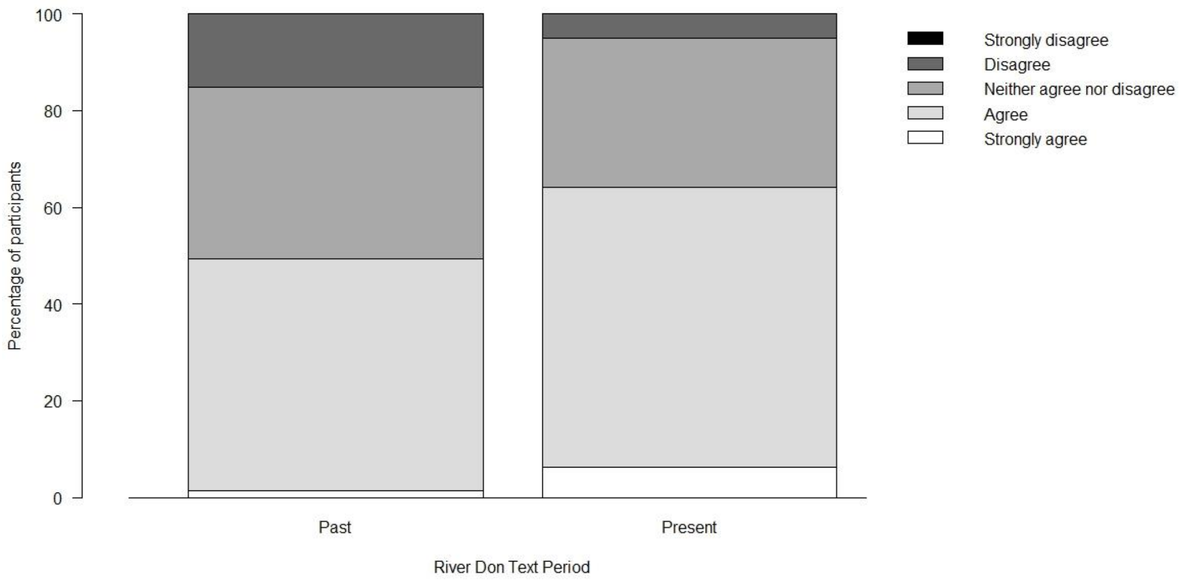


Figure 2. Extent to which participants who read the past and present texts on the River Don agreed with the statement "*The River Don benefits the local economy*" by whether they read the past or present text as part of the experiment (n=154: 71 Past and 83 Present)

The extent to which participants agreed with the statement "*The River Don and its immediate environment e.g. bridges and footpaths are more costly to maintain than they're worth*" was significantly related to the interaction between the frequency with which they visited the River Don and whether they read the past or present text on the river as part of the experiment (Tables 2 and 3, Figure 3). Reading past text slightly increased the extent to which people who had never visited the River Don before or visited it less than a few times a year disagreed or strongly disagreed with the statement relative to those who visited the River Don with the same frequency but read the present text (68.6% and 61.4% respectively). Reading past text had a more pronounced effect on those who visited the River Don at least a few times a year in the opposite direction. 76.9% of those who visited the River Don at least a few times a year and read the present text disagreed or strongly disagreed, whilst only 60.9% of those who read the past text and visited the River Don this frequently did.

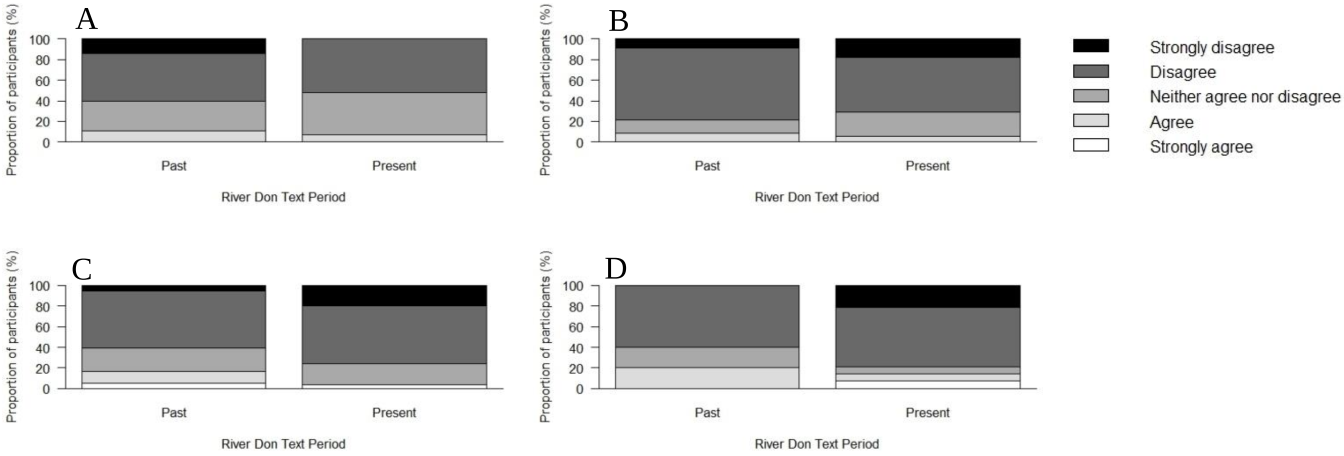


Figure 3. Extent to which the participants who visited the River Don with different frequencies (A=Never, At Least B=Once in Lifetime, C=At Least a Few Times a Year, D=At Least Monthly) and read past or present text on the River Don as part of the experiment agreed with the statement "*The River Don and its immediate environment e.g. bridges and footpaths are more costly to maintain than they're worth*". (n=157: see Table 3 for breakdown by text period and frequency of visits).

Table 3. Number of participants who stated the extent to which they agreed with the statement "*The River Don and its immediate environment e.g. bridges and footpaths are more costly to maintain than they're worth"* by the frequency with which they visited the river and whether they read past or present text on the river as part of the experiment (n=157).

Frequency of visit	Past	Present
Never	28	27
At Least Once in Lifetime (OiL)	23	17
At Least a Few Times a Year (FTaY)	18	25
At Least Monthly (ALM)	5	14

5.3.2.2 Environmental perspectives

Participants who visited the River Don more frequently were significantly more likely to agree with the statement "*Generally the quality of habitat which is provided by the River Don is high*" than those who visited it less frequently (Table 2, Figure 4). Those who visited the River Don at least a few times a year were 1.3 times more likely to agree or strongly agree with the statement than those who had never visited the River Don were (48.4% 36.4% respectively). Contrary to this trend, those who had visited the River Don only once in their lifetime were the least likely to agree with the statement with only 27.5% agreeing and none strongly agreeing.

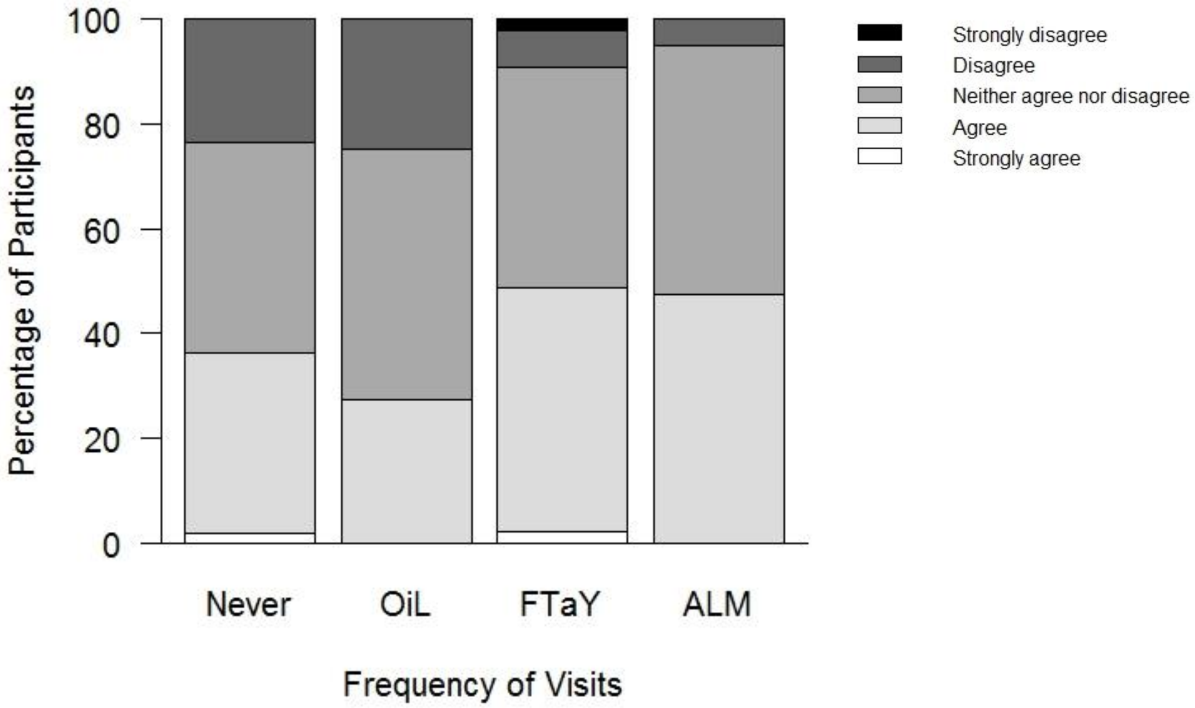


Figure 4. Extent to which participants agreed with the statement "*Generally the quality of habitat which is provided by the River Don is high*" by the frequency with which they visit the River (n=157: 55 Never, 40 OiL (At Least Once in Lifetime), 43 FTaY (At Least a Few Times A Year) 19 ALM (At least Monthly)).

Participants who read the past text agreed with the statement "*People who walk along the banks of the River Don are likely to see some exciting wildlife*" to a significantly lesser extent than those who read the present text (Table 2, Figure 5). Those who read the present text were nearly 1.5 times more likely to agree or strongly agree with the statement than those who read the past text (43.2% and 59.0% respectively). Those who read the past text were more than twice as likely to disagree or strongly disagree with the statement than those who read the present (65.6% and 30.6% respectively).

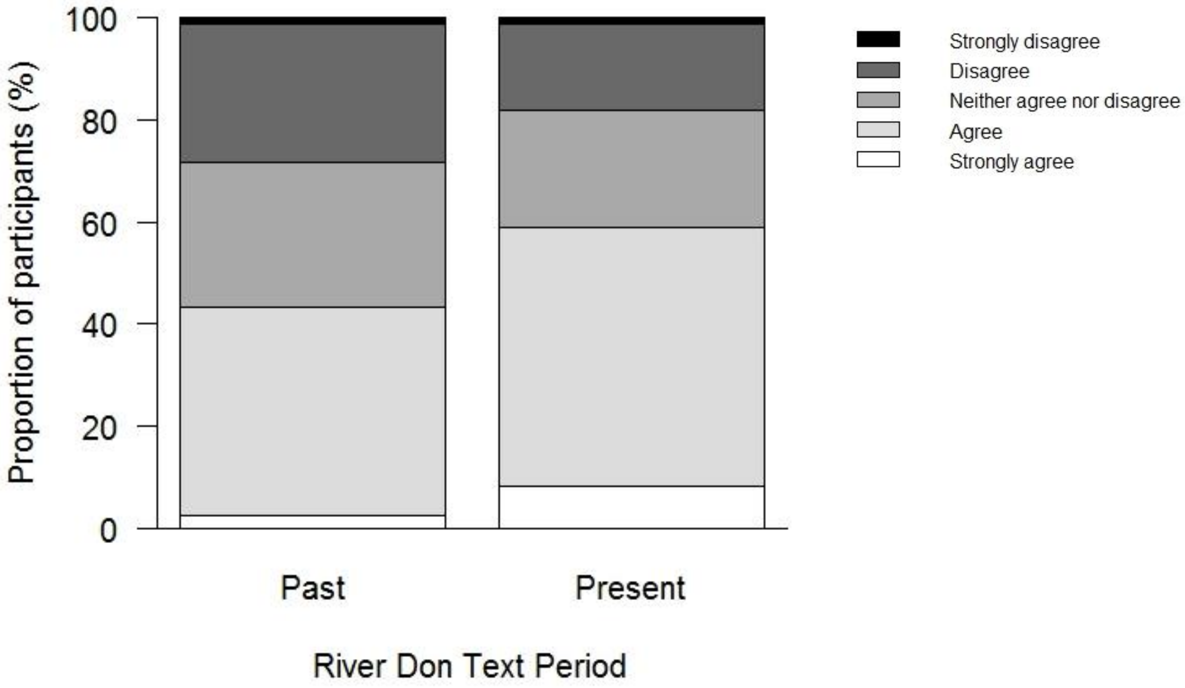


Figure 5. Extent to which participants who read the past and present texts on the River Don agreed with the statement "*People who walk along the banks of the River Don are likely to see some exciting wildlife*" by whether they read the past or present text as part of the experiment (n=157: n=74 Past and 83 Present).

Participants who read about the history of the River Don agreed with the statement "*The River Don harms local wildlife*" to a significantly greater extent than those who read the present text as part of the experiment (Table 2, Figure 6). Participants who read the past text were nearly three times more likely to agree or strongly agree with the statement than those who read the present text (20.3% and 7.2% respectively). Furthermore, participants who read the past text were 1.5 times more likely to disagree or strongly disagree with the statement than those who read the present text (73.5% and 54.1% respectively).

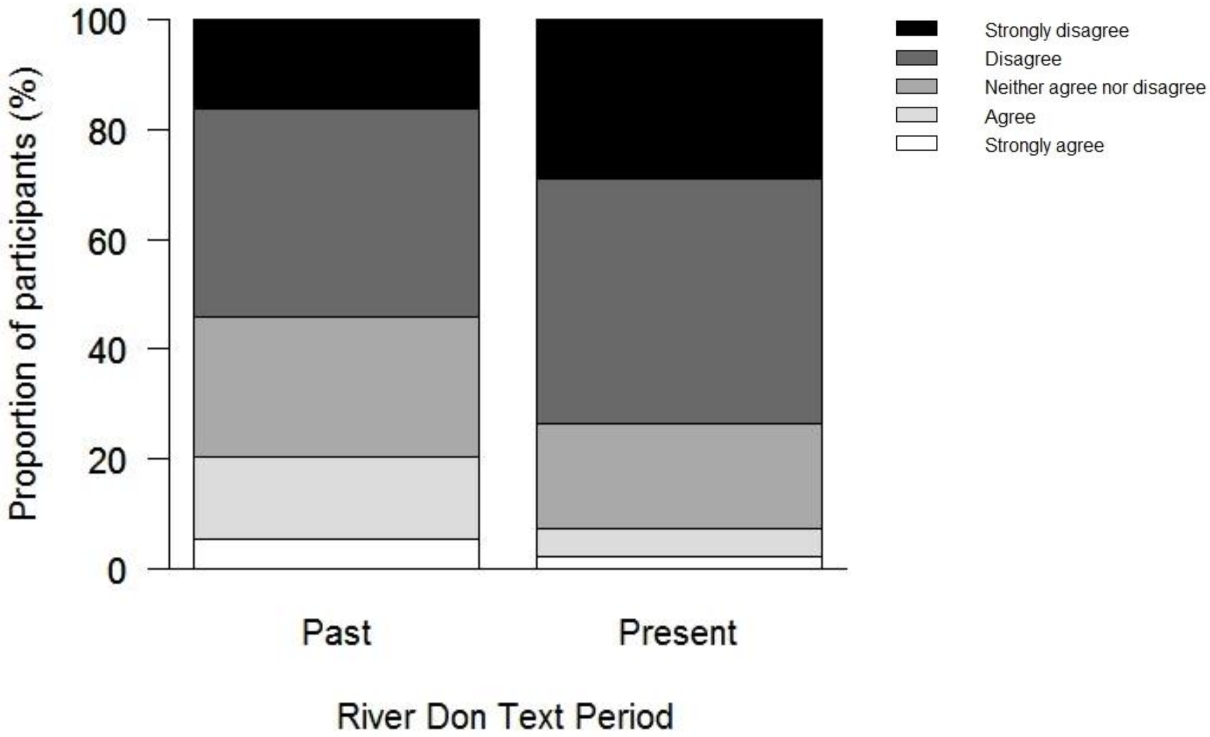


Figure 6. Extent to which participants who read the past and present texts on the River Don agreed with the statement "*The River Don harms local wildlife*" by whether they read the past or present text as part of the experiment (n=157: 74 Past and 83 Present).

5.3.3 Effects of Experimental Treatment and Frequency of Visits on Predictions Regarding the River Don's Future

Participants were asked how they expected the River Don to change over the next 25 years from a social, economic and environmental perspective. When Peres-Neto's (1999) sequential Bonferroni method was applied the significance threshold was p=0.000611 so participants' predictions regarding the River Don's future were not found to be significantly related to either experimental treatment or the frequency with which they visited the river (Table 4). With the exception of the increased likelihood of seeing charismatic species in the future and the River Don being more detrimental to wildlife in the future than it is today; neither experimental treatment nor frequency of visits were found to influence participants' predictions regarding the River Don in 25 years' time.

Table 4. Results of participant agreement with statements regarding the future state of the River Don. Model selection began with an interaction between two explanatory variables: Response statement~River Don text period*Frequency of visits (n=156-157 participants). The explanatory variables were those which remained in each model when they had been simplified by removing any non-significant variables (p>0.05). The direction of the relationship with regards to any significant experimental treatment was described in terms of the effects of reading past text. Any models with no significant variables remaining are denoted by a dash in the explanatory variables column.

Response statement	**Explanatory variables**	**Direction of relationship**
The River Don will be a greater asset to local communities than it is today.	-	-
The River Don will provide fewer good opportunities for leisure activities than it does today.	-	-
The River Don will provide fewer good opportunities to engage with local heritage than it does today.	-	-
The River Don will be a greater threat to local people and communities than it is today.	-	-
The River Don will pose a greater threat to local people and their property through flooding than it does today.	-	-
Antisocial behaviour will occur more frequently on the banks of the River Don than it does today.	-	-
The River Don will be of greater benefit to the local economy than it is today.	-	-
The River Don will have a greater positive impact on the productivity of workers with a view of it from their office window than it does today.	-	-
The River Don will attract fewer service sector businesses (e.g. those in administration retail and leisure, tourism and hospitality industries) to South Yorkshire than it does today.	-	-
The River Don will cause less harm to the local economy than it does today.	-	-
The River Don will pose a greater threat to local businesses through flooding than it does today.	-	-
The maintenance of the River Don and its immediate environment e.g. bridges and footpaths will become more costly than it is today.	-	-
The River Don will provide better quality habitats for local wildlife than it does today.	-	-
People who walk along the banks of the River Don will have a greater chance of seeing some exciting wildlife than they do today.	Frequency of visits	Positive
The River Don will be less physically attractive than it is today.	-	-
On balance the River Don will be more detrimental to local wildlife than it is today.	Frequency of visits	Negative
The River Don will be more polluted than it is today.	-	-
The River Don will be more physically degraded than it is today	-	-

5.3.3.1 Environmental perspectives

A significantly greater proportion of participants who visited the River Don more frequently agreed or strongly agreed with the statement "*People who walk along the banks of the River Don will have a greater chance of seeing some exciting wildlife than they do today*" (Table 4, Figure 7). This trend was true across all frequency of visit categories but the greatest difference was between those who had visited the River Don at least once in their lifetime and those who visited the River Don at least a few times a year (25.0% and 37.2% respectively).

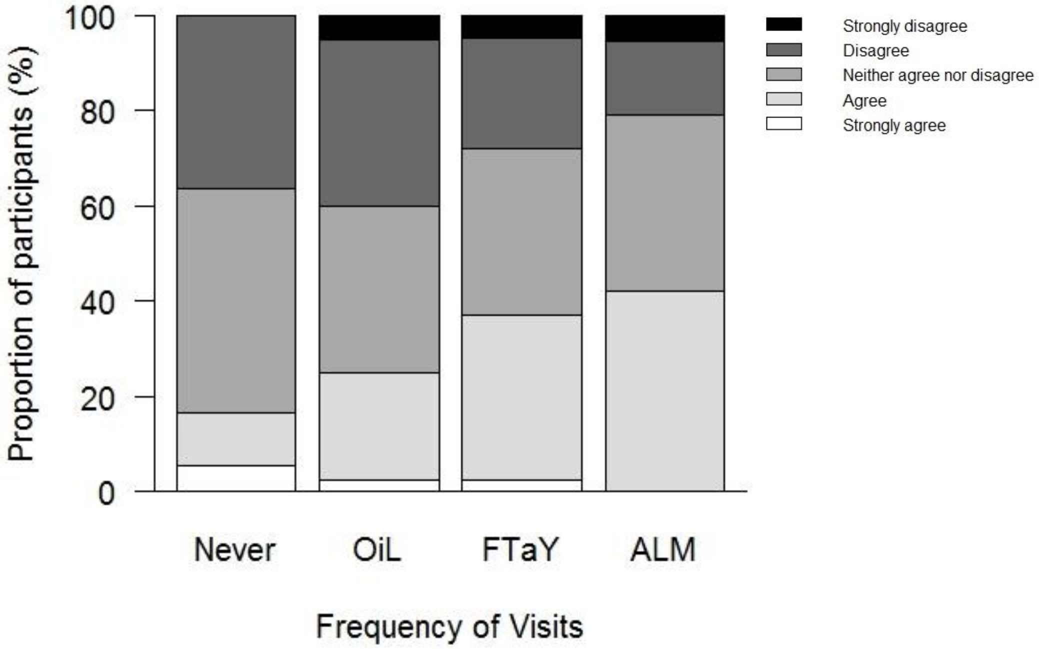


Figure 7. Extent to which participants agreed with the statement "*People who walk along the banks of the River Don will have a greater chance of seeing some exciting wildlife than they do today.*" by the frequency with which they visit the river (n=157: 55 Never, 40 OiL (At Least Once in Lifetime), 43 FTaY (At Least a Few Times A Year) 19 ALM (At least Monthly)).

Those who visited the River Don more frequently agreed with the statement "*On balance the River Don will be more detrimental to local wildlife than it is today*" to a significantly lesser extent (Table 4, Figure 8). 38.2% of those who had never visited the River Don agreed or strongly agreed with the statement whilst only 22.5% of those who had visited the River Don at least once in their lifetime but did not visit it at least a few times a year did. Visiting the river more frequently than this had little effect on the proportion of participants who agreed or strongly agreed with the statement as 18.3% of those in the "*Few Times a Year*" category and 15.8% of those in the "*At Least Monthly*" category agreed or strongly agreed with the statement.

