Changes in Perspectives of the Values and Benefits of Nature

Damian John Smith

School of Environment and Life Sciences

University of Salford

Salford

United Kingdom

Submitted in Partial Fulfilment of the Requirements of the Degree of Doctor of Philosophy, June 2013

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Acknowledgements

Sincerest and deepest gratitude to Philip James and Paul Oldfield for their unstinting guidance, faith, and support throughout this research project.

Of course, a multitude of academic staff, support staff, and researchers have played a large role in assisting me. These include Simon Hutchinson and Laurie Cunliffe for all areas of sedimentary work and analysis. Paul Ramage and Dan Alexander for extensive help with fieldwork; Gerard Brett for final proof reading.

Bob Hein of Sailing Yacht Jersey Lily, Jomtien, Thailand, for adding oxygen to the spark.

Enthusiastic encouragement has been unlimited from my fellow researchers in Peel 335, including and especially Cocker Ochieng for late night inspirational conversations, thank you.

Rallying around me at every point throughout this adventure, I offer my gratitude and thanks to my mum and dad, my sisters Claire, Bernadette, and Lucy, my brother Jeremy; brothers-in-law Andy, Ray, and Craig, favourite nieces Emily, Sarah and Erin, and nephews Liam, Ross, Josh and Ben. I am blessed.

Abstract

Social-ecological systems describe interactions between humans and nature. The ecosystem approach provides a holistic system to manage and understand these interactions, and to maintain and enhance ecosystem services - the benefits nature provides to humans. While much theoretical discourse posits various approaches to the ecosystem approach and ecosystem services, there exists a lack of practical applications examining these approaches, especially in urban and peri-urban environments.

The current research used a case study to examine the efficacy of integrating environmental management and ecosystem services within an urban greenspace social-ecological system. Initially, the most pertinent ecosystem services and management options were established. This was achieved through expert opinion, a rapid assessment, and a literature search which enabled the identification of a preferred management approach. This resulted in conservation grazing cattle over a 5 hectare salt marsh, typical of the Upper Mersey Estuary in the UK and situated within an urban area. The effects of cattle grazing on four relevant ecosystem services: (i) wild species diversity, (ii) environmental settings, (iii) carbon storage, and (iv) immobilisation of pollutants, were evaluated over two years. The aim of the evaluation was to examine how the grazing intervention affected ecosystem services. Both quantitative and qualitative measures - reflecting the interdisciplinarity of the ecosystem services concept - were used in the evaluation.

For the ecosystem services examined, the results add significant knowledge to the current discourse, and are used to inform new avenues for research. There was an increase in the cultural services (wild species diversity and environmental settings), regulatory services of carbon storage showed no change while differences in the immobilisation of pollutants observed were explained by local variation at the site. These findings show that by integrating ecosystem services and environmental management, larger scale benefits to humans from management options can be recognised and planned for in future natural spaces management, thereby increasing the positive rewards nature provides in abundance.

1. Introduction

1.1 Research Context

The expansion and influence of the human population on the Earth's ecological capacity is rapidly reducing the Earth's ability to deliver fundamental natural benefits (Kremen and Ostfeld, 2005). To address the growing requirements for food, timber, fuel, and fresh water, the last 50 year period has experienced more alteration of natural landscapes than any other time in comparable history (MA, 2005b). While the economic status and well-being of humans has increased, ecosystems have been subject to abrupt, non-reversible, and non-linear changes - these changes are unsustainable (MA, 2005b). Since the beginning of the industrial revolution, the concentration of carbon dioxide in the atmosphere has increased by 30% and species extinction rates have increased by a factor of between 100 to 1000 times (Vitousek et al., 1997; MA, 2005b). In the United Kingdom, the most recent report, 'The State of Nature', found 60% of wild species to be in decline (RSPB, 2013). Anthropogenic manipulation of the natural environment is cascading into an unparalleled degradation of freshwater, marine, and terrestrial ecosystems (Holt and Hattam, 2009). Ecosystem services, the benefits nature provides to humans, are in decline due to mismanagement and are undervalued, under-recognised, and undermanaged (Daily et al., 2009).

Humans have always understood the value and benefits provided by nature. These benefits have been increasingly managed by humans since the development of husbandry and agriculture *circa* 10 000 years ago (Fisher et al., 2009). Plato, writing in the fourth century BCE, provided one of the first literary references to nature providing benefits to humans through his description of soil erosion being caused by deforestation (Daily et al., 2009; Gómez-Baggethun et al., 2010). The term 'ecosystem services' as a description of the benefits provided by nature was introduced in 1981(Liu et al., 2007; Gómez-Baggethun et al., 2010). This term, ecosystem services, was derived from literature and concepts linking nature's benefits to humans and the interaction between the two (Gómez-Baggethun et al., 2010).

Increasingly, environmental management is moving away from a reductionist view to a holistic ecosystem approach, in which ecosystem services are maximised and managed to enhance all the components of ecosystems. The ecosystem approach was codified by the United Nations Environment Program as a holistic method of environmental management (CBD, 2000). A central idea in the ecosystem approach is that humans rely upon, and bring about changes, in ecosystems (Holt and Hattam, 2009). The ecosystem approach recognises the importance of the benefits that nature provides to humans; these benefits have become defined as ecosystem services (de Groot et al., 2002).

As the global population increases, so does the demand for natural resources (MA, 2005e). One of the primary threats to human well-being is the spread of urbanisation into agricultural and rural landscapes (Pickett et al., 1997). In 2009 the global population living in urban areas crossed the 50% level for the first time (UN, 2011). In Europe, this had already been crossed by 1950 and in 2011 the percentage of people living in urban areas was 72% (UN, 2011); in the United Kingdom (UK), at the same date, it was 80% (UK-NEA, 2011a; RSPB, 2013). The trend towards urbanisation continues to increase and it is estimated that by 2030 more than 60% of the global population will live in urban environments (Alberti, 2005; Eigenbrod et al., 2011). Urban growth increasingly affects wider ecological systems, although the urban area may be small in terms of area, the 'footprint' required to sustain populations within such areas is growing (Alberti, 2005). The area of this ecological footprint can be up to two orders of magnitude greater than the urban area itself (Gaston et al., 2013). Compared with other ecosystems such as coastal, grassland, and cultivated systems, urban ecosystems are ecosystem service sinks; they consume more natural resources than they produce (MA, 2005a).

The Millennium Ecosystem Assessment (MA) undertook a census of the world's ecosystem services. Published in 2005, under the auspices of the United Nations Environment Programme, the MA reported the current use of 60% of ecosystem services to be unsustainable (MA, 2005b; Haines-Young and Potschin, 2010; Hancock, 2010). Of the ten ecosystem services related to regulating the Earths' climate (for example: biohazard regulation and carbon sequestration) seven of these were in decline; and of the three cultural services, related to the intrinsic enjoyment of nature, two were in decline (MA, 2005b). The importance of these cultural services was found to be under acknowledged for local communities, including the importance of urban greenspace (MA, 2005b).

The United Kingdom National Ecosystem Assessment (UK-NEA) was published in 2011 as an inventory of ecosystem services in the UK (UK-NEA, 2011b). In compiling this report, it was found that 30% of the total ecosystem services over eight broad habitats were deteriorating to some degree, with 35% of broad habitats classified as being of high importance having a declining output of ecosystem services (UK-NEA, 2011b).

Urban greenspace plays a crucial role in the delivery of ecosystem services, especially intrinsic services related to mental well-being (Barbosa et al., 2007). Access to good quality greenspace in urban centres is necessary for residents' physical activities, positive mental well-being, and healthy childhood development (UK-NEA, 2011a). There are proven physical and mental health benefits as a result of contact with nature (RSPB, 2013). Aesthetically pleasing landscapes, which add to the well-being of humans (Barton and Pretty, 2010), have decreased in their quality and quantity since 1945 (MA, 2005e). Despite the fact that humans are an important and integral part of urban ecosystems and environments, there remains much scope for investigating this integration wherein humans interact with nature (Mace et al., 2012). The knowledge base of ecosystem services in urban areas is one of the least developed (Niemelä et al., 2010). In developing this knowledge base further, interdisciplinary research and developing a link between science and policymaking is required (Alberti et al., 2003).

Habitats and natural areas that provide ecosystem services should be managed carefully so that the ecosystem services provided by them are maintained for both present and future use (Egoh et al., 2008). There have been calls to include ecosystem services as a crucial aspect of managing the environment (Egoh et al., 2007; Crown, 2012). While a large tranche of ecosystem service theory exists, there is a lack of utilisation of planning for ecosystem services using a coherent and integrated approach at a practical level (Daily et al., 2009; de Groot, et al., 2010). Pilot and case studies have been recommended in order to address these research gaps (Daily et al., 2009).

In order to the address knowledge gaps related to the management of ecosystems and ecosystem services, the research reported here was carried out using interdisciplinary research of inductive (common in social sciences) and deductive (common in natural sciences) methodology (Grix, 2004; Pathirage et al., 2008) using a case study in the north-west of England, UK. The research takes an ecosystem approach, wherein all aspects of the ecosystem are included from traditional conservation, to recognising humans as being part of a healthy and sustainable ecosystem (CBD, 2000).

This thesis encompasses a programme of case study research undertaken between April 2010 and February 2013. The research had a main over-arching aim – to critically examine the efficacy of integrating environmental decision making into the ecosystem approach and ecosystem services in an urban greenspace. The case study falls within the context of developing a deliverable mitigation scheme for the construction of a tolled crossing, The Mersey Gateway Bridge, over the Upper Mersey Estuary in the north-west of England, UK. The estuary is situated within the unitary authorities of Warrington and Halton and is classified as urban by the UK-NEA (UK-NEA, 2011a). In 2009, when planning consent for construction of the bridge was granted, the UK Government's Planning Policy Statement 9 required that measures be taken to increase or maintain biodiversity which may be affected by the bridge construction (Crown, 2005). Measures are sought to bring underutilised areas within the Upper Mersey Estuary under management to mitigate for environmental damage as a result of the bridge construction. The case study and the development of the associated biodiversity management plan have presented an opportunity to investigate the efficacy of a practical application of the ecosystem approach and ecosystem services on an unmanaged greenspace in an urban area. The biodiversity management plan will be delivered as part of the thirty year vision developed by the Mersey Gateway

Environmental Trust to transform the landscape scale ecology of the Upper Mersey Estuary.

1.2 Thesis Structure

A framework for the current research is displayed in Figure 1. In Chapter 2 a critical examination of the extant knowledge and literature regarding social-ecological systems, the ecosystem approach, and ecosystem services is reported. The evolving nature of the relationship between humans and nature is examined with regard to the Anthropocene, the name of the current epoch (Crutzen, 2002). Social-ecological systems thinking, how humans and nature co-evolve and influence each other (Folke et al., 2005; Haines-Young and Potschin, 2010) is presented as a perceptive shift, a change in the common view, which facilitates the ecosystem approach. Following this, the history and rationale behind the ecosystem services approach and iterations of seminal literature and reports are presented. The literature review exposes research gaps within the theory of ecosystem services and translating this into current requirements for managing ecosystem services. A cyclical framework for the integration of ecosystem services and environmental decision making (Daily et al., 2009) is presented. At the end of the literature review, the aim and objectives of the current research, identified through research gaps in the literature review, are presented.

Chapter 3 consists of a description of the methodological approach behind the interdisciplinary research to address the aims and objectives identified from the literature review. Additionally, the research detailed in Chapter 3 explains the selection of the research site and provides a description of the site – a salt marsh within an urban conurbation– providing an ideal model in which the aims and objectives drawn from the literature review are addressed.

In Chapter 4 the optimal management intervention for the salt marsh was determined using triangulation of knowledge through a literature review, local expert opinion and an assessment of extant knowledge on ecosystem services. Two options to manage the salt marsh were considered, grazing or mowing. The triangulation method resulted in grazing by cattle to be the preferred management option. Following the result of the three methods, that grazing was the best option, methods pertaining to salt marsh management and grazing are critically examined and described.

Four ecosystem services were identified as being of high importance and ideal examples within the case study: wild species diversity, environmental settings, carbon storage, and the immobilisation of pollutants. The description of the effect of the management on these four ecosystem services is set out in chapters: 5, 6, 7 and 8 respectively. These four chapters, which contain descriptions of the effects of the management on ecosystem services, use both deductive and inductive methods to examine the data collected.

In Chapter 5 the effects of grazing on breeding bird occurrence, the vegetation structure, and invertebrate assemblage between grazing and the ungrazed treatments are described. Data from the two treatments are examined using descriptive and non-parametric statistics to ascertain differences between the two. The results are discussed with reference to previous research on salt marsh bird ecology and recommendations for future research.

Chapter 6, environmental settings, begins with unobtrusive observation to examine human visitor behaviour around the grazing area. Further to this, using inductive social research methods, informal interviews were undertaken and a thematic analysis was performed on the interview data to determine ecosystem services provided by the management intervention. A discussion follows this with the implications of the results with recommendations as to how these could be acted upon.

Salt marsh sediment is recognised as an important carbon store (Chmura et al., 2003). The research presented in Chapter 7 describes loss of ignition to determine any differences in stored carbon arising within the salt marsh as a result of the management regime. Using previously described methods (Ford et al., 2012b), the number of tonnes of carbon stored per hectare to a depth of 15cm is calculated between grazed and ungrazed treatments. These results are descriptively presented and statistically analysed using parametric statistics. Having established tonnes of carbon stored within the grazed and the ungrazed treatments, the economic value of the stored carbon in pounds sterling is calculated.

In Chapter 8 an analysis of the effects of grazing on the ecosystem service of the immobilisation of pollutants is investigated. Lead and arsenic were selected as ideal elements to examine as they are stable elements in sediments (Dudka and Miller, 1999) and maintain stability in salt marsh sediments (Cave et al., 2005). A repeated measures procedure is described which explored the change over time (after one year, and after two years) compared to the status of the two pollutants prior to the commencement of grazing. These data were compared using both descriptive and non-parametric statistics.

In Chapter 9, the findings, conclusions, and recommendations presented in the research, and the results thereof, are drawn together through a discussion. The current knowledge into the ecosystem approach and ecosystem services and how this has evolved in the current case study from current national and European environmental aims are brought together. The cyclical and iterative aspect of the research is examined using a framework which proposes to integrate environmental decision making and ecosystem services (Daily et al., 2009). The contribution to the body of knowledge by the current research is then discussed. Lastly, further recommendations to advance the body of knowledge in this field are presented at the end of this concluding chapter.

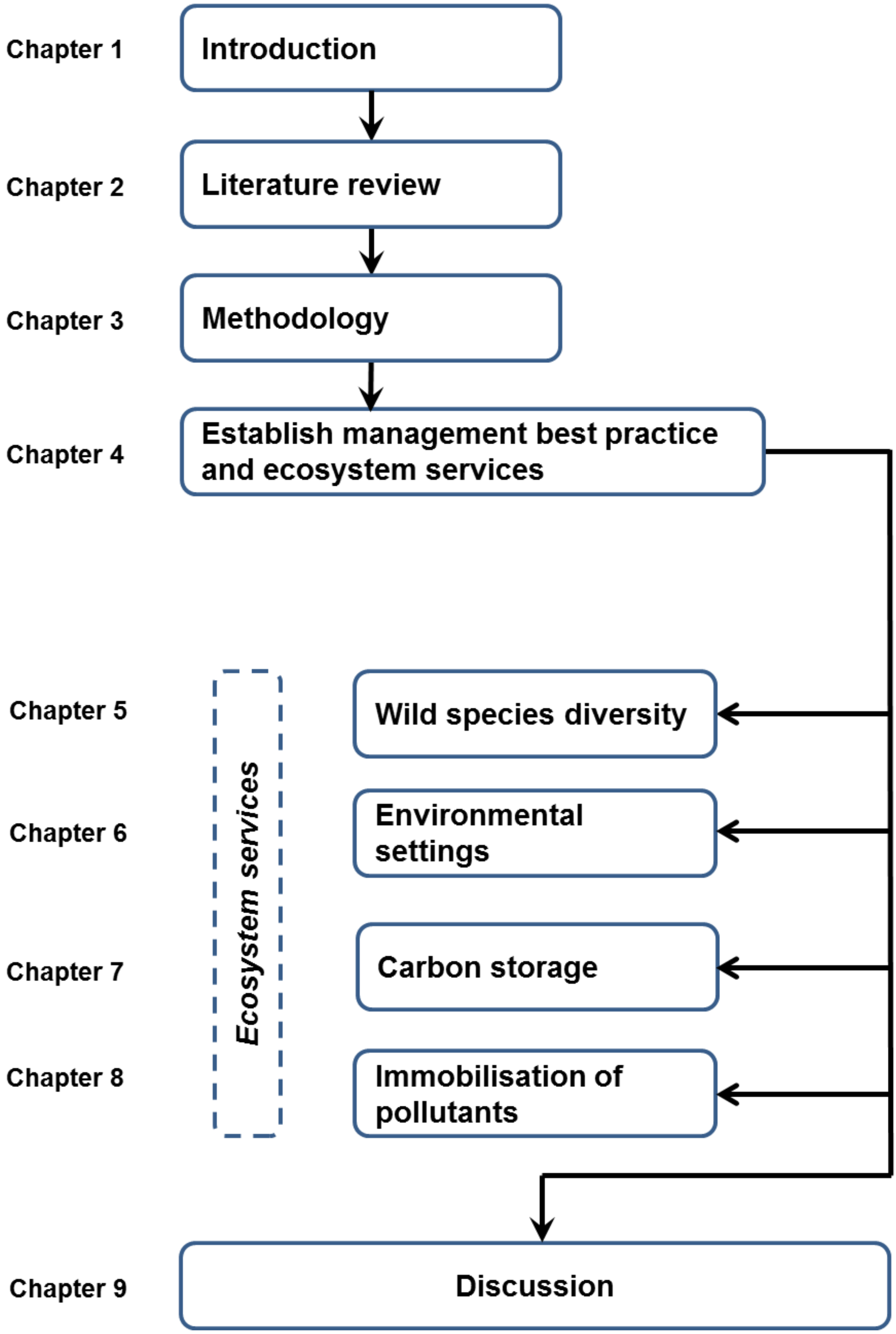

Figure 1: Conceptual overview of thesis. An iterative process is shown between chapters 4 to 9.

2. Literature Review

2.1 Introduction to Literature Review

This chapter has two aims: 1) to establish the current knowledge of literature surrounding the relationship of humans with nature, and ecosystem services and the ecosystem approach, and 2) from the extant literature, to identify emerging questions that may be translated into the aims and objectives of the current research. The aims of this chapter are achieved by beginning with a critical review of social-ecological systems knowledge, the ecosystem approach, and ecosystem services. A description of how social-ecological systems bridge the traditional divide between ecological and social sciences (Section 2.2) and a description of these systems (Section 2.3) is presented. This description focuses on the interplay between social sciences and ecological processes. In Section 2.4 the ecosystem approach, a holistic system of managing ecosystems is introduced. A mainstay of the ecosystem approach is maintaining and enhancing ecosystem services: the benefits provided by nature to humans, is presented in Section 2.5. Emerging questions from the literature review are identified, leading to the aims and objectives of the research project (Section 2.6).

2.2 Humans in Nature

Professor Sir Robert Watson, former chief scientific adviser for the UK's DEFRA and current vice-chair of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), during his plenary address delivered to the European Congress of Conservation Biology held in Glasgow, Scotland, August 2012 (attended by the author), made three statements:

1. 'Local knowledge is essential.'
2. 'We must work with end users.'
3. 'Nature and people are totally and utterly connected.'

The three statements refer to the need and requirement to bring together ecological and social sciences, to include people in decision making, and to practice interdisciplinary methods in scientific research related to managing the environment.

Ecology and sociology have traditionally been separated into different scientific disciplines with different approaches to data collection and analysis. The inclusion of humans in natural sciences has been challenging since the recognition of ecology as a distinct discipline (Pickett et al., 1997; Liu et al., 2007). The spectrum of opionion has an extreme range: starting with those for the inclusion of humans as an equal biological component and ending with those for complete exclusion of humans (Pickett et al., 1997). Integrating the two disciplines of natural and social science requires an approach recognising their reliance on one another and effective collaboration between the two.

In contrast to a seperation between the sciences, Adams (1938) asked if the same structures and relationships found in the natural world existed in urban environments, how feedback[1] crossed social boundaries, and how these related to each other. Adams (1938) called for a closer relationship between the biological and social sciences to better understand the social implications of managing urban environments at biological and biophysical levels.

Hollingshead (1940) fostered this closer relationship through his thesis that studies of humans should be viewed holistically, thus recognising the undisputable place of humans in the web of life. Hollingshead (1940) differentiated between plant, animal, and human ecology by the survival strategies exemplified by the social relationships of individuals. According to Hollingshead (1940), plants lack feeling, collective strategies, or familial networks obvious in the animal kingdom. Animals display strong elements of instinctive adaptations to their environments; higher animals display collective aims and family relationships. Humans are differentiated from the plant and

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[1] *Feedback* relates to signals produced as a result of management, refers to ‘any behaviour which may reinforce (positive feedback) or modify (negative feedback) subsequent behaviour’ (Berkes & Folke, 1998, p. 6).

animal kingdoms due to culturally and socially organised behaviour, learned since birth. Hollingshead's social versus ecological approach has been embedded within academia as a 'division of labour' in which social sciences are examined by sociologists, and the natural world by ecologists (Palsson, 1998, p. 48). This separate relationship is becoming highly questionable in light of increasing academic theory and empirical evidence which suggests the two are intertwined (Palsson, 1998). A significant indication of this is the name of a new epoch succeeding the Holocene, the Anthropocene.

This name emphasises the strong relationship between humanity and the environment and how they are now inexorably connected (Crutzen, 2002; Potschin and Haines-Young, 2011b). As the term Anthropocene, and the associated concept, has cascaded into academic discourse; the traditional divide between social and ecological sciences has been bridged by the development of social-ecological systems as conduits to integration (Berkes and Folke, 1998).

The Anthropocene was named as a result of increasing evidence of the influence of people on the environment (Crutzen, 2002). Crutzen (2002) marked the beginning of this period as the late 18th century. Crutzen (2002) noticed the increased levels of carbon dioxide and methane found in polar ice air pockets, dated the late 18th century, coincided with James Watts' steam engine design in 1784. Figure 2 clearly indicates the rise in number of publications the Anthropocene term has reflected in academic writing. This rise in the number of publications is indicative of the growing number of research investigating interactions between humans and the environment.

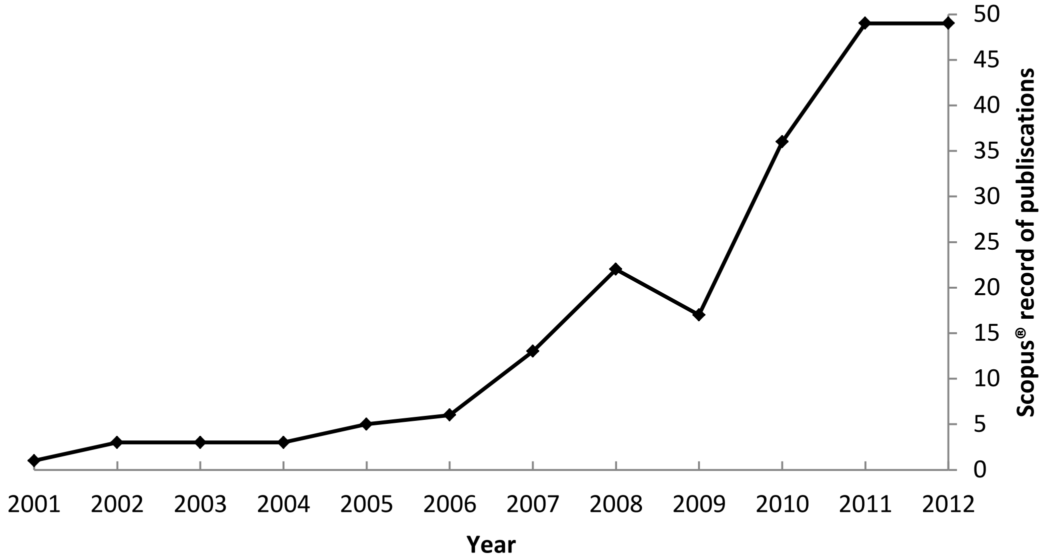

Figure 2: Number of publications with 'Anthropocene' in the 'Title, abstract or keywords'. The results show the use of the concept in academic thinking, discourse, and publication. Scopus® search engine. Search carried out 03/01/2013 (Elsevier, 2013).