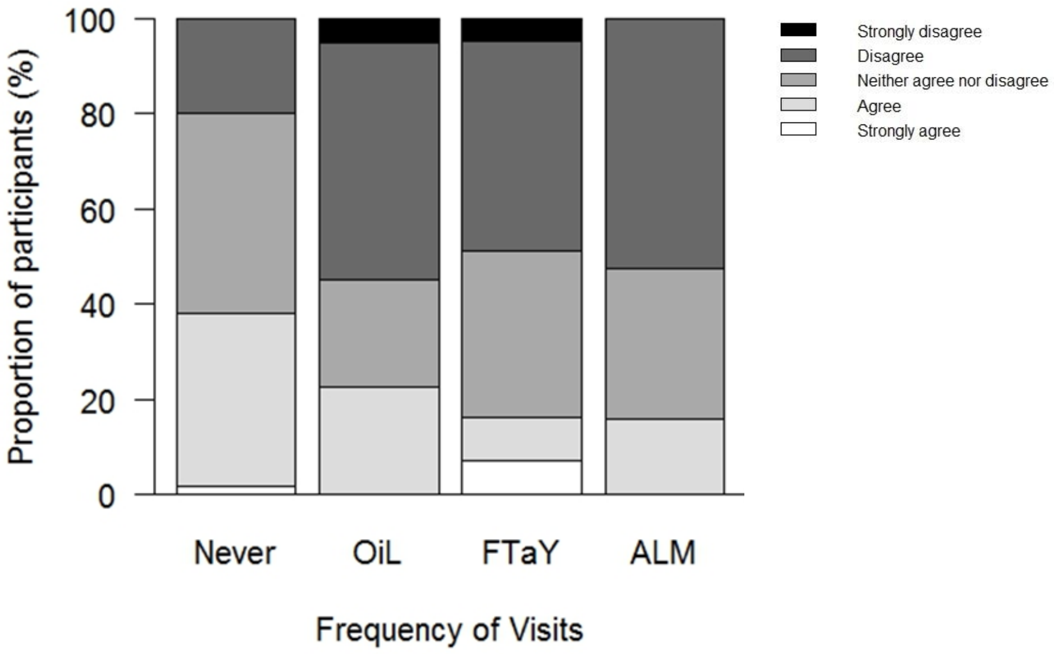


Figure 8. Extent to which participants agreed with the statement "*On balance the River Don will be more detrimental to local wildlife than it is today*" by the frequency with which they visit the river (n=157: 55 Never, 40 OiL (At Least Once in Lifetime), 43 FTaY (At Least a Few Times A Year) 19 ALM (At least Monthly).

5.3.4 Effect of Experimental Treatment on Future Intent to Visit the River

At the end of the experiment participants were asked to what extent and in what direction they thought that the frequency with which they visit the River Don would change after reading the experimental treatment text. Neither experimental treatment or the frequency with which participants currently visited the River Don was significantly related to the extent or direction in which they expected to change the frequency with which they visited the River Don in future having participated in the experiment (CLM: n=156, LR.stat=0.173, df=1, p=0.678). A small majority of participants, 53.8% stated that they did not expect to change the frequency with which they visited the river in future. The number of people who stated that they expected to visit the river more frequently in future was approximately 5.5 times greater than the number who expected to visit it less frequently in future (61 and 11 respectively).

5.4 DISCUSSION

Reading historical information about the River Don was found to significantly affect participants' perceptions of it in its current state from an environmental and economic perspective. Experimental treatment (reading information on the River Don as it was a century ago or as it is today) alone significantly affected the extent to which participants agreed or disagreed with only three of the 36 statements. Similarly, frequency of visits to the River Don alone was only significantly related to the extent to which participants agreed or disagreed with three of the 36 statements. Frequency of visits to the River Don only modified the significant effects of experimental treatment on the extent to which participants agreed or disagreed with one statement concerning the justifiability of the maintenance costs of the River Don and its associated infrastructure. Reading historical rather than current information was not found to significantly affect current perceptions from a social perspective or predictions regarding the River Don's future state.

Those who read historical information were: less likely to believe that the River Don benefited the local economy in its current state; less likely to believe that current visitors would see charismatic species; and more likely to believe that the River Don currently harms local wildlife. Reading historical information reduced the extent to which those who visited the River Don less than a few times a year believed that the cost of maintaining the river and its associated infrastructure was currently justified but had the opposite effect on those who visited it more frequently. Participants who visited the River Don more frequently were: more likely to believe that it currently provides good quality habitat; more likely to believe that visitors would have a greater chance of seeing charismatic species in 25 years' time than they do today; and less likely to believe that the river would be more harmful to wildlife in 25 years' time than it is today. Reading historical information was not found to significantly affect how the frequency with which participants expected that they would visit the River Don in future would change having participated in the experiment. This section will first discuss this experiment's significant results then discuss why experimental treatment and frequency of visits may have had such little effect on: participants' perceptions of the River Don as it is today and as they predict it will be in 25 years' time; and participants' intentions to visit the River Don in future.

5.4.1 Significant Effects of Experimental Treatment

5.4.1.1 Present economic perspectives

Those who read about the River Don as it was approximately one century ago as the experimental treatment disagreed with the statement "*The River Don benefits the local economy*" to a significantly greater extent than those who read about the River Don in its current state. This suggests that many of those who read the past text were aware that the river no longer substantially contributes to the manufacturing or logistics industries to the extent that it did historically but were not as aware of the economic benefits which it now brings to the service sector as those who read present texts which included this information were (Firth, 1997).

It was clear from the interviews in the previous studies that awareness of the economic benefits brought by the River Don at the beginning of the 20th century bore little relation to awareness of the economic benefits derived from the River Don today. People were very aware of the decline of the steel industry and other manufacturing industries and the river's role in the transportation of goods. Interview participants generally lacked knowledge of how the river benefited the local economy today and their considerations were largely limited to recreation, tourism and the productivity of workers. This lack of knowledge of current financial benefits gained from the river was also found in the interview study. Only six of the 23 interview participants believed that the River Don increased custom for organisations which provided services such as pubs, restaurants, cafés, hotels, shops and Kelham Island Museum. In addition to the small number of people who recognised that the River Don benefited industry today one participant lamented that the River Don has the potential to benefit industries in the hospitality sector if it is made more aesthetically pleasing but this has not been achieved to a great enough extent. Similarly, only six interview participants recognised that the opportunity to see the River Don from an office or visit it during one's lunchbreak could increase productivity. Only nine interview participants expressed the belief that manufacturing industries may still derive some of the benefits from the River Don which they derived in the past but they recognised that this would be on a much smaller scale than when Sheffield's manufacturing industries were at their peak. They suggested that they may still use the water for cleaning, cooling, brewing beer and supplying the canal with water which was still used to a small extent by industry for navigation. Taken together with the result of the experiment this demonstrates that whilst historical knowledge may increase the extent to which participants believe that economic benefits are still derived from the River Don in ways similar to practices at the start of the 20th century this effect is outweighed by the effects of present knowledge of the more novel economic benefits derived from the River Don by the service sector. This suggests that historical information will not be an important tool in educating people about the current benefits derived from the River Don.

Such knowledge may be important in fostering support for conservation, particularly from local businesses (Doick *et al*., 2009). This demonstrates the complementary values of quantitative experiments in being able to identify causal relationships between reading information and forming opinions and qualitative studies in explaining the likely reasoning behind these causal relationships (Lewin *et al*., 2009; Arceneaux, 2010).

Participants who visited the River Don frequently and read the historical information were significantly more likely to believe that the costs of maintaining infrastructure were justified than those who visited the river frequently but read the present text. Those who visited the River Don frequently and read the historical information had the opportunity to compare the River Don as it is now with the river when it was severely degraded. They were therefore likely to have the greatest awareness of how the River Don had improved through time in part due to the maintenance of the river itself and its associated infrastructure. They may have also been less aware of the costs than some of those who read the present texts, some of which included information on some of the costs associated with infrastructure on the River Don (Appendix C: C.2). Conversely those who visited the River Don less frequently and read past text were less likely to believe the costs were justified. This may be because they were unaware of the benefits which economic investments into infrastructure had brought or valued them less as they did not benefit from them personally.

The finding that the participants who were most aware of both pre-restoration and post-restoration states of the River Don believed that its maintenance costs were justified to the greatest extent reflects the findings of Tunstall *et al*. (1999). Tunstall *et al*. (1999) found that 62% of participants interviewed following the restoration of the River Skerne in North East England stated that they would have been willing to contribute financially towards its restoration suggesting that they believed the environmental management costs were justified. The majority of Tunstall *et al*'s (1999) participants were likely to have been more aware of the River Skerne both before and after its restoration than the experiment participants were of the River Don's state both before and after its restoration as the restoration of the River Skerne had been carried out within the last two years and all participants were given a map and text describing the restoration.

It is clear that the interviewees in the previous chapter saw the contrast between the River Don as they perceived it before its restoration and the River Don as it is now as evidence of management success and some lamented the fact that less money was being invested into maintaining the improvements that had been achieved with the consequences of them being reversed. They were particularly appreciative of the improved access which in large part was due to the construction of infrastructure such as the Five Weirs Walk and the information boards which provided the opportunity to learn about the river's heritage (The Five Weirs Walk Trust, 2015). However, one participant in the interview study did say that in her view the council had spent too much money on decorative aspects of the Five Weirs Walk infrastructure. In order to foster trust and ultimately support for conservation it is important to convince the public that those organisations who will be responsible for the management of the River Don in the future used financial resources responsibly and effectively in the past (Van de Walle and Geert, 2007). It is also possible that reading the present text and visiting the River Don led participants to conclude that the infrastructure that they had seen was not worth the amount of money which had been invested in it. In the interview study one participant complained that the council spent too much money on the underutilised Five Weirs Walk footpath and did not trust them to spend economic resources wisely in future. However, as only one of the six present paragraphs included the amount spent on any infrastructure other than flood defences this is unlikely to explain the overall trend.

5.4.1.2 Present environmental perspectives

Those who read the historical information significantly agreed with the statement "*The River Don harms local wildlife"* and disagreed with the statement "*People who walk along the banks of the River Don are likely to see some exciting wildlife*" to a greater extent than those who read the present text. These trends suggest that those who read the historical information valued the River Don to a lesser extent from an environmental perspective than those who read the present text. Those who read the past text may have underestimated the extent to which the River Don has been restored since the period which was described in the text. This would reflect Gobster and Westphal's (2004) and Pendleton's *et al*., (2001) findings that many people are unaware of the successes of local restoration efforts including reduced water pollution if they are unable to directly sense them. It is likely that many participants were aware that the River Don no longer would be described as an "*open sewer"* as improvements were strongly recognised by interview participants and basic knowledge of the ecological benefits brought from moving from an industrial to a post-industrial society would enable them to surmise that it was very likely that the River Don was substantially less environmentally degraded now than it had been a century ago (Simmons, 2001). However, the aim of this study was to compare the ways in which the River Don at present was perceived by those who read the historical information and the current text, not to describe how they perceived that the River Don had changed over the last hundred years. Reading the present text may have also increased the extent to which participants valued the River Don from an environmental perspective as information on several charismatic species and protected areas was available whilst for the historical text I had to rely on a few fish recordings and the opening of the sewage works as very little information was available on the positive aspects of the River Don's environment from an environmental perspective during this time period.

Although reading historical information significantly increased the extent to which participants believed that the River Don harmed wildlife it did not significantly affect participants' perceptions of the extent to which it was either polluted or physically degraded leaving the question how did participants think that the river harmed wildlife? Another way in which participants may have believed that the River Don harmed wildlife was the presence of non-indigenous species but this belief would be expected to be held by a greater proportion of those who read the present text than the historical information as non-indigenous species were only mentioned in one of the present texts. It may have been that a greater proportion of participants who read the historical information than those who read the present information believed that the River Don was both polluted and physically degraded but these differences were not large enough to detect individually but both of these differences led to a bigger difference between those who read the historical information and those who read the present text agreeing that the River Don harmed wildlife. In line with this hypothesis 53% of participants who read the historical information agreed or strongly agreed and 49% agreed or strongly agreed that pollution prevented wildlife from thriving on, in or by the river. However, contrary to this hypothesis 45% of those who read the historical information and 51% of those who read the present text agreed or strongly agreed that physical degradation prevented wildlife from thriving on, in or by the River Don. The most likely explanation is that participants' answers were based on the extent to which the historical or current information explicitly told them about the river's ability to support wildlife to a greater extent than they were based on the aspects of the river which could harm wildlife.

It is interesting to note that the proportion of participants who agreed or strongly agreed that the River Don was polluted or physically degraded was relatively similar and there was relatively little difference between those who read the historical information and those who read the present text in this aspect. Pollution was mentioned in five past texts and three present texts whilst physical degradation was mentioned in two past texts and one present text. A larger proportion of participants were therefore informed about the pollution than were informed about the physical degradation. Knowledge that the River Don used to be polluted and physically degraded may have had little influence on current perceptions as participants may be generally aware that the extent to which rivers are polluted in this country has fallen greatly as society transitioned from an industrial to a post-industrial economy (Simmons, 2001). This view was expressed by many interview participants. Knowledge that the River Don was previously physically degraded may have had little impact on current perceptions of the effects of such physical degradation on wildlife. Very few interview participants discussed physical degradation when discussing the River Don as it is today although just under half discussed historical physical degradation.

The previous chapter also found that historical information could increase the extent to which participants believed that the River Don harmed wildlife today. Many interviewees recognised that whilst wildlife was returning it was still depleted as a result of the river's industrial legacy. They were particularly aware that current abundances of flagship species such as salmon, water voles and otters were lower than they had been prior to the river's environmental degradation. Although the reading of historical information in the experiment did not significantly affect people's perceptions of pollution levels or physical degradation on the River Don, some of the interviewees' perspectives on these issues were influenced by historical knowledge in the previous study whilst others were not. For example, one interviewee said that due to the river's industrial past it was currently too polluted to kayak in. Another recognised that the river had previously been very polluted but described it in it its current state as "*very, very clean*". Whilst some recognised that the River Don's course had been greatly altered from its original path they did not consider the impacts that this had had on nature within the river. One recognised that the dams which were constructed to create the reservoirs still posed a barrier to fish migration. Another participant believed that whilst the weirs had been a barrier to wildlife in the past they no longer are due to their degradation. Collectively the findings of these two studies suggest that historical information may help people to understand the role of industry in the degradation of the River Don but in order to foster support for its environmental management such information will need to be complemented by information regarding the extent to which the river is still both chemically and physically degraded (Firth, 1997; Hull Biodiversity Partnership, 2008).

5.4.1.3 Influence of frequency of visits on effects of experimental treatment

It was expected that the effects of experimental treatment on perceptions of the River Don would be greatly influenced by frequency of visits. Previous experiments have demonstrated that an individual's interpretation and recall of information is often distorted by their wishes, motives and attitudes (reviewed in Hyman and Sheatsley, 1947). According to Relph (1976) personal experience of landscapes is the greatest factor in determining people's perceptions of them. The desire to use landscapes for recreational purposes is a motive which influences landscape preferences (Gobster and Westphal 2004). Prior knowledge can also negatively influence the extent to which participants' views are influenced by the novel information which they process as the experimental treatment (Iyengar *et al*., 1982). Previous experience of a landscape is thought to be positively correlated with knowledge of that landscape. The extent and type of outdoor recreational activities which people engage in is related to their philosophical views of nature (Dunlap and Heffernan, 1975). Further research is therefore needed to better understand the influence or lack of influence of prior experience of a landscape on the effects of novel historical information on perceptions of that landscape. However, this experiment found that the only relationship between reading historical information and current perceptions of the River Don which was influenced by frequency of visits to the river concerned the justification of the costs of maintaining the river and its associated infrastructure. This was discussed in section 5.4.1.1..

5.4.2 Relationships between frequency of visits, current perceptions and future predictions

This study also found that those who visited the River Don more frequently were significantly more likely to believe that it provides high quality habitat today and more optimistic that in the future it would be less harmful towards wildlife and visitors would have a good chance of seeing charismatic wildlife. The purpose of this experiment was to establish the effects of historical information on participant's current perceptions of and future predictions regarding the state of the River Don and the ways it benefits and adversely impacts people and wildlife so this will not be discussed in too much detail. However, a positive relationship between frequency of visits and current and future predictions regarding a landscape may be explained through the sense of place concept which recognises that the extent of previous experience which people have of a landscape positively influences the extent to which they value it (Tuan 1977; Williams *et al*., 1992).

5.4.3 Lack of Significant Results

Reading historical text rather than present text had less effect on participants' perceptions of the River Don as it is today and as they expect it will be in the future than expected (Sectin 5.4.1). Reading historical information only affected the extent to which participants agreed or disagreed with four of the 36 statements. It was expected that the effect would be greater as Pendleton *et al*., (2001) and von Klan (1996 cited in Gobster and Westphal, 2004) both reported time lags between restoration and public recognition of an ecosystem's improved state. With regards to the River Don Chapter Four corroborates the findings of these studies to an extent as one participant said how surprised she had been when she had first visited the River Don as her experience far exceeded her expectations which were based on its degraded past. The effects were expected to be particularly strong in this experiment as the past text described the River Don in a severely degraded state whilst the present text described it in a much restored state. Furthermore, approximately one third of the participants had never visited the River Don before so would not be expected to have much information other than that included within the text provided from which to form their opinions. Although it is possible for people to learn about the recent history of the River Don without visiting it, for example through word of mouth, websites and newspapers, the interview study described in Chapter Four found that the main source of information regarding recent improvements was personal experience. This does not mean that participants who read the past text were expected to assume that the River Don was still as degraded as it was approximately one century ago but that they would lack knowledge of the extent and details of the improvements. This is because people can infer that the River Don is a lot less degraded than it previously was from a basic understanding of Britain's transition from an industrial to a post-industrial society (Simmons, 2001).

Surprisingly this study found that experimental treatment had particularly little effect on current perceptions of the River Don from a social perspective despite interviewees in the previous study: attributing reduced current recreational opportunities to the legacy of chemical pollution and hazardous submerged objects left by industry; and valuing the recreational opportunities now afforded by the River Don to a greater extent as they recognised that the River Don did not provide these opportunities in the recent past. Furthermore, it may be expected that participants would take more from the social aspects of the content of the text as previous studies have found the public deem social aspects of the landscape such as recreational opportunities and aesthetics to be more important in shaping their landscape preferences than environmental factors (Edwards-Jones *et al*., 1995; Coles and Bussey, 2000; Brown and Raymond, 2007; Tyrväinen *et al*., 2007). Further research is needed to develop our understanding of the relationship between historical information and perceptions of landscapes from a social perspective.

It was expected that reading text on the River Don's past would affect participants' future expectations of it as other studies have demonstrated that historical information can influence people's hopes for the future state of landscapes in terms of restoring biota or ecosystem services which have been lost (Crate, 2006; Drenthen, 2009; Hanley *et al.*, 2009; Gomes, 2012). Of these Hanley *et al*. (2009) were the only ones to use experimental research techniques. They found that requiring visitors to view historical maps from the 18th and 19th centuries together with information on vegetation from the same time period and current vegetation information under experimental conditions increased support for proposed afforestation. Whilst the above studies all focused on restoring what had been lost and the interview study found evidence that many people hoped that wildlife which had been lost from the river would return; another participant saw the River Don's history as evidence that there was potential for its state to deteriorate greatly relative to its current conditions. This suggests that in a partially restored ecosystem the public perceive the potential for further restoration but also degradation reversing recent progress.

Given that other studies, including an experimental one, have found people's perspectives and behaviour to be influenced by historical information the lack of a significant effect of historical information on participant perceptions in this study could be a result of methodological differences between the studies or sensitivity of the effect to study-specific facts such as the type of environment or participants. With the exception of Hanley *et al*. (2009) all of the studies listed above were qualitative in nature and therefore the extent to which their findings were applicable at a population level is questionable (Bryman, 2008). Study-specific differences could include: 1) the focal landscape – this study is unique in focusing on a restored ecosystem within a post-industrial city; 2) participants' lack of personal experience of the focal ecosystem; 3) the historical information used – this study aimed to give a balanced account of the River Don as it was approximately 100 years ago from a social, economic and environmental perspective, whilst other studies have used elders' personal accounts (Gomes, 2012; Crate, 2006) and contemporary maps (Hanley *et al*., 2009); 4) the focus on present perceptions and future predictions when measuring participant perceptions whilst the other studies have focused on future hopes; 5) the use of intended future frequency of visits as an indicator of behavioural change in response to historical information whilst others have used engagement with the donation of voluntary labour or financial resources to the restoration or other environmental management of the landscape (Gomes, 2012; Drenthen, 2009; Hanley et al., 2009). Hanley *et al*. (2009) also benefited from a substantially larger sample size as they interviewed 504 people and only had two response variables and thus did not need to reduce their significance threshold to account for multiple tests. Further research is required to determine the relative effects of each of these factors in explaining the lack of significance in these results.

The fact that this study uses historical information from a time when the River Don was far more environmentally degraded than it is today (Firth 1997) is likely to influence the ways in which historical information influences current perceptions and future predictions. However, there is strong theory and empirical evidence from Chapter Four to suggest that these would be influenced by such historical information as discussed within this section above.

It was expected that prior knowledge and personal relevance of the landscape as indicated by frequency of visits would influence the extent to which participants' perceptions of it were influenced by the experimental treatment for three reasons. Firstly, the constructivist view of learning postulates that people develop their understanding and perceptions of a concept by combining their prior views and knowledge with the novel information to which they are exposed (Henricksen, 1998). Secondly, Ajzen *et al.* (1996) reasoned that those with who found greater personal relevance with regards to the issues addressed in the information presented to them are likely to be more motivated to give greater attention to processing the information and arguments contained within it; whilst those who found the issues to be of low personal relevance are more likely to be influenced by superficial cues, implicit moods or motivations or factors that are unrelated to the content of the message. Thirdly, the provisioning of balanced information has been found to polarise the opinions of those who found the issues covered in the information provided to be of high personal relevance and reduce the strength of the opinions of those for which the issues had low personal relevance (Millar and Tesser, 1986 cited in Bright and Manfredo, 1997). This is believed to be because: those with a vested interest are likely to develop counter arguments against information which is contrary to their prior beliefs whilst using information which is consistent with their prior beliefs to strengthen them; whilst those for which the issue is of low personal relevance are unlikely to be motivated to provide counter arguments (Petty and Cacioppo, 1986 cited in Bright and Manfredo, 1997). Given that only one of the four significant relationships between experimental treatment and participants' perceptions of the River Don as it is today and predictions for its future was significantly influenced by the frequency with which participants visited the River Don (Tables 1 and 2) it can be surmised that frequency of visit had less influence on the effects of information on influencing participants' perceptions than expected.

Relatively little research has been done on public predictions regarding future landscapes. However, historical information has been found to influence people's hopes for the future of landscapes by increasing the extent to which they wish to restore reference conditions, ecosystem services from which they and former generations previously benefited and traditional management practices and the extent to which they are open to change (Petts, 2006; Crate, 2006; Drenthen, 2009; Hanley *et al*., 2009; Gomes, 2012). Predictions of anthropogenic changes are generally based on intuitive understandings of the causal factors which influence human behaviours (Ajzen, 1977). People identify the presence and absence of causal factors from the information which is available to them and use these to inform their predictions. For example, this experiment found that those who read the past text were more likely to believe that the River Don currently harmed wildlife. If they viewed the desire to reduce the harm that degraded ecosystems do to wildlife as a causal factor driving behaviours to restore rivers they may be expected to predict that the River Don will harm wildlife to a lesser extent in 25 years' time than it does today. The interview study found that the restoration of depleted wildlife was a key motivator for the desire to restore the river. Statistical information can also influence predictions for example outcomes which were more common in the past would be expected to be more likely in future (Ajzen, 1977). It can therefore be inferred that if participants read the historical information and concluded that the river had not yet been restored to the same extent as other rivers they would predict better outcomes in the future. As those who read the past text were more likely to believe that the River was currently a threat to wildlife they may be expected to be more likely to believe that the River had not already been restored to a similar extent as other rivers. Conversely, hopes are based on personal goals assuming that the change which is hoped for is perceived by the individual to be possible and is thus influenced by available information to a lesser extent than predictions (Miceli and Castlefranchi 2002). It may therefore be surmised that the lack of significant effects of the experimental treatment in this study was unlikely to be due to asking participants about predictions rather than hopes.

The texts used in this experiment aimed to simply describe either the river in its present or historical state and how this affected its ability to provide ecosystem services and ecosystem disservices and sustain wildlife; rather than use persuasive arguments with the aim of influencing participants' views in particular directions. To minimise bias it was ensured that one positive and one negative social, economic and environmental point was made in each text. There is both theory and empirical evidence to support the notions that bias information can be both more and less influential than less bias information. Brosius (1994) found that despite having lower validity to describe social issues exemplars had a greater influence on people's perceptions of these issues than information from more credible sources which aimed to provide an overview of the issue supported by statistical information. The exemplars may have been more influential because exemplars are more effective at gaining the reader's attention as they are often more emotionally engaging and enable the formation of vivid images in the readers mind (Brosius, 1994). Conversely, the ability of such text to influence readers may be increased by their perceptions that the communicator was knowledgeable, open-minded and rational (Smith, 1984; Allen and Reynolds, 1989; Allen and Stiff, 1989 all cited in Allen, 1991; Allen 1991). This is supported by Hanley *et al*'s (2009) finding that an experiment which used objective information on vegetation cover elicited significant changes in participants' support for afforestation including their willingness to pay for it whilst an experiment which used bias contemporary information sources did not. As there were many differences in the focal landscapes and the sources of information used in these two experiments no causal effect can be assigned to the relative objectivity of the information source which had a significant effect. However, it does prove that objective historical landscape information can influence future hopes and behavioural intentions. Unfortunately Hanley *et al*. (2009) made no suggestions for the lack of a significant result when analysing the information from the experiment which used bias contemporary information.

The use of intended change in future frequency of visits was used as a measure of behavioural change in this study as it was a low cost behaviour in terms of both time and money and likely to reflect any change in the extent to which participants valued the river as a recreational resource. The River Don is only a 15-20 minute walk from the University. Given the low cost of the activity relative to contributing labour or finance to restoration projects I doubt that the use of this measure of behavioural change reduced the likelihood of finding a significant effect of treatment on it.

5.4.4 Implications for Other Ecosystems

As stated in section 5.1 the River Don was selected as a case study in part because of its similarity to other post-industrial rivers. Like other post-industrial rivers the River Don has been restored to a great extent but there is still a legacy of severe degradation some but not all of which could feasibly be reversed. Currently despite their severe need for effective environmental management and the great importance of public perceptions we have very little knowledge or understanding of how historical knowledge affects people's perceptions of such ecosystems. Findings from this study may therefore be useful in informing the management of other ecosystems and further research. According to Kennedy (1979) cases studies are often "*successfully used to draw inference about the general case*". However, the extent to which findings from single case studies are generalizable is not by those who undertook the initial case study (Kennedy, 1979). The more similar the ecosystem under consideration is to the case study, the more likely it is that the case study's findings apply. However, caution should be taken as all ecosystems and human populations differ and the effects of these differences on the applicability of the case study's findings may not be readily apparent. With that in mind it is worth highlighting the findings of this case study which are most likely to be generalizable to other ecosystems.

- Providing historical information on a partially restored river in its more degraded state without providing information on its current state can lead people to underestimate the extent to which an ecosystem has been restored. Although this study found no influence of the effect of frequency of visit on this effect it is likely that it applies particularly strongly to those who have little other information on the ecosystem's current state and the failure to find an interaction was simply down to small sample size (Pendleton *et al*., 2001).
- Providing historical information on a partially restored river in its more degraded state to those who visit it frequently can increase the extent to which they believe the cost of maintaining it and its associated infrastructure is justified. Although this may be in part due to some of those who read the current text being told some of the high costs it is also linked to theory that good past performance as evidenced by the River Don's transformation increases trust in managers. Case study findings which are linked to existing theory are more likely to be broadly applicable.
- Providing historical information on a partially restored river in its more degraded state can increase the extent to which people expect it to improve over the next 25 years. This may

be because they have more trust in management as they can see how the river has already been improved but it may simply be that they see more room for improvement if they believe the river to have been restored to a lesser extent than it has already.

- Simply providing historical factual information without making a conscious effort to influence people's perceptions of an ecosystem's current and future states may have relatively little effect on their perceptions even if the historical information describes the ecosystem in a very different state than its current state. This may be particularly true when those people have little prior knowledge of or interest in the particular ecosystem. This aim may be more effectively met by using historical information to more explicitly support environmental management aims. For example, by explaining how historical activities have left a legacy of degradation and how conservation practitioners aim to reverse them.

5.5 CONCLUSION

This study found that reading past or present text as an experimental treatment significantly influenced participants' perceptions of the River Don in its current state from an economic and environmental perspective. However, it did not significantly influence their perceptions of its current state from a social perspective or predictions regarding its future state or intentions to alter the frequency with which they visited it. Those who read the past text valued the River Don to a lesser extent than those who read the present text from both an economic and environmental perspective. However, those who visited the River Don frequently and read the past text believed that the cost of maintaining the infrastructure associated with the River Don was justified to a greater extent. This was the only effect of experimental treatment which was influenced by the frequency with which participants visited the River Don.

Significant results in this experiment reflected beliefs expressed by interviewees in the previous chapter regarding the influence of historical knowledge on their current perceptions. The experiment demonstrated the extent to which historical information caused changes in people's perception of the River Don whilst the interviews provided much more detail and a wider range of perspectives. This detail was useful for explaining why the experiment participants may have answered the questions in the way that they did. However, whilst many interviewees described how their current perceptions of the River Don from a social perspective and their future expectations of the river were influenced by knowledge of the river from the time that it was heavily exploited by manufacturing industries the experiment did not find any evidence to suggest that these perceptions were influenced by historical information. Further research will be needed to address this discrepancy. This study demonstrates that mixed methodological approaches including interviews and experiments are an effective way of developing our understanding of the effects of information and knowledge on landscape perceptions.

6 GENERAL DISCUSSION

A greater understanding of the environmental history of an ecosystem from both an ecological and a cultural perspective has the potential to facilitate decision making regarding its future management in terms of: describing reference conditions which may facilitate the setting of appropriate end goals; describing environmental degradation and its drivers which may facilitate their reversal; and evaluating the effectiveness of past conservation techniques in order to maximise return on investment. Broadly this thesis aimed to evaluate the extent to which the environmental and cultural history of an ecosystem could be described and explore the ways in which historical knowledge of this ecosystem influenced people's perceptions of it as it is today and their predictions for its future. The River Don in South Yorkshire was chosen as a case study as it has a long and varied history but has always been highly valued by people, albeit for very different reasons (Firth, 1997). People initially settled along the River Don because it was a source of water and provided defence. It then became an important commercial salmon fishery. By the industrial revolution it powered a wide range of industries including Sheffield's steel industry. These industries also benefited from the River Don as a navigation, a water supply and a conduit for the removal of waste. Industry severely polluted and physically degraded the river with grave consequences for its biota. However, it has since been restored to a great extent and is now valued highly for its recreational opportunities, heritage and wildlife. Despite this its biota are still adversely affected by pollution, physical degradation and non-indigenous species, meaning that it will need to be actively and effectively managed to a significant extent into the future. There is, therefore, great potential for benefit from the application of historical information to its uture management. More specifically this study aimed to:

1) Evaluate the extent to which biological records of fish from the River Don can be used to describe the historical changes in the composition of the river's fish community and assess the extent to which these changes are indicative of either the interactions between species traits, environmental changes and direct interactions between people and fish such as introductions and restocking which are likely to have shaped community composition; or recording biases. The findings were then used to assess the extent to which these records could be used to inform the river's future environmental management.
2) Describe the history of the River Don as conveyed through newspaper articles in terms of ecosystem services, ecosystem disservices and environmental management; and consider how this may contribute towards the effective future environmental management of the river.
3) Assess the extent to which local people are knowledgeable about the history of the River Don and describe how their perceptions of its current state and predictions about its future state are influenced by their historical knowledge. Consider how these findings may inform communications to foster support for and minimise opposition against the river's conservation.
4) Experimentally assess the effects of the provisioning of historical information about the River Don on people's perceptions of how it is now and how they expect it to be in the future. Use the findings to consider how historical information may be used as a tool to raise public awareness and foster support for the river's conservation.

6.1 PRINCIPAL FINDINGS

6.1.1 Fish Biological Records

Chapter Two evaluated the extent to which biological records of fish from the River Don dating back to the 14th century could be used to describe the historical changes in the composition of the river's fish community and assessed the extent to which these changes could be attributed to either the interactions between species traits, environmental changes and direct interactions between people and fish such as introductions and restocking which were likely to have shaped community composition; or recording biases. It used these findings to assess the extent to which these records could be used to inform the river's future environmental management. Biological records were collected from a diverse range of sources including: local biological records centres, a local natural history society, local libraries, a local museum, local angling clubs, the DCRT (Don Catchment Rivers Trust) and the EA. The data were analysed in three different ways. Firstly, changes in the number of: salmonid and coarse fish species; pollution tolerant and pollution sensitive species; and species which were of different levels of interest to recreational anglers; and species which had historically been eaten by people to different extents were described. Secondly the fish species were classified into the following categories according to the presence trajectory type which they showed in the biological records: extirpated, NIS (non-indigenous species), recently appeared, resident and restocked. These categories were compared with regards to their habitat preferences, functional traits and utilitarian values.

The only functional trait which differed significantly between presence trajectory type categories which was believed to influence the way in which actual fish composition had been modified by environmental changes was adult flow preferences. These species were predominately NISs and species which had only appeared recently suggesting that they benefited from the impoundments. However, strong evidence for recording biases was found as larger species which were of greater interest to anglers were more likely to have been recorded earlier. Previous studies have also found that impoundment results in fish communities becoming increasingly dominated by lentic species including NISs (Marchetti and Moyle, 2001; Clavero *et al*., 2004) and that species which are of greater interest to anglers are more likely to be recorded (Cooper and Wheatley, 1981). The biological records were particularly useful for identifying species which had been extirpated from the River Don. Once these had been identified it was possible to identify likely causes of their extirpations by assessing the extent to which the reasons for which they had been extirpated from other rivers was likely to have been applicable to the River Don based on its environmental history. It was surmised that both the pollution and physical degradation of the River Don were likely to have contributed towards their extirpation.

6.1.2 Newspaper Articles

Chapter Three described the history of the River Don as conveyed through newspaper articles in terms of ecosystem services, ecosystem disservices and environmental management. The analysis of historical newspaper articles from the 18th century onwards found that the River Don has been highly valued by local people throughout this time period but for very different reasons. It was initially valued by industry primarily for water, power and navigation but this led to its severe environmental degradation particularly with regards to pollution. Historical newspaper articles also evidence the number of times that structural flood defences have failed, highlighting the need for a more holistic approach from a social as well as environmental perspective (Johnson *et al*., 2005).

Today, like many post-industrial European rivers it is primarily valued and managed for recreation and wildlife (Firth, 1997; Bothmann *et al.*, 2006). This was reflected in substantial decreases in the proportion of articles which mentioned non-cultural ecosystem services particularly those mentioned above from the 19th century to the 20th century and a concurrent substantial increase in the proportion of articles which mentioned cultural ecosystem services, particularly angling, heritage and wildlife sightings. The way in which recreational opportunities were portrayed also changed greatly through time with much greater reporting of actual or narrowly avoided deaths as consequences of participating in recreational activities in the 19th century than the 20th century.

Decreased deaths together with few reports of crime could be used to educate the public that whilst it is important to take sensible precautions to stay safe whilst visiting the River Don they should not avoid it out of fear (Valentine 1989; Hillman, 1999; Zani, 2003 all cited in Prezza *et al.*, 2005; Prezza *et al*., 2005; Wyver *et al*., 2010). Increased use of the River Don for recreation could potentially foster greater support for conservation (Haslam, 1997). Improvements in angling opportunities were particularly well documented in the newspaper articles. In the 1970s there was very little chance of catching anything but in the mid-1980s it was reported that the river supported a high quality gaming fishery. Sightings of charismatic species such as salmon, otters and marine mammals generated much public excitement and received much media attention from the 1970s to the 1990s. Publicity of such species may help foster support for conservation (Heywood, 1995 cited in Bowen-Jones and Entwistle, 2002). However, it is important that this is well thought through as restoring habitat for single species may not yield the intended broader ecological benefits (Simberloff, 1998).

Although efforts to mitigate against the pollution of the River Don can be traced back to 1870 it was not reported in the newspaper articles that pollution levels had actually decreased until 1979. Concerns about the effects which pollution had on non-cultural ecosystem service provisioning and public health were first evidenced in the newspaper articles in the 19th century and there was much concern about the impact which pollution had on recreational fisheries in the 20th century. However, it is likely that the Rivers (Prevention of Pollution) Act (1961), which was explicitly referred to in one newspaper article, followed by the creation of the National Rivers Authority in response to higher water quality standards required under European legislation together with the loss of industry which was only mentioned in one article were the most effective drivers of reduced pollution (Firth, 1997; Johnson and Handmer, 2002; Langford *et al*., 2009). Despite this public support is essential for effective restoration and is likely to be maximised by recognition of what anglers and other community groups have achieved (Bandura, 1971 cited in Masia and Chase, 1997; Phillips, 1980; Phillips and Cartensen, 1986; Bandura, 1986 all cited in Rimal and Real, 2005). Several articles described such work, particularly with regards to litter removal. Very little attention was paid to the river's physical degradation and restoration and the threats posed by invasive species were not discussed so there is probably potential for environmental managers to foster more support to address these issues through greater publicity.

6.1.3 Public Perceptions: Interviews

Chapter Four assessed the extent to which local people were knowledgeable about the history of the River Don and described how their perceptions of its current state and predictions about its future state were influenced by their historical knowledge. Twenty-three members of local walking groups were asked: what they knew about the history of the River Don from before the industrial revolution onwards; how they perceived it today as a recreational resource; and how they expected that it would be in 25 years' time.

The key findings of this study were that although participants generally had relatively vague knowledge of the River Don's reference conditions they had a strong desire to restore them especially with regards to landscape aesthetics and the recovery of charismatic species populations. This study defined reference conditions as an ecosystem's "*non-degraded natural baseline"* (Bennion *et al*., 2011). Two participants explicitly stated the desire to learn more about the reference conditions before deciding how they hoped it would be in the future, suggesting that at least some members of the public would welcome greater efforts to communicate the river's reference conditions to them. Gooch (2003), Drenthen (2009) and Gomes (2012) also found that people had strong desire to restore reference conditions even if their knowledge of them was limited. They were particularly keen to restore landscape aesthetics and charismatic species. Awareness of pollution and general wildlife depletion was very good but there were substantial knowledge gaps with regards to physical habitat degradation and invasive species which could potentially be addressed through greater public communications. The participants generally showed strong desire to reverse the environmental degradation which they were aware of and appreciated the extent to which it had already been reversed. However, knowledge of historical degradation did not always lead to knowledge of current degradation. For example, there was much greater awareness of the historical effects of weirs on fish migrations than the need to address this in future. Furthermore, many were concerned that further improvements had not been made in recent years and some believed that the river had become more degraded as financial constraints had limited active management. Awareness of this increased their demand for more action to be taken.

Additionally, this study found that knowledge of environmental history could foster support for conservation through: a stronger desire to visit either because they are attracted by the river's heritage or because they appreciate its current state more in comparison to its previous state due to the contrast principle (Haslam, 1997; Cialdini, 2007). However, it could also foster opposition against environmental management by increasing support for the conservation of heritage remnants which adversely affect wildlife such as weirs and increasing support for microhydropower schemes which may contribute to the environmental degradation of the River Don (Abbasi and Abbasi, 2011). Ostergen *et al*. (2008) and Drenthen (2009) also found resistance towards the restoration of landscapes which had been valued in their modified state for generations. However, with regards to the management of the River Don this opposition may be relatively weak as extensive public consultation found no opposition towards the installation of fish passes on heritage grounds (personal communications with Edward Shaw, Trustee of DCRT, January 2016). Lack of historical knowledge also had the potential to reduce support for potentially environmentally harmful projects such as flood defences as participants were generally unaware that the River Don had a history of frequent flooding and were thus not too concerned about the future flood risk. Participants also lacked knowledge on historical crime and deaths which could lead to them feeling that it is a safer place to visit and thus increase the extent to which they use it for recreation and ultimately support its conservation (Haslam, 1997).

6.1.4 Public Perceptions: Experiment

The aim of Chapter Five was to experimentally assess the effects of the provisioning of historical information about the River Don on people's perceptions of how it is now and their predictions for its future and use the findings to consider how historical information may be used as a tool to raise public awareness and foster support for the river's conservation. Participants were asked to read information either on the River Don as it was approximately one century ago or as it is today. Participants were then asked to answer Likert scale questions about their perceptions of the River Don as it is today, their predictions for how it would be in the future, the frequency with which they currently visit the River Don and the extent to which they expect this to change having participated in the experiment.

Those who read historical information as the experimental treatment were: more likely to believe that the River Don currently harms local wildlife; less likely to believe that current visitors would see charismatic species; and less likely to believe that the River Don currently benefited the local economy. This suggests that those who read historical information about the river believed that its current state is more similar to its historical state as described in the text than it is in reality as they did not recognise the extent to which it had been restored in recent decades. Gobster and Westphal (2004) and Pendleton *et al*. (2001) also found that local people did not recognise the extent to which the environmental quality of local recently restored ecosystems had improved and thus believed them to be more degraded than they were. Reading historical information reduced the extent to which those who visited the River Don less than a few times a year believed that the cost of maintaining the river and its associated infrastructure was currently justified but had the opposite effect on those who visited it more frequently. This further suggests that they were unable to recognise the extent to which the river had been restored as a result of such expenditure. However, knowing about the River Don during the industrial period and today as a result of reading historical information and visiting it frequently led participants to believe that the money which had been invested into its maintenance had been spent wisely. The interview study found that knowing about the history of the River Don could have both a positive and negative affect on the way in which it is viewed today. It could have a positive effect through the contrast effect and by increasing its heritage value (Cialdini, 2007). It could have a negative effect as people realised that not all of the environmental degradation caused by industry and associated urbanisation had been reversed. The benefit of the experiment was that it was able to identify which effect was stronger at a population level. This also showed the benefit of a mixed method study in that the qualitative component helped explain the quantitative results.

6.2 SYNTHESIS

6.2.1 History of the River Don

This section will draw insights from Chapters Two, Three and Four to describe what can be learned about the history of the River Don from biological records, historical newspapers and interviews with local people; compare the extent to which different aspects of the history of the River Don are evidenced by the different information sources; and identify the historical aspects of the River Don which are not well covered by any of these information sources.

The clear narrative shared by all three studies was that the river had become degraded leading to the depletion of wildlife then to a large extent restored towards its reference conditions. The driving forces behind the depletion or recovery of the fish populations could not be inferred from the fish biological records alone. Attempts to achieve this by: comparing how pollution tolerant and pollution sensitive fish and coarse fish and salmonids had changed through time; and comparing the functional traits and habitat preference of species with different presence trajectories (resident, extirpated, recently appeared, restocked and NISs) on the River Don provided very little insight due to the sparsity and bias nature of the historical records. The most useful information which the fish records provided and which were not provided by the other two sources was a list, albeit probably incomplete, of species which had been extirpated from the River Don. This provided insights into the ecological consequences of the pollution and physical degradation of the River Don including the construction of weirs, the loss of wetlands and abstraction.

The newspaper articles and interviews with local people provided much more insight into the drivers behind the degradation and restoration of the river from a chemical, physical and social perspective. Chemical pollution and physical degradation of the River Don and its reversal was evidenced by both the newspaper articles and the interviewees but the negative ecological impacts of NISs were only recognised by the interviewees. The key shared findings of these two chapters were: the River Don played a very important role in the development of industry; the demise and recovery of the River Don was largely due to increased followed by decreased pollution; the river was also physically degraded in terms of impoundment, channelisation, abstraction and dredging which contributed further to wildlife degradation and have been reversed to a lesser extent than the pollution; today the River Don is largely valued as a place to participate in recreational opportunities including engaging with wildlife and heritage.

A key strength of the newspaper articles over the interviews was that they communicated the changes in attitudes which led to early changes in management practices. These benefited from the opportunity to read attitudes which were expressed at the time rather than retrospectively. For example, in 1864 it was argued at a Sheffield Town Council meeting that the reduced flow caused by abstraction rather than the increased quantity of effluents being discharged into the River Don was responsible for the severity of its pollution. This was a commonly held belief in Victorian times known as negative pollution (Sheail, 1984 and 1986 both cited in Sheail, 1996). By 1874 it was reported that efforts had been taken to reduce the amount of pollution entering the river. Similarly, in 1845 an article indicated that industrialists believed that the River Don provided an almost unlimited supply of water but by 1874 great efforts were being made to conserve water. Documenting efforts to reduce pollution from 1870 onwards facilitated comparisons between strategies of varying levels of effectiveness. This information suggests that the enforcement of The Rivers (Prevention of Pollution) Act 1961 cited in Langford *et al.* (2009) was the turning point for effectively reducing the extent to which the River Don was polluted and made more effective by the transition of regulation responsibilities from the Water Authorities, who were some of the biggest polluters to the National Rivers Authority. These dates illustrate another key strength of the newspaper articles over the interviews: they provided a more detailed timeline for both changes in the use and management of the river and changes in the extent to which it was polluted and able to support wildlife.

The newspaper articles also provided a lot more information on how the River Don had adversely affected people in the past in terms of flooding, deaths and crime. Interview participants were generally only aware of the 1864 and 2007 floods. The lack of awareness about historical flooding may simply be due to the fact that all interviewees were members of Sheffield walking groups so most lived in Sheffield and were more familiar with the history of the Sheffield section of the River Don. The only floods which were reported to affect Sheffield in the newspaper articles between 1960 and 2006 were those which occurred in 1968 and these were reported to have only flooded two roads (Daily Mirror: 24th September 1968)! Similarly no deaths associated with the River Don were reported to have occurred in the Sheffield area since the 1960s. Furthermore, as deaths which are not part of a larger incident generally affect relatively few people they are unlikely to remain in the public consciousness for a long time. Whilst the shocking numbers of deaths which have occurred historically may be more likely to be remembered such information is not readily available to the public. Crime was only reported in 23 of the 429 articles which were analysed suggesting that it has never been that prevalent or well reported so public knowledge of crimes associated with the River Don would be expected to be low. Only three articles published from the 1960s onwards mentioned crime, none of these mentioned violent crime and the latest was reported in 1984.

The newspaper articles and interviewees also provided further evidence to support the hypothesis that larger fish which were of greater interest to recreational anglers were more likely to have been recorded when present on the River Don before the more comprehensive surveys were undertaken initially in the 1970s by Sheffield City Museums (Mander, 1976) and from the 1980s onwards by the EA. This illustrates the benefits of using qualitative research to help explain quantitative data (Lewin *et al*., 2009). The species which received the most attention in both sources were salmon (*Salmo salar*) and trout (*Salmo trutta*). The newspaper articles also mentioned the recovery of pike (*Esox lucius*), roach (*Rutillus rutilus*) and minnow (*Phoxinus phoxinus*). Salmon, trout and pike are three of the five largest species ever to have been recorded on the River Don in terms of maximum length. All of the species with the exception of minnow which were recorded to be recovering in the newspaper articles were of major interest to recreational anglers. Information on sources of information on fish functional traits and utilitarian values is provided in Chapter 2 and Appendix A. The interview participants recognised that salmon, trout, pike, carp (*Cyprinus carpio*), barbel (*Barbus barbus*), roach, dace (*Leuciscus leuciscus*), chub (*Leuciscus cephalus*), grayling (*Thymallus thymallus*) and perch (*Perca fluviatilis*) populations had all recovered at least to an extent in recent decades. With the exception of dace and perch all of these species were of major interest to recreational anglers. The first five of these were amongst the eight largest species ever to have been recorded on the River Don in terms of their maximum length as they all had maximum lengths over one metre. Furthermore, 42% of the conservation newspaper articles which mentioned fish mentioned anglers and demonstrated that the desire to restore recreational fisheries was a strong driver of fish and habitat restoration. Similarly, one of the two interviewees who stated that they visited the River Don in order to fish named six fish species which he reported to be recovering plus one additional species which was previously present and one additional species which was now present, demonstrating much greater awareness of the River Don's past and current fish communities than any other participant.