Describing the relationship between social and ecological systems in the Anthropocene has involved various approaches and semantic issues. Examples including coupled human-environment systems, ecosocial systems, and socio-ecological systems have been suggested by scholars (Folke et al., 2005). However, treating 'social' or 'ecological' as suffixes and prefixes does not correctly display the equal part these factors play in the system. Berkes and Folke (1998) use 'social-ecological systems' to illustrate the influence on each other, describing attempts to delineate between social and ecology as being 'artificial and arbitrary' (Berkes and Folke, 1998, p. 4).

Social-ecological systems are described as human and natural systems with dynamic relationships involving shared feedback, resilience, non-linear changes, and heterogeneity (Liu et al., 2007). In other words, social-ecological systems are dynamic across time and place at various levels of different intensities. For this reason, the current research uses 'social-ecological' to describe the system that exists between humans and ecology.

Urban ecosystems are a prime example where highly dynamic social-ecological relationships exist. An example of this dynamism is the observed close link in the human behaviour patterns in the urban environment with pressure on existing natural resources (Pickett et al., 1997). This connection exemplifies the need for social and ecological integration within ecosystem management (Pickett et al., 1997). Such social-ecological relationships cannot be ignored and conceptual frameworks describing these aid their understanding (Pickett et al., 1997).

2.3 Social-ecological Systems Analysis

Social-ecological systems occur where an ecological system interacts with, and is affected by, two or more social constituents (Anderies et al., 2004). Society was asked to identify, recognise, and analyse social-ecological systems by Berkes and colleagues in 2003 (Berkes et al., 2003). Social-ecological systems facilitate the bridging of disciplines through discourse between scientists, conservation practitioners, administrators, and resource users (Glaeser et al., 2009). A social-ecological approach to managing landscapes and ecosystems makes it unnecessary to divide the social and natural sciences, and compliments the understanding of both disciplines' reliance upon one another (Wang et al., 2013). Knowledge of links between the two disciplines within social-ecological systems are weak and there remains much scope for further understanding of these (Glaeser et al., 2009). In complex social-ecological systems, feedback between ecological and social management of ecosystems needs to be defined and characterised as the two interact (Liu et al., 2007).

In order to be understood, complex social-ecological systems should be viewed from multiple perspectives (Berkes et al., 2003). Walker and Meyers (2004) describe feedback within social-ecological systems and how these systems are interrelated through changes in their components and constituent parts. These descriptions make explicit reference to changes in one part of the social-ecological system, for example governance or human actors having an effect on another. Governance in a social-ecological system involves humans making decisions concerning managing structures and processes (Folke et al., 2005).

Governance involves decision making by authoritative bodies that creates shifts in an ecological system: for example land use change by introducing grazing to a landscape, driven by changes in the social system (Walker et al., 2006). Governance can result in non-linear, negative results. Where governance has decided on grazing, for example, high grazing intensity can create soil conditions in which seeds are unable to germinate (Walker et al., 2006; Doody, 2008). Hence, a link exists between governance and ecological results.

Hardin wrote of the unsustainable exploitation of natural resources in his treatise 'The Tragedy of the Commons' in which he debated the negative consequences of unmanaged use of natural resources (Hardin, 1968). Hardin argued that ungoverned open areas create degraded, unusable landscapes because of over-exploitation by individuals and posed the question as to whether increased governance of environmental resource would be desirable (Hardin, 1968; Anderies et al., 2004). In a 'Tragedy' scenario, humans are short sighted and concerned with their own individual requirements, extracting their own resources, the resultant damage being borne by the collective community and the environment (Glaeser et al., 2009).

Historically, the exploitation by humans of natural resources to increase outputs has led to a homogeneity of terrestrial and marine habitats which in turn leads to lower environmental variability and increases uncertainty (Folke et al., 2005). The relationship between humans' use and exploitation of nature reveals a pattern of adapting this use to the conditions humans create (Folke et al., 2005): an iterative process. The capacity of ecosystems to adapt to, and maintain pace with this increased management, from local to global scales, has been reduced in modern times (Folke et al., 2005).

Social-ecological systems have been placed under severe threat because of changes in biophysical and human processes including, but not limited to, increased carbon emissions, population flux, overharvesting of resources, and pollution (Ostrom, 2007). Humans have transformed ecosystems more in the last 50 years than all prior recorded history (Collins et al., 2010; Chapin et al., 2011). The unprecedented loss of ecosystem services over the last 50 years is mitigated by managing social-ecological interactions (Carpenter et al., 2009). A method to manage large scale social-ecological systems has been proposed in the ecosystem approach.

Complex social-ecological systems require a multiple perspective approach. In order to best understand the current status of a social-ecological system, a historical perspective is required (Berkes et al., 2003). This is especially true in social systems as each has a unique history and context providing a different perspective (Berkes et al., 2003). Two approaches are used in the analysis of social-ecological systems: modelling, and writing scenarios (Glaeser et al., 2009). Analysis of social-ecological systems has followed two distinct strands: through interdisciplinary research in an applied and participatory paradigm; and through epistemological discussion on scientific knowledge (Glaeser et al., 2009).

A conceptual framework for humans and ecosystems is ‘a concise summary in words or pictures of relationships between people and nature’ (Ash et al., 2010). In keeping with this, Berkes and Folke (1998), Folke et al. (2005) and Liu et al. (2007) describe social-ecological systems as systems which illuminate or describe the relationships and interactions between social and ecological factors in the area under research, to include all ecological and social aspects and how these are related to each other through management. A conceptual framework of a social-ecological system illustrating the three components that constitute these systems can be seen in Figure 3, below.

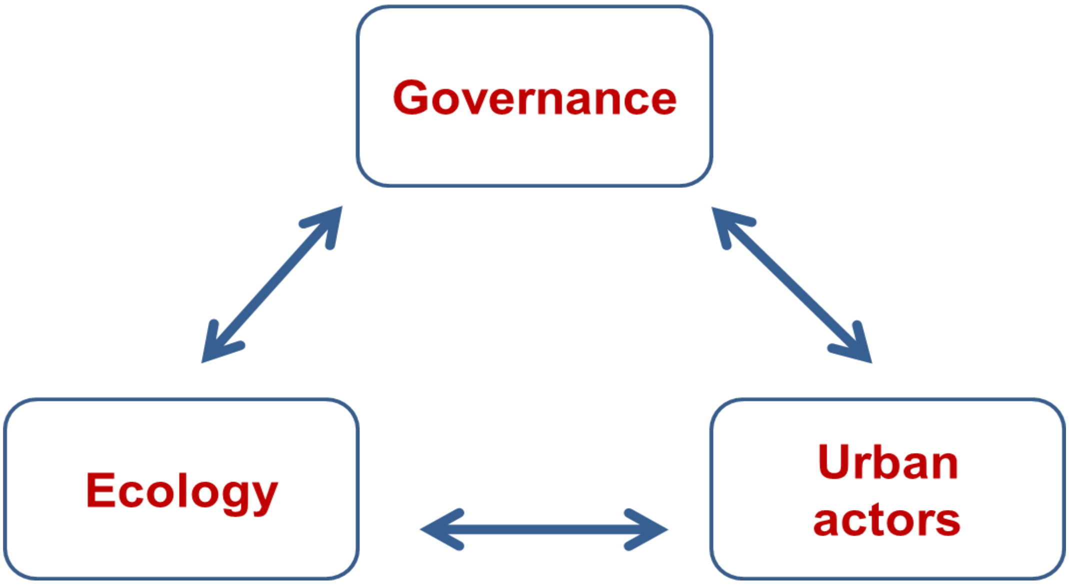

Figure 3: Representation of a social-ecological system. Adapted from Berkes and Folke (1998) and Folke et al. (2005)

2.4 The Ecosystem Approach

In the modern environmental management era, the ecosystem approach has encapsulated a strategy for a holistic, sustainable management of all components of landscapes. Incorporating social, scientific, and economic issues, this approach is described as 'a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way' (CBD, 2000, p. 104) enabling decisions to be made for all parts of the ecosystem (Haines-Young and Potschin, 2008). This equitable and sustainable use of natural resources, promoting conservation of the environment, is connected with the improvement and enhancement of human well-being (Alfsen et al., 2011). The practical application of the ecosystem approach implies 'intersectoral cooperation, decentralisation of benefits, and the use of adaptive management policies' (CBD, 2000, p. 91).

Adaptive management is a crucial part of the ecosystem approach; as relationships between various parts of ecosystems are often non-linear, responses to management are required when such situations arise (CBD, 2000). An adaptive ecosystem approach through governance, management, and monitoring has been proposed (Folke et al., 2005). In this three pronged adaptive method: governance determines trade-offs and actions for sustainability; management implements these actions; and monitoring provides the necessary information to inform the effectiveness of governance, thereby establishing optimal future management (Folke et al., 2005).

The ecosystem approach is a flexible framework; its principles, for example, adaptive management, are integrated into management strategies to maximise ecosystem services (Haines-Young and Potschin, 2008). Adaptive management takes place as a fluid process; as strategies are implemented, the results of these inform the next decision creating results which are acted upon for the following stage (Berkes et al., 2003). Adaptive management allows on-going decision making to take place in experimental resource policy situations for continual learning by resource managers (Berkes et al., 2003).

The ecosystem approach and its principles in managing the environment were endorsed at the United Nations Environment Programme's fifth conference of parties to the Convention on Biological Diversity in Nairobi in May 2000 (CBD, 2000). Twelve complementary and interlinked principles were adopted by the Nairobi conference. These form the backbone of the approach (CBD, 2000):

1. The objectives of management of land, water and living resources are a matter of societal choice.

2. Management should be decentralised to the lowest appropriate level.

3. Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

4. Recognising potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:

a) Reduce those market distortions that adversely affect biological diversity

b) Align incentives to promote biodiversity conservation and sustainable use.

c) Internalize costs and benefits in the given ecosystem to the extent feasible.

5. Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

6. Ecosystems must be managed within the limits of their functioning.

7. The ecosystem approach should be taken at the appropriate spatial and temporal scales.

8. Recognising the varying temporal scales and lag-effects that characterise ecosystem processes, objectives for ecosystem management should be set for the long term.

9. Management must recognise that change is inevitable.

10. The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

11. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous, and local knowledge, innovations and practices.

12. The ecosystem approach should consider all relevant sectors of society and scientific disciplines.

The emphasis within the ecosystem approach relates to the fifth principle which creates a 'priority target' (CBD, 2000, p. 106) and states that by conserving the structure and functions of ecosystems, ecosystem services can be maintained (CBD, 2000).

2.5 Ecosystem Services

2.5.1 The History and Modern Relevance of Ecosystem Services

Humans have recognised the connection between personal well-being and healthy sustainable ecosystems since time immemorial (Braumann et al., 2007;

Fisher et al., 2009). The unsustainable use of ecosystems and ignoring nature's benefits was noted by Diamond (2006) who used the example of the Easter Island civilisation's unsustainable use of timber, and the resultant deforestation and soil erosion and subsequent collapse of the population (Diamond, 2006; Fisher et al., 2009). In the modern era, Hardin' s tragedy, wherein unmanaged land is unsustainably used and therefore degraded to such an extent so as to produce no benefit to people (Berkes and Folke, 1998).

Modern academic discourse and research has termed these benefits 'ecosystem services', the phrase first being used in 1981 (Fisher et al., 2009). Three seminal studies have led the research into ecosystem services since 2005: The Millennium Ecosystem Assessment (MA) (MA, 2005e), the Economics of Ecosystems and Biodiversity Study (TEEB) (TEEB, 2010d), and the United Kingdom National Ecosystem Assessment (UK-NEA) (UK-NEA, 2011b). Ecosystem services can be enumerated, bundled, and categorised to facilitate the ease of which these benefits are described and presented to policy makers and society at large.

Ascribing values for ecosystem services is a mainstay of the ecosystem service approach. The monetisation of nature's services was discussed, initially as an abstract idea by Westman (1977), posing questions in order that objective decisions regarding use of ecosystems could be made. The highest impact article in the field of ecosystem services to date described an economic value for 17 ecosystems in 16 biomes based on previously published and original calculations (Costanza et al., 1997). This seminal work instigated much discussion and research on ecosystem services (Fisher et al., 2009; Gómez-Baggethun et al., 2010). Costanza et al. (1997) valued the total biosphere as at least \$33 trillion year $^{-1}$ (£20.8 trillion year^{-1}). This monetisation of ecosystem services may create markets and an easily understandable reference point for managing ecosystems that economists may embrace, but anthropologists and philosophers urge restraint in simply monetising natural assets given high intrinsic values attached to nature by non-business sectors of society (Glaeser et al., 2009).

The monetisation of ecosystem services has been much debated and in some cases found to be highly questionable (Heal, 2000). Determining nature's economic values from the philosophical 'water-diamond paradox', wherein the market value of diamonds is compared to water, water clearly has more value to sustain life (Heal, 2000). The water-diamond paradox has been used to show how economic values of ecosystem services is a questionable precept, often contextual, and related to market forces (Heal, 2000; de Groot, Fisher, et al., 2010). In managing ecosystem services, economic translation is often not required, whilst economic valuation aids decision making it is not a single panacea (Everard, 2009).

Yet, monetary valuation is clearly valid in many cases, for example in deferred, or avoided, costs of the Catskill and Delaware watershed case study (Hancock, 2010). In this case, it was found that building new water filtration infrastructure by the City of New York would have cost $6- 8 billion in contrast to the $1.5 billion cost of restoring the watershed areas using conservation methods (Hancock, 2010). The New York municipal authorities restored the watershed, thereby making a substantial financial saving through avoided costs (Hancock, 2010; Liu et al., 2010). This is a very good example of how the economic valuation of ecosystem services provides a way of communicating the value of nature to aid decision making for economic and politically driven governing bodies (de Groot, et al., 2010).

A seemingly exponential increase in interest and research in ecosystem services in literature was shown by Fisher et al. (2009) and Liu et al. (2010) who carried out an ISI Web of Science® search using the term 'ecosystem services' up to 2007. Similarly, Potschin and Haines-Young (2011b), using the term 'ecosystem services' in Scopus® up to 2010, found 60% of literature to have been published between 2006 and 2010 inclusive. The Potschin and Haines-Young (2011b) method has been modified and is updated, the results of which are illustrated in the linear graph in Figure 4. The results display the impact of the concept on academic publication and research

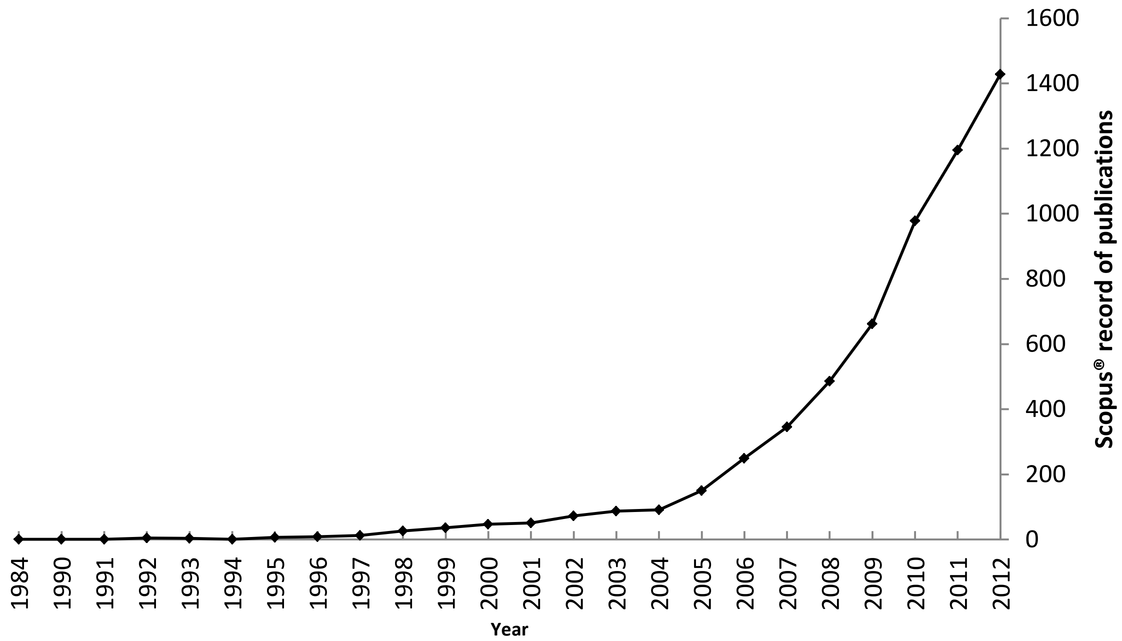

Figure 4: Number of publications with ‘ecosystem services’ in the ‘Title, abstract or keywords’. The results show the impact of the concept on academic publication and research. Scopus® search engine. Search carried out 03/01/2013 (Elsevier, 2013).

2.5.2 Ecosystem Service Definition

Various typologies and definitions have been suggested for ecosystem services (de Groot et al., 2002; Wallace, 2007; Fisher et al., 2009) and discussion in the research literature often revolves around semantic differences between ecosystem services, processes, and functions (Fisher et al., 2009). The Millennium Ecosystem Assessment (MA), which set the modern benchmark for ecosystem service science, posits ecosystem services as ‘the benefits provided by ecosystems that contribute to making human life both possible and worth living’ (MA, 2005c, p. 300). Costanza et al. (2007) define ecosystem services as ‘ecosystem goods (such as food) and services (such as waste assimilation) which represent the benefits human populations derive, directly or indirectly, from ecosystem functions’; while (Fisher et al., 2009, p. 645) use this definition: ‘ecosystem services are the aspects of ecosystems utilised (actively or passively) to produce human well-being’. Hooper et al. (2005) define ecosystem services as properties of ecosystems (hydrological cycles, processing and cycling of nutrients, pollination, and air and water purification) which directly benefit human requirements (food, fibre, wood for construction, and leisure). Liu et al.'s (2010, p. 54) definition perhaps best simplifies all of the above as 'the benefits people obtain from ecosystems'.

The underlying theme of these definitions is an anthropocentric perception: services are explicitly provided by nature to humans (Egoh et al., 2007). A primary precept of the ecosystem service paradigm and one on which this thesis rests, is that ecosystem services can only be described and received if human recipients are identified (Potschin and Haines-Young, 2011a). A simple way to view this precept is that while nature continuously creates and provides function and structure, in a world devoid of humans, there would be no services (Fisher et al., 2009). The delineation between ecosystem processes and functions, and ecosystem services, is the presence of human beneficiaries (Chan et al., 2006). The ecosystem service approach's uniqueness rests with the presence of human beneficiaries.

Concomitant with scientific literature, government and organisations have readily embraced the ecosystem service concept. The UK's Department for Environmental, Food and Rural Affairs (DEFRA) implemented the ecosystem services approach in 2007 as a means of effective environmental management (Everard, 2009). The current UK Government, in a discussion document published in July 2010, acknowledged the close link between a healthy natural environment and human happiness, prosperity, and well-being, citing the ecosystem services framework as a valuable conservation approach (Crown, 2010). The United Kingdom National Ecosystem Assessment (UK-NEA), discussed below, was the first full national ecosystem assessment carried out at the instigation of a government, illustrating the United Kingdom's high commitment to the concept (UK-NEA, 2011b). Using ecosystem services as a toolkit for management of ecosystems to enhance benefits was recognised by the incorporation of the MA's recommendations into the Convention on Biological Diversity, and the RAMSAR Convention on Wetlands, within a year of the MA's publication (Tallis and Polasky, 2009). In addition, the structure and aims of the MA were incorporated into the AICHI Biodiversity targets, a list of 20 targets agreed by delegates to the tenth conference of the Convention on

Biological Diversity to halt losses in biodiversity and enhance ecosystem services through the Living in Harmony with Nature (UNEP, 2010).

In ecosystem service management, ecosystems are viewed as environmental assets, comparable with capital assets and as such, a sustainable, integrated method of management not degrading their value is required (Defra, 2007; TEEB, 2010a). At present, conservation practice using the ecosystem service concept is a growing field with gaps in areas of research (Egoh et al., 2007) for example, cultural services of salt marsh (Everard, 2009). Ecosystem services should be seen as bundles which provide a range of services, the level and quality of which is dependent on management of the services, where effort is placed, and the interaction of the services with each other, and exogenous drivers of change (Bennett et al., 2009; TEEB, 2010a).

Linking ecosystem services, science, policy makers and interest groups creates a strong and robust management system. The ecosystem service framework has the capacity to investigate relationships between land use change and the delivery of services to society (Bennett et al., 2009). While theoretical approaches abound, questions remain regarding integrating decision making and ecosystem services so that landscape management for multiple ecosystem services can be attained (Egoh et al., 2007; Bennett et al., 2009). A methodological problem within the ecosystem service framework is the different perspectives between natural and social scientists and the search for generalisation in the approach to managing for ecosystem services (Haines-Young and Potschin, 2013). Generalisation of the approach is recommended so that ideas are made testable, but also so that the research experience can be transferred between assessments and case studies (Haines-Young and Potschin, 2013).

Two seminal assessments now guide the ecosystem service approach globally and nationally, these are the MA and the UK-NEA respectively. The importance of their findings should not be underestimated. Therefore, these two assessments are discussed here.

2.5.3 The Millennium Ecosystem Assessment

Overwhelmingly, the current discourse and understanding of ecosystem services has been encapsulated by the MA (Boyd and Banzhaf, 2007; Defra, 2007; Egoh et al., 2007; Haines-Young and Potschin, 2008; Carpenter et al., 2009; Seppelt et al., 2011). Published in 2005 and drawing on approximately 1 360 experts, the MA posited a basic typology of ecosystem services, and how these could be viewed and managed (MA, 2005b; Fisher et al., 2009). Additionally, existing knowledge was summarised, analysed, collated, and presented in a focussed manner, aiming to provide scientifically robust solutions to policy relevant questions (MA, 2005e). The layout displayed in Figure 5 illustrates the flow between ecosystem services and human well-being as used by the MA conceptual framework (MA, 2005b). Ecosystem services are divided into four categories which are now widely recognised and used in ecosystem service science (Braumann et al., 2007; Defra, 2007; Haines-Young and Potschin, 2010). These four categories are: provisioning services (providing tangible direct effects such as wood or food); regulating services (flood prevention, climate control, or water quality); cultural services (the less tangible benefits such as recreation, education or spiritual upliftment); and finally, supporting services (primary production, nutrient cycling, and soil formation).

As shown in the individual sections of Figure 5, supporting services have no direct relationship with humans but enable the delivery of provisioning, regulating, and cultural services. For example, soil formation does not directly benefit humans but feeds into flood prevention, a regulating service, with concomitant benefits to society. This relationship between supporting services and provisioning, regulating, and cultural services is complex and under much discussion in literature (MA, 2005b; Wallace, 2007) and was further clarified in the UK through the UK-NEA (UK-NEA, 2011c).

The last two columns of Figure 5 illustrate the link between human well-being and ecosystem services. The common elements of human well-being are divided into four categories: security, basic material for good life, health, and good social relations. The relationships between these constituents and ecosystem services are displayed in the set of arrows between the ecosystem services and the common elements (Figure 5). The four constituents of well-being ultimately provide the final requirement: that of freedom of choice and action for all human beings (MA, 2005b).

A limitation of the MA is the absence of a regional, contextual approach (MA, 2005e). The MA recognised a paucity of knowledge connecting changes in ecosystems to changes in human well-being, specifically recognising that local level research would provide clearly identifiable relationships between the two (MA, 2005e). In July 2011, the UK-NEA was published to augment the MA at a national level as a fact finding and national inventory.

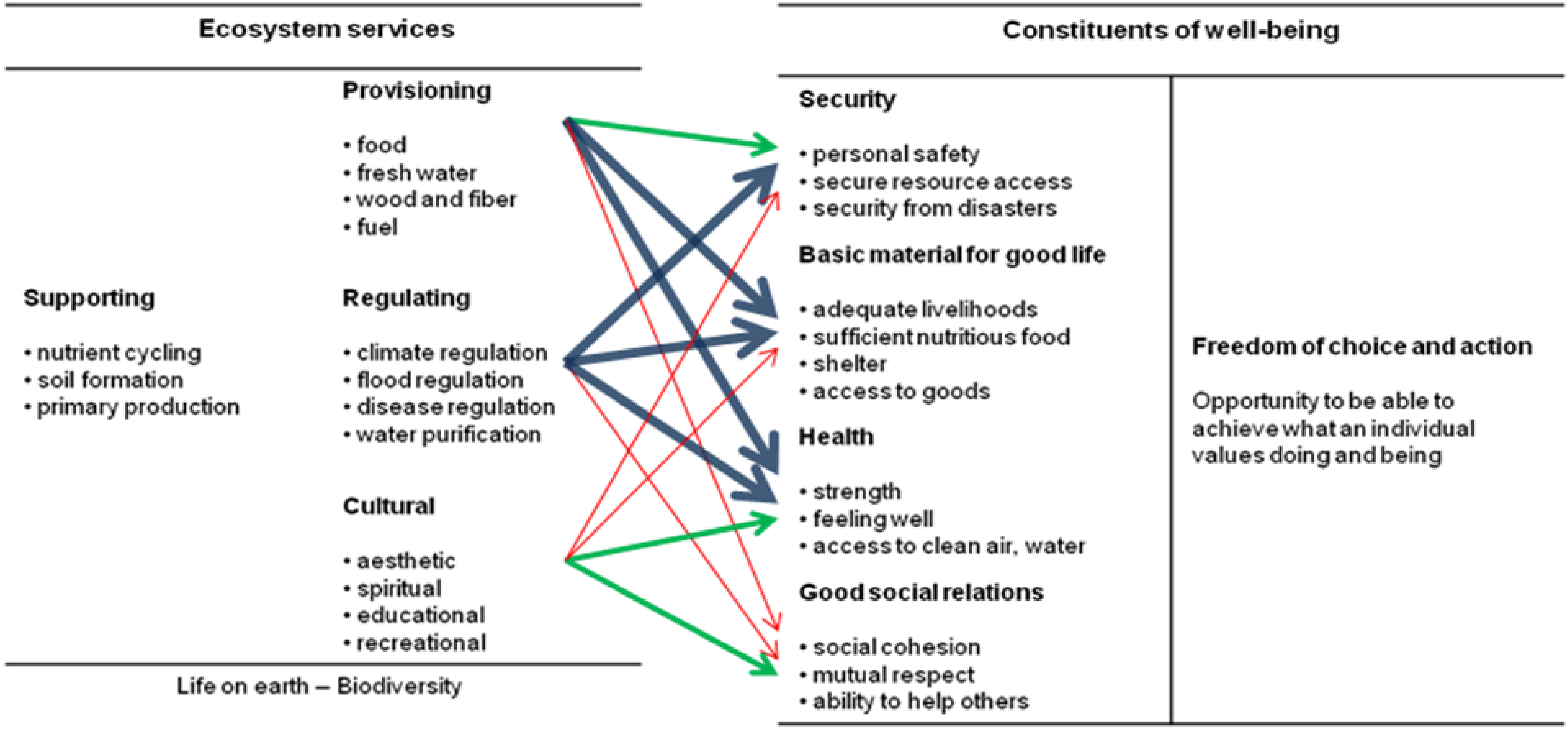

Figure 5: The relationship between ecosystem services and freedom of choice and action for human beings. Ecosystem services are divided into four categories which supply four constituents of well-being and finally, the freedom of choice and action for humans. Thickness and colours of lines between the ecosystem services and constituents of well-being represents the amplitude of the effect; thicker, blue lines have more of an impact than green, medium width, with the least effect designated by the thinnest, red lines. Adapted from the Millennium Ecosystem Assessment (MA, 2005b).

2.5.4 The United Kingdom National Ecosystem Assessment

The UK-NEA's framework was built on the MA's concepts insofar as services were broken into the same four categories: supporting, provisioning, regulating, and cultural (MA, 2005b; UK-NEA, 2011c). Additionally, the UK-NEA included the contextual elements of the nation by incorporating UK broad habitats (UK-NEA, 2011c). A primary objective of the UK-NEA was to systematically provide a valuation mechanism of categories and services provided by nature: while economics may constitute a part of this, it is by no means the main arena in valuation (UK-NEA, 2011c).

The definition of an ecosystem service as defined by the UK-NEA is 'the outputs of ecosystems from which people derive benefits' (UK-NEA, 2011c, p. 2). The conceptual framework under which the UK-NEA was formed followed the predication that conceptual frameworks should clearly represent those subjects, issues or components being examined, with relationships and linkages displayed (UK-NEA, 2011c). In addition, this conceptual framework was used to identify where data, knowledge, and gaps existed (UK-NEA, 2011c). The UK-NEA framework centres on processes which connect the natural environment and human well-being (UK-NEA, 2011c).

The conceptual image of the UK-NEA shows the path from processes and interactions, to environmental planning. In the lower right hand corner of Figure 6 ecosystem services are nested within two larger frames. The largest of these relates to the relationships between all biotic and abiotic elements of an ecosystem. These elements combine to form an ecosystem which in turn delivers ecosystem services.

Goods (lower middle block in Figure 6) are perceived as the outputs of ecosystem services from which well-being is received by people (UK-NEA, 2011c). Goods are those benefits which directly create well-being in people and threaten the sense of well-being when absent. Defined as 'the objects people value' (UK-NEA, 2011c, p. 8), goods can be directly used, such as drinking water or enjoying recreation, or they may be valued for their presence, for example large habitats in remote places being managed for conservation and preservation (UK-NEA, 2011c).

As the functions of ecosystems produce services and goods, these goods translate into human well-being (lower left block, Figure 6). This human well-being is divided into economic value, the health value generated from the goods, and shared social value (UK-NEA, 2011c). As previously noted, ecosystem service science and literature has dwelt much on economic values for goods and services (Costanza et al., 1997; MA, 2005b; Natural England, 2009c; TEEB, 2010b), the UK-NEA contextualisation has assigned an equal weighting to shared, social values and health benefits (UK-NEA, 2011c).

The upper level block of Figure 6 shows the relevance given to drivers of change in the environment in the UK. The growing global human population has resulted in large scale changes in land use, which the UK-NEA acknowledges as one of the most significant causes of environmental changes over the last 50 years (UK-NEA, 2011c).

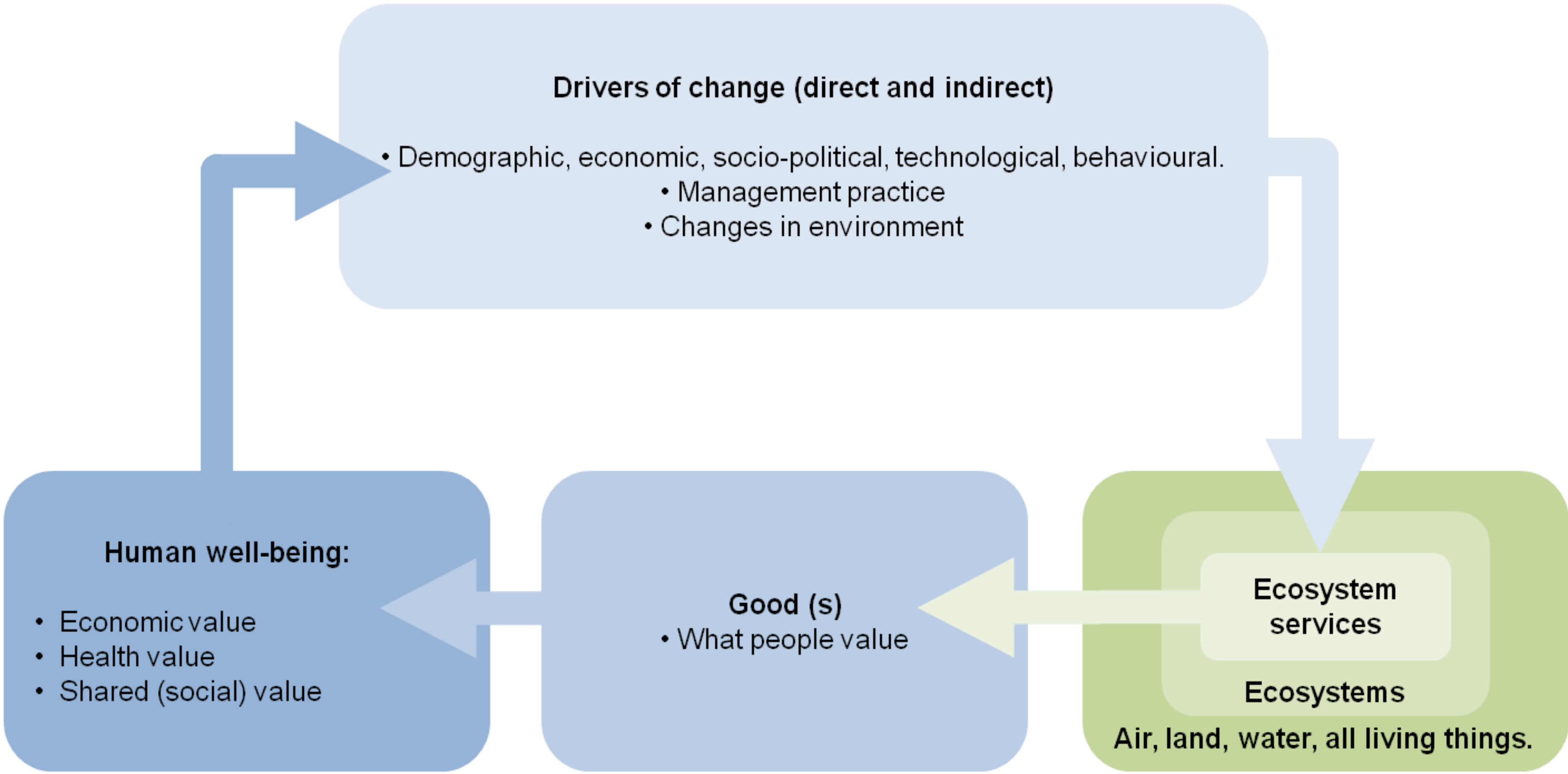

Figure 6: Conceptual image of the UK-NEA, showing the relationship between elements of ecosystems: ecosystem services and how these produce goods, adding to and effecting human well-being, which in turn influences drivers of change through social feedbacks and institutional interventions (adapted from the UK-NEA, 2011a).

2.5.5 Relationship between Ecosystem Processes and Human Well-being

Differentiating ecosystem processes and functions from ecosystem services is an important part of understanding how these flow from the initial abiotic or biotic process to the human beneficiary. Early descriptions of ecosystem services demonstrated areas of ambiguity in the exact classification of the relationship between ecosystem processes (what happens at biotic and abiotic levels). This has been described as an *ad hoc* approach by Boyd and Banzhaf (2007). In order to practically manage and review ecosystem services, ecosystem services as final outcomes need to be clearly defined.

There are discrepancies in the MA conceptual framework: if ecosystem services are defined as the final outcomes humans receive from nature, the MA's framework creates a certain ambiguity by having supporting services feeding into the regulating, provisioning, and cultural services. Further to this, while the MA defines ecosystem services on a broad-based scale, this can result in double counting when managing environments for ecosystem services (Fisher et al., 2009). For example, in the MA nutrient cycling and water regulating are services providing the same benefit- usable water, however, nutrient cycling provides more benefits that simply usable water through the process of cleansing polluted water for example (Fisher et al., 2009). An ecosystem practitioner, in taking these services into account, would define and analyse both of these MA ecosystem services, thereby introducing double counting, rendering the investigation both time consuming and assigning a double benefit when only one exists (Fisher et al., 2009).This double counting was addressed by the UK-NEA.

Ecosystem processes/ intermediate services		Final ecosystem services (examples of goods)	
Supporting	Intermediate services • Nutrient cycling • Water cycling • Primary production • Soil formation Ecosystem processes • Decomposition • Weathering • Climate regulation • Pollination • Disease and pest regulation • Ecological interactions • Evolutionary processes • Wild species diversity	**Provisioning**	• Crops, livestock, fish (food) • Trees, vegetation, peat (fibre, energy, carbon sequestration) • Wild species diversity (bio-prospecting, medicinal plants) • Water supply (domestic and industrial use)
		Regulating	• Climate regulation (equitable climate) • Pollination • Detoxification, purification of soils, air, and water (pollution control) • Noise regulation (noise control) • Disease and pest regulation (pest control)
		Cultural	• Wild species diversity (recreation) • Environmental settings (recreation, tourism, spiritual/religious)

Table 1: The United Kingdom National Ecosystem Assessment view of the relationship between ecosystem processes, intermediate and final ecosystem services, and goods. Note the departure from the 'all in one' approach of the Millennium Ecosystem Assessment shown in Figure 2. Examples of goods are by no means exhaustive as more goods become evident through practical applications. This figure adapted from the (UK-NEA, 2011c)

The UK-NEA differentiates between processes, intermediate services, final ecosystem services, and goods (Table 1). Ecosystem processes and intermediate services are found within the supporting services category; final ecosystem services and goods are found within the provisioning, regulating, and cultural services (UK-NEA, 2011c). In agreement with Chan et al. (2006), ecosystem services are distinguished from ecosystem functions or processes through the explicit reference to a beneficiary involvement by society. Final ecosystem services 'directly deliver welfare gains and/or losses to people' (UK-NEA, 2011c, p. 2); ecosystem goods are 'the objects people value' which are received from ecosystem services (UK-NEA, 2011c, p. 8). Goods encompass use and non-use outputs from ecosystems as well as material and non-material (UK-NEA, 2011c).

This distinction in the UK-NEA provides clarity not evident in the MA. The pathways in Figure 7 display how this flow exists between ecosystem processes and well-being. Ecosystem processes and intermediate services produce final ecosystem services, which are goods people directly receive, these goods are divided into two themes by the UK-NEA; individual well-being values and shared well-being values. Individual well-being values are further divided into economic and health values. Shared well-being values are those which provide a shared social value to society. (UK-NEA, 2011c)

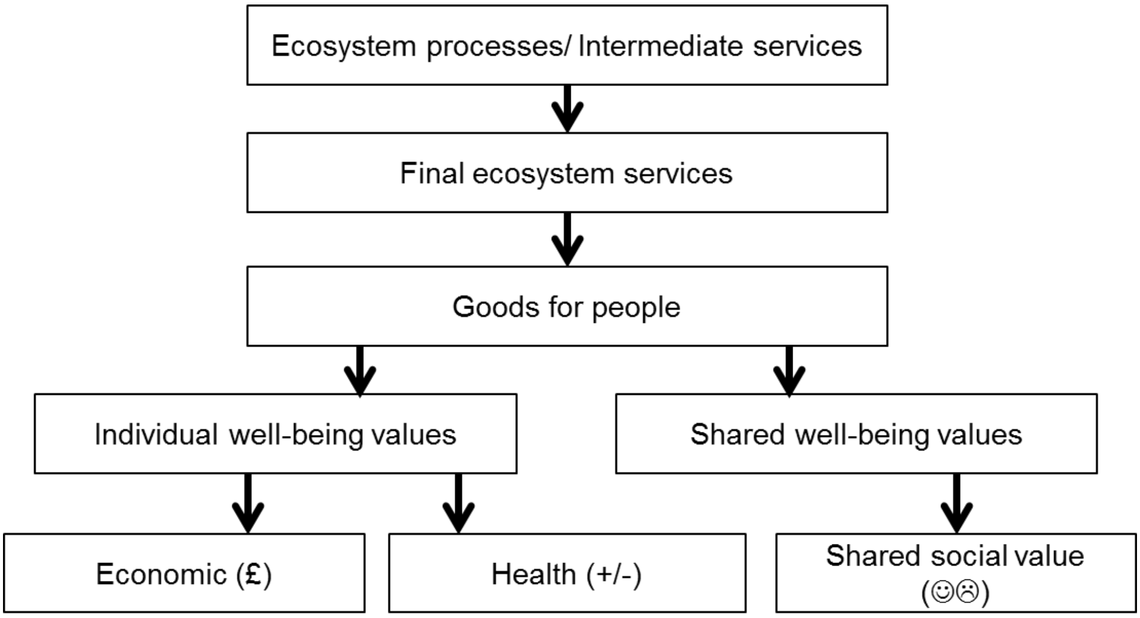

Figure 7: The pathway between abiotic and biotic interactions in ecosystem processes to human recipients of goods.

For the purposes of the current thesis, final ecosystem services and goods are defined as those which are received directly by humans. In agreement with Boyd and Banzhaf (2007), while ecosystem processes and intermediate services have value, these are not directly ecosystem services if one follows the described and accepted definition of ecosystem services being directly received by humans.

2.5.6 Ecosystem Services and Biodiversity

Complex relationships exist between biodiversity and ecosystem services (Costanza et al., 2007; Fisher et al., 2009). Biodiversity is the foundation of both basic sustenance and well-being for humans (Costanza et al., 2007) and it is an accepted axiom that ecosystem goods and services and their properties are dependent on biodiversity (Hooper et al., 2005). Biodiversity, in addition to an intrinsic value, contributes to human well-being through access to water and safety in the face of detrimental environmental change (Díaz et al., 2006). Biodiversity also acts as a measure of resilience for future challenges which may be otherwise unavailable in less diverse ecosystems (UK-NEA, 2011c).

Changes in society, for example population growth, have detrimental effects on biodiversity as pressure mounts on food resources resulting in intensive agriculture and application of fertilisers (MA, 2005b).

Bakkenes et al. (2002) found a strong correlation between biodiversity and the delivery of ecosystem services in a multi-scale analysis of research, where biodiversity decreased in modelling forecasted higher future temperatures. In a review of agri-environment schemes in the UK, Whittingham (2011) found that more ecosystem services are delivered by heterogeneous landscapes with high diversity than homogeneous landscapes with low diversity. The interaction between biodiversity and ecosystem change takes place across temporal and spatial scales (MA, 2005b; Balvanera et al., 2006).

The MA posited biodiversity as the underlying foundation of the ability of ecosystems to provide ecosystem services (MA, 2005b), as illustrated in the conceptual diagram in Figure 5, above. In the UK-NEA, however, biodiversity is seen through three lenses (Table 1) which differentiates the review with that of the MA. These three lenses are: firstly, that biodiversity is a foundation of the many ecosystem processes required for ecosystem services and goods to be delivered to humans (in agreement with the MA); secondly, biodiversity contributes to the fitness of ecosystems which gives these ecosystems insurance against any future negative change; and thirdly, through the recognition that biodiversity is in itself an ecosystem service when present, adding to humans' well-being and appreciation of nature and wild-life in the cultural services (UK-NEA, 2011c). The MA found three primary areas of anthropogenically led changes relating to biodiversity:

1. areas are created in which species within ecosystems either benefit or are at a disadvantage;
2. ecosystem processes and therefore human well-being are impacted; and
3. any changes have greater impact on poor communities than on richer communities (Díaz et al., 2006).

Managing biodiversity and ecosystem functioning is a crucial step towards maintaining ecosystem services under the ecosystem approach adopted by the Convention for Biological Diversity (CBD, 2000).

2.5.7 Cultural Ecosystem Services in Urban Areas

Cultural ecosystem services are those pertaining to peoples' enjoyment and spiritual enrichment derived from nature and the natural environment. As the global population has expanded, a large scale migration to cities and urban areas has taken place (Breuste, 2004). In 1900, 13% of the global population lived in urban areas; in 2009 the global urban population crossed the 50% threshold and by 2030 this is expected to increase to 60% (Eigenbrod et al., 2011; UN, 2011). Recreational enjoyment and urbanisation means urban cultural ecosystem services are being driven to the forefront of planning. In the MA, cultural ecosystem services' strongest relationship is with constituents for well-being of health and good social relations (Figure 5) (MA, 2005b).

Relationships exist between human well-being and spending time in nature. Evidence suggests recreational activities, exercising and spending time in nature, improves physical and psychological health and well-being (Mind, 2007; Tzoulas, et al., 2007; Tzoulas and James, 2010). From day to day activities such as commuting from work or school, people find value in a 'special place' where they can be in nature (Lawton et al., 2010), enjoying the intrinsic value such interactions offer. Grahn and Stigsdotter (2003) reported a highly significant relationship between subjects' increased levels of stress and least time spent in urban centred greenspace. People's perception and use of urban greenspace is linked to the structure, composition, and management of the greenspace (Tzoulas and Greening, 2011). Barton et al. (2009) found that time spent exercising in nature improves states of self-esteem while stress is reduced and well-being increases through experiencing the natural environment (Groenewegen et al., 2006). Recognising this, Natural England, the regulatory body for the environment in the United Kingdom, recommends a 300 m minimum distance from home to naturally accessible greenspace for urban dwellers (Barbosa et al., 2007).

In the UK, urban greenspace plays a significant role in providing health and well-being benefits to urban populations (UK-NEA, 2011b). Urban environments offer the least amount of greenspace of any environment (UK-NEA, 2011b). Well managed greenspace encourages local communities to spend more time in nature whether this be on foot or by bicycle (UK-NEA, 2011b). Research has shown how, when provided with safe environments, children spend more time in nature and are, therefore, less likely to be overweight (UK-NEA, 2011b). A sense of community is improved in areas where a strong sense of natural and effective management exists (UK-NEA, 2011b). In ever expanding urban areas, urban greenspace provides important places for interaction between nature and humans (Barthel et al., 2005).

Greenspace in urban centres contributes to humans' living experience by providing areas for recreation and nature education (Breuste et al., 2008). Distance from residence and the aesthetics of recreational areas was concluded to be a key part of urban residents' decision making process when undertaking outdoor activity and recreation (Neuvonen et al., 2007).

Cultural ecosystem services are 'arguably the least understood, and most controversial areas of the (ecosystem service) framework' (Fish, 2011, p. 674). While the numeration and quantification of marketable ecosystem services such as potable water, carbon sequestration, and food production have been extensively studied (Wilson and Carpenter, 1999; Chmura et al., 2003; Kremen and Ostfeld, 2005), conceptualising cultural ecosystem services into units has evaded ecosystem service practitioners for the most part (Fish, 2011).

A challenge in the current context of ecosystem service cultural category is the prevalence of economic values of services. It is obvious that intrinsic values need a different approach which recognises a non-market approach; forgoing this only leads to the undervaluing of cultural ecosystem services (Chan et al., 2012). More social-science tools are required to bring this about (Chan et al., 2012). Ecosystem services and urban ecosystems should be regarded from both ecological and social science perspectives, given the obvious and inherent influence by humans (McIntyre et al., 2001).

The research in this literature review has revealed how the ecosystems approach encapsulating ecosystem services has evolved in the modern conservation era. Managing urban greenspace to improve ecology and biodiversity increases ecosystem services and benefits the physical and mental well-being of recreational users. The ecosystem approach and ecosystem services require a critical examination as to whether their implementation is effectual and feasible.

2.6 Research Aim and Objectives

The literature review illustrates the lack of practical use of the ecosystem service approach and how this can be combined with environmental management by decision making bodies. Daily et al. (2009) developed a framework connecting decision making and ecosystem services creating a useful conduit between environmental management decisions, ecosystem services, and relaying the results of the decisions to decision makers.

Daily et al. (2009) in their call for a ‘time to deliver’ on practical methods of assimilating ecosystem services within conservation management, developed a basic framework (Figure 8). In this framework, management decisions produce drivers of change in ecosystems which are quantified or modelled against other scenarios to show how, if at all, services are improved or degraded. The links between actions and ecosystems can be measured using both biophysical and social science methods, the former for measuring the ecological benefits that people receive and the latter for measuring those directly relating to cultural benefits people receive (Daily et al., 2009). It is then possible to relate the services to either monetary or intrinsic values (Daily et al., 2009). Institutions, be they regulatory (for example, tiers of government) or social (for example, interest groups), are given information of the change in the ecosystem service, thereby, fostering a greater appreciation of ecosystem services by these institutions. Finally, these regulatory or social institutions are better equipped to make decisions based on societal benefits recognised and established in the previous cycle (Daily et al., 2009). Daily et al. (2009) specifically mention pilot studies and demonstration projects benefitting from this framework. Exploratory case studies provide the ideal platform to provide answers to theoretical frameworks (Blaxter et al., 2010).

Daily et al.'s (2009) model provides a framework to implement the ecosystem service approach within and through environmental management. Daily et al.'s (2009) framework provides a pathway to a shift in management perceptions - from decisions on nature, to valuing ecosystem services. A challenge posed here is to implement and critically evaluate the approach through a practical method, thereby providing recommendations for future applications.