A key strength of the interviews over the newspaper articles was that the interviewees explained the ecological effects of environmental degradation to a greater extent than the newspaper articles. They were particularly aware of the historical impacts of the construction of weirs on fish migrations but did not consider how this affected the River Don today. Another key strength of the interviews over the newspaper articles was that they discussed the negative environmental effects of NISs. Although NISs were generally not discussed from a historical perspective the ability to identify what is non-indigenous is dependent on historical knowledge concerning what was naturally present. Several interview participants also explicitly recognised that in recent years, particularly since the economic recession, there has been less funding for managers which has resulted in the restoration of the River Don not continuing at the same rate and in some respects successes have been reversed.

Overall there was far less information in the newspaper articles and held by the interviewees regarding the physical degradation of the River Don and the ecological effects which the NISs have had on native species over recent decades. Historical physical degradation was only mentioned in three of the 429 newspaper articles which were analysed. One was published in the 1970s but the other two were reported within the last ten years. The one which was published in the 1970s recognised the need to restore the river's physical "*purity*" without explaining what was meant by this. The remaining two reported: the creation of a wetland which was designed to provide habitat for wildlife and recreational ecosystem services as well as flood defence; and returning a short section of the River Don to its old course. These articles did not describe the ecological consequences of the loss of wetland in the Don catchment which Firth equated to "*the present day destruction of rainforests*" (Firth, 1997) or the severe ecological consequences of channelisation (Nagayama *et al*., 2008). Whilst all interviewees were aware that the River Don had been polluted in the past only 11 of the 23 were aware that it had been physically degraded. Their collective knowledge included: the impacts of weirs on migratory fish, flow and sedimentation; and the effects of channelisation and wetland drainage on habitat heterogeneity and wildlife including water voles (*Arvicola amphibious*), trees and birds. Interview participants were even less aware of action which had been taken to mitigate against this. However, one was aware of the boulders which had been installed to increase habitat heterogeneity.

The only newspaper article which mentioned a NIS was published in 2000. It mentioned Japanese knotweed (*Fallopia japonica*) but touted its ecological benefits as food for caterpillars and shelter for otters rather than expressing concern over its negative ecological impacts. Eight of the 23 participants recognised that potentially invasive NISs were present on the River Don. Although only one of them considered a potentially invasive NIS from a historical perspective, historical knowledge regarding what was naturally present and what was introduced is needed to distinguish between native and non-indigenous species. Media content and public knowledge are generally considered to be quite similar because they both heavily influence each other which may help to explain why they had similar information gaps (Parlour and Schatzow, 1978; Kellert, 1985). However, this study found that only four of the 23 participants had learned anything about the history of the river from newspapers suggesting that they had both drawn their information from similar sources rather than heavily influenced each other directly.

6.2.2 Effects of Historical Knowledge on Public Perceptions

Public perceptions of landscapes play an important role in fostering support for and opposition against environmental management, ultimately having great influence over its success or failure (Stoll-Kleemann, 2001; Wohl *et al.*, 2005). The limited research on the relationship between historical knowledge and public perceptions which has been undertaken to date has indicated that historical knowledge may influence public perceptions of landscapes in ways which both foster support for and opposition against environmental management (Gooch, 2003; Ostergen *et al*., 2008; Drenthen *et al*., 2009; Hanley *et al*., 2009; Gomes *et al.*, 2012). Given the limited extent to which the relationship between historical knowledge and public and stakeholder perceptions of landscapes has been researched to date, particularly in the context of recently partially restored ecosystems, and the potential importance of this relationship in determining the success or failure of environmental management, such research is a priority. The aim of Chapters Four and Five was to increase our knowledge and understanding of this relationship, using the River Don as a case study, using a mixed methodology approach combining both qualitative and quantitative studies.

6.2.2.1 Mixed methodology approach

According to Swanwick (2009) the most useful studies of public perceptions of landscapes often use a mixed methodology approach, combining both quantitative and qualitative research techniques. This view reflects the increased value and utilisation of mixed methodologies in social research more broadly (Brannen, 2004; Bryman, 2008). Proponents of mixed methodology research recognise that all individual methods have inherent biases and limitations but their complementary use can help offset these and thus answer questions more comprehensively and with greater reliability and validity (Greene and McClintock, 1985; Greene *et al*., 1989; Bryman, 2008; Neuman, 2011). The key benefits of qualitative methods are that they allow participants to: express what is most important to them with minimal influence from the researcher; describe their often complex perspectives in detail; and explain their understanding of the reasoning behind their perspectives (Bryman, 2008). The key benefits of quantitative research include the ability to: quickly gain information regarding the views of many people in a short time period; measure individual variables; and identify and quantify associations and relationships between different variables (Black, 1999).

Previous studies using mixed methods to develop our understanding of how landscapes are perceived and used recreationally by the public have benefited greatly from the complementarity of quantitative and qualitative methodologies. Such studies have benefited from the opportunity to broadly describe the views of large numbers of people, whilst collecting more detailed responses from some in order to better understand the reasoning behind the views identified in the quantitative components of mixed method studies. For example, when Scott (2002) used quantitative questionnaires to broadly describe public perceptions of the Denbighshire landscape in Wales he was able to collect the views of 100 people but these were quite vague. For example, he found that a minority of participants disliked the trees. Using focus groups he was better able to describe what people disliked about the trees. For example, one of his focus group participants specified that they did not like the unnatural spatial distribution of the trees.

Furthermore, by giving participants the opportunity to express themselves freely researchers using mixed methodologies have identified issues which may be important in gaining support for environmental management but may have been completely overlooked by a purely quantitative approach through which participants' answers are constrained by the researcher's prior assumptions to a much greater extent (Bryman, 2008). For example, Gobster and Westphal (2004) used quantitative research to establish the extent to which local people believed it was important to make the Chicago River cleaner. Through focus groups they then established that the public believed that if the Chicago River was cleaned it would be much more similar to a mountain stream than it was in its reference conditions, about which participants had little knowledge. Gobster and Westphal (2004) were concerned that this would negatively influence public evaluations of the outcomes of the river's environmental restoration.

The use of quantitative methodologies within mixed methodology research has enabled researchers to test statistically for relationships between knowledge, perspectives and behavioural intentions. For example, Milman and Pizam (1995) used focus groups to identify what issues were important to the public when evaluating the Central Florida landscape in the US and the extent of agreement and disagreement on different issues to identify the variables to use in their quantitative questionnaire. This minimised the influence of the researcher's prior conceptions of which variables were important in the results of the quantitative questionnaire (Bryman, 2008). Quantitative methodologies within mixed methodology research have also enabled researchers to assess the relationship between landscape perceptions and actual behaviour. For example, by giving children the freedom to map and describe in their own words what was important to them within their home and neighbourhood landscapes and quantitatively measuring their activity levels Hume *et al*. (2005) were able to describe the relationship between children's perspectives of their home environments and their activity levels.

In addition to the benefits which quantitative experiments share with other quantitative research techniques described within this section above, experiments have the additional advantage of being able to determine causality between the variable which is manipulated by the experimenter (the treatment) and post experimental differences between treatment groups (Arceneaux, 2010). Whilst the use of qualitative methodologies in experiments aiming to describe the relationship between perceptions of landscapes and preferences for different management options or visiting different landscapes is relatively common this is largely restricted to the use of the findings of qualitative studies to inform experimental design (e.g. Huybers, 2003; Kim and Richardson, 2003; Christie *et al*., 2007; Scarpa *et al*., 2007; Ruto and Garrod, 2009). For example, focus groups have been used to identify which landscape attributes are likely to be most important to experiment participants (Huybers, 2003; Christie *et al*., 2007; Scarpa *et al*., 2007). These landscape attributes were then taken into consideration when deciding on the content of the landscape descriptions used in the experiments. Those who participated in the focus groups had similar relevant characteristics to those who later participated in the experiment. They were asked open questions regarding the factors which affected their perceptions of existing landscapes or management options. Kim and Richardson (2003) used a focus group to decide what film to show to experiment participants in an experiment which aimed to describe how being shown a film set in a landscape affected perceptions of that landscape. Christie *et al*. (2007) used focus groups to inform decisions regarding which stakeholder groups to include in an experiment which evaluated participant preference for different landscape management options. Although this experimental design technique is likely to reduce the extent to which participants' answers are limited by the experimenter's assumptions it does not realise the potential which qualitative research methodologies have to develop our understanding of the complexity of and reasoning behind participants' perspectives and behaviours as discussed within this section above.

The use of qualitative research in substantiating and explaining quantitative results from social experiments is better demonstrated in health and social care, a field in which qualitative studies are used increasingly frequently to provide detailed descriptions of participants' experiences of, and attitudes towards, illness, medical treatments and care (Lewin *et al*., 2009). Such studies have benefited from the freedom of participants to identify and explain the issues that are most important to them when evaluating trials with minimum influence from the researcher. For example, Fokkema and Knipscheer (2007), using an experimental approach found that the provisioning of computers and computer lessons reduced the loneliness of elderly people. The collection of qualitative data through in-depth interviews and evaluation forms enabled participants to explain how the intervention had elicited this effect. It had brought the expected benefit of facilitating communication with others but the act of learning something new had increased the confidence of one individual which in turn had given her more confidence to socialise in the real world. This could have easily been missed if the researchers had analysed the quantitative data collected through the experiment without the qualitative data. Similarly, Lord *et al*. (2010) found experimentally that a singing teaching intervention in people with chronic obstructive pulmonary disease quantitatively reduced measured anxiety but did not significantly affect quantitative measures of their physical health. Quantitative evaluations showed the high proportion of participants who enjoyed and believed that they benefited from attending singing lessons. Qualitative evaluative statements expressed by participants in in-depth interviews detailed more specifically how the participants believed that the singing lessons positively influenced their emotional state, medical symptoms and experiences of other activities. Some statements expressed how strongly the participants believed that they had benefited from the treatment e.g. "*It opened up a new lease of life" "I feel on top of the world"*.

6.2.2.2 Key findings

In this section I use the key findings from the mixed methodology research described in Chapters Four and Five to discuss the effects of historical knowledge on public perceptions of the River Don as it is today and public predictions of the river's future state. Historical knowledge of reference conditions and environmental degradation was found to lead interview participants to desire the restoration of reference conditions and the reversal of environmental degradation. This supports Higgs' (2003) assertion that restoration is driven by the desire to restore valued aspects of an ecosystem which have been lost and the findings of other studies that people were motivated to volunteer to restore an ecosystem because they valued its reference conditions (Gooch, 2003; Drenthen, 2009; Cuerrier *et al*., 2015). Participants were particularly keen to restore aesthetic aspects of the landscape, flagship species and the river's ability to provide recreational opportunities and were appreciative of evidence that this was already happening. The experiment participants who read about the River Don in its historical state and visited it frequently were the most likely to agree that the cost of its maintenance was justified. These improvements were viewed as evidence that society had learned from the past degradation and increased optimism for the future that the River Don would continue to become more similar to its reference conditions. Participants even suggested what they viewed as improvements with regards to ecosystem service provisioning such as making the river deeper to benefit recreational boaters but said that they did not want these improvements to be made if it increased the extent to which the River Don differed from its reference conditions. The ability to compare current degraded conditions with historical less degraded conditions and desire to return an ecosystem to its less degraded state underpins the shifting baseline syndrome (Pauly, 1995; Miller, 2005; Papworth *et al*., 2009). This syndrome recognises that as knowledge of the previous less degraded ecosystem is lost from a community desire to restore it is reduced.

However, some interview participants and the experiment participants who were given information about the River Don in its most degraded state underestimated the extent to which the River Don had been restored. This reflects Gobster and Westphal's (2004) and Pendleton *et al*'s (2001) findings that people underestimated the extent to which ecosystems had been restored including the extent to which water pollution had been reduced when it was not visible. The interview participants who underestimated the extent to which the River Don had been restored expressed the desire for the river to be restored and the frequency with which the experiment participants expected to visit the river in future was not adversely affected by them undervaluing the River Don in its current state. However, given that the interview study found that people extrapolate past trends into the future it can be expected that those who underestimated the extent to which it had already been restored would have more pessimistic predictions for the future and less trust in the river's managers as trust to a large extent is based on perceptions of past performance (Van de Walle and Geert, 2007). That said, historical information provided in the experiment was not found to significantly affect people's future predictions regarding the River Don even though it reduced the extent to which they currently valued its ecological conditions.

Other participants explicitly recognised that the restoration of the River Don to its reference conditions was not feasible due to the social consequences of flooding much property by restoring a meandering river in an urban area. These limitations are recognised by Bernhardt and Palmer (2007). One participant explicitly stated that he would not want the River Don to be restored completely to its reference conditions because he appreciated the weirs from a heritage perspective even though he realised that they had adverse environmental impacts. Drenthen (2009) also found that valuing anthropogenically modified landscapes from a heritage perspective could reduce support for their restoration. 18 of the 23 participants stated that they valued the River Don's heritage so the River Don's future is likely to be driven by a desire both to restore it from an ecological perspective and a desire to conserve its heritage. Furthermore, knowledge of historical environmental degradation did not always lead to knowledge that the issue currently affected wildlife. Participants generally did not discuss the current impacts of the weirs despite being aware of their historical impact and one even reasoned that the weirs had been degraded to the extent that they were no longer a barrier to wildlife. Additionally, in the same way that participants who had seen how the River Don had improved from its most degraded state extrapolated this trend into the future those who believed that in recent years management efforts had been limited by financial constraints were less optimistic about its future.

People also drew conclusions regarding the River Don's future from an understanding and assumptions regarding the ways in which people had valued it, used it and been adversely affected by it in the past. Knowledge that it had always been valued by society, albeit for very different reasons increased participants' confidence that it would be valued by people in the future and managed accordingly. Beliefs that it had been highly valued in its reference conditions increased the belief that it would be increasingly valued as its conditions became more similar to those of its reference conditions. Recognition of the increased role of grassroots organisations in its management increased optimism that they would be increasingly involved in the management of the River Don in future. Knowledge of historical ecosystem services may foster the desire to increase the extent to which they are provided in future. For example, one participant recognised the extent to which the River Don had been used to generate hydropower in the past and reasoned that it should be used to generate microhydropower in the future to reduce society's dependence on fossil fuels. The desire to restore landscapes to benefit from the provisioning of ecosystem services which previous generations benefited from was also found by Gomes (2012). Although interview participants greatly underestimated the frequency with which the River Don had flooded in the past some feared that the 2007 floods indicated that it could cause much damage if it flooded again. Siegrist and Gutscher (2006) and Botzen *et al*. (2009) also reported that historical knowledge of floods increased the risk of future flooding. However, this belief was reduced by knowledge of the work which had been done on the River Don to reduce future flooding.

6.3 IMPLICATIONS FOR FUTURE MANAGEMENT

6.3.1 Use Reference Conditions to Set Restoration Goals

Restoration can be defined as restoring an "*ecosystem to a close approximation of its condition prior to disturbance*"(The National Research Council, 1992 cited in Schmidt *et al*., 1998). This condition is frequently called the ecosystem's reference condition (Bennion *et al*., 2011). Historical information is thus frequently used to describe an ecosystem's reference conditions and ultimately set restoration goals (Brenner *et al.*, 1993; Eden & Turnstall, 2006; Drenthen, 2009). Unfortunately because the River Don has been too polluted to be potable since medieval times and impounded since the 12th century little information regarding the its reference conditions could be gained either from the fish biological records which were analysed in Chapter Two, the newspaper articles which were analysed in Chapter Three or the interview participants in Chapter Four (Walton, 1952; Hey, 1979). Despite the lack of information, however, clear differences between the River Don's current state and reference conditions were identified.

Of particular relevance to environmental managers are the names of fish species which have been extirpated from the River Don. As discussed in Chapter Two this list needs to be treated with caution as although spine loach has been recorded to have been present in the River Don it's historical geographical range suggests that it is unlikely to have ever been present there (Davies *et al*., 2004). Furthermore, only vagrant individual sturgeon are likely to have ever been present in the River Don as they do not spawn in British waters. With this in mind, of the four species which were recorded in the River Don historically but not recently, environmental managers should aim to re-establish viable populations of burbot and smelt. This is likely to require the installation of fish passes; restoration of coarse spawning sediments; and the restoration of wetlands connected to the river (Howes and Kirks, 1991 cited in Maitland, 2003; Slavík & Bartoš, 2002; Maitland, 2003; Davies *et al*., 2004; Worthington *et al*., 2012). Restoring the river for the benefit of species which are evidenced by the historical records to have been extirpated from the River Don is therefore likely to benefit a wide range of other species. This corroborates with previous studies which have found that describing reference conditions, particularly through the identification of extirpated species, can be useful for informing conservation goals; but the utility of historical records in describing reference conditions can be limited by their sparcity (Fritts and Rodda, 1998; Seddon and Soorae, 1999; Lotze *et al*., 2006; Bernard and Parker, 2006; Boshoff and Kerley, 2010; Seddon, 2010; Gillette *et al*., 2012; Jørgensen, 2013). Furthermore, Chapter Two demonstrates the great extent of these limitations even when describing the composition of socially and economically valued communities in urban areas of the UK though this is the context in which the most historical records would be expected to be available. The extent of these limitations in this context which would be expected to minimise them suggests that they apply to a great extent in many other contexts (Siggelkow, 2007). The limitations of sparse records may be overcome to some extent through the use of palaeoecological methods (Birks, 2012).

6.3.2 Learn from Past Successes and Failures to Address Pollution

The newspaper articles evidence both successful and unsuccessful attempts to minimise pollution in the River Don. The earliest evidence analysed in this thesis which evidenced efforts to reduce pollution was a newspaper article published in 1870 which reported legal action against polluters but the first evidence that they had been successful was reported in 1976 and most likely to have been a result of the Rivers (Prevention of Pollution) Act (1961). This act was viewed by Langford *et al*. (2009) as the earliest legislation which "*imposed strict and enforceable controls on all identified existing point-source discharges*". The newspaper articles evidenced that the "r*ight to demand improved standards from thousands of firms and authorities who had been polluting rivers until then virtually at will*" (The Guardian on 8th October, 1965). Environmental managers should therefore ensure that organisations which discharge pollutants into the river are forced to adhere to strict controls regarding the amount of pollution which they can discharge through effective legal action. However, the newspaper articles also evidenced that most organisations were given five years in which to adapt their technology and processes to comply with this legislation. It is therefore important that if new controls are introduced they do not increase operating costs to the extent that organisations need to cease trading and that organisations are given time to implement the necessary changes. These findings corroborate with Johnstone and Horan's (1996) national account of the history of river pollution in the UK and their suggestions for less economically developed countries and these recommendations are thus likely to be relatively broadly applicable.

6.3.3 Control Invasive Species

Both the newspaper articles which were in Chapter Three and the interview participants in Chapter Four provided evidence that invasive species were present in or by the River Don. The only reference to an invasive species in the historical newspaper articles which were analysed was a letter written by an urban ecologist which was published in the Times in 2000. The letter largely dismissed the negative environmental impacts of Japanese knotweed and touted the ways in which it benefited other species, using a sighting of two caterpillar species eating its leaves on the River Don to support this point. Approximately one third of the interview participants mentioned the presence of invasive species in or by the River Don. Japanese knotweed and Himalayan Balsam were both recognised as invasive species which out-competed native plant species. However, more comprehensive information on the invasive species which are present in or by the River Don is available elsewhere. For example, the DCRT website lists three invasive plants and two invasive animals which are present on the River Don, explains the ecological threats which they pose and advises readers on how to report sightings of them to facilitate their control (DCRT, n.d.c). Whilst it is very unlikely to be feasible to eradicate the most invasive species which are present on the River Don such as Japanese knotweed and Himalayan Balsam, past invasions are likely to play an important role in informing environmental managers how to minimise the risk of further invasions and minimise the spread of invasive species which are already present. For example, advising anglers on the importance of cleaning their fishing tackle effectively to minimise the spread of American signal crayfish and other pelagic invertebrates which threaten to invade the River Don in future and informing the public of how to recognise and report non-indigenous species so that control efforts can be targeted effectively. Reichard and Hamilton (1997) developed a model to predict the invasiveness of species which may be introduced to America in the future based on the functional traits of the species which became invasive and were introduced but did not become invasive in America historically. This may be a useful approach to take to assess the likeliness that species which are introduced to the UK in future will become invasive.

It is also important to identify non-indigenous species which have not been invasive to date as they may be more invasive in future as habitat suitability increases through a combination of habitat restoration including the installation of fish passes, improved wetland connectivity and increased habitat heterogeneity; and elevated water temperatures due to climate change (Kottelat and Freyhof, 2007; EA, 2009; Britton *et al*., 2010). The widespread distribution of introduced game fish in Britain and other European countries means that many ecosystems are likely to be adversely affected if they become invasive in future as a result of climate change and other habitat changes. Identifying the likely pathways through which non-indigenous species which to date have not been invasive are likely to have been introduced to the River Don also give insights into the pathways through which invasive species may enter the river. Management actions can then be focused on blocking these pathways. However, the most likely pathways for invasive species to be introduced to the River Don may also change through time. Identifying the species which have been introduced to other UK rivers but not yet the River Don may help to identify these pathways. There is strong evidence to suggest that all of the River Don's non-indigenous fish species were introduced to the

River Don due to the use of the river and adjacent rivers for angling as they are all of high interest to anglers and have been introduced to other UK rivers for such purposes. However, sunbleak (*Leucasius delineatus*) has not yet been introduced to the River Don though it has been introduced to many rivers since the mid-1980s when it was first introduced to the UK through the aquarium trade. This suggests that it is likely that sunbleak will be introduced to the River Don soon and pose a major threat to the River Don's native fish as it has already adversely affected native fish in many other UK rivers both as a competitor and as a pathogen carrier (Pinder and Rodolphe, 2003; Gozlan *et al*., 2003 cited in Pinder and Gozlan, 2004; Zięba *et al*., 2010). Those responsible for managing the River Don should therefore focus on minimising this likelihood through education and be ready to quickly identify the species and eradicate it before a viable population forms. Good historical environmental knowledge, at a national scale, and education using that knowledge, is needed to distinguish between native and non-indigenous species. The role of public education in developing support for eradication programmes and thus increasing the likelihood of their success is recognised by Wittenberg and Cock (2005). Conservation practitioners may therefore benefit from establishing the extent to which local people are knowledgeable about invasive species and their attitudes towards them and if necessary using media communications to increase knowledge and support for eradication programmes before eradicating invasive species in a broad range of contexts.