Management of natural and semi-natural environments under the ecosystem service framework is lacking (Daily et al., 2009). Incorporating ecosystem services into decision making has suffered a time lag between the conceptual descriptions of ecosystem services and their implementation in management (Chan et al., 2006; Colding, 2011). Recent years have seen calls for the practical application of the approach (Egoh et al., 2007; Daily et al., 2009; Crown, 2010). The UN sponsored Millennium Assessment recommended that meeting this challenge is best attempted in unmanaged greenspace with potential conservation measures to be implemented on a local scale (MA, 2005e).

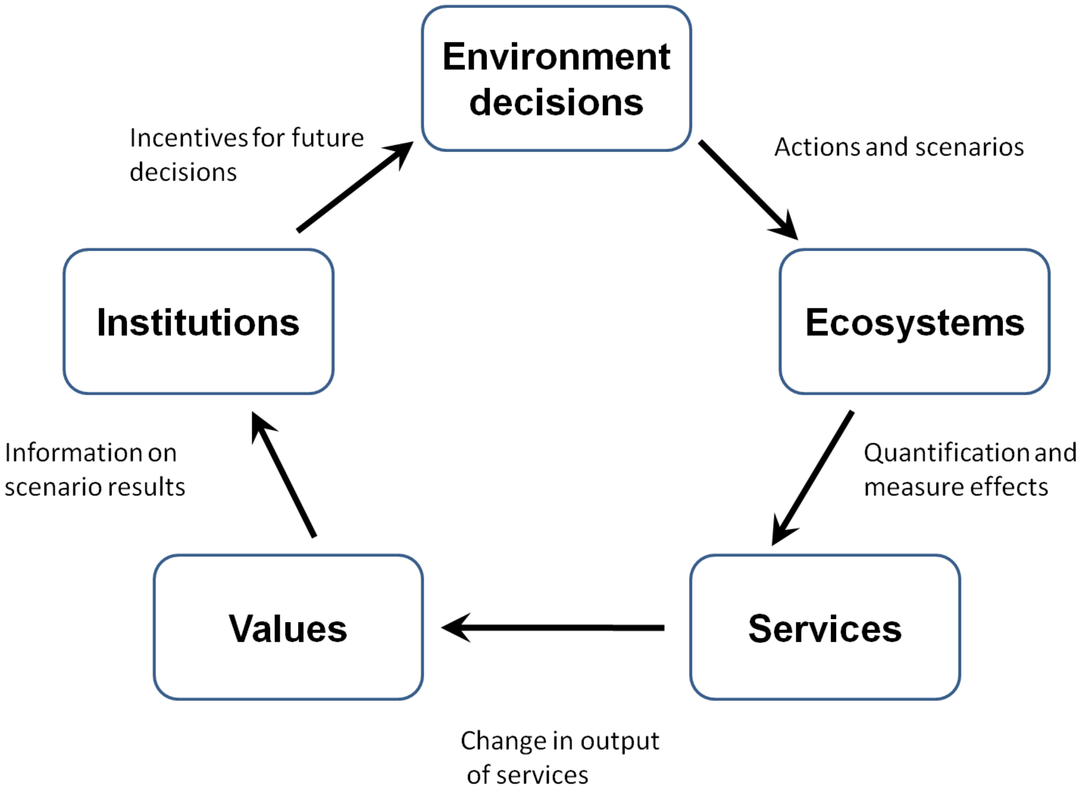

Figure 8: Integrating the ecosystem service framework into environmental management. Adapted from Daily et al., (2009).

An emerging question in response to Daily et al.'s (2009) model is therefore formed. **How can decisions regarding conservation methods be translated into the ecosystem service approach?**

The research reported herein requires a robust, yet adaptive approach appropriately matched to answer the research question, aims, and objectives. Taking into account the iterative nature of Daily et al.'s model for the integration of ecosystem services into environmental management (Daily et al., 2009), the current study follows both an inductive and deductive process. Mixing inductive and deductive methods in research creates opportunities which may be otherwise thwarted were a research stream constrained by a reductionist approach to one or the other (Blaxter et al., 2010).This multi-method research is common in interdisciplinary research and allows triangulation of data following iterative research processes (Blaxter et al., 2010). As the emphasis of environmental management shifts towards managing for ecosystem services, the need for practical application is required. This translates into the aim of the current research:

To evaluate critically the implications of using the ecosystem approach, and specifically ecosystem services, in the management of an urban greenspace.

To achieve this aim, four objectives will be systematically investigated:

1. Using local experts, to establish the optimal management of an unmanaged urban greenspace.
2. Using a rapid assessment, to investigate the effects of such management on relevant salt marsh ecosystem services.
3. Having identified optimal the relevant ecosystem services and the optimal management, to measure the effects of management on the relevant ecosystem services.
4. Provide a set of conclusions and recommendations on the efficacy and amenability of integrating ecosystem services into environmental management.

This aim and accompanying objectives are addressed with reference to Daily et al’s (2009) model and the process used within the model to translate and change the management perspective in values and benefits provided by nature.

3. Methodology

3.1 Introduction to the Chapter

The interdisciplinary nature of the current research defines and drives the methodology and methods upon which successful outcomes rely. The description in this chapter begins with an overview of the methodological approach. The research paradigm (post positivist) adopts a mixed method, using both inductive and deductive research to meet the interdisciplinary aims and objectives of the research. Following this, the justification and reasons for the selection of Widnes Warth, an unmanaged urban centred salt marsh in Halton, North-West England is presented.

3.2 Research Paradigm and Theoretical Approach

The interactions between the ecosystem approach and ecosystem services, social-ecological systems, and natural and social sciences were discussed in the literature review. Neither natural nor social sciences take precedence in these interactions. There is disparity between various authors and approaches. The three research paradigms most commonly recognised in research are, positivism, post-positivism (also known as critical realism), and interpretivism (Grix, 2004). Table 2 summarises the key facets of the three common paradigms and the relevance to the research presented in this thesis.

Table 2: Three main research paradigms (Grix, 2004)

Research paradigm	Features	Relevance to current thesis
Positivism	'Classic' scientific method. Empirical - asks 'why'	Not relevant
Interpretivism	Human and natural sciences are separate entities. Relies on subjectivity.	Not relevant
Post-positivism	Also known as 'critical realism'. Asks both 'how' and 'why' questions.	Interdisciplinary nature of research question and objectives makes this paradigm relevant.

A post-positivist paradigm is employed here as the current research clearly includes facets related to natural and social sciences (through ecological and social themes) and is indeed a tenet of the ecosystem approach and social-ecological systems.

The post-positivist paradigm has, within it, a combination of the two primary strands of research theory: deductive (natural science) and inductive (social research) methods, which have been shown to separately favour quantitative and qualitative approaches respectively (Pathirage et al., 2008). Deductive research is directed by theory: hypotheses are tested and results are achieved by collecting data to either support the theory or not. Inductive research investigates empirical evidence to reach conclusions leading to the development of theory; this involves seeking patterns in the data without pre-lead hypotheses (Grix, 2004). Inductive theory and research begins with specific data and flows towards generalisations (Grix, 2004; Pathirage et al., 2008). The differences between these methods are shown in Table 3.

Pathirage et al. (2008) make a clear distinction between deductive and inductive research (Table 3). Grix (2004) points out, separating inductive and deductive research creates a dichotomy as rarely can research begin without a theory (or idea) of some nature. The question could be asked why researchers would start a research project without at least an initial theory. To ascribe a single theoretical approach would therefore risk marginalising either one of the sciences.

Table 3 Differences between inductive and deductive approaches to research (Pathirage et al., 2008).

Deduction	Induction
Common in natural sciences	Common in social sciences
Flows from theory to data	Moves from data to theory
Highly structured	Variable structure and often iterative
Explains causal relationships between variables	Investigates how humans attach meaning to events/ situations
Sample size must be sufficient to allow generalisations	Less concern with the need to generalise

The study framework described in Figure 1 uses iteration to inform the next research stage. The iterative process in ecosystem service research is a crucial aspect when analysing or building future scenarios (Ranganathan et al., 2008). Integrating the biophysical and social sciences using iteration has been successfully used to describe the effects of ecological and human processes on ecosystem services in Israel (Collins et al., 2010). In discovering outputs and values of ecosystem services, the acknowledgement that iterative processes are necessary and important has been made by the Environment Protection Agency (EPA) of the United States (EPA, 2009). The iterative process has been recommended as a naturally epistemic pathway based on receiving knowledge of processes and implementing this knowledge in future evaluation studies (EPA, 2009). In urban areas within Stockholm, Sweden, the iterative process in managing ecosystem services has been shown to be effective as stakeholder, professional, and academic engagement draws together best practice of urban greenspace (Ernstson et al., 2008). In social science, iteration has been acknowledged as being a pathway to engaging relevant stakeholders that may be otherwise suspicious of scientific claims (Fish, 2011). Iteration has been used to analyse the social costs of differing fishers' methods to further inform wider perspectives of social-ecological scenarios in coastal management (Glaeser et al., 2009).

The current research uses iteratively refined knowledge to satisfy the steps laid out in the integration model proposed by Daily et al. (2009). These iterations match the research objectives to achieve the main aim of the current study. This research proposes using mixed-methods of both deductive and inductive approaches in the research pertaining to the natural and social sciences to answer the aims and objectives.

3.3 Research Area

The selection of the research site to meet the research aim and associated objectives is discussed here. Social-ecological systems have an interconnected characteristic which assigns both humans and natural components an equal load within the system (Liu et al., 2007). Within these social-ecological systems, humans are a key influence on the structure and direction of the ecosystem (Berkes et al., 2003). Urban environments present a strong interface between habitat management and landscapes where these interconnected characteristics have a high impact (Alfsen et al., 2011). To meet the needs of the social aspect, the study area requires an urban component. Further to this, the current study requires an area of currently unmanaged nature to be managed using the ecosystem approach; this would allow the area to be used as a baseline. In addition, it would be an advantage for the landowner responsible for the area to be co-operative and interested in the research, as management decisions are made by them.

Thus, the criteria used to identify the research site were that the site should be:

1. situated within an urban environment
2. a semi-natural landscape
3. the landowner is about to undertake measures, to bring the site into management which would potentially alter ecosystem services of the unmanaged area in order that these may be measured
4. the landowner should be willing to co-operate with the research

The Upper Mersey Estuary lies within the boundaries of Halton and Warrington Borough Councils. Stretching from the Runcorn Gap in Halton (British National Grid SJ 511 835) to Howley Weir in Warrington (SJ 616 876), the estuary comprises 1655 hectares of mud flats, salt marsh, open water, and reed beds (Figure 9). Estuaries are highly dynamic environments and can be subject to large scale effects from urbanisation (Baldwin, 2011). There are significant areas of unmanaged, homogeneous salt marsh found on the northern and southern banks. The proximity of houses and associated infrastructure in Halton and Warrington explains the ‘urban’ classification ascribed to the Upper Mersey Estuary in the UK-NEA (UK-NEA, 2011a). Between the salt marsh and housing areas are a series of brownfield sites that are a result of the demolition of factories associated with the late 20th century and these are predominated by ruderal vegetation. Plans exist to build houses on the brownfield sites. Widnes Warth is a 45 ha truncated upper salt marsh on the north bank of the Upper Mersey Estuary, situated at SJ 525 846 (HBC, 2003), approximately 1 km east of the Jubilee Bridge (Figure 10). Widnes Warth salt marsh is locked within an urban environment. This comprises the areas of West Bank, directly adjacent to and overlooking the salt marsh, Central Widnes and Halton View, both within 500 m of the research area (Figure 10).

The study site is in a semi-natural area about to be brought into management which could potentially alter the ecological state of the area, including ecosystem services. During initial enquiries relating to the current study, officials of Halton Borough Council were receptive to and enthusiastic about the over-arching research aims.

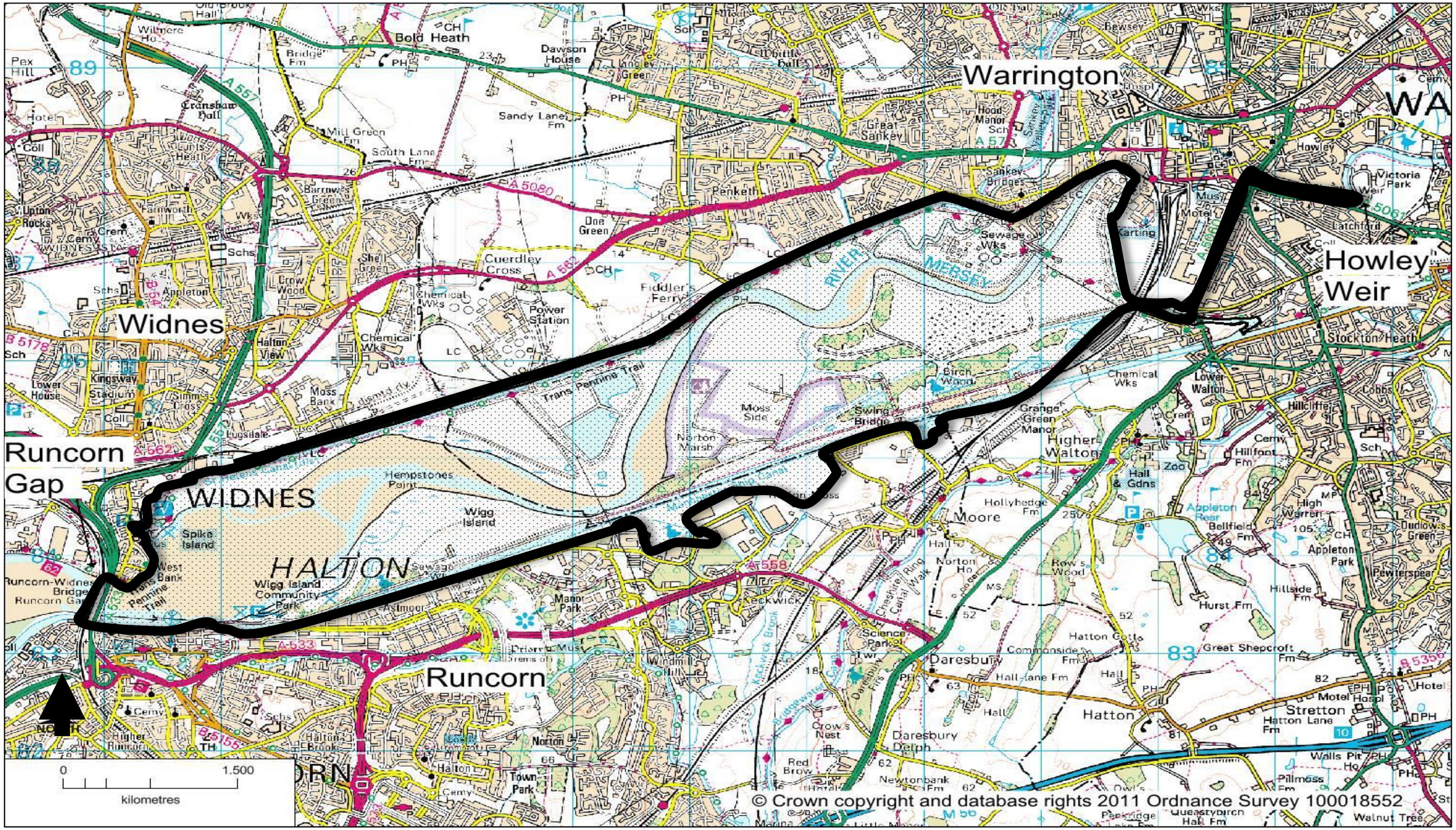

Figure 9: The Upper Mersey Estuary within black line boundary. Showing the location within the urban towns of Warrington, Runcorn, and Widnes.

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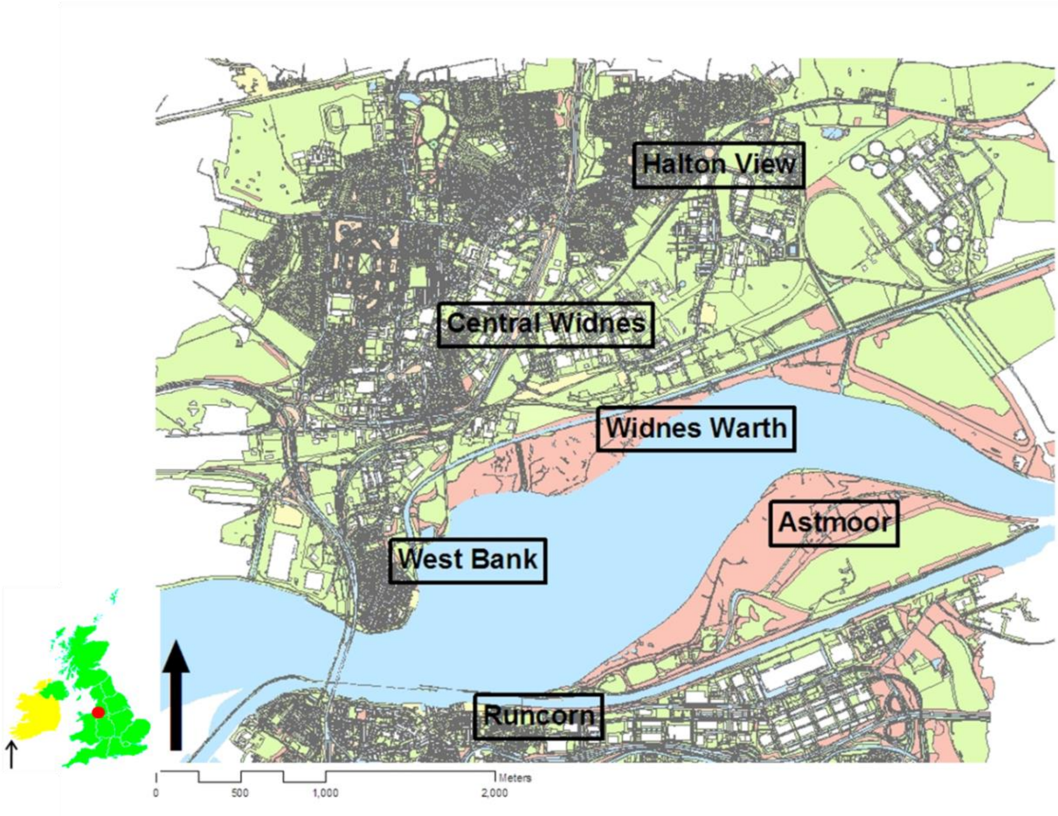

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Figure 10: Research area including Widnes Warth salt marsh. The local urban areas of West Bank, Widnes Central and Halton View are within 1 km of the research area. Inset shows location within the United Kingdom.

3.4 Description of the Research Site

Widnes and Runcorn have an iconic position in the historical development of the chemical industry, with large scale chemical production taking place on both shores of the River Mersey (Fox et al., 1999). Early chemical production included inorganic chemicals: ammonia, chlorine, sodium carbonate, caustic soda, and the smelting of copper (Fox et al., 2001). By the end of the 19th century, Widnes was described as the ‘dirtiest, ugliest town in England where vegetation withered and died, mounds of chemical waste covered the landscape, and noxious seepings polluted the rivers and brooks’ (Fox et al., 1999, p. 314). Local anecdotal evidence abounds with stories of high levels of undetermined contaminants and a highly polluted river and nearby canal. In the Widnes Warth context, previous studies have found various levels of heavy metal contaminants in, or close to, the study area. These levels have been identified as having a non-significant risk to natural habitats downstream. The sediment is in a stable condition; heavy metals are bound with organic matter, and are in insoluble form (HBC, 2008a). Historically, the urbanisation of Widnes and the West Bank received the largest impetus in the 19th century when the Sankey Canal was opened to transport goods to St Helens in the north (HBC, 2008c).

The location has strong social (through visitors) and ecological (estuarine and salt marsh) elements. An art installation, 'The Future Flower' is directly to the east of the salt marsh, with visitors from Halton View and West Bank regularly visiting the feature. For fishermen, the Sankey Canal is managed under the auspices of Warrington Anglers as a popular fishing spot. The Trans-Pennine Trail has recreational value extending from local to national as this trail traverses England between Southport, on the west coast, to Hornsea, on the east coast. The Trans-Pennine Trail is used by local walkers and dog-walkers and people carrying out other associated recreational activities. The salt marsh itself is used by wild fowlers for hunting during the shooting season, under licence from the Duchy of Lancaster, which owns the inter-tidal edge. Adjacent to the salt marsh area is a brownfield site awaiting housing development and a leisure area containing a cinema, bowling alley, and restaurants. The salt marsh is owned by Halton Borough Council having been purchased in 2009 to facilitate the building of the proposed new bridge.

Overwhelming anecdotal evidence from local members of the public, representatives of Halton Borough Council, and members of the Halton Natural Environment Round Table (a local authority supported forum for environmental practitioners and local residents) indicates that previous intensive grazing and any other forms of management of the salt marsh had ceased by 1999. In 2003, the salt marsh was recorded as having large homogeneous areas of vegetation (HBC, 2008b), in line with what is expected of abandoned salt marsh (Doody, 2008).

3.5 Case study methods overview

In the case study various methods were utilised to address the aims and objectives identified from the review of literature (Chapter 2). Firstly, salt marsh management methods were investigated in a literature review followed by a walk –over of the research site to decide on the relevance of each method. This was followed by a local expert forum and a rapid assessment to decide on the final management method. Having decided on the management method, a review of grazing management was conducted. Finally, four ecosystem services to the case study were established. These reflect the interdisciplinary nature of the research (Chapter 4). The four ecosystem services were: wild species diversity, environmental settings, carbon storage, and immobilisation of pollutants. Wild species diversity was investigated as grazing effects on habitat selection by breeding birds using ecological and desk study techniques, differences in vegetation structure between the grazed and ungrazed treatments, and the invertebrate assemblages between the grazed and ungrazed treatments (Chapter 5). Social research of the environmental settings ecosystem service was achieved using ethnographic methods of surveying visitor behaviour and conducting informal interviews, these interviews were then thematically analysed (Chapter 6). Laboratory techniques using loss on ignition of organic matter and desk study were utilised to ascertain mean differences in carbon storage between the grazed and the ungrazed treatments and the economic value of the storage capacity between the two treatments (Chapter 7). The final ecosystem service, immobilisation of pollutants, used laboratory x–ray fluorescence techniques to compare median levels of lead and arsenic in pre-grazing surface sediment samples, with samples extracted after one year, and samples extracted after two years of grazing (Chapter 8). Findings, conclusions, and recommendations are presented in the final chapter of the thesis (Chapter 9). A framework of these is presented in Figure 11.

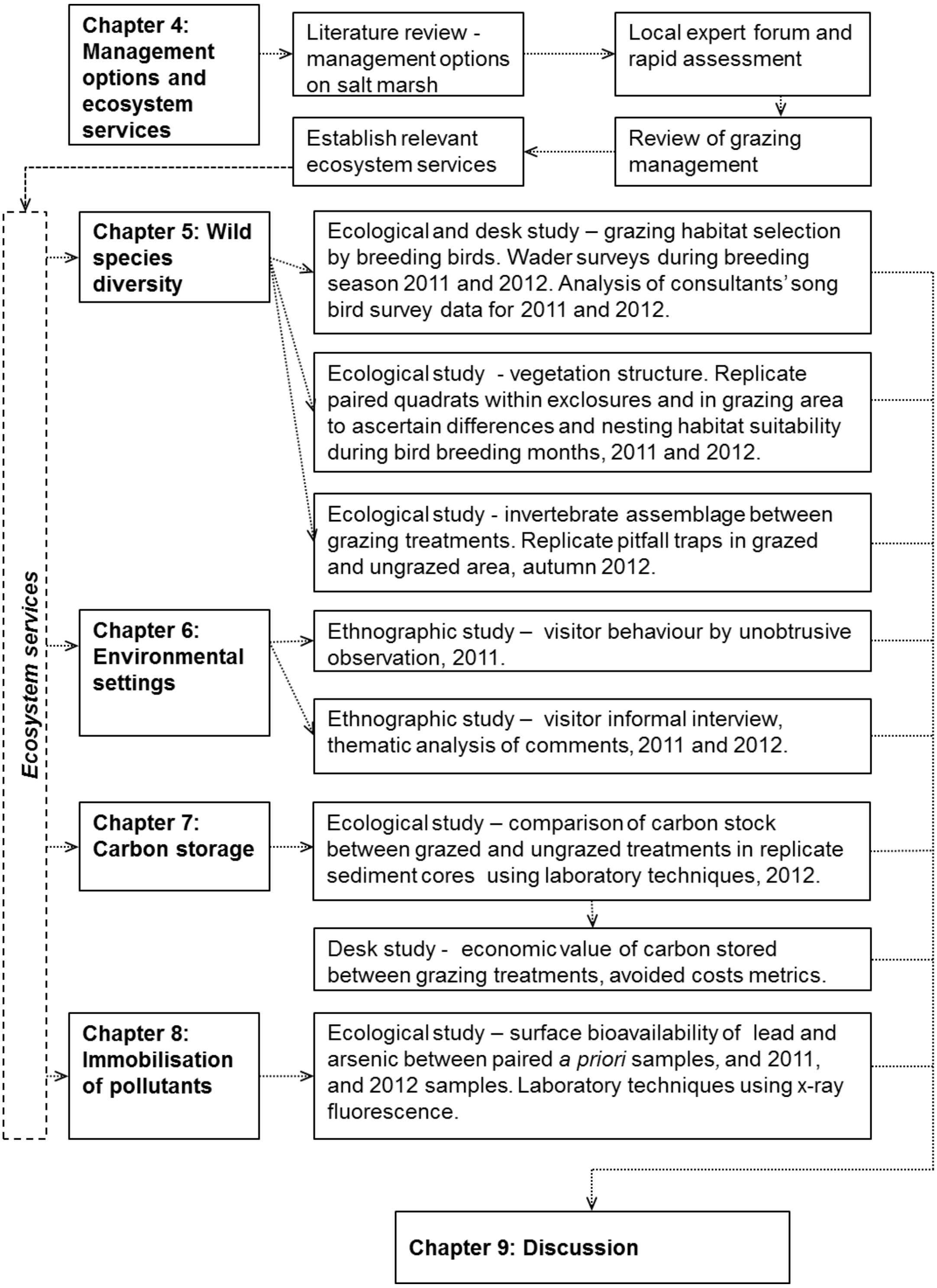

Figure 11: Methods used in the case study.

4. Identifying Optimal Management Decisions and Contextual Ecosystem Services

4.1 Introduction to the Chapter

The research in this chapter addresses the first two components of the Daily et al. (2009) framework (Figure 8). These relate to environmental management decisions and the ecosystems and ecosystem services affected by them. Four steps are used in the current chapter to achieve this:

1. a systematic review of literature in managing salt marsh to identify and critically appraise management options, followed by a walkover of the research area to assess those which are relevant,
2. having identified options which may be relevant, to use the ecosystem service framework to assess which option would be most likely to deliver the greatest benefit in terms of ecosystem services. This was achieved using a local expert forum and a rapid assessment of the literature in terms of ecosystem services, and
3. having identified the best option in terms of management, to provide a review of the literature with recommendations.
4. finally, the ecosystem services to be investigated are presented.

4.2 Salt marsh management options

4.2.1 Method

4.2.1.1 Literature review

In order to determine the best method to manage a salt marsh wherein management enhances the value of the salt marsh at both ecological and anthropocentric levels, a critical review of extant management practices for salt marsh was performed. This review had two functions; to identify techniques used in managing salt marsh and to detail the advantages and disadvantages of each technique.

Literature review resources were obtained from the ISI Web of Knowledge®, Science Direct®, Scopus®, and Google Scholar™ using the search terms in Table 4. Furthermore, the University of Salford's library search engine was used to identify text books relating to salt marsh management options. The literature review was carried out in August 2010.

Table 4: Search terms used in literature review for salt marsh best practice.

salt marsh*	saltmarsh†	ecology	cattle
mow (ing)	graz (e) (ing)	cut (ting)	bird
avifauna	density	manage (ment)	conservation
vegetation	waders	wildfowl	livestock

* 'salt marsh' is used to describe the habitat as a noun, in conjunction with 'reed beds' for example
† 'saltmarsh' is used as an adjective, 'saltmarsh grasses' for example

In search engines, inverted commas '…', and the Boolean connector, AND, was used to further define the search. Inverted commas force the search to restrict results to those words as they appear in their entirety. Using AND as a Boolean connector ensures both terms are displayed in results.

4.2.1.2 Walkover feasibility survey

The walkover survey involved a number of visits during September 2010. During these, the research area was viewed with each of the potential methods as possible options. The walkover surveys were undertaken with a view to implement all the possible options. The general topography, vegetation, and the abandoned state of the salt marsh were included as being important components as to whether the option was feasible or not.

4.2.2 Result

4.2.2.1 Literature review

Historically, salt marsh and anthropogenic manipulation have been inextricably linked since the dawn of agriculture in Mesopotamia, (Gedan et al., 2009). In Europe, the use of salt marsh for cattle and sheep grazing has a centuries long tradition (Jensen, 1985; Adam, 1990; Bouchard et al., 2003) and has been in practice in the Wadden Sea since at least 1350 B.C (Knottnerus, 2005) and possibly even since 3000 BC in Denmark (Jensen, 1985). On the Severn Estuary in the UK, *Phragmites australis* was cut and burned to herd animals during the Mesolithic period (Doody, 2008). *Spartina* was cut to provide hay in Europe probably since the dawn of the last millennium (Esselink et al., 2009). In modern conservation management methods, grazing by domestic stock has become almost the sole method of maintaining and enhancing biodiversity (Bakker et al., 1993; Bakker et al., 2005; Doody, 2008). Other modern methods include: mowing, haymaking, reed cutting, and turf cutting (Adam, 1990; Bakker and Vries, 1992; Adam, 2000; Doody, 2008). These are examined in closer detail below.

Mowing

Mowing is commonly used as a management tool on abandoned salt marsh (Doody, 2008). Mowing increases plant diversity and halts the continued growth of coarse and matted vegetation (Doody, 2008). In a ten year controlled experiment on 40 ha of abandoned salt marsh on Schiermonnikoog Island, The Netherlands, plant diversity increased more rapidly on mown areas than on grazed areas for the first five years; this trend was reversed in the following five years with a higher plant diversity on the grazed area (Bakker, 1985). Over the full ten years, the mown site had an increased mean species diversity from 6.2 species to 8.5; on the grazed site, species diversity increased from 6.5 to 12 species (Bakker et al., 1985). In the same study, when lower marsh seedlings were planted in the mown and grazed sample plots, there was a significantly higher germination success rate in the grazed compared with that in the mown areas (Bakker and Vries, 1992). Mowing is highly labour intensive and on salt marsh with creeks there are obvious problems related to the manipulation of machinery (Doody, 2008). The evidence reviewed indicates that although there is a short term (5 years) benefit for plant diversity on abandoned salt marsh from mowing, in the longer term grazing results in greater species diversity.

Hay making

Commonly practiced in North America (Gedan et al., 2009) and in particular to harvest *Spartina patens* on upper marshes in the north-eastern USA (Bakker et al., 1985; Gedan et al., 2009), haymaking probably originated as a result of the development of iron scythes in north-western Europe around the later part of the first millennium B.C (Doody, 2008). In North America, this practice was primarily carried out in the early 1900s to provide a market for fodder for horses used in logging operations. As a result of the proliferation of fossil fuels, haymaking for this market ceased by the 1930s (Doody, 2008). Haymaking, to maintain the growth of *Festuca rubra* is not so common in Europe anymore and its use has decreased (Bouchard et al., 2003). Hay making produces similar results to the vegetation of heavily grazed marsh; the nature of the effect is due to the maintenance of a dense turf which is intrinsically part of the haymaking process (van Wijnen et al., 1997). Cessation of haymaking on a high marsh led to the increase of cover of *Elymus pungens* (Bouchard et al., 2003). Haymaking in north-west Europe has largely been discontinued (Andresen et al., 1990).

Reed cutting

Phragmites australis propagates in brackish marsh at the limits of tidal inundation and forms dense stands on open marsh and at the upper reaches of estuaries (Doody, 2008). In North American salt marsh, this species has become invasive and recommendations are made for direct cutting and/ or the use of herbicides to restrict further growth where *P.australis* has become the dominant vegetation (Silliman and Bertness, 2004). Historical use of *P.australis* includes burning to herd animals in the Severn Estuary in the UK (Doody, 2008) and the production of baskets, arrow shafts, and musical instruments by native North Americans (Gedan et al., 2009). *P.australis* is primarily used for roof thatching in the U.K and when cut at an early stage, young roots provide suitable grazing material for domestic stock (Doody, 2008; Gedan et al., 2009).

On salt marsh where *P.australis* has become the dominant vegetation through invasion, cutting provides measures which will improve the diversity and ability of other halophyte vegetation to succeed (Silliman and Bertness, 2004). Grazing by cattle reduces cover of *P. australis* (Pehrsson, 1988). Esselink et al (2002) report that cutting may be the preferred option in managing *P. australis* where dominance has been reached in brackish marshes of Baltic shore meadows. *P.australis* is of low value to waterbirds nutritionally (Pehrsson, 1988).

Turf cutting

Found on heavily grazed marsh, this practice provides turf for bowling greens, cricket pitches and lawns (Doody, 2008). Morecambe Bay salt marshes have a fairly well defined history of turf cutting (Gray, 1972; Adam, 2000) with *Festuca rubra* being the most profitable sward species. Turves are cut between October and November and cut areas are left to regenerate for a minimum of five years (Gray, 1972). Turf cutting is still carried out on Morecambe Bay salt marsh but only under licence from Natural England, the UK's nature regulatory body (Doody, 2008). Studies of the effects of turf cutting have shown a progression in cut areas to primarily *Puccinellia maritima,* a less favoured economically viable turf species (Gray and Scott, 1977). On areas where no cutting or grazing occurs on the Morecambe Bay salt marsh, *Limonium vulgare*, *Limonium humile* and *Halimione portulacoides* are known to proliferate (Natural England, 1990). Turf cuttings are carried out on grazed marsh and it is therefore difficult to view this practice in a separate context to grazing.

Grazing

Grazing by domestic livestock is overwhelmingly the most employed use of anthropological manipulation of salt marsh in modern times (Adam, 2002; Environment Agency, 2005; Doody, 2008; Gedan et al., 2009), effecting both biotic and abiotic features of salt marsh (Bos et al., 2002). Benefits of grazing on salt marsh include the provision of grazing stock with a resource that is less prone to vectoring disease than other traditional pasture (Lambert, 2000) and the flat topography and absence of rocks makes this a promising grazing habitat (Gedan et al., 2009). Chatters' (2004) anthropogenic viewpoint in terms of graziers' optimal management is summarised in the effects and challenges displayed in Table 5.

Table 5: Benefits and challenges presented by grazing cattle on salt marsh (Chatters, 2004).

Benefits	Challenges/ potential difficulties
Milder coastal climates produce early spring; cattle can be grazed earlier in the year than other inland habitats.	Salt marsh creeks of various depths are hazardous if cattle fall into them.
Tidal sediment provides natural fertilisation.	Salt marshes can be harmful to cattle inexperienced in this environment as tides and creeks provide a negative behavioural response. Older, experienced cattle may help in guiding younger stock.
Intestinal worms are generally unable to survive in the saline environment.	Lameness may result in cattle if the salt marsh is wet for long periods.
On common land, there is no rent to pay.	The tide may bring rubbish and other foreign objects which could pose health risk to the cattle.
Salt marsh fed meat commands a higher price, the French market being a good example.	Heavy damage of vegetation can occur if fresh water resources and refuge at high tide are not monitored.

4.2.2.2 Option feasibility process through walkover exercise

The literature review revealed five options available for management of the salt marsh. The walkover exercise to examine the feasibility of the options revealed by the literature review (Section 4.2.2.1) is summarised in Table 6.

Table 6: Results of options feasibility walk over exercise performed in September 2010.

Option	Notes to feasibility	Is the option viable?
Mowing	Large areas of homogeneous grass and vegetation over relatively flat areas.	Yes
Hay making	No *Spartina spp* present on salt marsh. Result of hay making leads to low diversity, mimicking a heavily grazed salt marsh.	No
Reed cutting	Two small areas (100 m^2) of *Phragmites australis* are present.	No
Turf cutting	Requires high density grazing to be in place. The research site is not subject to management interventions.	No
Grazing	Large open area of dense vegetation. Salt pans and shallow creeks containing water.	Yes

The management options available to the current research were reduced to two methods: grazing or mowing. These were subjected to a local experts' forum and a rapid assessment using ecosystem services as the reference point for the decision making process.

4.3 Local expert forum and rapid assessment

4.3.1 Local expert opinion method

In order to establish the best option between grazing and mowing for the research site, a group of local experts was invited to attend a workshop. The aim of the workshop was to derive the best option using the experts' opinion on local environmental and cultural matters. The workshop was used to ascertain the experts' views on how grazing or mowing would affect a set of relevant salt marsh ecosystem services. The ecosystem services used in the workshop were derived from the Millennium Ecosystem Assessment (MA, 2005b) these were used because the UK-NEA was not in existence at the time as it was published in 2011.

Delegates were invited for their expert knowledge of either ecological or social elements relating to salt marsh and their work, or knowledge of local ecology and, or social issues. Potential delegates were selected in conjunction with an official of Halton Borough Council with over 15 years' experience of working in environmental matters in the Borough. Eligible experts were selected by matching them to one or all, of three criteria:

1. A professional working knowledge of the Halton area, especially of the surrounding local communities;

2. An acknowledged level of expertise in conservation management in the Upper Mersey Estuary; and/or

3. A high level of knowledge of the ecology in the Upper Mersey Estuary.

The experts are listed in Table 7 with area of expertise and which of the three criteria they fit to be eligible. Of the 17 local experts invited 14 attended and three sent their apologies.

Table 7: Local experts' forum attendees, listing relevant area of expertise, and how the attendees met the eligibility criteria.

Delegate	Area of expertise	Matches eligibility criteria
1	Natural environment and people's interaction with nature.	1,2,3
2	Connecting people with nature.	1,2,3
3	Connecting people with nature.	1
4	Long established local ecological knowledge.	2,3
5	Long established local ecological knowledge.	2
6	Local ecology and peoples' interaction with nature.	2
7	Avifauna, managing for wildlife in local area.	1,2,3
8	People's appreciation for urban ecology.	1
9	Long established local knowledge.	2,3
10	Biodiversity Officer	1,2,3
11	People's appreciation for urban ecology.	1
12	The Upper Mersey Estuary.	2,3
13	PhD Student investigating urban ecological processes in Halton.	1,2
14	The Upper Mersey Estuary and riparian habitats.	2,3

The forum was held on 8 March 2011 at Wigg Island Visitor Centre in Runcorn, Halton. A ten minute presentation using Microsoft ® Powerpoint ® 2010 was delivered to the attendees. The presentation focussed on the definition of ecosystem services and their impact in humans' lives. Following this, the salt marsh management options of grazing and mowing were shown with a brief description of these; care was taken not to sway the experts' opinions with any data reflecting the impacts of either method on salt marsh ecosystem services.

The local experts were asked to work in groups, each group with a separate set of ecosystem services. These groups discussed how each of the management options (grazing or mowing) would impact on the set of ecosystem services. The consensus of the group drove their decision as to what the impact of the management option was on the ecosystem services. Using a table of ecosystem services, the groups used a set of arrows to indicate what the consensus had agreed upon. The groups were asked to use the arrows so that the direction of the arrow indicated the direction of the impact of the management option on the ecosystem service. For the arrows, 🡅 showed a marked increase in the delivery of the ecosystem service; 🡕 indicated a medium increase; no change ➔; medium decrease🡖; and a marked decrease was indicated by 🡇.

The results of these were collected and tabulated.

4.3.2 Rapid assessment method

In a similar vein as the local experts' workshop, the rapid assessment used a system of arrows. The aim of the rapid assessment was to indicate how ecosystem services are affected by management options of grazing or mowing, derived from literature. Grazing and mowing as restoration techniques were subjected to a rapid assessment using literature to establish the effects of each method against relevant ecosystem services. The ecosystem services used in the workshop were derived from the Millennium Ecosystem Assessment (MA, 2005b). This was adapted from a previous exercise by the author, presented at the Vegetation Management Conference, Sheffield Hallam University, United Kingdom in April 2011 (Smith et al., 2011) .

In order to rapidly assess the effects of grazing or mowing on these ecosystem services, a literature search was performed with the addition of the Boolean connector ‘AND’ with the term ‘ecosystem service*’ in order to link the terms of ‘grazing’, ‘mowing’, and ‘salt marsh’. The review was carried out in the month of January 2011.

The results of the rapid assessment were displayed using a system of arrows to indicate whether each method had a marked increase 🡅; a medium increase 🡥; no change ➔; medium decrease🡦; or a marked decrease 🡇 in the delivery of ecosystem services associated with salt marsh (Smith et al., 2011). Having been completed prior to the publication of the UK-NEA, the rapid assessment was developed around relevant ecosystem services established by the (MA, 2005b).

Connecting salt marsh management and ecosystem services using literature is a novel approach and therefore results were inferred where necessary. The selection of which arrow was representative of the process was taken in two stages: first the effect in relation to the *status quo* was shown by whether there was an increase or decrease, and second – how either grazing or mowing compared to each other.

4.3.3 Local expert forum

The results of the local expert’s workshop revealed there were three upward direction arrows in the grazing option compared with none in the mowing; for mild increase there were four in the grazing option and three in the mowing option, for the no change option, four were found in each of the options, for the mild decrease in ecosystem services in the grazing option, none were found whereas two were established in the mowing option. The collated results are displayed in tabular form in Table 8. A summary of these results is shown in grazing and mowing options displayed in Table 9. The local experts’ forum using ecosystem services revealed grazing to be the preferred option.

Table 8: Results of the Local experts' opinion workshop.

Category and example of Service	Grazing	Mowing
Supporting		
Primary Production (PP)	↗	↗
Provision of habitat for wildlife.	↑	↗
Nutrient cycling	↗	↘
Provisioning		
Food production	↑	→
Regulating		
Flood regulation	→	↘
Water purification	→	→
Carbon sequestration	→	→
Cultural		
Aesthetic	↑	↗
Educational/ research	↗	→
Recreation	↗	→

Table 9: Number of arrows for Local Experts Forum.

	↑	↗	→	↘	↓
Grazing	3	4	4	0	0
Mowing	0	3	6	2	0

4.3.4 Rapid assessment results

On a categorical scale, there were six upward direction arrows in the grazing option compared with one in the mowing, for mild increase there was one in the grazing option and four in the mowing option, for the no change option, four were found in the grazing option and five in the mowing option, for the mild decrease in ecosystem services in the grazing option, none were found whereas one was established in the mowing option Table 10. A summary of these results is displayed in the grazing and mowing options in Table 11. The rapid assessment using ecosystem services revealed grazing to be the preferred option.

Table 10: A rapid assessment showing effects of either conservation grazing or mowing on selected salt marsh ecosystem services.

Category and example of Service	Grazing	Mowing	Notes	Reference
Supporting				
Primary Production (PP)	↑	↗	Higher PP in continuous grazing. Mowing would be bi-annual therefore less ‘continuity’.	(Hik and Jefferies, 1990)
Provision of habitat for wildlife.	↑	↗	Restoring abandoned salt marsh using conservation measures provides extra habitat.	(Doody, 2008)
Nutrient cycling	↗	↗	Removal of litter and increase in bacteria drives denitrification.	(Nedwell, 2000)
Provisioning				
Food production	↑	→	Beef cattle grazed on salt marsh.	(Everard, 2009)
Regulating				
Flood regulation	→	→	Effect very minimal if at all, occurs over larger spatial scale on salt marsh ecosystem.	(Everard, 2009)
Water purification	→	→	Re-alignment case study found this to be unaffected. Again, much larger scale.	(Defra, 2007)
Carbon sequestration	→	→	High storage of carbon in plants. Complex	(Defra, 2007); (Bakker et al., 1985)
Cultural				
Aesthetic	↑	↘	While choice experiments of salt marsh restoration and managed realignment have been carried out (T Luisetti et al., 2008), little is known of these options for cultural services and indications here are estimates.	(Doody, 2008)
Educational/ research	↑	↑		(Doody, 2008)
Recreation	↑	↗		(Doody, 2008)

Table 11: Number of arrows per management option for the rapid assessment.

Option	↑	↗	→	↘	↓
Grazing	6	1	4	0	0
Mowing	1	4	5	1	0

4.4 Aspects of Grazing Management

Having identified grazing as a management tool, a review of the options was carried out for grazing salt marsh. The aim of this review is to identify the details of the grazing management regime.

4.4.1 Method

The review was carried out using the methods described above in Section 4.2.1 and Section 4.3.2. The results of the literature searches carried out in the salt marsh management options and rapid assessment were used to provide a critical review of the management options of grazing.

4.4.2 Results

As a biodiversity management tool, grazers affect spatial heterogeneity of vegetation with concomitant changes in invertebrate, avian and mammalian communities (Adler et al., 2001). Grazing reduces the build-up of litter, further encouraging less dominant plants to be able to grow and an increase in plant species diversity (Bakker et al., 1985; Adam, 1990). Grazing favours early successional short plants (Bos et al., 2002) and inhibits the domination and extensive spread of highly competitive species (Adler et al., 2001; Bouchard et al., 2003). When setting aims for grazing effects, type of grazer and density is crucial (Loucougaray et al., 2004).

Domestic grazers are most commonly cattle, sheep, or horses (Levin et al., 2002; Bakker et al., 2003; Loucougaray et al., 2004; Doody, 2008). In addition to grazer type, grazing intensity affects vegetation structure and composition, and reduces both above and below ground biomass, net primary production, and plant height (Adam, 2000; Levin et al., 2002; Loucougaray et al., 2004).

The impact of grazing on salt marsh is recognised in that vegetation typology in this habitat is based on the relationship between grazing, the composition of species, and the structure of vegetation (Doody, 2008). Bakker et al., (2005) suggest vegetation states relating to the resulting vegetation as a result of grazing in three simple classes: no grazing, intensive grazing, and moderate grazing. A recent categorisation by Doody (2008) follows from the Bakker et al., (2005) system and a synthesis follows here.

Vegetation State 1: Heavily grazed.

The history of a salt marsh is characterised by high stocking rates, general short sward, standing crop is absent with sensitive species removed, and succession by plants reduced (Bos et al., 2002; Doody, 2008). Tillering grass pervades, most notably *Puccinelia maritima* (Bouchard et al., 2003; Doody, 2008). On an intensively grazed high salt marsh of 1.3 livestock units ha^{-1} (livestock unit = 500 kg) on Hallig Langeness, Germany, a *Festuca rubra* sward maintained uniformity and stability over seven years (Kleyer et al., 2003). Where topographical gradients exist, grazers spatially aggregate towards higher levels although grazing pressure will increase towards lower elevations when the foraging quality decreases under higher stocking rates (Esselink et al., 2002). In brackish marshes of *Phragmites australis* high density grazing is recommended to maintain halophytic vegetation communities and prevent *P. australis* dominance (Esselink et al., 2002). Densities of cattle range from 2 to 2.5 young cattle or 9-10 sheep ha^{-1} for the summer period or 6.5 sheep year round (Andresen et al., 1990; Esselink et al., 2002; Environment Agency, 2005; Doody, 2008). Trampling of nests of breeding birds occurs (Adam, 1990). This would not satisfy the criteria of the current project except on the initial introduction where increased densities are recommended when restoring previously grazed marsh (Doody, 2008).

Vegetation State 2: Moderately Grazed

The sward is patchy with a high structural diversity of other plants and coarse grasses such as *Elymus* spp. are less dominant than State 4 marshes (see below) (van Wijnen et al., 1997; Doody, 2008) as is the level of leaf litter (Bakker et al., 1985). In north-west European salt marsh, plants showing susceptibility to grazing, e.g. Sea Lavender (*Limonium* spp.) and Sea Purslane (*Atriplex portulacoides*), are present in stands throughout the mosaic (Doody, 2008). Height of vegetation ranges throughout (Bakker et al., 1985; Doody, 2008) with dominance of competitively superior plant species in abandoned salt marsh broken (Kleyer et al., 2003). Densities over a summer grazing period range between 1.0 to 1.5 young cattle or 5-6 sheep ha^{-1} (Doody, 2008). This grazing regime offers a high value for breeding redshank (Norris et al., 1998) and waterfowl habitats in general with a higher diversity of invertebrates (Bouchard et al., 2003). Plant species richness and diversity is highest in this state for sheep grazing (Bouchard et al., 2003). In the longer term, moderate levels of grazing intensity will provide a habitat which offers the most prospects for a salt marsh with a high species diversity and the associated benefits thereof (Doody, 2008).