6.3.4 Reverse Physical Environmental Degradation

The newspaper articles which were analysed in Chapter Three provide plenty of evidence regarding the ways in which the river has been physically degraded through the construction of weirs and channel modifications to mitigate against flooding and improve the river's navigability. The interview participants also had limited knowledge of the drainage of wetlands and the associated alteration of the River Don's course in the early 17th century; and the ecological consequences of weir construction. Furthermore, much physical degradation such as the presence of weirs and straight river sections is readily observable in the field and secondary historical sources such as Firth's (1997) book on the history of the River Don and Thirsk's account on the drainage of Hatfield Chase provided more information on wetland drainage than was evident from the data analysed in this thesis. Changes in the River Don's fish community composition such as decreased abundances of migratory salmon also provide indirect evidence for the river's physical degradation though the analysis of species' presence trajectories found less evidence of the effects of physical degradation on community composition than was expected. Knowledge of how the River Don has been degraded historically does not always mean that historical physical degradation can be feasibly reversed due to the high social and economic costs of flooding land adjacent to the river's current course (Bernhardt and Palmer, 2007). However, much has already been done to reverse the consequences of physical degradation, particularly with regards to the construction of fish passes. For example, a fish pass which was installed in 2000 "*proved extremely efficient and for the first time in more than 700 years fish were able to move freely between the tidal and non-tidal reaches of the River Don"* (Canal and River Trust, 2016). This is reassuring and can be used to help evaluate the likely effectiveness of fish passes elsewhere as weirs are still present on many rivers (Purseglove, 1988). Despite this, there is still much potential to further reverse the river's physical environmental degradation without actions being too costly from a social or economic perspective (EA, 2014a). A particularly interesting finding of this thesis was that a newspaper article reported that a farmer had complained that his land would no longer be fertilised by floodwaters when the construction of a railway prevented his land from being flooded regularly as it had been previously (The Times, 24th November 1870). This suggests that farmers may benefit from this ecosystem service in future and thus require less compensation when wetland is restored on their agricultural land (Morris *et al*., 2004; Verhoeven and Settler, 2010). This knowledge can also be applied to inform wetland restorations in many other catchments.

6.3.5 Holistic Rather than Structural Flood Defences

The newspaper articles which were analysed in Chapter Three made it clear that structural defences and dredging have been used a lot more widely than holistic defences from the mid-19th century onwards. Although the newspaper articles did not mention the environmental effects of flood defences it is widely recognised by ecologists that structural defences and dredging cause much environmental degradation by destroying aquatic and bankside vegetation, reducing habitat heterogeneity, reducing connectivity between rivers and adjacent lentic ecosystems and thus ultimately reducing biodiversity (Hey, 1987 and Hey *et al*., 1990 both cited in Hey, 1994). The newspapers provided substantial evidence that structural flood defences have frequently failed and surprisingly little evidence that they were effective at reducing flood damage. Most notably in 1857 it was reported that a hole was knocked through a flood wall by mariners and inhabitants to minimise the potential damage caused by the build-up of water which it prevented from escaping. Wider public recognition of the ineffectiveness of the River Don's structural flood defences could potentially increase support for a more holistic to flood management as has occurred a national scale (Johnson *et al*., 2005). The history of the River Don has therefore demonstrated that structural flood defences and dredging do not reduce flood risk to the desired extent and contribute towards the physical environmental degradation of the river. This suggests that a different approach should be taken to flood management on the River Don in the future. Since the 1950s controlled washlands have been constructed along the River Don and they now have a combined capacity of over 3.5 million cubic metres (Firth, 1997; EA, 2010). However, there is relatively little evidence of holistic approaches to flood managment in the newspaper articles which were analysed and none of the interview participants mentioned holistic approaches to flood defences. The EA (2010) recognises that given the extent to which the Don Catchment has been developed a mixed approach of structural and holistic flood defences will be required and Sheffield Local Biodiversity Action Partnership (n.d.) reasons that "*innovative architectural solutions and sympathetic landscape design offer an excellent opportunity to restore the biodiversity of the waters, to mitigate flood risk, and to reap the socio-economic and environmental benefits provided by attractive, well-managed waterways"*. However, the Sheffield Local Biodiversity Action Partnership (n.d.) also lamented the consequences of enhancing structural defences at the expense of nature following the 2007 flood. This suggests that the needs to conserve the habitats afforded by the River Don and defend local communities from floods can be balanced much more effectively than they are currently. Both in the Don Catchment and elsewhere it is likely that educating people about the historical ineffectiveness of structural defences will increase support for less environmentally harmful holistic methods which is likely to increase connectivity between rivers and their adjacent wetlands (Johnson *et al.*, 2005).

6.3.6 Increase public desire to improve the river's environmental quality, aesthetic value and accessibility

Wohl *et al.* (2005) stated that "*Societal perceptions and expectations of ecosystem performance ultimately determine whether restoration is a viable management option*". This thesis found many ways in which historical knowledge may help foster support for environmental management as well as a few ways in which it may increase opposition against environmental management. The answers from the interview participants showed that knowledge of reference conditions, particularly the presence of charismatic species which were more abundant prior to degradation such as trout, heron, kingfishers and otters, and positive aesthetic aspects of the river and its surrounding landscape in their natural state can increase public support for environmental management. However, caution must be taken when using this knowledge to set environmental management aims as managing ecosystems primarily for their aesthetic value and charismatic species may not restore the ecological processes on which the sustainability of ecosystems depends (Simberloff, 1998; Gobster *et al*., 2007). The applicability of these findings to other ecosystems depends on the extent to which stakeholders view the ecosystem's reference conditions favourably relative to its current state. Gooch (2003), Drenthen (2009) and Gomes (2012) all gave examples of local people contributing towards the restoration of particular ecosystems as they favoured its reference conditions over its *status quo*. Conversely, Stolkeemann (2001), Drenthen (2009) and Ostergen *et al*. (2008) all gave exmples of local people opposing efforts to resore particular ecosystems as they favoured the *status quo* over the ecosystem's reference conditions.

Chapter Four also found important gaps in interview participants' knowledge of the River Don's reference ecosystems. Assuming that these knowledge gaps are present in the wider local population, and there is no reason why we would expect them to be specific to walkers, environmental educators may benefit from addressing them with the aim of further increasing support for environmental management. The most important was a lack of awareness of one of the fish species which as evidenced in the historical fish records analysed in Chapter Two has been extirpated from the River Don, burbot. The prior presence of this species is particularly important because it is a species which is not native to many UK rivers so restoring populations in the River Don would enable the river to be compared positively to other restored rivers (Davies *et al*., 2004). Furthermore, it can be described as an umbrella species because its successful reintroduction is likely to require the restoration of wetlands, increased physical habitat heterogeneity and the installation of fish passes and thus benefit many other species if these changes to the abiotic environment are feasible (Slavík and Bartoš, 2002; Roberge and Angelstam, 2004; Aarts *et al*., 2004 and Stapanian *et al*. 2010 both cited in Worthington *et al*., 2012). There is also substantial evidence that both the British public and to a greater extent British anglers want to restore populations in UK rivers (Worthington *et al*., 2010b). More broadly, Kellert (1986) recognised that rarity can increase a species' value from the perspective of both naturalists and recreationalists. Encouragingly for environmental educators, interview participants showed a willingness to allow experts to fill their knowledge gaps by saying that they would only want certain environmental management actions to be taken such as the introduction of sea otters or the deepening of the river channel if this would increase the similarity of the River Don to its reference conditions. It is widely recognised that over time as generations who remember an ecosystem in its less degraded state die, communities forget aspects of an ecosystem's environmental degradation such as species which have been depleted and that this can reduce the difference between their desires for the ecosystem's restoration and the ecosystem's reference conditions (Pauly, 1995; Miller, 2005; Papworth *et al*., 2007). This theory has been coined the shifting baseline phenomenon by Pauly (1995). Evidence of this phenomenon has been reported in a broad range of ecosystems (Papworth, 2007; Turvey *et al*., 2010; Kai *et al*., 2014). The findings and recommendations of this study are thus likely to be broadly applicable to many ecosystems.

Chapter Four also showed that knowledge of the River Don's most degraded state could help foster support for environmental management. For example, interview participants stated that they valued the River Don more in its current state because they knew how much better it was than when it was most degraded. This could potentially increase their desire to visit it and ultimately their desire to support its environmental management (Haslam, 1997; Zedler and Leach, 1998). This is likely to be most applicable when substantial positive changes have been made to an ecosystem's aesthetic value within living memory. Furthermore, Chapter Five's experiment participants who read past text on the River Don and visited the river more frequently were more likely to believe that the costs of maintaining and improving the river and its associated infrastructure were justified. The belief that management organisations have invested money well in the past with regards to the management of the River Don is likely to foster trust that they will do so in the future and thus support for future projects (Van de Walle and Geert, 2007). This is likely to be most applicable when visible return on financial investment in historically managing an ecosystem is high. However, many interview participants lacked knowledge of the River Don's environmental degradation legacy, particulalry with regard to the establishment of invasive species and physical environmental degradation such as channel modifications and weir construction. This meant that they did not consider the need to control invasive species and reverse physical environmental degradation when talking about how they expected the river to change over the next 25 years, particularly reducing their support for projects with these aims. Failing to recognise that the River Don was still more degraded than many other British rivers may also have reduced support for its environmental management as Botrill *et al*. (2008) found public support for a triage system which prioritises the most degraded ecosystems meaning that if people believe the River Don not to be more degraded than other rivers they are less likely to actively support its restoration. Interview participants' lack of knowledge of the problems which needed to be resolved led to the belief that nature would restore itself relatively quickly left to its own devices. Even when participants were aware that weirs had historically blocked fish migrations this did not necessarily lead them to believe that they were currently acting as a barrier. One participant explicitly stated that he believed the weirs had been degraded to the extent that they no longer blocked fish migratory pathways. Addressing these knowledge gaps through environmental education could thus increase support for reversing these types of environmental degradation. People who fail to recognise aspects of the River Don's environmental degradation are also unable to see how these have, at least to an extent, been reversed. Conclusions made by these people regarding the feasibility of addressing similar problems to those which have already been addressed are therefore not informed by previous management successes. Not recognising management successes can also potentially reduce trust in those responsible (Van de Walle and Geert, 2007). The need to educate peope about the environmental degradation of their local ecosystems to foster support for conservation is likely to be broadly applicable, particularly when the majority of local people are not aware of changes in the abiotic environment and their effects on biota. Such education is likely to be most effective when the environmental degradation affects charismatic species, such as salmon in this case, and can feasibly be reversed at least to a substantial extent.

Raising public awareness of recent environmental degradation counter to the main environmental restoration narrative can also help foster support for environmental management. For example, in Chapter Four some interview participants identified that abundances of some charismatic native species such as water voles and hedgehogs had decreased in recent years whilst populations of invasive species such as Himalayan balsam and Japanese knotweed had increased. They were concerned that if no action was taken these trends would continue. This suggests that explaining the need for action in terms of halting and potentially reversing recent environmental degradation could increase support for such action. Attributing broader environmental degradation to reduced funding for management associated with the economic recession could also increase the extent to which local people believe that they can personally make a positive difference through donations of voluntary labour and finance. Given the widespread consequences of the economic recession on funding for environmental management these recommendations are likely to be broadly applicable (Somper, 2011).

Evidence from the participants who were interviewed in Chapter Four suggests that interest in heritage which is likely to be positively related to historical knowledge can both increase and decrease support for environmental management. Heritage remnants in situ are likely to attract people, particularly those who are interested in the river's history, to visit the River Don which can in turn increase the extent to which they value the river and ultimately support its conservation (Haslam, 1997; Zedler and Leach, 1998). Furthermore, the preservation of historical remnants such as old industrial buildings can prevent the land which these buildings occupy being further developed. The construction process often causes substantial environmental degradation in itself (Cole, 2000). The environmental costs and benefits of conserving historical remnants valued from a heritage perspective should be carefully evaluated on a case by case study to reach the best trade-off with regards to the conservation of these remnants and the ecosystem's environmental management.

The newspaper articles also evidence the role of local community groups, particularly anglers, in improving the river's environmental quality and ability to provide good recreational opportunities. Environmental managers should learn from this so that anglers and other volunteers can make great contributions to the further restoration of the River Don through practical work such as the removal of litter and therefore make every effort to establish good working relationships with these groups. Furthermore, although not captured by the data which were analysed for this thesis, these groups can also greatly influence political decisions which determine the environmental quality of the river. For example, according to Firth (1997) substantial restoration of the River Don began in 1975 with an abstraction licence being challenged by the Salmon and Trout Association whose membership is largely comprised of anglers because trout were present upstream of Penistone and there were fears that abstraction could increase the concentration of pollutants and thus prevent them from surviving there. Environmental managers should therefore work collaboratively with community groups to maximise the benefits which they can derive from them in terms of voluntary work and political lobbying. Given that according to social learning theory people are more likely to copy the behaviours of those who are similar to them, historical evidence that anglers have actively contribute towards the restoration of the River Don in the past is likely to help foster active support from anglers in the future (Phillips, 1980; Phillips and Cartensen, 1986; Bandura, 1986 all cited in Rimal and Real, 2005). More broadly in line with social learning theory it may be expected that conservation practitioners will be more effective at fostering support for the environmental management of any particular ecosystem when they can evidence that people similar to those they aim to recruit have effectively contributed to the ecosystem's environmenta management in the past.

Despite all the ways in which historical information may potentially be used to foster support for the environmental management of the River Don and other ecosystems, discussed in the previous paragraphs, historical information can also potentially decrease support for restoration. For example, if local people are made aware of the extent to which the river was degraded but not of the extent to which it has been restored they may be discouraged from visiting which is likely to reduce the extent to which they value it and ultimately the extent to which they support its environmental management (Haslam, 1997; Zedler and Leach, 1998). This was evidenced in Chapter Four by the surprise which a participant expressed having visited the river and found it to be a lot nicer than she had expected based on her historical knowledge. Chapter Five also found that experiment participants who read the past text generally believed that the River Don currently harms wildlife to a greater extent and those who visited the River Don were likely to see charismatic species to a lesser extent than those who read the present text. Those who read the past text also valued the river's current contribution to the local economy to a lesser extent. This may reduce predicted returns on investment in the river's future environmental management and thus the incentive for people, particularly those with strong business interests, to contribute towards it (Doick *et al*., 2009). This time lag between restoring an ecosystem and public perceptions of its environmental quality was also found by Pendleton *et al*. (2001) with regards to coastal waters off a beach and by Gobster and Westphal (2004) with regards to a river. This time lag is thus likely to be relatively widespread so addressing it has the potential to help foster considerable support for further environmental management.

Conflict can also arise between preserving historical remnants for their heritage value and conserving nature. One interview participant explicitly stated that they were keen for remnants to be preserved even if it reduced the potential value of the river to wildlife. However, the fact that this argument was only made by one of 23 interview participants and DCRT have received no objections to the installation of fish passes on weirs on heritage grounds despite extensive public consultation suggests that this view is only held by a small majority though (personal communications with Edward Shaw, Trustee of DCRT, January 2016). As stated within this section above the trade-off between managing an ecosystem's heritage and nature should be balanced on a case by case basis.

Furthermore, knowledge of historical management actions which are viewed negatively may reduce trust in those organisations responsible. For example, one interview participant argued that as in her view the council had wasted lots of money on decorative aspects of the Five Weirs Walk infrastructure, they would probably waste financial resources made available to them in future. The provision of historical information on flooding and flood defences should be managed particularly carefully as knowledge of historical flooding can increase the perceived risk of future floods and thus demand for flood defences. The relationship between past performance and trust in future performance is likely to be widespread as according to psychological theory knowledge of past management successes are likely to increase public perceived efficacy and trust in management by evidencing the ability of managers to achieve outcome desires when given appropriate support (Axelrod and Darrin, 1993). This relationship is also recognised in the micro-performance hypothesis which is based on empirical evidence demonstrating that governments which have a good track record of delivery are more trusted than those which do not (Van de Walle and Geert, 2007). Another example of people losing trust in environmental managers due to their past performance being viewed negatively by the public concerns opposition towards the establishment of protected areas in Germany as historically this has not been done with enough consideration for the social needs of the people who lived in them before they became protected areas resulting in the replacement of landscapes valued by local people which are integral to their way of life being replaced with landscapes which do not afford them the same opportunities and which are in their opinion sometimes less aesthetically pleasing Stoll-Kleemann (2001).

The provision of historical information on flooding and flood defences should be managed particularly carefully as knowledge of historical flooding can increase the perceived risk of future floods in line with heuristics theory and thus increase demand for flood defences (Tversky and Kahneman, 1982 cited in Siegrist and Gutscher, 2006; Siegrist and Gutscher, 2006; Botzen *et al*., 2009). When discussing the 2007 floods most participants reasoned that although they had been sad to see trees felled to reduce the future flood risk they thought it, together with dredging and the construction and maintenance of heavily engineered flood defences, were necessary. This highlights the need to use historical information to educate the public on the pros and cons of structural and more holistic flood defences such as washlands in terms of both their effectiveness and their environmental impact. The newspaper articles discussed in Chapter Three evidence the lack of public communication regarding holistic flood defences and the environmental impact of structural defences. Furthermore, they evidence that structural defences have never been effective on the River Don and in 1857 local people and mariners were so fearful that a flood wall would exacerbate the severity of the impacts of the flood that they knocked a hole in it. The relationship between increased public awareness of the environmental impact and ineffectiveness of structural flood defences and increased support for holistic defences is recognised on a national scale by Tunstall *et al*. (2004) and Johnson *et al*. (2005) and educating people about the failures and environmental impact of local structural defences is thus likely to foster greater support for holistic approaches in many catchments.

Chapter Four's interview participants were also asked how they gained their historical knowledge. From this it could be concluded that they gained it from a wide range of sources including: information boards, books, museums and websites such as Wikipedia and local news websites as well as through word of mouth. Of these the most frequently mentioned source was information boards though it is likely that the proportion of participants who had read information boards on the River Don was higher than that of local citizens as all participants said that they had visited the River Don before and they were all members of local walking groups which increased the likelihood that they would have done. The historical information which they gained from these sources was largely limited to the river's environmental history. Environmental educators may therefore benefit from working collaboratively with local historians to combine information on the history of the River Don's industry with information on its environmental degradation legacy, what has been done to date to reverse this and proposals for action to reduce it further. Although much information is freely available online regarding the history of environmental degradation and restoration of the river, interview participants were not aware of this, suggesting the need for better signposting to it. Websites with such information include: the DCRT website where Our Plan for the River Don and Firth's book on the history of the River Don can be downloaded; and the River Don's Biodiversity Action Plan (DCRT, n.d.b; DCRT, n.d.e; Sheffield Local Biodiversity Action Partnership, n.d.). It is clear from this study that people gain historical information from a broad range of sources but information boards *in situ* are particularly effective in disseminating information to many visitors. Making information freely available online does not always mean that it reaches a large audience and effective signposting to these webpages is therefore important. Given the extent to which interview participants were more knowledgable about the River Don's heritage than its environmental legacy, environmental educators should work collaboratively with historians to produce information boards and other sources of information which combine information on an ecosystem's heritage with information on the legacy of this heritage if future studies find this trend to be prevalent across ecosystems. Clearly this is most likely to be effective for those ecosystem's with substantial heritage value.

6.4 DIRECTIONS FOR FUTURE RESEARCH

Information on an ecosystem's reference conditions and historical environmental degradation is frequently taken into consideration when restoring landscapes (Jackson and Hobbs, 2009; Drenthen, 2009; Eden and Tunstall, 2006; Rood *et al*., 2003). This thesis set out to answer the question "*Can Environmental History Inform Future Management?*" It found that it had the potential to inform future management in many different ways and that conservation practitioners were already using historical information to guide their decisions and communicate with the public.

However, it is not clear under what circumstances the outcomes of historically informed restoration are significantly better than the outcomes of restoration efforts which are made in the absence of such information especially when the historical degradation which needs to be reversed in order to restore the ecosystem is obviously apparent from the current landscape. For example, historical knowledge of the River Don is not required to recognise that if biodiversity and ecosystem functioning are to be increased pollution needs to be reduced, invasive species controlled, impoundments removed or at least made passable by fish and physical habitat heterogeneity increased by enabling the river to take a more natural path through wetland where this is possible. A better understanding of when historical information has the greatest benefits for restoration outcomes would facilitate the more efficient utilisation of resources for restoration as collecting and analysing historical information is very labour intensive.

The three main ways in which degradation of a target ecosystem can be identified are: direct observations which enables the most obvious degradation to be described; the combination of such observations with historical knowledge of human activities which degraded the environment and the ecosystem in its previous less degraded state; comparisons between the degraded ecosystem and reference ecosystems which are believed to be currently similar to the target ecosystem before it was degraded; and a combination of all of the above. Comparisons of the outcomes of restoration projects which have used different methodologies have previously been used to evaluate their comparative effectiveness providing useful insights to guide future efforts, so such comparisons of restoration projects which use the above approaches to set restoration goals are likely to be fruitful (Miller *et al.*, 2010). The extent to which historical information increases the effectiveness of restoration projects is likely to depend on: the extent to which the degradation can be readily observed (Crumley, 1994 cited in Hull *et al.*, 2001); the availability of reference ecosystems (Sparks, 1995); the quantity and quality (Newbold, 2010) of available historical information; and practical limitations to achieving restoration goals (Jackson and Hobbs, 2009; Bernhardt and Palmer, 2007).

The limitations of biological records such as sparsity and bias may be overcome in part through the complementary use of palaeoecological records in addressing gaps in knowledge (Birks, 2012). However, the utility of palaeoecological records alone and combined with historical records will need to be evaluated as their use to describe reference conditions and historical environmental degradation is also limited by low spatial, temporal and taxonomic resolution. The application of palaeoecological data to conservation biology is in its infancy and there have been several advances in palaeoecogical techniques in the 1990s and early 21st century so assessing its true potential is likely to take time.

Together Chapters Four and Five found that historical knowledge greatly influenced people's perceptions of the River Don as it is today and as they expect it to be in the future. This had the potential to: increase the desire to reverse environmental degradation and restore reference conditions; increase appreciation for the River Don in its current state; and foster trust in those who had successfully contributed towards the river's restoration historically. Similarly, Gomes (2012) and Drenthen (2009) found that historical knowledge of an ecosystem's reference conditions motivated people to contribute towards its restoration. Environmental managers such as the Don Catchment Rivers Trust (n.d.a) are already trying to use historical information to foster public support for conservation. Future research should use experimental approaches to evaluate the effectiveness of communications which use historical information in different ways with the aim of fostering public support for conservation. The benefit of an experimental approach is that it enables the identification of causal relationships (Arceneaux, 2010). Qualitative research could be undertaken alongside experiments in order to better understand why some messages are more effective than others in fostering support.

6.5 CONCLUSION

The aim of this thesis was to answer the question "*Can Environmental History Inform Future Management?"* using the River Don as a case study. I found that historical information can and indeed already does inform future management in many ways. Historical information can be used to: set goals for restoration by describing an ecosystem in its previous less degraded state and identifying historical environmental degradation which ecosystem managers aim to reverse; evaluate the effectiveness of past management actions with the aim of continuously improving environmental management methods; and foster the public support on which the success of environmental management depends. However, the value of historical information in informing environmental management may be limited by: the sparsity and bias nature of historical records; the extent to which restoration goals can be derived from obvious current signs of environmental degradation and comparisons with reference ecosystems; and physical limitations on the realisation of restoration goals. Currently our understanding of the effectiveness of environmental management and environmental education which is informed by history relative to that which is not is poor. Future research should thus aim to address this through the use of meta-analyses and mixed methodology experiments.