Vegetation State 3: Historically Ungrazed/ Lightly Grazed

This habitat is most commonly found on the south and east coasts of England and parts of the Mediterranean (Doody, 2008) and is rare in the Wadden Sea area (Jensen, 1985; Heinz et al., 1999). Vegetation is structurally diverse which means a very high level of biodiversity, with terrestrial invertebrate diversity being the highest (Adam, 1990, Doody, 2008). Grazing sensitive species (*Limonium vulgare*) are found here (Doody, 2008). Domestic grazer levels average 0.3 cattle or 2.0 sheep ha^{-1} (Doody, 2008). Levels of 0.5 cattle ha^{-1} on a year round basis are suggested for ideal conservation management by (Andresen et al., 1990). Salt marsh with no history of grazing holds the highest priority for nature conservation given the rarity of these sites and the unique flora and fauna (van Wijnen et al., 1997).

There are various similarities produced between the lower levels of State 2 and upper levels of State 3 grazing densities (Doody, 2008) given the site specific historical trends for salt marsh sites. Referring to the intermediate disturbance hypothesis and disturbance effects on diversity (Connell, 1978), these two states would support results showing a level of disturbance which negatively effects the dominance capabilities of single species which are able to rapidly regenerate photosynthetic tissue (Kleyer et al., 2003) thereby allowing those with dispersal and growth limitations, such as *Puccinellia* spp. or *Agrostis stolonifera* to proliferate in the presence of grazing (Bos et al., 2002; Bouchard et al., 2003).

Vegetation State 4: Previously Grazed/ Abandoned

This was the extant state of Widnes Warth prior to the introduction of the cattle. Loss in species diversity and richness, and number of biotypes declines and formation of dense areas of vegetation occur on salt marshes where grazing has ceased, high accumulation of leaf litter, and dominance by a single species is well recorded in literature (Adam, 1990; Andresen et al., 1990; Lambert, 2000; Bos et al., 2002; Kleyer et al., 2003; Doody, 2008). Dominance by coarse vegetation and high standing crops, for example *Elymus* spp. and *Atriplex* spp., and an increase in dead organic litter occurs, further leading to various functional losses and the outcompeting of other species through light (Bakker et al., 1985; Andresen et al., 1990; Esselink et al., 2002). In a long term study on Schiermonnikoog, Netherlands, van Wijnen et al. (1997) found *Elymus athericus* became dominant on these sites and that plant diversity decreased. This increase in *E. athericus* was also positively correlated with the age of the marsh in that this grass took longer to become dominant on younger marsh due to the thickness of the clay and its associated nutrient availability (van Wijnen et al., 1997). In a trend analysis, following cessation of grazing on Hallig Langeness, Germany it was shown that *Elymus* dominance occurs at the expense of *Festuca rubra* and *Aster tripolium* over a period of 10 – 15 years (Kleyer et al., 2003). On brackish marsh within the Wadden Sea area, abandonment led to the complete loss of halophytes and dominance by *Phragmites australis* (van Wijnen et al., 1997); similar results have been found in the Baltic Sea. Doody (2008) and Esselink et al. (2002) recorded dominance of *P. australis* on previously grazed marsh on the Dollard Estuary in The Netherlands. Using enclosures, Bouchard et al. (2003) showed how grazing cessation led to a loss in cover of *Puccinellia maritima* as this species was outcompeted by *Elymus pungens* and *Atriplex portucaloides*. In addition to the dominant growth of *Elymus* spp. on this state, there is a concomitant loss of community diversity on halobiontic invertebrates, herbivorous waterfowl, migrating and breeding avifauna, and small mammals (Andresen et al., 1990; van Wijnen et al., 1997; Bouchard et al., 2003; Kleyer et al., 2003; Doody, 2008). Studies on abandonment of salt marsh show this *Elymus* effect occurs after ten years with this period becoming a benchmark from which to confidently ascertain the effect of this grazing practice on vegetation (Doody, 2008). Cessation of grazing is the least favourable option when management for conservation is the objective (Environment Agency, 2005).

Vegetation State 5: Overgrazed

In this state the surface vegetation is destroyed and the higher salinity and increased anoxic condition of the sediment prevents ecological re-establishment (Bertness and Silliman, 2008; Doody, 2008). This occurs following ‘eat outs’ by native geese mostly in Arctic regions and is not geographically widespread (Doody, 2008). In the Arctic study, Lesser Snow Geese (*Chen caerulescens caerulescens*) extended staging periods on the Arctic/ sub-Arctic ecotone during migration; as a result the vegetation was completely decimated by the geese grubbing for roots and rhizomes (Jefferies et al., 2004).

Grazing for structural and vegetation diversity

Differences in effects of grazing, at a micro scale level, between cattle and sheep grazing have been provided by (Bos et al., 2002), Jensen (1985) and Doody (2008): sheep are more selective in herbage choice and select between leaves, grazing lower down the plant, leaving less damage than cattle on plant root systems. Cattle use a tearing motion, creating more disturbance to the vegetation on the whole and in some plants will uproot the entire plant, especially in softer sediment (Jensen, 1985; Doody, 2008). There seems to be slight disagreement between the authors listed above - Doody (2008) postulates sheep grazing will result in a uniform sward due to their close grazing to the substrate whereas Jensen (1985) states a more heterogeneous layout of patches will be the outcome. However neither authors stipulate grazing density which is clearly an additional factor and needs to be taken into account.

A further consideration is the issue of hoof prints. Hoof area has different ramifications. Hoof prints add a further element of heterogeneity and create micro-habitats for various marsh communities, cattle (Jensen, 1985). Hooves have been measured at 320 cm^2 creating a force of 1.56 kg cm^{-2} as opposed to the smaller and lighter sheep with total hoof area of 80 cm^2 and a force of 0.94 kg cm^{-2} (Jensen, 1985). Such factors need to be closely monitored on salt marsh sediment as treading can produce deleterious effects on vegetation and soil structure around fences, drinking water sources, and other features (Jensen, 1985).

Re-introducing grazing cattle for avian conservation interest

Managing salt marsh to increase conservation value, bird use and enhance biodiversity adds to the value of the salt marsh as an intrinsic habitat (Environment Agency, 2005) and enhances the ecosystem service of recreation through bird watching, biodiversity, and the provision of habitat for wildlife (MA, 2005b, d). It should be recognised that there is a clear chain of causality between grazing by domestic and wild herbivores, vegetation composition and structure, and avian use of salt marsh (Olff et al., 1997; Hart et al., 2002; Smart et al., 2006). Vegetation structure is especially important for the use of salt marsh by birds (Doody, 2008).

The columns in Figure 12 represent a generalised view of stocking densities and how these serve conservation objectives (Doody, 2008). The take home message from this figure is that if increasing ecology or biodiversity are part of the management criteria, then light or moderate grazing are the best options. The evidence provided by this figure is that optimising habitat for one section of an ecosystem allows trade-offs with other aspects. There are crossovers. For example, it is recommended that grazing stock densities should be low (or indeed absent) during the bird breeding season and if overwintering birds are a management objective, then this should be increased towards the end of summer (pers. comm. S. Schrafer and M. Maier, 30 September 2010). Holton and Allcorn (2006) increased grazing density following the breeding season to prevent regrowth leading to an increase in breeding Snipe (*Gallinago gallinago*).

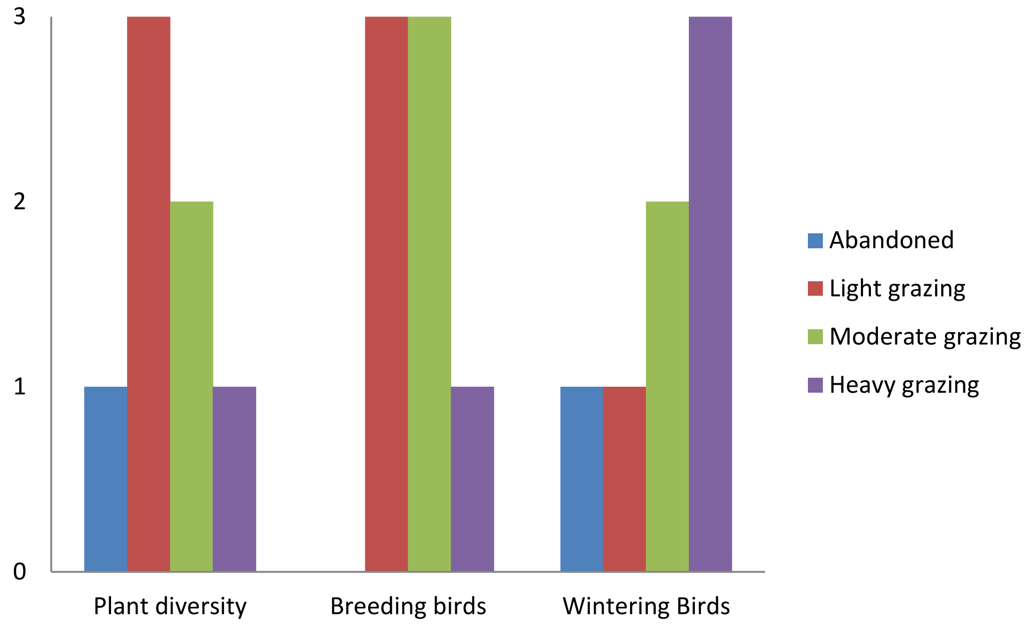

Figure 12: Managing salt marsh for conservation interest using grazing. 0 = little or no conservation interest; 1 = limited conservation interest; 2 = medium and 3 high biodiversity. Adapted from Doody (2008).

The effects of mixed grazing of sheep and cattle on Lapwing breeding success show how ungrazed marsh had a higher nesting success and has led to recommendations to significantly lower grazing intensity or provide nesting refuges during the breeding period (Hart et al., 2002). The diet of Lapwing and Redshank (*Tringa totanus*) indicate that wet areas should be maintained until May and June, later than previously thought (Ausden et al., 2003). The relationship between the use of coastal grazing marsh by breeding waders and marsh hydrology and typography, shows preferential use by adult Redshank and Lapwing chicks in areas where wetness has been maintained in rills (relict drainage ditches) and ditches (Milsom et al., 2002; Ausden et al., 2005). Using a habitat preference index and direct observations, Milsom et al., (2002) found that Redshank highly favoured wet rills and ditch banks for feeding. Thus, increasing water edge length increases breeding success of Redshank and Lapwing. This research also promotes the use and maintenance of wet features on marsh as they provide increased opportunities for foraging Lapwing chicks (Milsom et al., 2002).

Merricks (2010) has recently identified five components of managing sites for breeding Lapwing: first, grazing management should create and maintain a heterogeneous structure to facilitate requirements during the breeding season; second, water management of rills and pans to create feeding habitat for chicks; third, invertebrate diversity is maintained through a mixture of wet and drying areas; fourth, creating wintering birds' habitat with high waterlogging ensures slow spring grass growth; and fifth, controlling predators.

Lapwing have been shown to preferentially select cattle grazed coastal grazing marsh (Smart et al., 2006). However: with breeding Redshank there is a feedback that needs to be taken into account; trampling of nests by cattle can be lessened by either reducing or suspending grazing during the breeding season (Norris, 2000; Smart et al., 2006). Reducing the density during the breeding season at the start of the summer grazing period will minimise trampling by cattle to be followed by an increase of stock density in June in order to maintain pressure on coarse grass which may become unpalatable as the growing season progresses (Lambert, 2000).

These methods lead this author to recommend that in order to best satisfy the criteria of managing the salt marsh for environmental objectives, grazing by domestic stock, with a high first year density of 1.2 cattle ha^{-}1, to be maintained with 0.6 cattle ha^{-1} and 0.8 cattle ha^{-1} in subsequent years (Bakker et al., 2003; Doody, 2008), and the implementation of scrapes, should be the preferred option.

4.5 Ecosystem Services

Salt marsh provides a myriad of ecosystem services and benefits (Gedan et al., 2009; UK-NEA, 2011d) as does urban greenspace (Bolund and Hanhammar, 1999). The selection of ecosystem services to be examined was determined after discussion with an officer of Halton Borough Council and an examination of documents related to the Mersey Gateway Bridge (HBC, 2008a).

In addition, the author wanted to reflect the interdisciplinary nature of the research by including services relating to the sediment, wildlife, and the social element of the research site. This would lend the research to the full extent of the social-ecological aspect of the research site. The four services are:

1. Cultural - Wild species diversity – people enjoy managed greenspace that has heterogeneous natural facets. Derived from the UK-NEA conceptual framework where wild species existence was described as having cultural value (UK-NEA, 2011c).
2. Cultural - Environmental settings – the experiential benefits provided by open greenspace in urban environments. These are described in Chapter 10 of the UK-NEA relating to urban environments (UK-NEA, 2011a).
3. Regulating - Carbon storage - the amount of carbon stored in the sediment, thereby having less harmful carbon dioxide in the atmosphere. This was derived from the climate regulation final ecosystem service described in Chapter 11 of the UK-NEA (2011d).
4. Regulating- Immobilisation of pollutants - the salt marsh acts as a large store for pollutants that would otherwise be in the water column with potential threats to wildlife and the human food chain through fish. This service was described in Chapter 11 of the UK-NEA (2011d) relating to Coastal Margins and the final ecosystem service of waste breakdown and detoxification.

The ecosystem service of food production, through the meat production from the cattle was discounted during the decision making process because there was extant knowledge of high levels of heavy metals and pollutants within the salt marsh that had been historically deposited and a discussion with the Food Standards Agency revealed little was known as to how this affected acceptability onto the food chain as cattle were in contact with the sediment.

The relationship between these four ecosystem services and the management intervention through grazing is examined in the research presented in Chapters 5-8.

4.6 Conclusion to the Chapter

The aim of the research presented in this chapter was to establish management options and use a decision making process to arrive at the most effective options. This is encompassed in the first three parts of the Daily et al. (2009) framework (Figure 8). The first part of the framework, environment decisions, was addressed through the use of a critical literature review to reveal five possible methods to manage salt marsh; three of these (hay making, reed cutting, and turf cutting) were eliminated through a walkover of the research site. Using ecosystem services as a reference point for the effects of the two remaining management options (grazing or mowing), the results of the local expert workshop (Table 8) and the literature review (Table 10) assessing the impact on ecosystem services arrived at the same conclusion, that grazing be the preferred option for the management of the research site.

The next four chapters in this thesis relate to the effects of grazing on the four ecosystem services identified as having high relevance to the case study.

Having identified grazing as the best practice this method was implemented in 2011. Fencing the area to be grazed was completed in January 2011. On 13 April 2011, six English Longhorn cattle were introduced to the 5 ha grazing area to graze the salt marsh for the summer periods of 2011, thereafter being removed to wintering pasture on the 23 August 2011. In 2012, three English Longhorn were introduced to the grazing area on the 11 June 2012 and were moved to winter pasture on 15 October 2012. A photograph of one of the six cows introduced in 2011 is shown in Figure 13.

Figure 13: An English Longhorn cattle on the research site with the Jubilee Bridge, Runcorn in the background.

5. Ecosystem Service 1 - Wild Species Diversity

5.1 Introduction to the Chapter

Wild species diversity was identified as a relevant ecosystem service in Chapter 4.5. The presence of wild species adds to the recreational enjoyment of natural spaces, a cultural benefit, especially for bird watchers for example (Everard, 2009; Tiziana Luisetti et al., 2011).

The research presented in this chapter investigates three factors found to be applicable to the cultural ecosystem service of wild species diversity; each of these three factors has a separate method and results section describing these in a systematic way. The discussion addresses all three of these investigations as the overarching objective (Objective 3) is to address whether the delivery of ecosystem services is increased by conservation management on the open greenspace.

A key question here is what constitutes ‘wild species diversity’ and how could this be measured in the current study. One of the main results of conservation grazing is to create a habitat favouring breeding birds (song birds, waders, and wildfowl) (Doody, 2008); therefore the research in this chapter investigates the impacts of grazing on three inter-connected biophysical elements which reflect wild species diversity in regard to the habitat management aim above. These three are:

1. breeding birds,
2. vegetation structure, and
3. invertebrate community assemblage.

The results of the literature review into salt marsh best practice for grazing management (Section 4.4.2) revealed a strong relationship between grazing and wild species change in wading and wildfowl habitat selection, vegetation composition and structure (Bakker et al., 1985; Andresen et al., 1990; Bos et al., 2002; Bakker et al., 2003; Doody, 2008). The diet of breeding Lapwing and

Redshank consists of a range of invertebrates taken from the soil, the grass sward, and shallow water pools (Ausden et al., 2003).

Previous research at the research site, in its unmanaged state, found 42 species of Coleoptera, this order favours structural and species diversity within salt marsh habitats and as such, grazing was recommended in the previous research to instigate disturbance and further increase the diversity and abundance of Coleoptera (Hacking, 2010).

Grazing introduces spatial heterogeneity in vegetation which has implications for habitat diversity affecting, *inter alia*, birds and invertebrates (Adler et al., 2001). Grazing by cattle affects the structure and assemblage of vegetation, then bird use and plant diversity in turn (Bakker et al., 1985; Pöyry et al., 2006; Smart et al., 2006; Doody, 2008). Clearly, grazing will affect vegetation structure as a primary element. Heterogeneity in vegetation height and structure is a key factor in providing ideal nesting habitat for wading birds and wildfowl (Bakker et al., 1985; Doody, 2008).

5.2 Breeding birds

As part of the investigation, both breeding song birds, and waders and wildfowl were surveyed. Data were collected and collated from two sources, the first from ecologists' data commissioned by Halton Borough Council for the presence of breeding song birds; the second through scan and transect sampling for the presence of waders and wildfowl.

5.2.1 Method

To establish if there was a preference between the grazed and the ungrazed sections of the salt marsh for breeding birds, two sampling techniques were performed. The first used current and relevant reports, the second used direct observation scan sampling, and transect observations carried out through the census method described by Sutherland et al. (2004).

Using reports to collect data of bird presence or habitat use has been recommended as a simple method where such data are available (Gilbertson et al., 1985). The grazed area is 5 ha and the ungrazed, 21.5 ha. Halton Borough Council commissioned a series of bird nesting surveys over the research area during 2011 and 2012. The surveys were performed by experienced consultant ecologists using the Common Bird Census method (R. Smith, 2011, Smith, 2012) involving visits during the breeding season at least once every ten days. The results of these surveys were examined to explore nesting preference between key breeding birds in either the grazed or the ungrazed salt marsh. The density of breeding pairs per hectare was calculated by dividing the number of pairs surveyed by the number of hectares in the survey area, as per equation 1.

$$breeding\ density = \frac{number\ of\ pairs\ surveyed}{number\ of\ hectares}$$ **Equation 1**

Habitat maps were produced to display the prominence of pairs of song birds' habitat selection over the grazed and the ungrazed area. A map showing the grazed and ungrazed areas is displayed in Figure 14. Statistical tests were not performed on the results of the breeding density as providing statistical significance on ratios without replicates (to use ANOVA for example) therefore using Chi-squared is not recommended (Dytham, 2003).

To establish habitat selection by waders and wild fowl, the grazed and ungrazed areas were surveyed for at least two hours per week between April and July of 2011 and 2012. The two hours were divided so that one hour was utilised for scan sampling and one hour for the transect surveys. These months encompassed the time period when birds displaying breeding behaviour or chick rearing would be identified if present. Eglington et al. (2010) surveyed Lapwing between May and July whereas Milsom et al. (2002) and Hart et al. (2002) carried out surveys between April and June. The period for breeding and chick rearing by Lapwing can be extended due to predation on early clutches (Smart and Gill, 2003).

Scan surveying took place from the raised area at the main viewing point shown in Figure 14 and by walking along the pathway on the northern boundary of the salt marsh (the Trans Pennine Trail) between points 1 and 2 on Figure 14. Minox™ BF 10 × 42 binoculars were used. All wading birds and wildfowl showing behaviour relating to breeding and nesting were recorded. These behaviours were:

1. Birds sitting ‘sentinel’ or vigilant on a raised piece of driftwood for example.
2. Two birds in the same area for an extended period without long periods of feeding or loafing (head tucked under wing), indicating their presence was other than feeding or loafing.
3. Wading birds or wildfowl ‘mobbing’ any birds of prey or larger birds as a defence mechanism.

In addition, the grazed and ungrazed area were surveyed by transects shown in Figure 14. The transect routes were selected so that the full area of the salt marsh was covered. The transect surveys were used as an adjunct to the scan surveys but also to elicit defensive behaviour by nesting and breeding waders such that any birds present that were nesting or protecting young would fly and ‘call’ in such a manner as to suggest this. The transect was walked at a slow pace (approximately 400m per 10 minutes) and the assumptions laid out in Bibby et al. (1992) were accepted in that breeding behaviour birds live in pairs, in fixed, separate, and non-overlapping ranges and secondly that all breeding and chick rearing birds would be detected on the transect. The results of these surveys were descriptively examined to explore nesting and or chick rearing preference between waders and wildfowl birds in either the grazed or the ungrazed salt marsh.

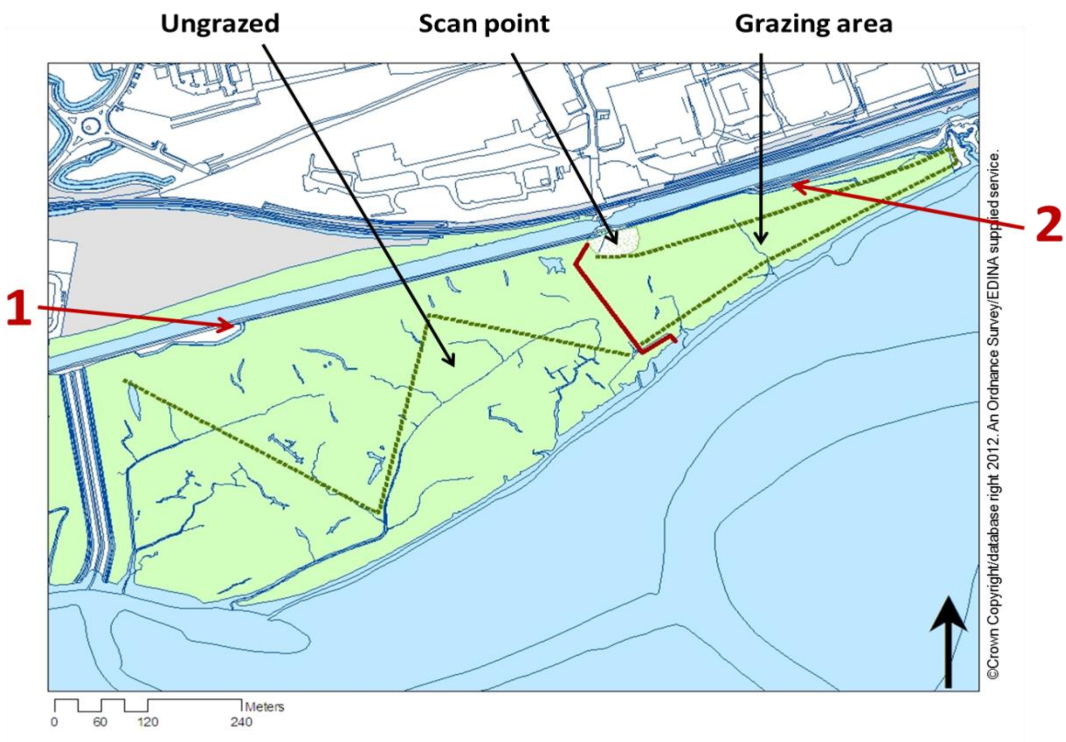

Figure 14: Bird survey transect. The green, hashed line indicates the route of the transect. The surveys took place through scan sampling from the scan point and while walking along the path between points 1 and 2. The red line indicates the boundary between the grazed and the ungrazed area.

5.2.2 Results

5.2.2.1 Breeding song bird results

The results of the 2011 surveys revealed the breeding density for the grazed area was 1.8 pairs ha^{-1} and for the ungrazed area 1.2 pairs ha^{-1}. In the grazed area six pairs of Meadow Pipit and three pairs of Skylark were recorded during the surveys. In the ungrazed area, ten pairs of Meadow Pipit, three pairs of Reed Bunting, and 13 pairs of Skylark were recorded during the surveys (Table 12).

The results of the 2012 surveys revealed the density of pairs of breeding song birds for the grazed area was 0.8 pairs ha^{-1}, for the ungrazed area the breeding density was 1.4 pairs ha^{-1}. In the grazed area two pairs of Meadow Pipit, one pair of Linnet, and one pair of Skylark were recorded. In the ungrazed area nine pairs of Meadow Pipit, two pairs of Reed Bunting, and 20 pairs of Skylark were recorded during the surveys (Table 12). A visualisation of these results is provided in the maps displayed in Figures 15 and16. These results indicate that the breeding density in the ungrazed area increased over the two years, however in the grazed area the breeding density decreased over the two years.

Table 12: Breeding pairs of song birds recorded on grazed and ungrazed areas during 2011 and 2012.

Date	Species	Grazed	Ungrazed
29/03/2011	Meadow Pipit	5	4
	Reed Bunting	0	2
	Skylark	0	3
12/04/2011	Meadow Pipit	0	0
	Reed Bunting	0	0
	Skylark	0	3
02/06/2011	Meadow Pipit	1	6
	Reed Bunting	0	1
	Skylark	1	5
21/06/2011	Meadow Pipit	0	0
	Reed Bunting	0	0
	Skylark	2	2
Total breeding pairs 2011		9	26
21/02/2012	Meadow Pipit	0	0
	Reed Bunting	0	0
	Skylark	0	5
04/03/2012	Meadow Pipit	0	1
	Reed Bunting	0	0
	Skylark	0	0
13/04/2012	Meadow Pipit	2	3
	Reed Bunting	0	2
	Skylark	0	3
30/04/2012	Meadow Pipit	0	1
	Reed Bunting	0	0
	Skylark	0	2
10/05/2012	Meadow Pipit	0	1
	Reed Bunting	0	0
	Skylark	0	0
24/05/2012	Meadow Pipit	0	2
	Reed Bunting	0	0
	Skylark	0	5
13/06/2012	Meadow Pipit	0	1
	Reed Bunting	0	0
	Skylark	0	4
	Linnet	1	0
27/07/2012	Meadow Pipit	0	0
	Reed Bunting	0	0
	Skylark	1	1
Total breeding pairs 2012		4	31

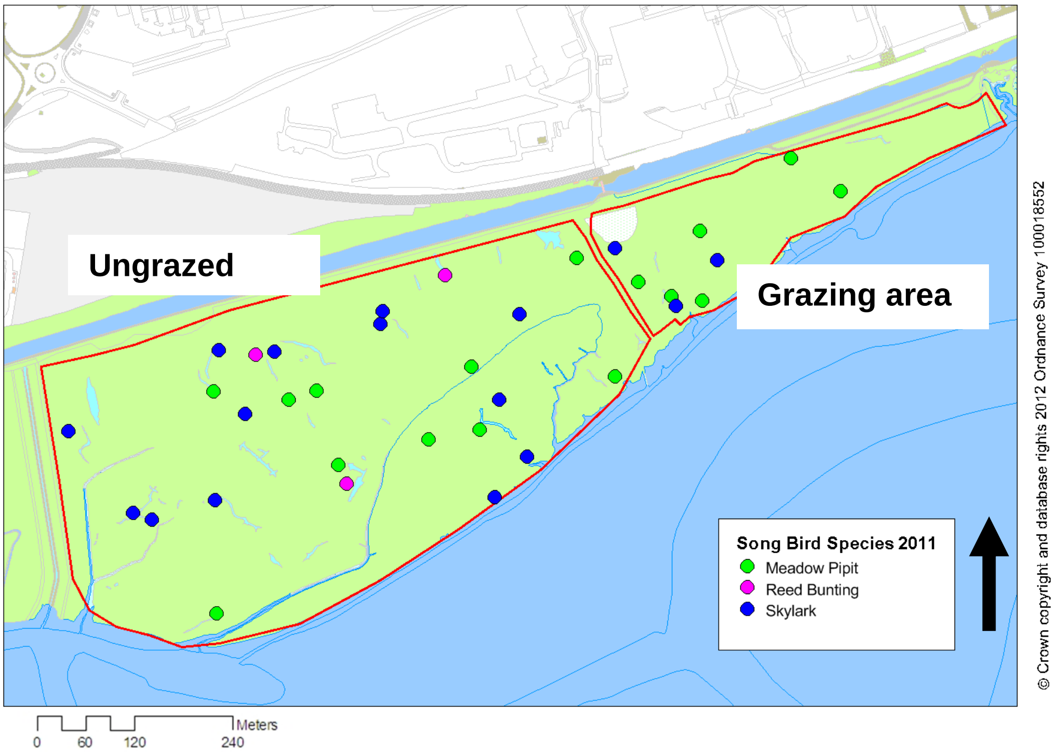

Figure 15: Breeding song birds data 2011.

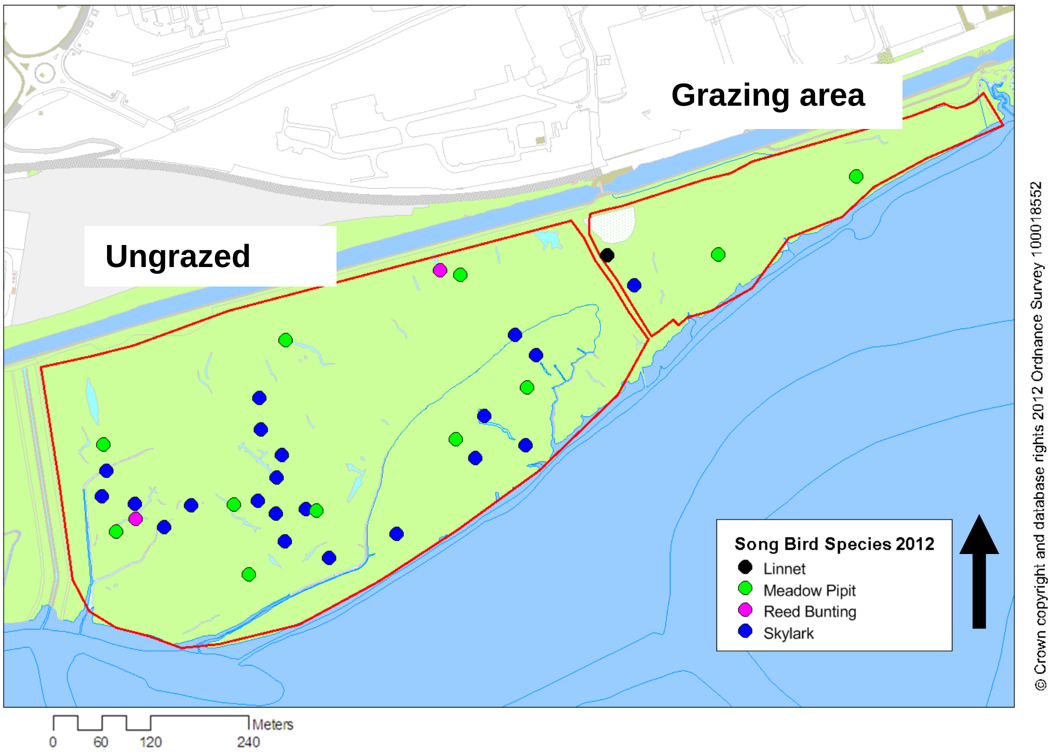

Figure 16: Breeding song birds data 2012.

During the 2011 surveys, there were no records of breeding wading birds or wildfowl. During the 2012 survey period, a pair of Lapwing and a pair of Redshank were observed. Both these pairs were observed in the same area of the grazing area, as shown in the map in Figure 17. The pair of Lapwing was observed weekly in 2012 between 17 June and 21 July and the pair of Redshank was observed between 17 June and 14 July. On 16 July 2012 a set of juvenile Redshank feathers were found near to the area the adult pair was observed. The feathers were identified *in situ* by Dr. Tim Melling, a Conservation Officer for the Royal Society for the Protection of Birds.

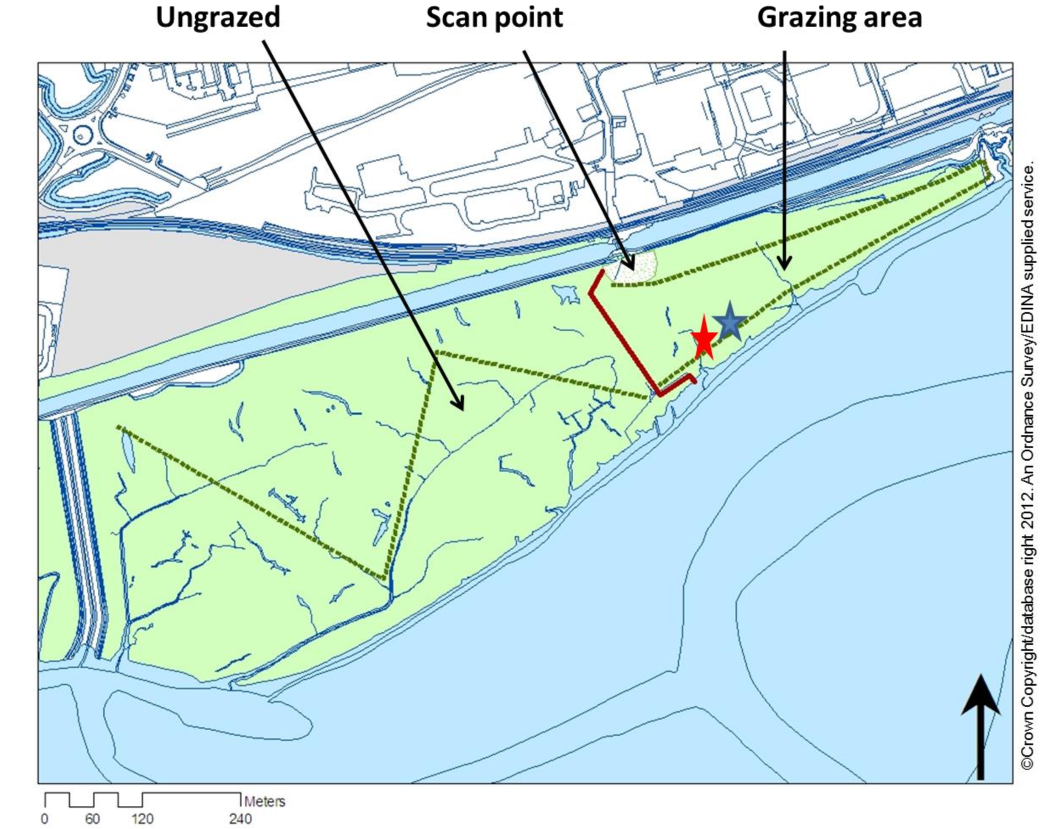

Figure 17: Results of bird surveys. Breeding pairs of waders shown as red star for Lapwing (*Vanellus vanellus*) and blue star for Redshank (*Tringa totanus*). The green line represents the transect route for the surveys.

5.3 Vegetation

5.3.1 Method

Exclosures as a method of sampling vegetation in grazing experiments is well documented on grassland (Pöyry et al., 2006), coastal grassland areas (Loucougaray et al., 2004), and salt marsh (Jensen, 1985; Bazley and Jefferies, 1986; Bos et al., 2002; Esselink et al., 2002; Bouchard et al., 2003).

The total grazing area is 5ha, including six 10 m × 10 m size exclosures. The main justification for the size and number of the exclosures follows discussions held with national and European salt marsh specialists at the Coastal Ecology Workshop held in September 2010 at Conwy, North Wales, United Kingdom. The workshop drew an expert body of salt marsh scientists and practitioners with many years' experience in the management and measuring of vegetation effects of management on salt marsh throughout Europe. Exclosures of 10 m × 10 m are sufficient in size so that edge effects would not impact on the vegetation structure during the experimental period of two years, six exclosures would not have a negative impact on the available grazing area and would provide enough space for paired quadrats to be utilised with two in each exclosure. The experts additionally pointed out the added benefit of a visual aide for visitors to the area to see the obvious effects of grazing as an educational resource (Figure 18).

Ground truthing revealed that *ex situ* placement of the exclosures and quadrats could lead to sample error due to the variant areas covered by *Elymus. x drucei* and unmapped creeks. Therefore the position of the exclosures and quadrats was carried out within the field using a random sampling system (Kent and Coker, 1992). A random number table (generated using the =RAND function in Microsoft ® Office Excel ® 2007) was used to place each exclosure. The exclosures were placed by pacing out numbers from the random number table, starting arbitrarily in the top north-eastern corner of the salt marsh. Stratified selection of positioning of the exclosures was determined by > 95% cover of the dominant vegetation of the salt marsh *E. x drucei* as there were large parts of the salt marsh with high cover of *Agrostis* *stolonifera.* A map of the placement of exclosures and associated paired permanent quadrats is shown in Figure 19.

Figure 18: An exclosure at the sampling site, with a full exclosure shown in the background (August 2011).

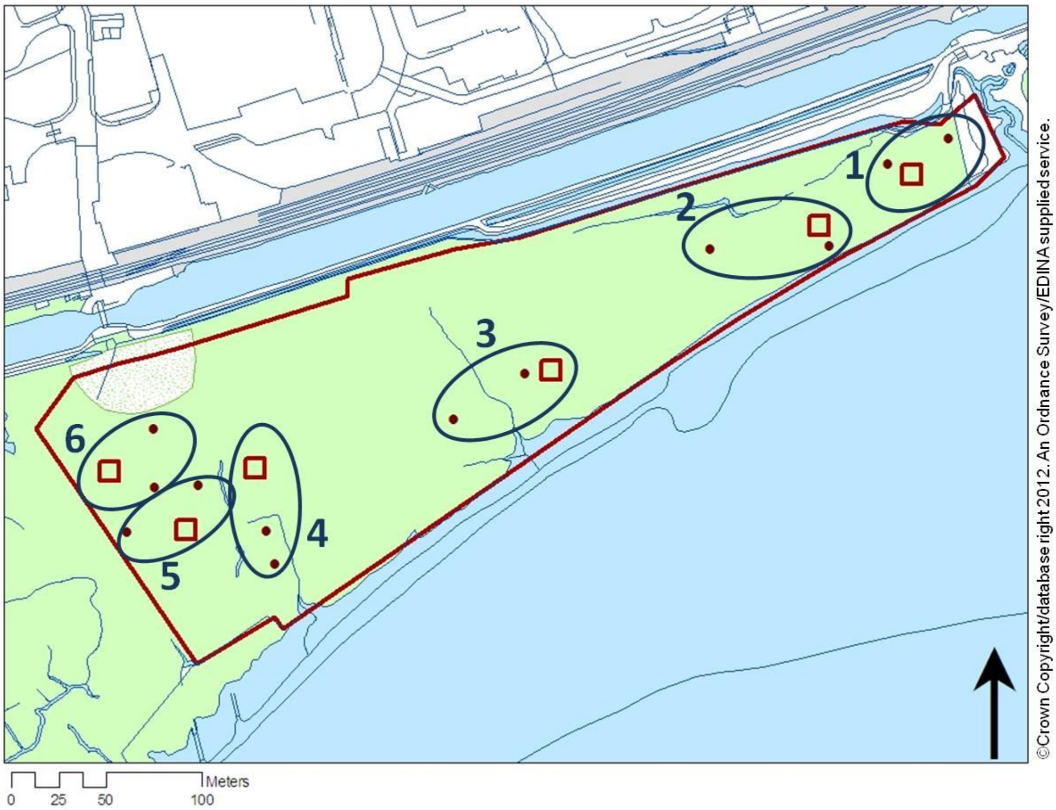

Figure 19: Placement of exclosures and paired quadrats. Open squares represent exclosures, red dots represent paired quadrats. Exclosures measure 10m × 10m and permanent quadrats 2m × 2m. Blue, oval circles represent each site.

Two 2 m × 2 m quadrats were placed within and without the grazing treatments in a paired design, giving a total of twelve quadrats in grazed and twelve in the ungrazed areas. The 2 m × 2 m size quadrats are recommended by (Rodwell et al., 2000) for UK vegetation studies.

A paired design was utilised to examine differences in the grazed and ungrazed exclosures (Whitlock and Schluter, 2009). This layout is displayed in graphical form in Figure 20. This paired design eliminates any factors throughout the salt marsh not related to the grazing treatment (Whitlock and Schluter, 2009). In each of the six sites, two permanent quadrats were placed randomly within each exclosure and two were placed in the grazing area; care was taken to ensure the permanent quadrats for each site matched the conditions in the paired exclosure.

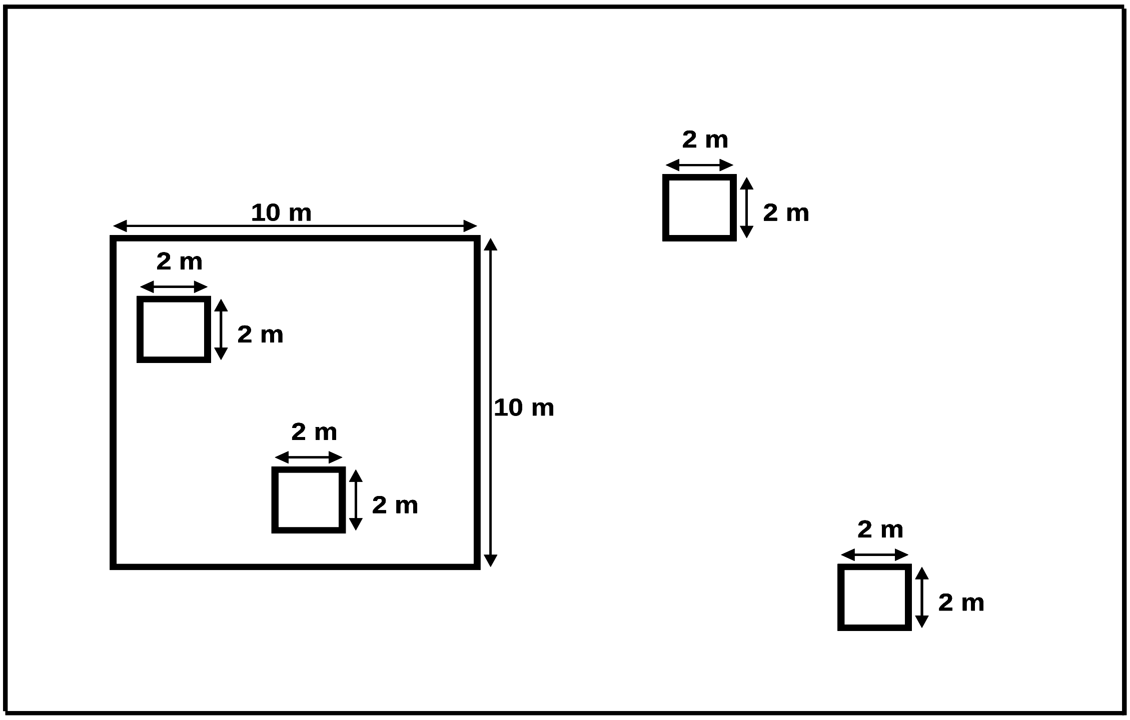

Figure 18: Showing the arrangement of design of the exclosures and quadrats. Exclosures were 10 m × 10 m, quadrats both within and without the exclosurse were 2 m × 2 m.

The exclosures and quadrats were randomly placed within areas of at least 95% *E.x drucei* cover. Many of the large scale salt marsh studies carried out in the UK and Europe are on swards of *Elymus* species (Esselink et al., 2002; Loucougaray et al., 2004; Milotic et al., 2010). The long term monitoring of species' composition as an adjunct to the current research will enable the management site at Widnes to add to current and future comparison projects in the long term.

In order to satisfy questions relating to vegetation structure across the salt marsh, the following measurements were taken in each quadrat:

1. Three randomly placed measurements of vegetation height using the 'direct measurement' method (Stewart et al., 2001). This method uses a ruler placed on the substrate and moving a hand down the ruler until 80% of the growing vegetation is below the hand (Stewart et al., 2001). This method has been proven to be appropriate in experiments measuring varying heights of vegetation (Stewart et al., 2001). Measurements were taken to the nearest centimetre as ascribing millimetres was found to be impractical for this method.

The first survey was carried out two weeks after the cattle arrived (26 April 2011). Following this, the vegetation was surveyed once per month on the same date, or as close to this date as possible (Table 13). Grass height survey data are reported for April – July of 2011 and 2012. The results are presented for the spring and early summer period, when wading birds and wildfowl are most likely to breed.

Table 13: Months of vegetation heights monitoring.

2011*	April	May	June	July
2012†	April	May	June	July

*Six cattle grazed the salt marsh during 2011 from 13 April – 23 August.
†Three cattle grazed the salt marsh during 2012 from 11 June – 15 October.

Descriptive analysis

To show variation in vegetation structure across the grass lengths in the grazed areas and the exclosures, boxplots were generated using Minitab ® 15.1.0.0 © 2006. Boxplots were used as an effective method to display the results over the varying time periods in relation to the introduction of grazing. Boxplots show the data set in a distributional range around medians. The box displays the interquartile range, being 50% of the data. The box lower end and top are bordered by the 1st and 3rd quartiles, respectively. At the 1st quartile, 25% of data are less than or equal to this value, at the 3rd quartile, 75% of the data are less than or equal to this value. The middle line represents the 2nd quartile (the median), 50% of the data are less than or equal to this value. In addition, boxplots show extended ranges, and outlying readings (Figure 19).

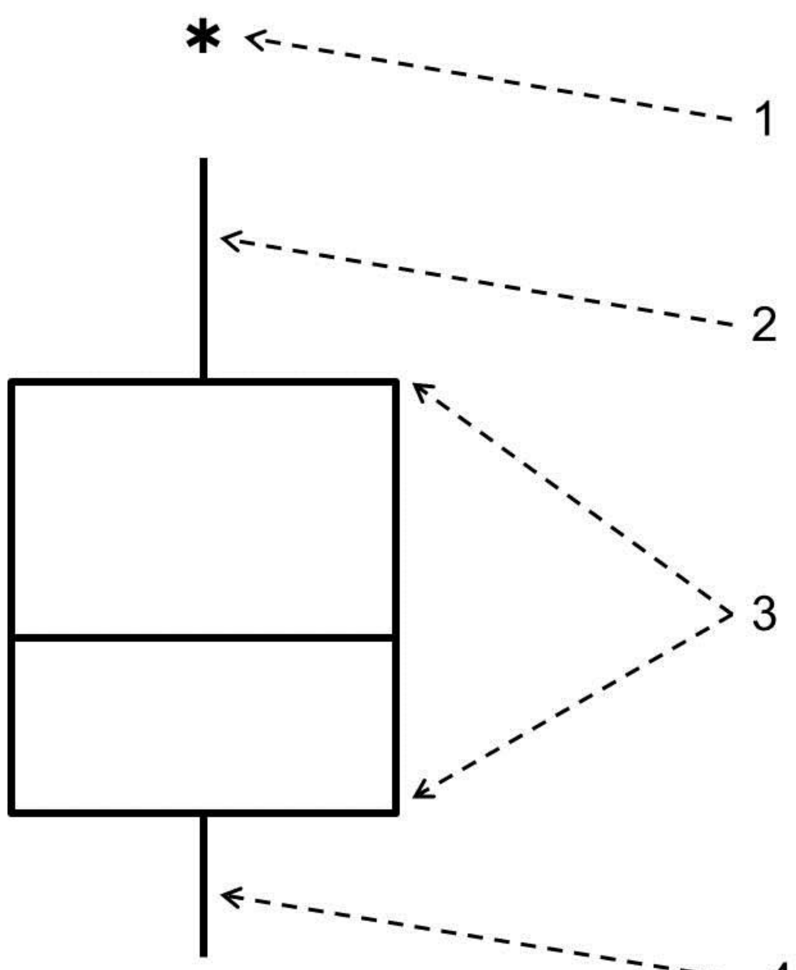

Figure 19: The constituent parts of the boxplots (ref. Minitab ® 15.1.0.0 ©2006). 1- Outliers – datum points beyond upper or lower whiskers. 2- Upper whisker extending to maximum datum point to within 1.5 box heights from top of box. 3 – Interquartile range box, bounded at the bottom by the 1st quartile, 25% of data are ≤ this point; the top line represents the 3rd quartile, 75% of the data are ≤ this value; the middle line represents the 2nd quartile (the median), 50% of the data are ≤ this point. 4 – The lower whisker extends to the minimum datum point within 1.5 box heights from the 1st quartile.

Data Analysis

The data were explored on a month by month basis to examine the effects of the grazing each month on the grass length and variability for each month.

For each month, the experiment had two constant factors, treatment (grazed vs ungrazed), and site. The response factor to these two factors is the length of the grass. With normally distributed data, this presents a hierarchical element allowing parametric analysis of variance (ANOVA) between the factors in a general linear model, and if significant, an *a postieri* Tukeys Test to examine where the differences lie (Dytham, 2003).