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APPENDICES

A. APPENDIX TO CHAPTER TWO

Table A.1. Description of habitat preferences, functional traits and utilitarian variables used to compare fish species according to presence trajectory types. Variables which were not used due to a lack of data giving a sample size below ten are shown in brackets.

Variable category	Variable	Description
Habitat preferences	Migratory behaviour	1) Potamodromous or non-migratory 2) Facultatively andadromous or catadromous – reports of populations which migrate between marine and freshwater habitats and those which don't. 3) Obligately anadromous or catadromous – reports only of populations which migrate between marine and freshwater habitats.
	Pollution tolerance	1) Tolerant – information sources recognise their ability to survive pollution levels which many other species can't. 2) Sensitive – information sources explicitly state that they are unable to tolerate high levels of pollution or recognise pollution as a threat.
	Maximum temperature	The highest temperature in °C which species are able to tolerate whether this be gained from the habitats in which they naturally survive or lethal temperature experiments performed in the laboratory.

Spawning temperature	The temperature at which species prefer to spawn in °C. When multiple values were reported the median value was used.
Physical degradation tolerance	1) Tolerant – explicit references in the literature to the ability of species to thrive in physically degraded habitats such as reservoirs. 2) Sensitive – explicit references in the literature to the adverse effects which physical degradation such as impoundments and channelisation have on them.
Spawning sediment	1) Fine – Require fine sediments (mud, sand and/or silt) for spawning. 2) Either – Can use either fine or coarse sediment for spawning. 3) Coarse – Require coarse sediments (gravel and/or rocks) for spawning.
Spawning flow	1) Still to slow – Require still to slow flowing water for spawning. 2) Either – Can spawn in either still to slow flowing water or moderate to fast flowing water. 3) Modertate to fast – Require moderate to fast flowing water for spawning.
Spawning river section	1) Upstream – Only spawns in upstream river sections. 2) Either – Spawns in both upstream and downstream river sections. 3) Downstream – Only spawns in downstream river sections.
Spawning main channel	1) Yes – Spawns in the main channel e.g. in pools and riffles. 2) Sometimes – Spawns in either the main channel or backwaters and tributaries.

	3) No – Does not spawn in the main channel. The majority of these spawn in backwaters or tributaries.
Spawning depth	1) Shallow – Only spawns in waters qualitatively described in the information sources as shallow. 2) Either – spawns in shallow or deep waters. 3) Deep – Only spawns in waters qualitatively described in the information sources as deep.
(Juvenile sediment)	1) Fine – Require fine sediments (mud, sand and/or silt) during their juvenile stages. 2) Either – Can use either fine or coarse sediment during their juvenile stages. 3) Coarse – Require coarse sediments (gravel and/or rocks) during their juvenile stages.
Juvenile flow	1) Still to slow – Only lives in still to slow flowing water during juvenile stages. 2) Either – Can live in either still to slow flowing water or moderate to fast flowing water during juvenile stages. 3) Moderate to fast – Only lives in moderate to fast flowing water during juvenile stages.
(Juvenile river section)	1) Upstream – Only lives in upstream river sections during juvenile stages. 2) Either – Lives in both upstream and downstream river sections during juvenile stages. 3) Downstream – Only lives in downstream river sections during juvenile stages.
(Juvenile main channel)	1) Yes – Only lives in upstream

	river sections during juvenile stages. 2) Sometimes – Lives in both upstream and downstream river sections during juvenile stages. 3) No – Only lives in downstream river sections during juvenile stages.
(Juvenile depth)	1) Shallow – Only spawns in waters qualitatively described in the information sources as shallow. 2) Either – Spawns in shallow or deep waters. 3) Deep – Only spawns in waters qualitatively described in the information sources as deep.
Adult sediment	1) Fine – Require fine sediments (mud, sand and/or silt) during their adult stages. 2) Either – Can use either fine or coarse sediment during their adult stages. 3) Coarse – Require coarse sediments (gravel and/or rocks) during their adult stages.
Adult flow	1) Still to slow – Only lives in still to slow flowing water during adult stages. 2) Either – Can live in either still to slow flowing water or moderate to fast flowing water during adult stages. 3) Moderate to Fast – Only lives in moderate to fast flowing water during adult stages.
Adult river section	1) Upstream – Only lives in upstream river sections during adult stages. 2) Either – Lives in both upstream and downstream river sections during adult stages. 3) Downstream – Only lives in

	downstream river sections during adult stages.
Adult main channel	1) Upstream – Only lives in upstream river sections during adult stages. 2) Either – Lives in both upstream and downstream river sections during adult stages. 3) Downstream – Only lives in downstream river sections during adult stages.
Adult depth	1) Shallow – Only spawns in waters qualitatively described in the information sources as shallow. 2) Spawns in shallow or deep waters. 3) Deep – Only spawns in waters qualitatively described in the information sources as deep.
Habitat heterogeneity	1) Not required – Do not require habitat heterogeneity. 2) Beneficial – Benefit from but do not require habitat heterogeneity. 3) Required – Require habitat heterogeneity. Species were deemed to benefit from habitat heterogeneity when they used different habitats in their different life stages, at different times of day or for different purpose e.g. for hiding from predators. Species were deemed to require habitat heterogeneity when migration was obligate rather than facultative.
Require vegetation	1) Not required – Do not require vegetation 2) Beneficial – Benefit from but do not require vegetation. 3) Required – Require

	vegetation. Species were deemed to benefit from vegetation when they used it for hiding from predators, spawning or as nursery grounds. When they always used vegetation for any one or more of these purposes they were deemed to require it.
Spawning sediment width	1) Require a particular sediment category (either fine e.g. mud, sand or silt or coarse sediment e.g. gravel or rocks) and vegetation for spawning. When fish spawn in vegetation but when no information on sediment type is given this category is used. 2) Require a particular sediment category for spawning (either fine e.g. mud, sand or silt or coarse sediment e.g. gravel or rocks) but not vegetation. Three spined stickleback was placed in this category as all we know is that they make nests from plant fragments and detritus so it is likely that they spawn on a fine sediment which is rich in organic material. 3) Can spawn in or over either fine (e.g. mud, sand or silt) or coarse sediment (e.g. gravel or rocks) but require vegetation. 4) Can spawn in or over either fine (e.g. mud, sand or silt) or coarse sediment (e.g. gravel or rocks) and do not require vegetation.
Spawning flow width	1) Require one of the following flow speeds for spawning: still to slow or moderate to fast. 2) Can spawn in both still to slow and moderate to fast flowing water.

Juvenile sediment width	1) Require a particular sediment category (either fine e.g. mud, sand or silt or coarse sediment e.g. gravel or rocks) and vegetation in their juvenile stages. 2) Require a particular sediment category (either fine e.g. mud, sand or silt or coarse sediment e.g. gravel or rocks) but not vegetation in their juvenile stages. 3) Can occupy habitats with either fine (e.g. mud, sand or silt) or coarse sediment (e.g. gravel or rocks) in their juvenile stages but require vegetation. 4) Can occupy habitats with either fine (e.g. mud, sand or silt) or coarse sediment (e.g. gravel or rocks) in their juvenile stages and do not require vegetation.
Juvenile flow width	1) Require one of the following flow speeds during their juvenile stages: still to slow or moderate to fast. 2) Can live in both still to slow and moderate to fast flowing water during their juvenile stages.
Adult sediment width	1) Require a particular sediment category (either fine e.g. mud, sand or silt or coarse sediment e.g. gravel or rocks) and vegetation in their adult stages. 2) Require a particular sediment category (either fine e.g. mud, sand or silt or coarse sediment e.g. gravel or rocks) but not vegetation in their adult stages. 3) Can occupy habitats with either fine (e.g. mud, sand or silt) or coarse sediment (e.g. gravel or rocks) in their adult stages but require vegetation.

		4) Can occupy habitats with either fine (e.g. mud, sand or silt) or coarse sediment (e.g. gravel or rocks) in their adult stages and do not require vegetation.
	Adult flow width	1) Require one of the following flow speeds during their adult stages: still to slow or moderate to fast. 2) Can live in both still to slow and moderate to fast flowing water during their adult stages.
Functional traits	(Eggs)	Maximum number of eggs laid per reproductive cycle
	(Egg diameter (mm))	Maximum egg diameter. Maximum value from all information sources reported.
	(Fry length (mm))	Maximum fry length. Maximum value from all information sources reported.
	Hatching period (days)	Maximum hatching period. Maximum value from all information sources reported.
	Parental care	The highest number which described parental care provided by each species was used: 1) No nest or adhesive eggs – Do not construct a nest or produce adhesive eggs. 2) Adhesive or strings – Eggs adhere to or strings of eggs are wrapped round vegetation or other surface. 3) Bury/shelter eggs – bury eggs in sedment or shelter them behind submerged structures such as rocks. 4) Make nests 5) Guard eggs 6) Provide nursery – provide parental care after hatching.
	Usual length (cm)	Median length of all the usual lengths which were provided in the literature.
	Maximum length (cm)	Greatest length of all the lengths which were provided in

	the literature.
Lifespan (years)	Greatest lifespan of all the lifespans which were provided in the literature
Juvenile diet width	Food types were categorised as below and the number of categories from which the fish ate during their juvenile stages was counted: A. Plankton and detritus (Insect larvae were assumed to be benthic unless it was stated that they were planktonic or drifting, plant material and vegetable matter were assumed to be fragments and thus detritus.) B. Vegetation including algae C. Invertebrates other than plankton (Although "benthic organisms" could be vegetation or fish they were assumed to be invertebrates). D. Fish including eggs (includes lamprey which are parasitic on fish). E. Other vertebrates
Adult diet width	Food types were categorised as above and the number of categories from which the fish ate during their adult stages was counted.
Lowest trophic level	The lowest trophic level at which adults will feed on the scale below: 1) Plankton and detritus 2) Plants including algae 3) Macroinvertebrates 4) Fish
Circadian rhythm	1) Not active nocturnally – Not active nocturnally during their adult stages. 2) Somewhat active nocturnally – somewhat active nocturnally during their adult stages but more active in the day. 3) Seasonally active nocturnally – active

		nocturnally at particular times of year during their adult stages e.g. when spawning or migrating. 4) Most active nocturnally – Adults always more active at night than during the day.
	Hiding	1) None – Adults do not exhibit hiding behaviour. 2) Circumstantially – Adults exhibit hiding behaviour under specific circumstances e.g. when they detect threat or are hiding from potential prey. 3) Seasonally – Adults exhibit hiding behaviour seasonally e.g. during times of high flow. 4) Usually – Adults spend most of the time hiding throughout the year.
	Gregarious transience	1) Not gregarious at all – Do not exhibit gregarious behaviour at all. 2) Seasonally – Exhibit gregarious behaviour seasonally e.g. when spawning, migrating or overwintering or as juveniles. 3) Throughout year – Adults exhibit gregarious behaviour throughout the year.
	Group size	1) Usually solitary – Do not exhibit gregarious behaviour or described as being usually solitary. 2) Small – Typically small shoals (Fewer than 20 individuals) 3) Large – Typically large shoals (more than 20 individuals)
Utilitarian values	Eaten	1) Not eaten by people 2) Eaten outside UK – Not eaten by people in the UK but eaten elsewhere. 3) Minor – Eaten in the UK

		either today or in the past to a minor extent. 4) Unspecified extent – Eaten in the UK either today or in the past to an unspecified extent. 5) Major – Eaten in the UK either today or in the past to major extent.
	Angling	1) None – Of no interest to anglers. 2) Angled outside UK – Of no interest to anglers in the UK but of interest to them elsewhere. 3) Bait – Only used by anglers in the UK as bait. 4) Minor – Only of interest to anglers in the UK to a minor extent. 5) Major – Of interest to anglers in the UK to a great extent.

Table A.2. References for information on functional traits, habitat preferences and utilitarian values by functional trait in addition to those which are listed in the method.

Species	**Variable**	**Citation**
Barbel	Maximum temperature tolerance	Phillippart and Vranken (1983) cited in Daufresne and Boët (2007)
	Spawning temperature	Küttel *et al*. (2002) cited in Daufresne and Boët (2007) Phillippart and Vranken (1983) cited in Daufresne and Boët (2007)
Bleak	Pollution tolerance	Bruslé and Quignard (2001) cited in Daufresne and Boët (2007)
	Maximum temperature tolerance	Daufresne and Boët (2007) Phillippart and Vranken (1983) cited in Daufresne and Boët (2007) Alabaster and Downing (1966) cited in Daufresne and Boët (2007)
	Spawning temperature	Küttel *et al*. (2002) cited in Daufresne and Boët (2007) Phillippart and Vranken (1983) cited in Daufresne and Boët (2007)

	Circadian rhythm	Aguzzi *et al*. (2007)
Bream	Maximum temperature tolerance	Phillippart and Vranken (1983) cited in Daufresne and Boët (2007)
	Spawning temperature	Phillippart and Vranken (1983) cited in Daufresne and Boët (2007)
Bullhead	Maximum temperature tolerance	Elliott and Elliott (2006)
	Hiding	JNCC (Joint Nature Conservatin Committee) (2007)
Burbot	Maximum temperature tolerance	Hofmann and Fischer (2002) Shodjai (1980) cited in Hardewig *et al*. (2004)
	Spawning temperature	McPhail and Paragmian (2000)
Carp	Hiding	Matsuzaki *et al*. (2009)
Chub	Pollution tolerance	Truslé and Quignard (2001) cited in Daufresne and Boët (2007) Verneaux (1981) cited in Daufresne and Boët (2007)
Crucian carp	Spawning temperature	Holopainen *et al*. (1997) Seymour (1981)
	Hiding	Petterson *et al*. (2000)
Dace	Pollution tolerance	Verneaux (1981) cited in Daufresne and Boët (2007) Bruslé and Quignard (2001) cited in Daufresne and Boët (2007)
	Maximum temperature tolerance	Phillippart and Vranken (1983) cited in Daufresne and Boët (2007)
	Spawning temperature	Phillippart and Vranken (1983) cited in Daufresne and Boët (2007)
Eel	Pollution tolerance	Pierron *et al*. (2008) Maes *et al*. (2005)
	Maximum temperature tolerance	Sadler (1979)
	Spawning temperature	Tesch (2003)
	Adult sediment	Food and Agriculture Orgnization of the United Nations and International Council for the Exploration of the Sea (2009)
	Adult diet	Deelder (1984)
	Hiding	Food and Agriculture Orgnization of the United Nations and International Council for the Exploration of the Sea (2009)

	Gregarious transience	Deelder (1984)
	Group size	Deelder (1984)
	Eaten	Purseglove (1988)
Grayling	Spawning temperature	Gönczi (2007)
Gudgeon	Spawning temperature	Küttel *et al*., (2002) cited in Daufresne and Boët (2007)
	Hiding behaviour	Stott (1967)
Minnow	Circadian rhythm	Jones (1956)
Perch	Pollution tolerance	Böhling *et al*. (1991) Lappalainen *et al.* (1998) Hansson (1987) Leach *et al*. (1977)
	Spawning temperature	Küttel *et al*., (2002) cited in Daufresne and Boët (2007) Elliott (1981) Thorpe (1977) Craig (1974)
Pike	Maximum temperature tolerance	Phillippart and Vranken (1983) cited in Daufresne and Boët (2007) Scott (1964)
	Spawning temperature	Küttel *et al*. (2002) cited in Daufresne and Boët (2007) Raat (1988) Phillippart and Vranken (1983) cited in Daufresne and Boët (2007) Inskip (1982)
	Circadian rhythm	Cook and Bergersen (1988)
Rainbow trout	Pollution tolerance	Scrimgeour (1989) Davis (1975)
	Maximum temperature tolerance	Ihssen (1986) Hokanson *et al*. (1977) Bidgood and Berst (1969) Black (1953)
	Spawning temperature	Muhlfeld *et al*. (2009)
	Circadian rhythm	Boujard and Leatherland (1992)
	Hiding	Schjolden *et al*. (2005)
River Lamprey	Pollution tolerance	Maitland (2003)
	Spawning flow	Narberhaus *et al*. (2012)
	Spawning river section	Narberhaus *et al*. (2012)
	Juvenile sediment	Maitland (2003) Mallatt (1981)
	Juvenile flow	Maitland (2003) Mallatt (1981)
	Juvenile river section	Maitland (2003) Mallatt (1981)
	Adult sediment	Narberhaus *et al*. (2012)
	Juvenile diet	Maitland (2003) Mallatt (1981)
	Hiding	Maitland (2003)

		Mallatt (1981)
Roach	Pollution tolerance	Hansson (1987)
		Verneaux (1981) cited in Daufresne and Boët (2007)
	Maximum temperature tolerance	Daufresne and Boët (2007)
		Philippart and Vranken (1983) cited in Daufresne and Boët (2007)
		Horoszewicz (1973) cited in Coutant (1977)
		Alabaster and Downing (1966)
	Spawning temperature	Philippart and Vranken (1983) cited in Daufresne and Boët (2007)
	Circadian rhythm	Hammer *et al*. (1994)
Rudd	Pollution tolerance	Scrimgeour (1989)
	Maximum temperature tolerance	Daufresne and Boët (2007)
		Phlippart and Vranken (1983) cited in Daufresne and Boët (2007)
		Horoszewicz (1973) in Coutant (1977)
	Spawning temperature	Phlippart and Vranken (1983) cited in Daufresne and Boët (2007)
	Hiding behaviour	Lake *et al*. (2002)
Ruffe	Pollution tolerance	Spraque and Drury (1969) in Scrimgeour (1989)
Salmon	Maximum temperature tolerance	Kangur *et al*. (2007)
Smelt	Maximum temperature tolerance	Jörg (2003)
	Eaten	(Maitland, 2003)
	Angling	(Maitland, 2003)
Spined loach	Adult sediment	Vostradovsky (1973)
	Adult flow	Vostradovsky (1973)
	Circadian rhythm	Staaks *et al*. (1999)
Sturgeon	Maximum temperature tolerance	Phillippart and Vranken (1983) in Daufresne and Boët (2007)
	Circadian rhythm	Westin and Aneer (1987)
	Hiding	Herczeg *et al*. (2009)
Tench	Maximum temperature tolerance	Alabaster and Downing (1966) in Coutant (1977)
	Spawning temperature	Phillippart and Vranken (1983) in Daufresne and Boët (2007)
	Circadian rhythm	Herrero *et al.* (2003)
	Hiding	Krause *et al.* (1998)
Three spined stickleback	Circadian rhythm	Worgan and Fitzgerald (1981)

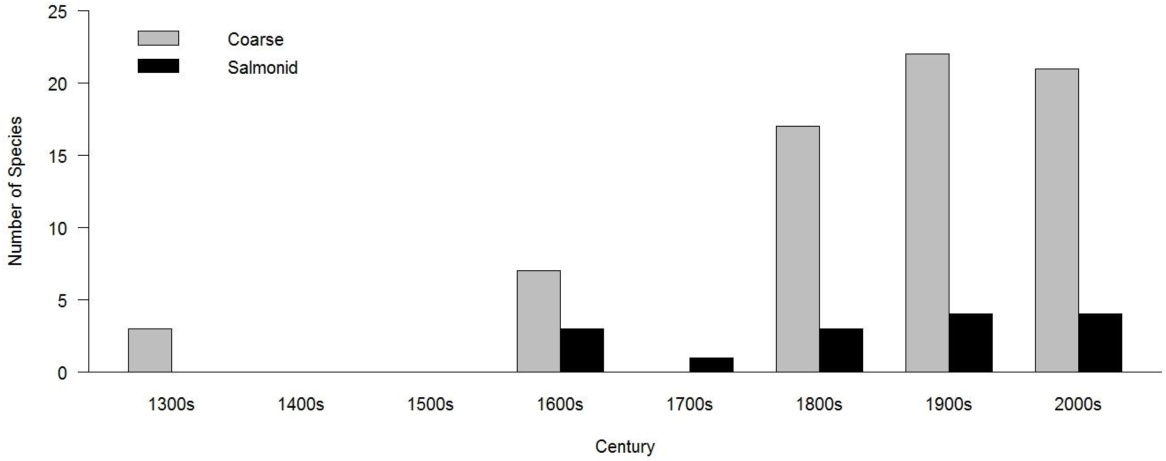


Figure A.1a. Changes in the number of coarse and salmonid fish species in the River Don for which there are existing records since records began.

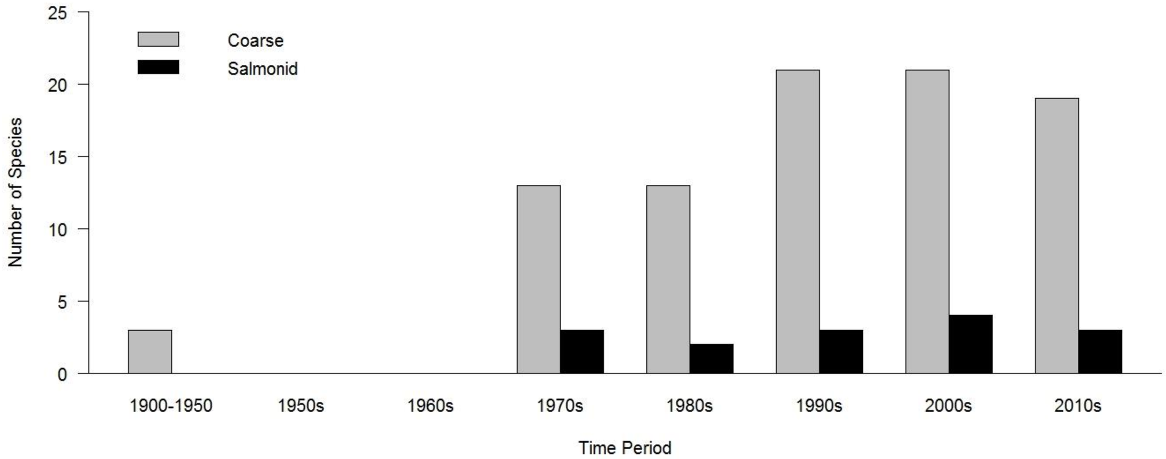


Figure A.1b. Changes in the number of coarse and salmonid fish species in the River Don for which there are existing records through the 20th century.

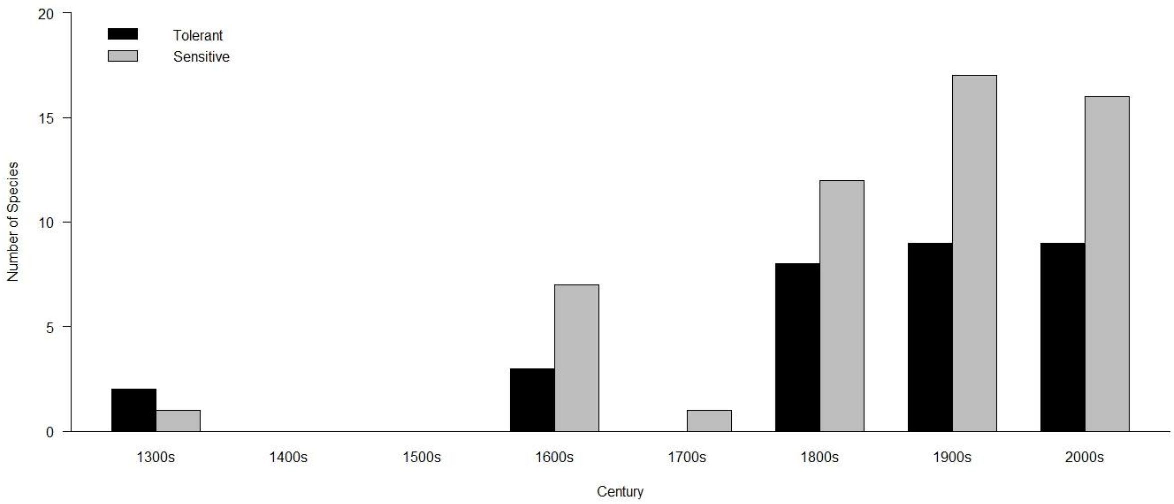


Figure A.2a. Changes in the number of pollution tolerant and pollution sensitive fish species in the River Don for which there are existing records since records began.

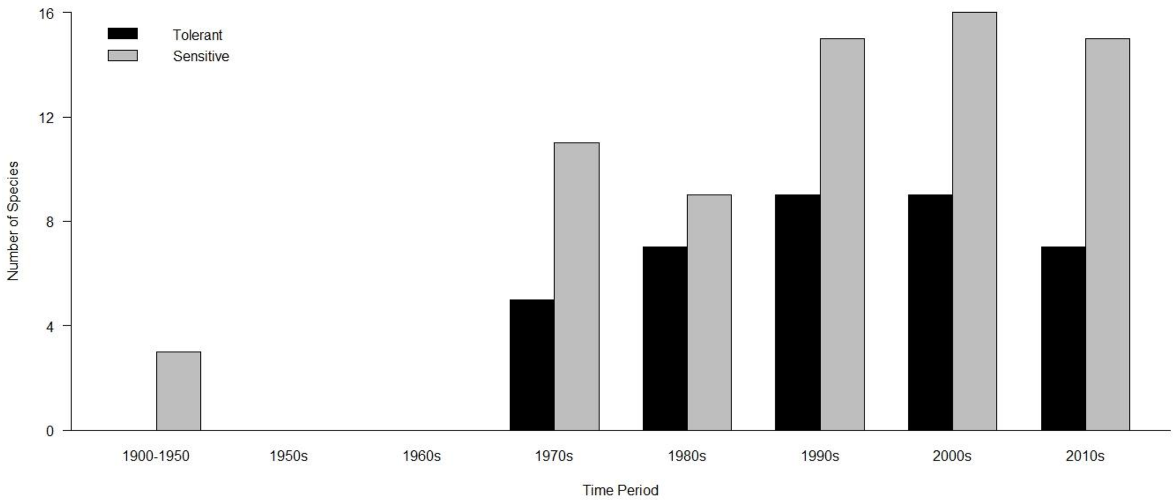


Figure A.2b. Changes in the number of pollution sensitive and pollution tolerant fish species in the River Don for which there are existing records through the 20^{th} century.

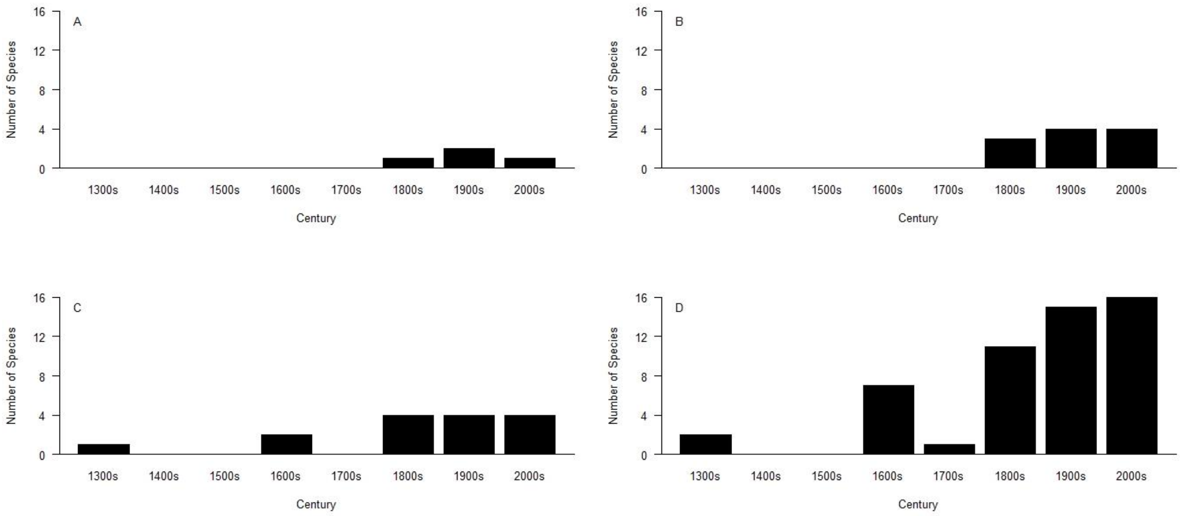


Figure A.3a. Changes in the number of fish species in the River Don for which there are existing records since records began by interest to recreational anglers (A=None, B=Bait, C=Minor and D= Major). Note the only species which was of interest to anglers elsewhere but not in the UK was burbot, which was documented by Firth (1997) to have been present on the River Don prior to 1850. As it was ambiguous which century it was recorded in no graph was produced for this category.

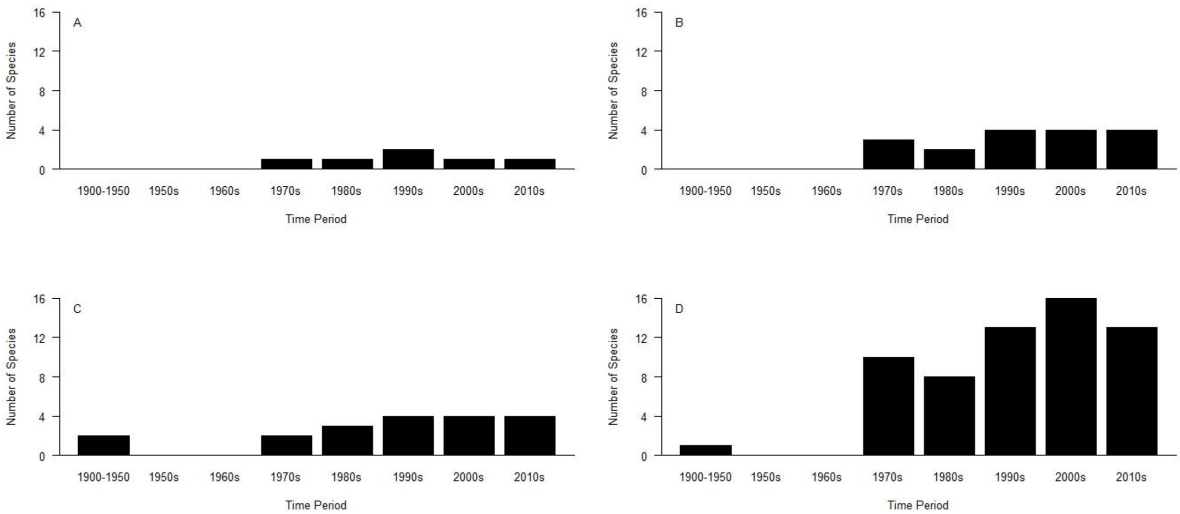


Figure A.3b. Changes in the number of fish species in the River Don for which there are existing records over the 20th century by interest to recreational anglers (A=None, B=Bait, C=Minor and D= Major).

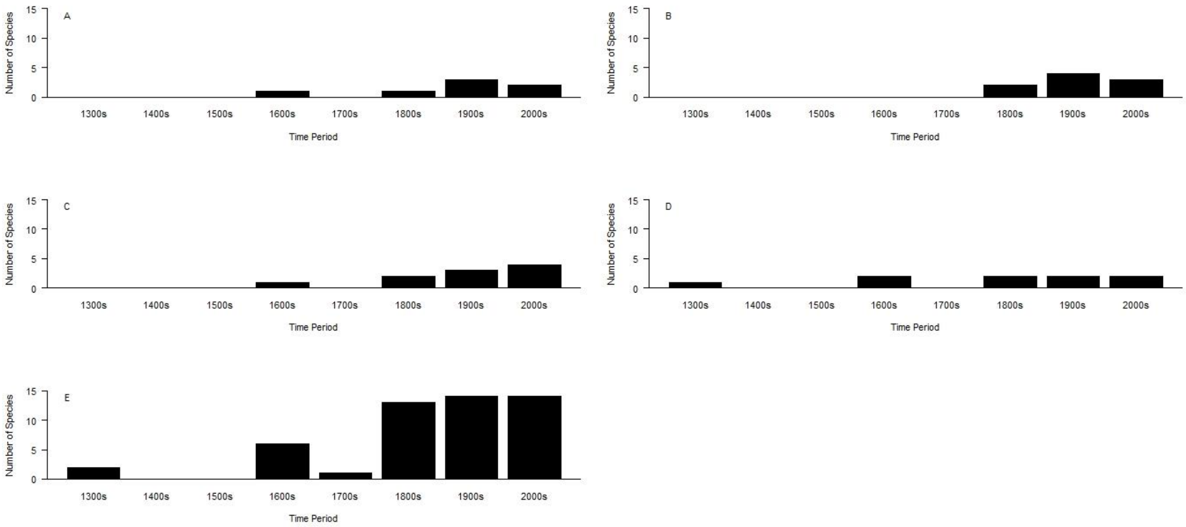


Figure A.4a. Changes in the number of fish species recorded in the River Don by the extent to which they were eaten historically (A=No, B=Elsewhere, C=Minor, D=Yes and E=Major).

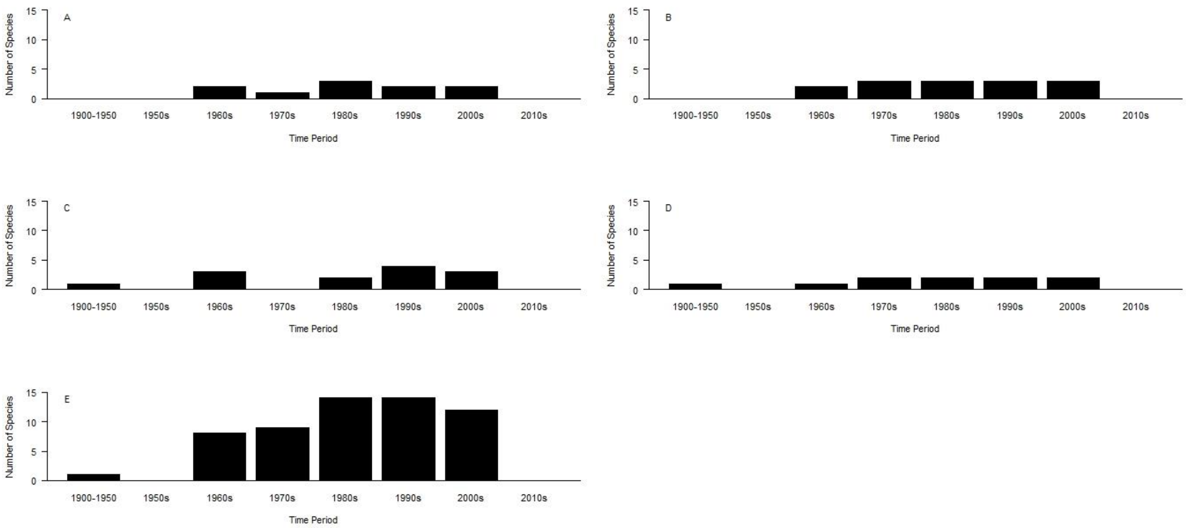


Figure A.4b. Changes in the number of fish species in the River Don for which there are existing records over the 20th century by the extent to which they were eaten historically (A=No, B=Elsewhere, C=Minor, D=Yes and E=Major).

Table A.3. Fisher Tests of qualitative habitat requirements, functional traits and human usages and presence trajectory categories.

Response	N	P
Migratory behaviour	33	0.866
Pollution tolerance	33	0.909
Physical degradation tolerance	24	0.120
Spawning sediment	23	0.584
Spawning flow	23	0.450
Spawning river section	12	0.115
Spawning main channel	13	0.842
Spawning depth	22	0.481
Juvenile flow	15	0.246
Adult sediment	20	0.131
Adult flow	26	0.010
Adult river section	26	0.804
Adult main channel	19	0.475
Adult depth	10	1.000
Habitat heterogeneity	32	0.670
Require vegetation	33	0.840
Spawning sediment width	23	0.558
Spawning flow width	22	0.386
Juvenile flow width	14	1.000
Adult sediment width	13	0.938
Adult flow width	26	0.865
Parental care	31	0.911
Juvenile diet width	22	0.326
Adult diet width	29	0.310
Lowest trophic level	29	0.596
Circadian rhythm	27	0.927
Hiding	29	0.460
Gregarious transience	27	0.444
Group size	16	0.191
Eaten	33	0.466
Angling	31	0.033

Table A.4. ANOVAs of quantitative habitat requirements and functional traits and presence trajectory categories.

Response	N	DF	F	p
Maximum temperature tolerance	21	4, 16	0.444	0.775
Spawning temperature	26	3, 22	0.990	0.416
Hatching period	22	3,18	2.278	0.114
Usual length	32	4, 27	1.754	0.168
Maximum length	33	4, 28	2.788	0.046
Maximum length without sturgeon	32	4, 27	5.917	0.001
Lifespan	30	4, 25	0.736	0.576

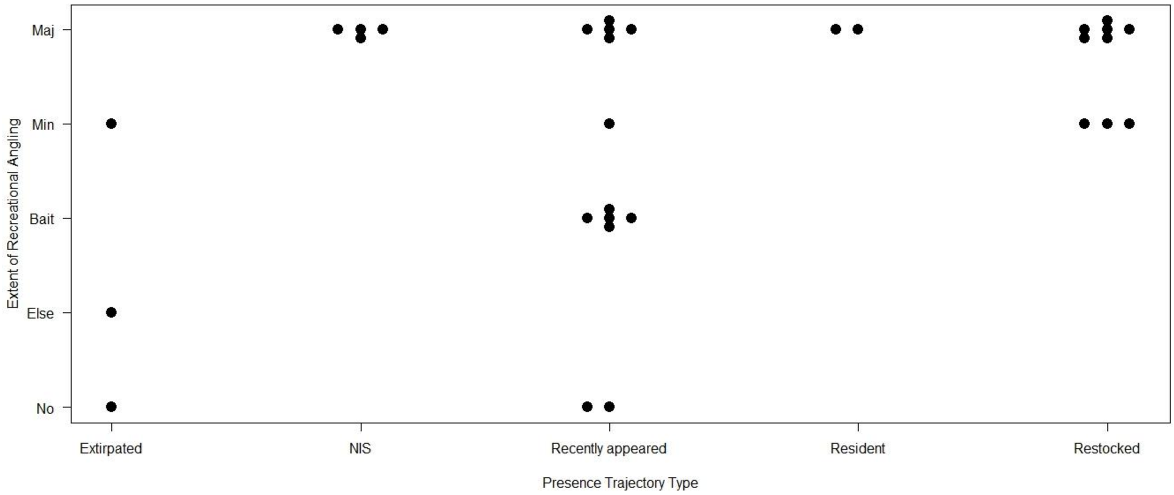


Figure A.5. Extent to which fish species which show different presence trajectory types in the River Don are angled for recreational purposes in Britain (y-axis: No=No extent, Else= Elsewhere only, Bait= Bait only, Min=Minor and Maj=Major) (n=31: Three extirpated, four NISs, 13 recently appeared, two resident and nine restocked).

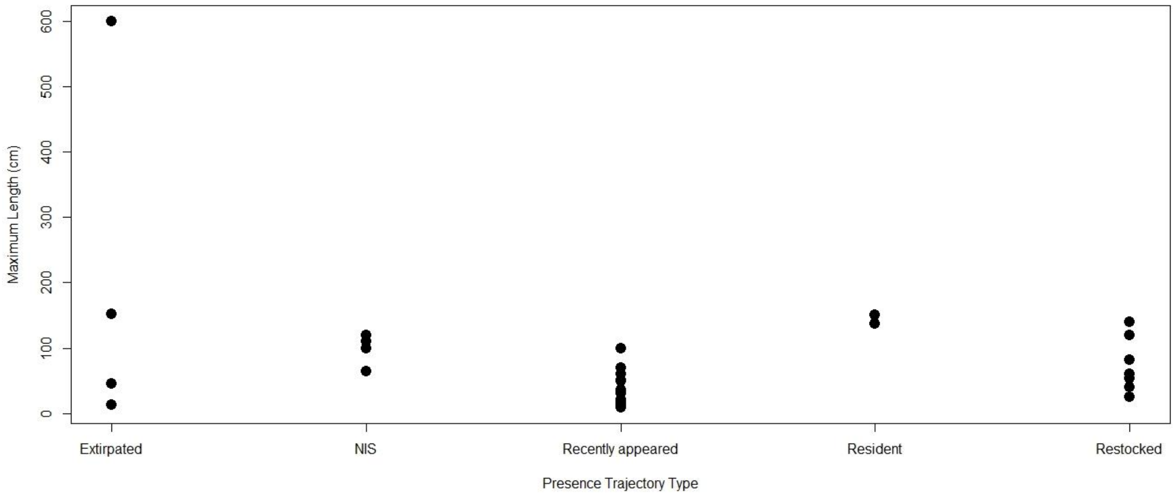


Figure A.6. The maximum body length of fish species which show different presence trajectory types in the River Don (n=33: four extirpated, four NISs, fourteen recently appeared, two resident and nine restocked).

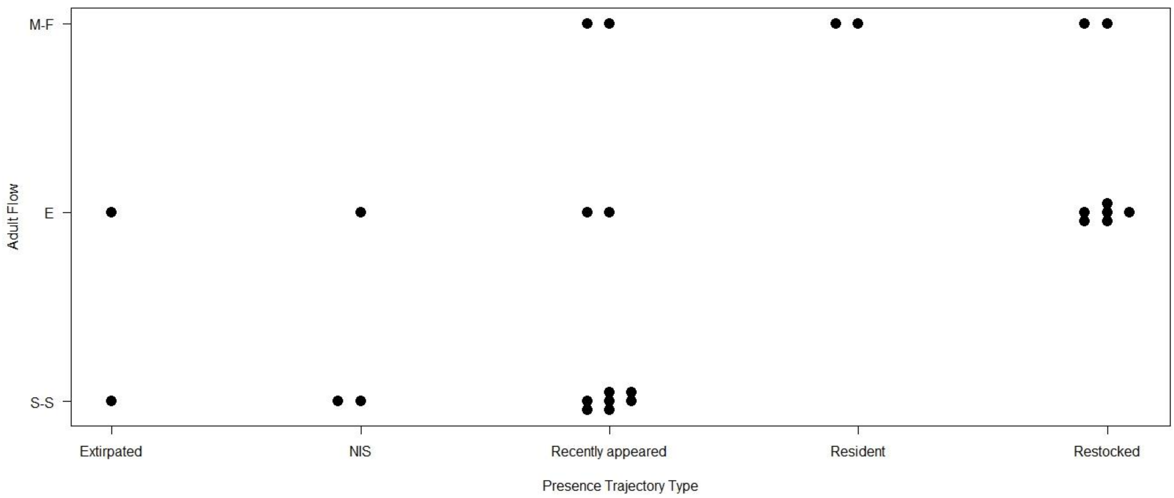


Figure A.7. The flow speeds of adult habitats of fish species which show different presence trajectory types in the River Don (y-axis: S-S=Still-Slow, E=Either, C=Moderate-Fast) (n= 26: Two extirpated, three NISs, 11 recently appeared, two residents and eight restocked).

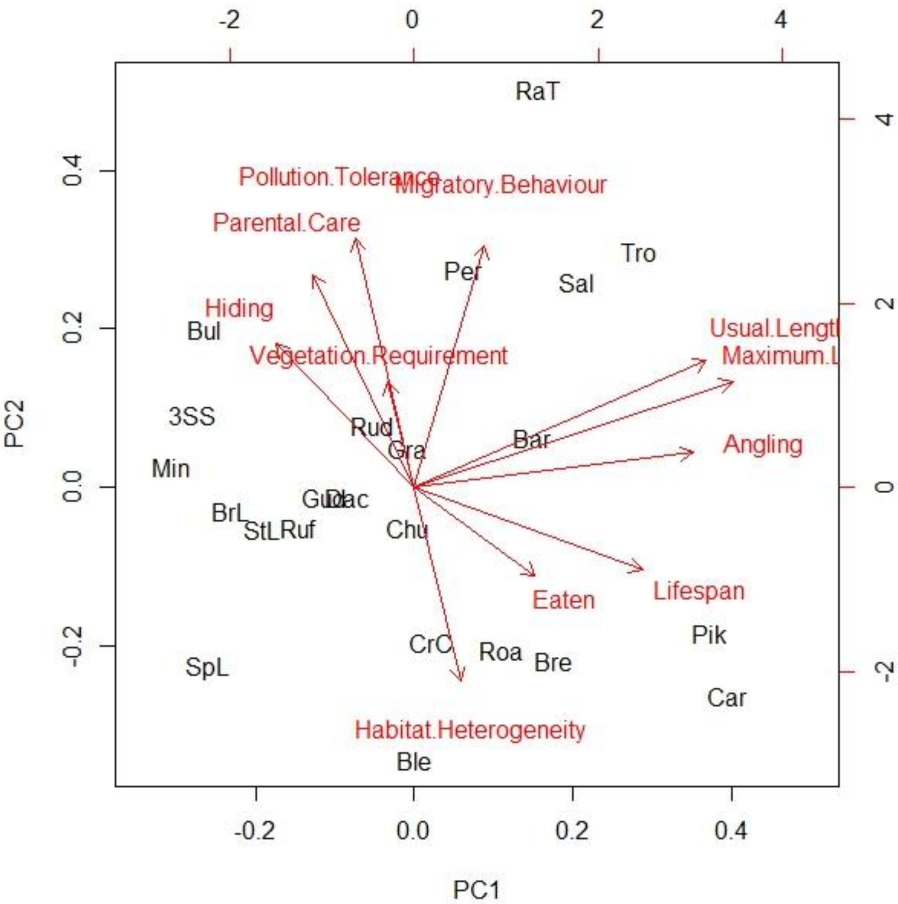


Figure A.8. Relationships between traits, habitat requirements and utilitarian values of fish which have been recorded in the River Don (n=23: One extirpated, three NISs, eight recently appeared, two resident and nine restocked).

Table A.5. Relationships between functional traits, habitat requirements and utilitarian values of fish which have been recorded in the River Don (n=23: One extirpated, three NISs, eight recently appeared, two resident and nine restocked).

	PC1	PC2	PC3	PC4
Proportion of Variance Explained (%)	27.14	20.39	12.12	9.02
Parental Care	-0.166	0.404	-0.375	0.000
Usual Length	0.479	0.241	-0.101	-0.081
Maximum Length	0.522	0.200	-0.074	-0.097
Lifespan	0.374	-0.157	-0.120	0.493
Hiding	-0.228	0.271	-0.183	-0.614
Vegetation Requirement	-0.044	0.200	0.660	0.098
Pollution Tolerance	0.097	0.473	0.141	0.140
Migratory Behaviour	0.115	0.458	-0.050	0.220
Angling	0.458	0.066	0.018	-0.338
Eaten	0.198	-0.168	0.473	-0.389
Habitat Heterogeneity	0.076	-0.367	-0.336	-0.145

Table A.6. ANOVAs of the PCs from the Full PCA and presence trajectory categories of fish which are recorded in the available records of the River Don (n=23: One extirpated, three NISs, eight recently appeared, two resident and nine restocked).

Response	**DF**	**F**	**p**
PC1 (Long body length and relatively important for recreational angling)	4, 18	12.927	<0.001
PC2 (Relatively migratory, provides relatively high levels of parental care and relatively tolerant of pollution)	4, 18	0.331	0.853
PC3 (Require vegetation)	4, 18	0.102	0.980
PC4 (Relatively long lived and exhibit low levels of hiding behaviour)	4, 18	0.325	0.858

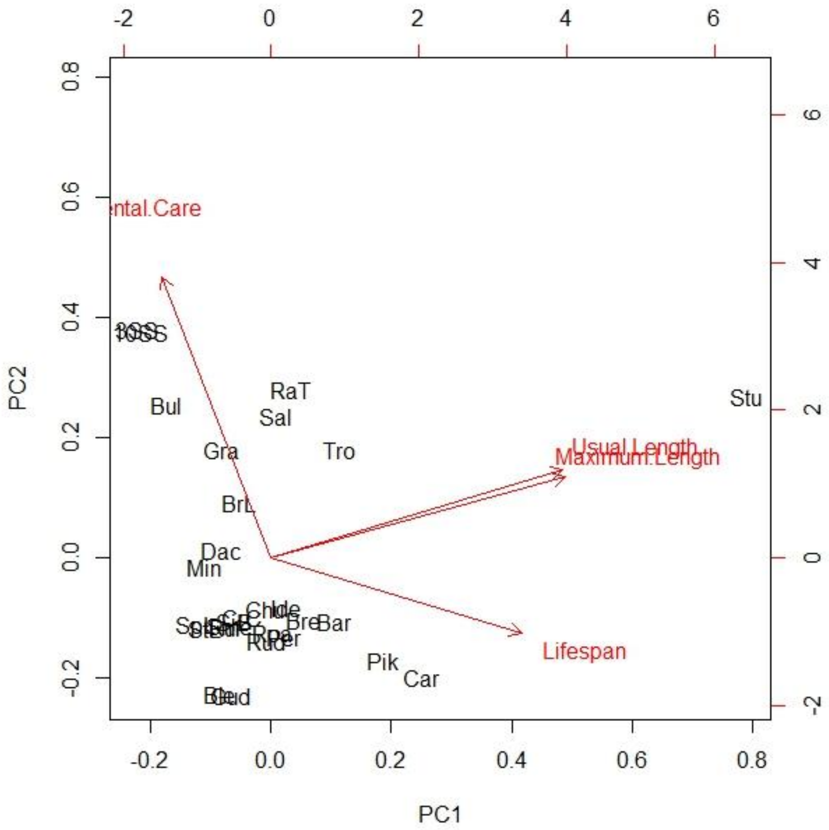


Figure A.9. Relationships between life history traits of fish which have been recorded in the River Don (n=28: Three extirpated, four NISs, ten recently appeared, two resident and nine restocked).

Table A.7. Relationships between life history traits of fish which are recorded in the available records of the River Don (n=28: Three extirpated, four NISs, ten recently appeared, two resident and nine restocked).

	PC1	**PC2**	**PC3**	**PC4**
Proportion of variance explained (%)	62.97	25.37	10.90	0.75
Parental care	-0.220	0.894	-0.390	0.012
Usual length	0.587	0.281	0.288	0.702
Maximum length	0.593	0.257	0.277	-0.712
Lifespan	0.505	-0.237	-0.830	-0.012

Table A.8. ANOVAs of the life history PCs and presence trajectory categories of fish which are recorded in the available records of the River Don (n=28: Three extirpated, four NISs, ten recently appeared, two resident and nine restocked).

Response	**DF**	**F**	**p**
PC1 (Long body length and lifespan)	4, 23	2.301	0.089
PC1 (Long body length and lifespan) without sturgeon	4, 22	8.310	<0.001
PC2 (Provides little parental care)	4, 23	0.233	0.917
PC3 (Short lifespan)	4, 23	0.816	0.528

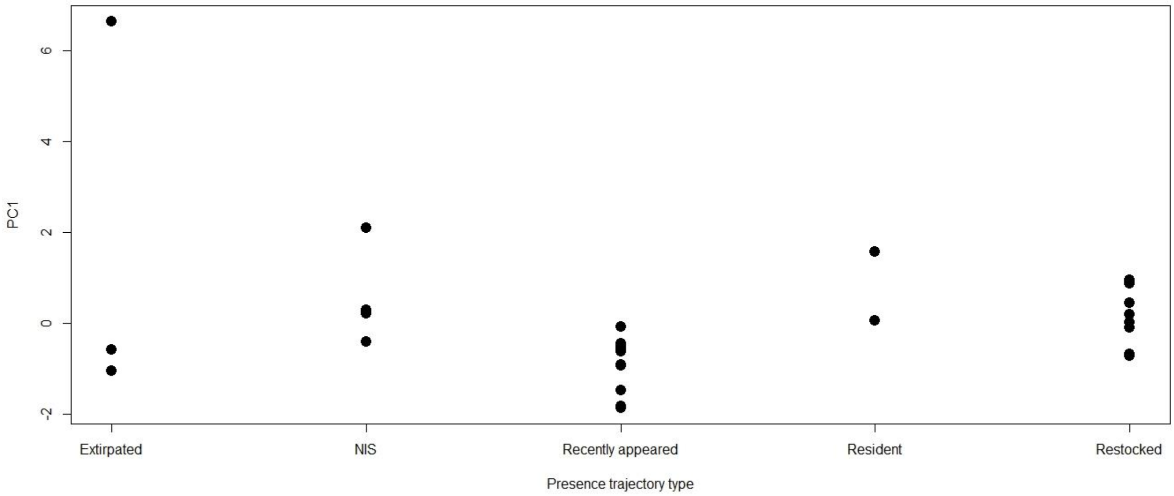


Figure A.10. Life history PC1 values (long body length and lifespan) of fish species which show different presence trajectory types in the River Don (n=28: Three extirpated, four NISs, ten recently appeared, two resident and nine restocked).

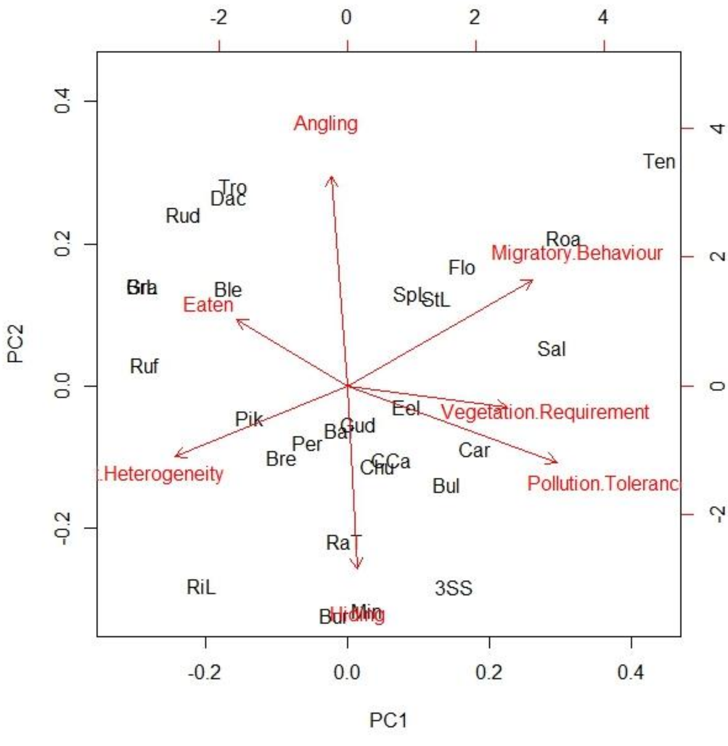


Figure A.11. Relationships between functional traits, habitat requirements and utilitarian values, which are likely to affect the extent to which fish species are affected by physical habitat degradation, of fish species which have been recorded in the River Don (n=28: Two extirpated, three NISs, twelve recently appeared, two resident and nine restocked).

Table A.9. Relationships between functional traits, habitat requirements and utilitarian values, which are likely to affect the extent to which fish species are affected by physical habitat degradation, of fish species which have been recorded in the River Don (n=28: Two extirpated, three NISs, twelve recently appeared, two resident and nine restocked).

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Proportion of variation explained (%)	28.12	20.14	16.01	13.73	8.88	7.07	6.06
Hiding	0.024	-0.567	0.115	-0.672	0.186	0.051	0.420
Vegetation Requirement	0.417	-0.065	0.517	0.444	0.077	-0.364	0.468
Pollution Tolerance	0.548	-0.237	0.181	-0.040	0.403	0.119	-0.657
Migratory Behaviour	0.484	0.328	-0.333	0.024	0.160	0.601	0.400
Angling	-0.044	0.649	0.107	-0.412	0.496	-0.388	0.018
Eaten	-0.290	0.204	0.739	-0.048	-0.046	0.568	-0.035
Habitat Heterogeneity	-0.452	-0.220	-0.138	0.421	0.724	0.128	0.106

Table A.10. ANOVAs of likelihood of being affected by physical habitat degradation PCs and presence trajectory categories of fish species which have been recorded in the River Don (n=28: Two extirpated, three NISs, twelve recently appeared, two resident and nine restocked).

Response	**DF**	**F**	**p**
PC1 (Relatively pollution tolerant)	4, 23	0.876	0.494
PC2 (Exhibit relatively low levels of hiding behaviour and relatively important for recreational angling)	4, 23	3.517	0.022
PC3 (Require vegetation and were historically an important food source for people)	4, 23	0.215	0.928
PC4 (Exhibit relatively low levels of hiding behaviour)	4, 23	0.403	0.805

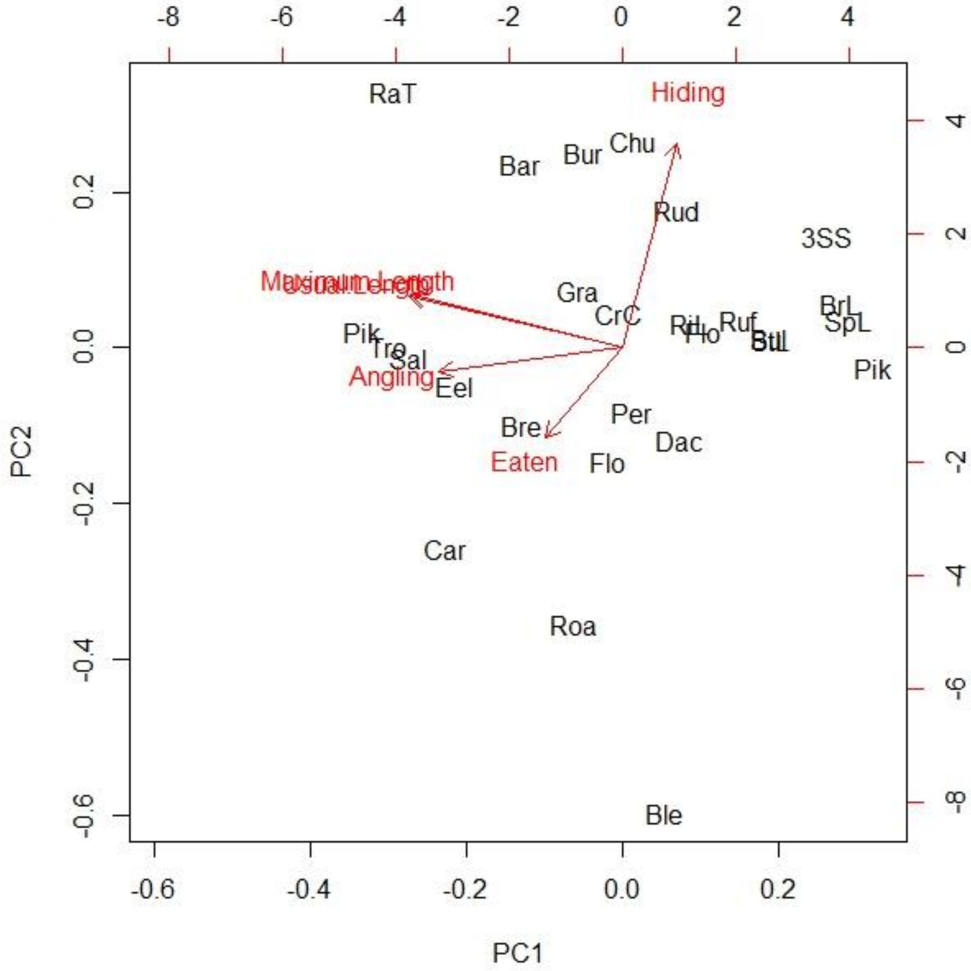


Figure A.12. Relationships between variables which may affect the likelihood of a species being recorded when present of fish species which have been recorded on the River Don (n=27: Two extirpated, three NISs, 11 recently appeared, two resident and nine restocked).

Table A.11. Relationships between functional traits, habitat requirements and utilitarian values of fish species, which are likely to affect the probability of them being recorded when present, of fish species which have been recorded in the River Don (n=27: Two extirpated, three NISs, 11 recently appeared, two resident and nine restocked).

	PC1	**PC2**	**PC3**	**PC4**	**PC5**
Proportion of variance explained (%)	47.84	20.05	18.82	10.40	2.90
Maximum Length	0.580	-0.225	0.027	-0.381	-0.683
Usual Length	0.584	-0.216	0.170	-0.258	0.718
Eaten	0.214	0.377	-0.885	-0.139	0.099
Angling	0.505	0.099	0.021	0.853	-0.079
Hiding	-0.146	-0.866	-0.432	0.201	0.033

Table A.12. ANOVAs of likelihood of being recorded when present PCs of and presence trajectory categories of fish species which have been recorded in the River Don (n=27: Two extirpated, three NISs, 11 recently appeared, two resident and nine restocked).

PC	DF	F	p
PC1 (Short body length and of low interest to recreational anglers)	4, 22	6.352	0.001
PC2 (Exhibit high levels of hiding behaviour)	4, 22	0.646	0.636
PC3 (Of high importance as a food source for people historically)	4, 22	0.491	0.743
PC4 (Of high interest to recreational anglers)	4, 22	3.684	0.019

B APPENDIX TO CHAPTER FOUR

B.1 Interview Participant Recruitment Email

Dear (name of group contact),

I am a PhD student at the University of Sheffield studying people's perceptions of Sheffield Rivers under the supervision of Phil Warren and Lorraine Maltby. I am particularly interested in the views of members of local walking groups, and I am contacting you to ask whether you would be willing to circulate the email below amongst your members. I would be most grateful if you are in a position to do this. If you have any questions about the study I would be very happy to discuss them. Thanks very much.

Best wishes,

Victoria Wright
………………………………………………………………………………………………

Dear Sir or Madam,

I am a PhD student at the University of Sheffield studying people's perceptions of Sheffield rivers under the supervision of Prof. Phil Warren and Prof. Lorraine Maltby. I am particularly interested in the views of members of local walking groups. I am interested in the views of all members and am aiming to understand the perspectives of walkers with varying levels of experience of Sheffield's rivers so whether your regularly visit Sheffield rivers or never visited a river in Sheffield before, your views will be equally important for the study.

I would be very pleased if you could spare some time to participate in this study. If you are interested in doing so please email me at bop12vnw@sheffield.ac.uk and we can arrange to meet at a time and place which best suit you (usually either a quiet café, or here at the University). The duration of the interviews varies a bit, but generally they take about an hour. To thank you for your participation I would be very happy to buy you a coffee and snack or similar and to reimburse reasonable travel expenses. If you have any questions which you would like to ask before deciding whether or not you would like to participate please contact me at the above email address.
This study has received University of Sheffield ethics approval.

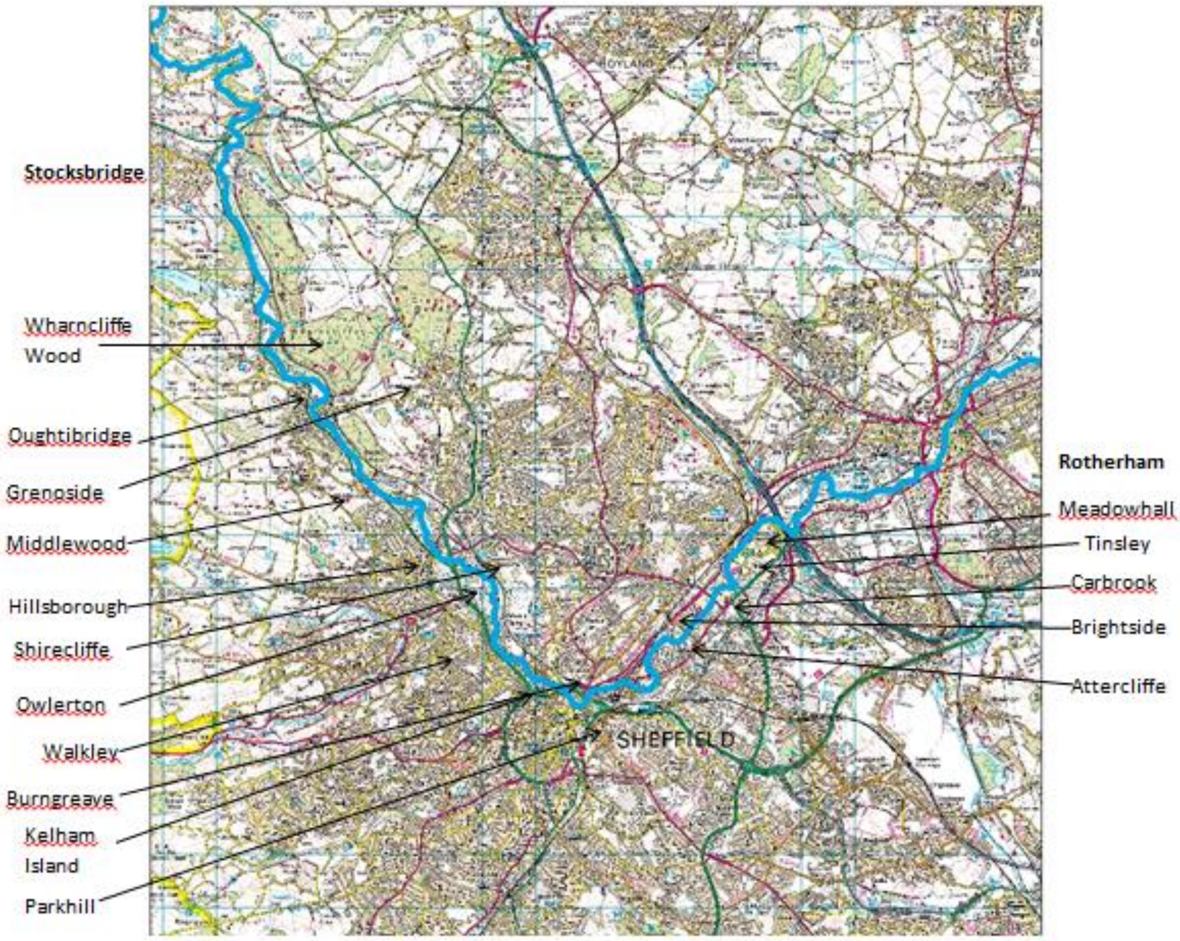
Many thanks,

Victoria Wright

B.2 Interview Participant Information Sheet

Participant Information Sheet for Perceptions of the River Don Study

As part of my PhD research at the University of Sheffield I am studying local people's perceptions of the River Don. The River Don has its headwaters in the Peak District before flowing through Penistone, Sheffield, Rotherham, Doncaster and Goole (please see the map below showing the section of the River Don through Sheffield). I am interested in your opinions on the river itself and the area alongside it. The interview will last approximately an hour. Please don't feel that you need to answer any questions which make you feel uncomfortable and feel free to drop out of the study at any time. All of your answers will be used anonymously.



B.3 Interview Participant Consent Form

Title of Research Project: How do Local People Perceive the River Don?

Name of Researcher: Victoria Wright

Participant Identification Number for this project: Please initial box

1. I confirm that I have read and understand the information sheet/ dated *[insert date]* explaining the above research project and I have had the opportunity to ask questions about the project.

2. I understand that my participation is voluntary and that I am free to Withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline.

3. I understand that my responses will be kept strictly confidential. I give permission for members of the research team to have access to My anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research.

4. I agree for the data collected from me to be used in future research

5. I agree to take part in the above research project.

________________________	________________	____________________
Name of Participant (*or legal representative*)	Date	Signature

________________________ _______________ ___________________

Name of person taking consent Date Signature
(*if different from lead researcher*)
To be signed and dated in presence of the participant

________________________ _______________ ___________________

Lead Researcher Date Signature
To be signed and dated in presence of the participant

Copies:

Once this has been signed by all parties the participant should receive a copy of the signed and dated participant consent form, the letter/pre-written script/information sheet and any other written information provided to the participants. A copy of the signed and dated consent form should be placed in the project's main record (e.g. a site file), which must be kept in a secure location.

B.4 Skeletal Structure of Interview

1) Participant's usage of the river:
   - Activities
   - Who they visit with
   - Frequency of visits
   - Historical use including earliest experiences
   - What attracted them to the River Don

2) Participant's rating of the river in its current state as a recreational resource on a scale of one to ten.
   - State how confident they are in their judgement on a scale of one to five.
   - Explain why they gave this rating – both why they gave a rating above one and why they gave a rating below ten.

3) Participant's views of what was positive and negative about the river in its current state. Participants were encouraged to consider this question from the following perspectives:
   - Social
   - Economic
   - Environmental

4) Participant's rating of how they expect the River Don to change over the next 25 years on a scale of one to ten, one being greatly deteriorate and ten being greatly improve.
   - State how confident they are in their judgement on a scale of one to five.

- Explain why they had made these predictions.

5) Summary of participant's knowledge of the history of the river from ancient times through to deindustrialisation from the following perspectives:
    - Social positive and negative
    - Economic positive and negative
    - Environmental positive and negative

6) Where participants got their knowledge on the history of the River Don from.
    - Encouraged to consider: formal information sources; friends, family and other people; and personal experiences.
    - Broad description of content of historical knowledge gained from each source.
    - Opinions on different sources.

7) Participant's rating of the extent to which they believed their current perceptions and future predictions of the state of the river to be influenced by their historical knowledge.
    - Confidence in judgement on a scale of one to five.
    - Explanation of rating

8) Information about participant:
    - Interest in local history on scale of one to five.
    - Interest in environmental issues on scale of one to five
    - Time lived in local area
    - Age
    - Career

C. Appendix to Chapter Five

C.1 Experiment Participant Recruitment Email

Dear Sir or Madam,

Perceptions of local issues and impressions of the area in which we live are influenced by our everyday experiences and our interpretations of information from a wide range of sources.

In this study, which is part of my PhD, I am aiming to understand the effects of different information on people's perceptions of the area in which they live. You will be asked to read information on different topics of local interest then complete a short questionnaire. The full study will take up to ten minutes to complete and has received Departmental ethics approval from the University of Sheffield.

The survey can be accessed here: https://www.surveymonkey.com/r/Local_Perceptions

If you choose not to answer any particular questions, you may leave them blank. If you wish to withdraw from the questionnaire, simply close your browser.

Having completed the survey, you will be given the option to enter a prize draw to win £30 worth of Amazon Vouchers. At this stage you will be asked for your name and email address so that we can contact the winner. Such information will be separated from the survey data prior to the analysis to protect your anonymity.

If you feel that you have enough information about the study to proceed, then please select the 'I agree' option below and continue to the first question. If you have any questions, please email Victoria Wright at bop12vnw@sheffield.ac.uk.

Supervisors:

P H Warren (p.warren@sheffield.ac.uk)
L Maltby (l.maltby@sheffield.ac.uk)

Thank you in advance,

Victoria Wright