To test the data for a normal distribution, on which the application of parametric tests lies (Fowler and Cohen, 1996; Dytham, 2003), each month's data were examined for normality using a Kolmogorov Smirnov test (Dytham, 2003). Results are displayed in tabular form in Table 14. Six of the month's data could not be considered normally distributed so the data were log transformed, and square root transformed, to fit assumptions of normality (Whitlock & Schluter, 2009). The results of the Kolmogorov Smirnov Tests for normal distribution of raw and transformed data (using a natural and a square root transform) are displayed in tabular form in Table 14.

Table 14: Kolmogorov Smirnov results to test for normality of grass height data over the two 4 month grazing periods in 2011 and 2012. P values in bold indicate a normal distribution.

Grazing Month	Raw data P value	Natural log transform P value	Square root transform P value
2011			
April	**> 0.15**	**> 0.15**	**> 0.15**
May	< 0.01	< 0.01	< 0.01
June	< 0.01	< 0.01	< 0.01
July	< 0.01	< 0.01	< 0.01
2012			
April	< 0.01	=0.035	=0.035
May	<0.01	=0.022	**>0.150**
June	< 0.01	< 0.010	<0.010
July	**= 0.134**	<0.010	<0.010

The results of the tests revealed that normal distribution existed for April 2011 for all forms, May 2012 for square root transformed data, and July 2012 for raw data. All the other tests resulted in a non-normal distribution (Table 14) In the absence of this requirement for parametric tests, the non-parametric, Scheirer-Ray-Hare was used to test the following null hypotheses relating to the grass structure data:

1. H_0- There is no significant difference in median grass height between grazed vs ungrazed.
2. H_0- There is no significant difference in median grass height between the six sites.
3. H_0- There is no significant interaction in grass height between grazing treatment (grazed vs ungrazed) and sites (the change in median grass height at each site is the same between treatments).

The Scheirer-Ray-Hare test is a non-parametric equivalent of a two-way ANOVA using replicates and has been successfully used in conservation projects on habitat use by red deer (Sánchez-Prieto et al., 2010) and investigating biodiversity metrics in grassland (Questad et al., 2011). The Scheirer-Ray-Hare uses ranks of the data in an extension of the Kruskall-Wallis test and examines medians of more than two sets of data at a single hierarchical level (Dytham, 2003).

5.3.2 Results

Vegetation during the breeding season of 2011

For April 2011, there was a highly statistically significant difference between the medians of the grazed and exclosure sites ($P< 0.001$), the difference in medians between the sites was not significant ($P= 0.446$). There was no significant interaction between treatment and site ($P= 0.836$), indicating that grass heights from all sites showed the same significant decrease in grass height between the grazed and the ungrazed sward (Table 15 and Figure 22).

Table 15: Results of the Scheirer-Ray-Hare test for April 2011. Significant differences indicated by * (P< 0.05), ** (P < 0.01), * (P< 0.001). Where the difference was not significant, this is shown as ns.**

Source	H	d.f.	P-value	Significance level
Treatment	47.96	1	0.001	***
Site	4.76	5	0.446	ns
Interaction	2.09	5	0.836	ns
Total		71		

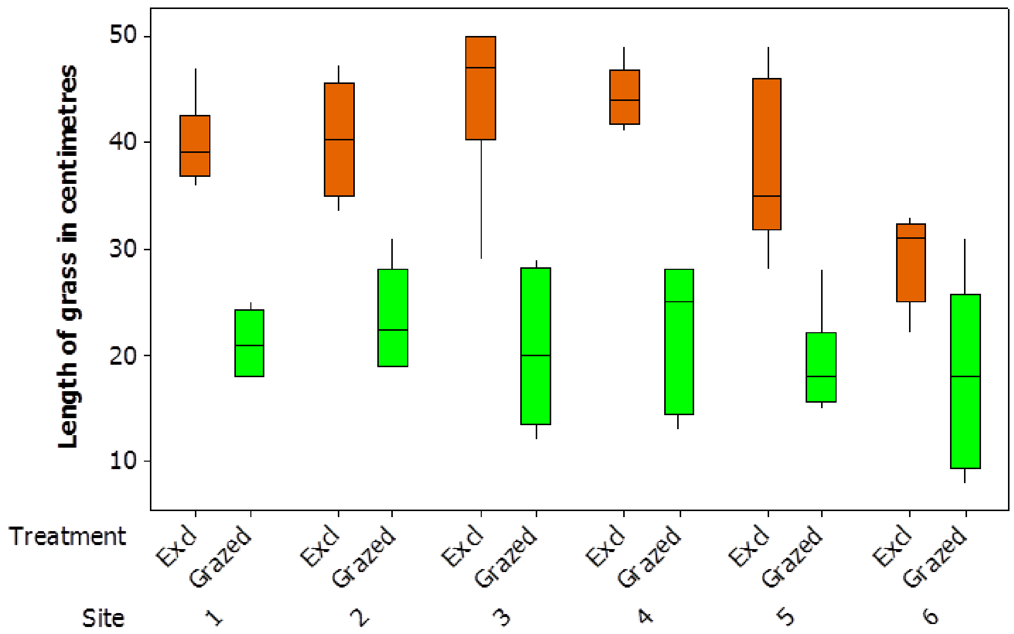

Figure 20: Boxplots of April 2011, two weeks after the introduction of the high density grazing. Orange boxes represent the ungrazed, green represent the grazed areas.

For May 2011, the difference between the median grazed and ungrazed grass heights was highly significant (P< 0.001). There was no significant difference between the median grazed heights between the six sites (P= 0.893), the same result held for the interaction between treatment and site (P= 0.642) (Table 16), thus indicating the same direction of change between the treatments at all sites (Figure 21).

Table 16: Results of the Scheirer-Ray-Hare test for May 2011. Significant differences indicated by * (P< 0.05), ** (P < 0.01), * (P< 0.001). Where the difference was not significant, this is shown as ns.**

Source	H	d.f.	P-value	Significance level
Treatment	53.36	1	0.001	***
Site	1.67	5	0.893	ns
Interaction	3.38	5	0.642	ns
Total		71		

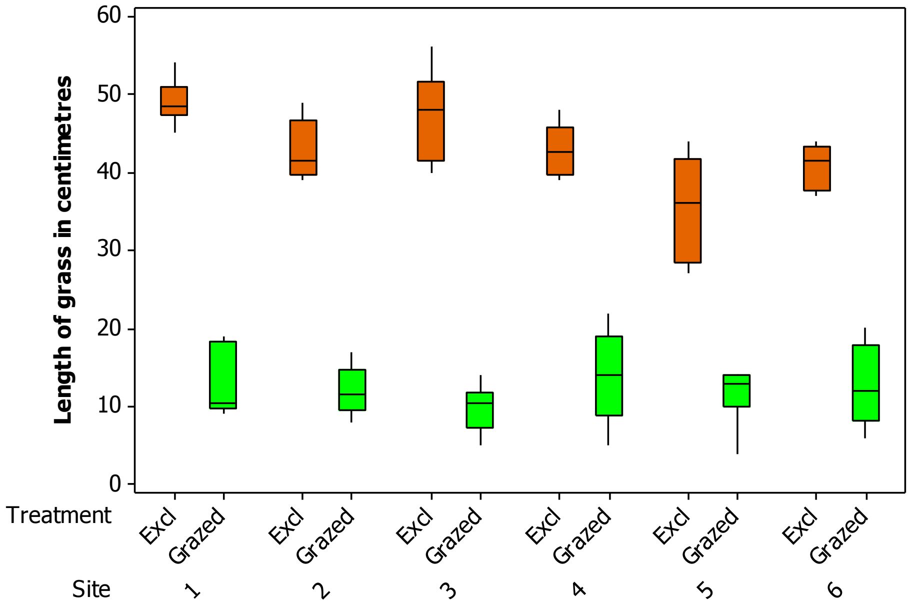

Figure 21: Boxplots of May 2011, during the second month after the introduction of high density grazing. Orange boxes represent the ungrazed, green represent the grazed areas.

During June 2011, the difference between the median grazed and ungrazed grass heights was highly significant (P< 0.001) There was no significant difference between the median grazed heights between the six sites (P= 0.626) nor was the interaction between treatment and site (P= 0.542) (Table 17) indicating the same direction of change between the treatments at all sites. The difference after three months' grazing was stark (Figure 22).

Table 17: Results of the Scheirer-Ray-Hare test for June 2011. Significant differences indicated by * (P< 0.05), ** (P < 0.01), * (P< 0.001). Where the difference was not significant, this is shown as ns.**

Source	H	d.f.	P-value	Significance level
Treatment	53.38	1	0.001	***
Site	3.48	5	0.626	ns
Interaction	4.05	5	0.542	ns
Total		71		

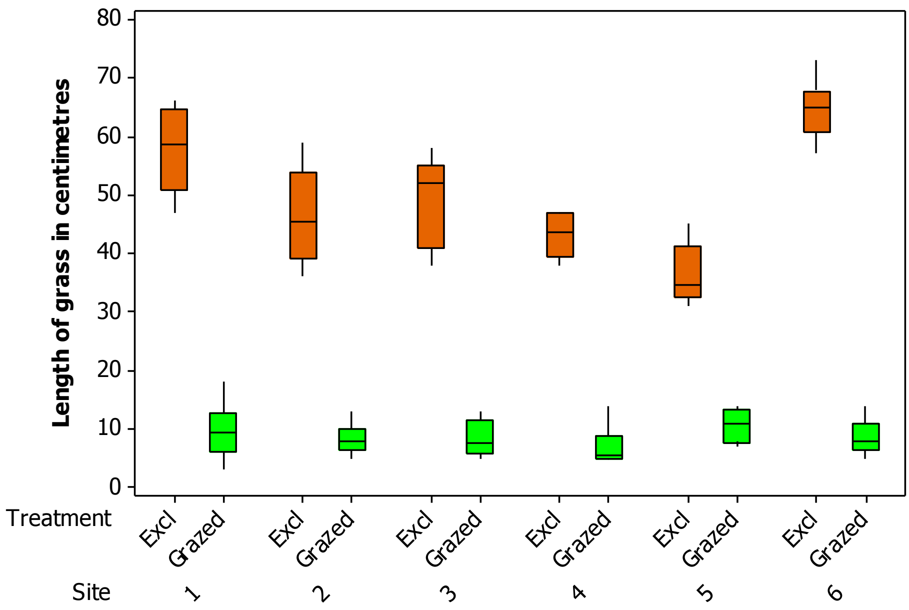

Figure 22: Boxplots of June 2011, after three months of high density grazing. Orange boxes represent the ungrazed, green represent the grazed areas. The grazed areas show a low median (<10 cm) with a narrow inter-quartile range.

For the July data, there was a highly significant difference between the medians of the grazed and ungrazed areas (P< 0.001) (Table 18). The difference between the medians of the sites was not significant (P= 0.537), nor was this the case for the interaction between grazing treatment or site (P= 0.518). As was the case with June 2011, the difference was highly apparent from the boxplots (Figure 23).

Table 18: Scheirer-Ray-Hare test results for July 2011, the last month of grazing before the cattle were removed for 2011. Significant differences indicated by * (P< 0.05), ** (P < 0.01), * (P< 0.001). Where the difference was not significant, this is shown as ns.**

Source	H	d.f.	P-value	Significance level
Treatment	53.47	1	0.001	***
Site	4.09	5	0.537	ns
Interaction	4.22	5	0.518	ns
Total		71		

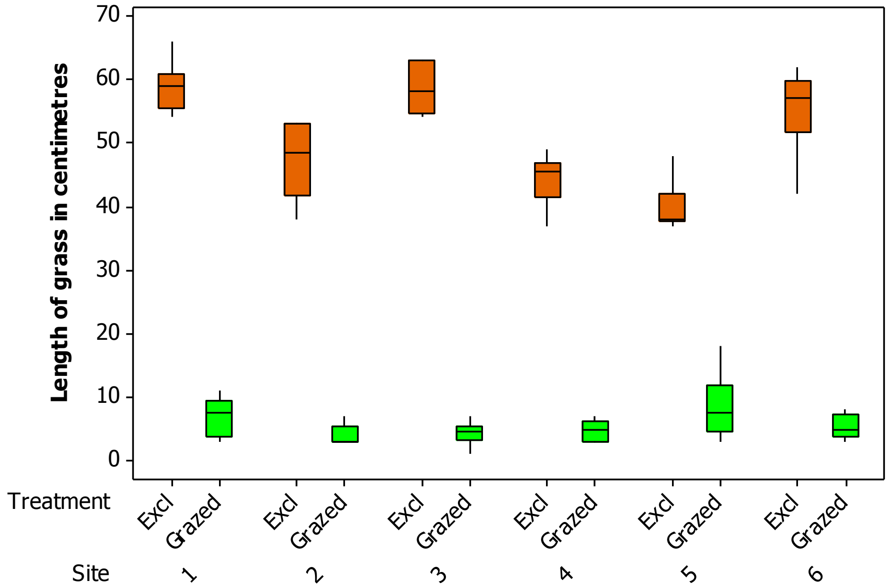

Figure 23: Boxplots of July 2011, after four months of high density grazing. Orange boxes represent the ungrazed, green represent the grazed areas. The grazed areas show a low median (<10 cm) with a narrow inter-quartile range.

Vegetation during the breeding season of 2012

Three cattle were reintroduced to the grazing area on June 11 at a grazing density of 0.6 cattle ha^{-1}; this is within the recommended grazing density for conservation grazing purposes (Doody, 2008).

During April 2012, one month prior to low density grazing of 2012, the difference between the grazed and the ungrazed was highly significantly different (P< 0.001). The difference between the medians of the sites was not significant (P= 0.445), nor was this the case for the interaction between grazing treatment or site (P= 0.836) (Table 19). Visually, there was a wide range of grass lengths throughout the sites (Figure 24).

Table 19: Scheirer-Ray-Hare test results for April 2012, the first month recorded and the start of the breeding season for waders. Significant differences indicated by * (P< 0.05), ** (P < 0.01), * (P< 0.001). Where the difference was not significant, this is shown as ns.**

Source	H	d.f.	P-value	Significance level
Treatment	48.01	1	0.001	***
Site	4.77	5	0.445	ns
Interaction	2.09	5	0.836	ns
Total		71		

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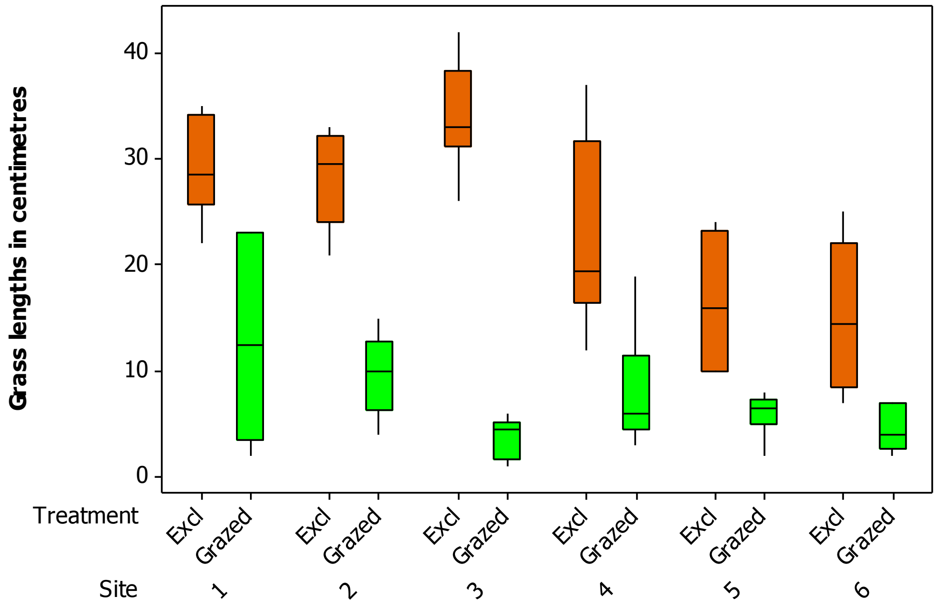

Figure 24: Boxplots of April 2012 at the start of the breeding season for birds. There was a certain amount of overlap between the treatments as shown in sites 4,5, and 6. Orange boxes represent the ungrazed, green represent the grazed areas. This was one month prior to low density grazing of 2012.

During May 2012, the difference between the grazed and the ungrazed was highly significantly different (P< 0.001). The difference between the medians of the sites was not significant (P= 0.254), nor was this the case for the interaction between grazing treatment or site (P= 0.178) (Table 20). The overall length of the quartile ranges in the boxplots indicate a narrow range for the exclosures which could be attributed to a spring burst of growth in this uniform, ungrazed environment (Figure 25)

Table 20: Scheirer-Ray-Hare test results for May 2012. Significant differences indicated by * (P< 0.05), ** (P < 0.01), * (P< 0.001). Where the difference was not significant, this is shown as ns).**

Source	H	d.f.	P-value	Significance level
Treatment	45.44	1	0.001	***
Site	6.58	5	0.254	ns
Interaction	7.62	5	0.178	ns
Total		71		

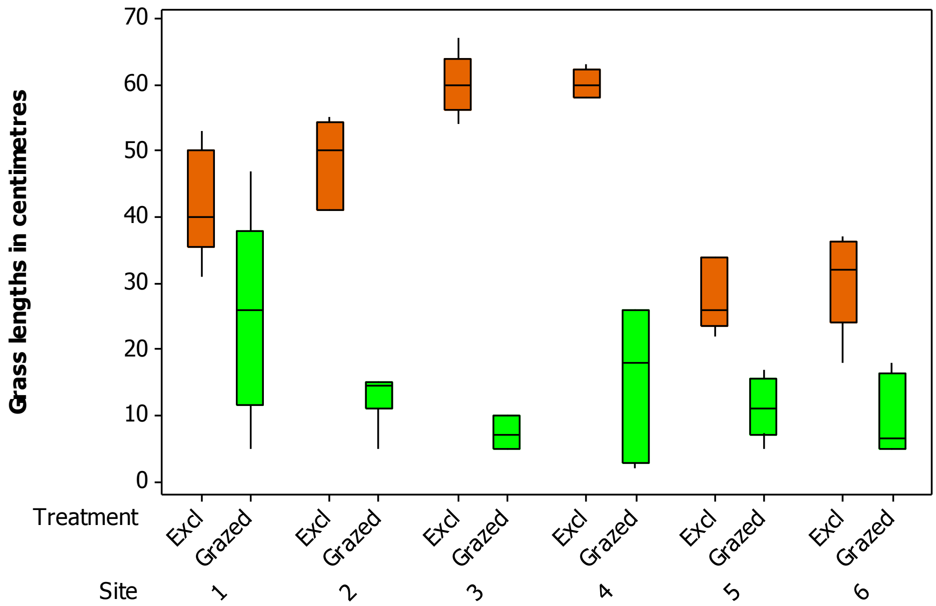

Figure 25: Boxplots of May 2012. Orange boxes represent the ungrazed, green represent the grazed areas. The boxplots indicate the range in the exclosures was narrower than the grazed area which could be attributed to the steady increase during spring growth.

The June 2012 results show that the difference between the grazed and ungrazed was highly significantly different (P< 0.001). Between the sites the grass heights were found not to be significant (P= 0.846) (Table 21). However, there was a highly significant difference in the interaction between the grazing treatment and the sites, indicating that changes in grass height at each site were different between sites (P< 0.001) (Table 21). The boxplots (Figure 26) show overlaps of the quartile boxes and median lines, indicating that the introduction of grazers may have had localised impacts.

Table 21: Results of the Scheirer-Ray-Hare test for June 2012. Significant differences indicated by * (P< 0.05), ** (P < 0.01), * (P< 0.001). Where the difference was not significant, this is shown as ns.**

Source	H	d.f.	P-value	Significance value
Treatment	17.11	1	0.001	***
Site	2.02	5	0.846	ns
Interaction	25.91	5	0.001	***
Total		71		

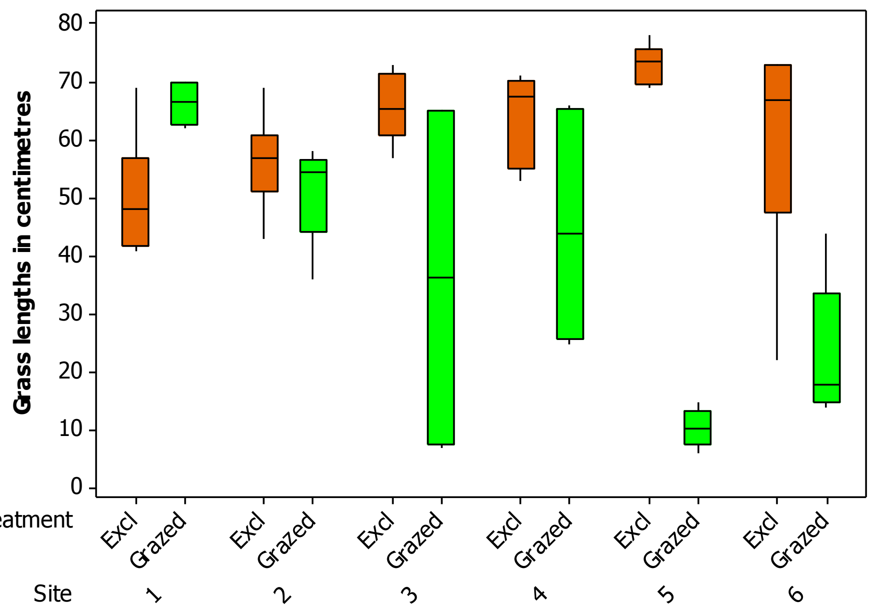

Figure 26: Boxplots of June 2012, two weeks after the introduction of the cattle for the second year with a conservation grazing density (0.6 cattle ha^{-1}). Orange boxes represent the ungrazed, green represent the grazed areas. The ranges of the grazed area vary in response to the grazing.

For July, 2012, there was a highly significant difference between the medians of the grazed and ungrazed grass heights (P< 0.001). The difference between the medians of the sites was not significant (P= 0.103) although the interaction between the treatments and the sites was highly significant (P< 0.001) (Table 22). This interaction result indicates the grass heights between the grazed and ungrazed areas between the sites were different. The boxplots show a varied spatial overlap due to a spread of ranges and medians in the grazed area (Figure 27).

Table 22: Scheirer-Ray-Hare results for July 2012, the second month of the second year. Significant differences indicated by * (P< 0.05), ** (P < 0.01), * (P< 0.001). Where the difference was not significant, this is shown as ns.**

Source	H	d.f.	P-value	Significance value
Treatment	4.63	1	0.001	***
Site	9.16	5	0.103	ns
Interaction	28.67	5	0.001	***
Total		71		

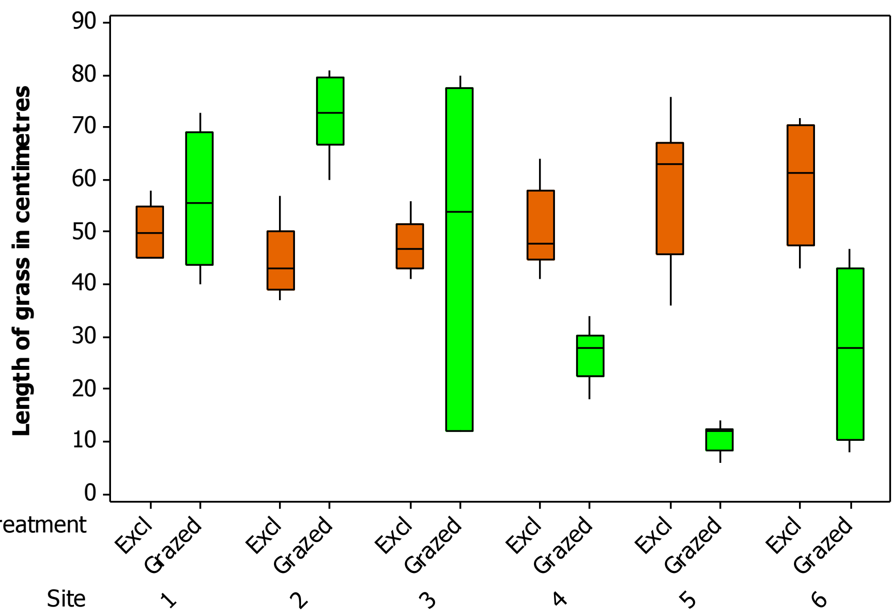

Figure 27: Boxplots of grass height data for July 2012. Orange boxes represent the ungrazed, green represent the grazed areas. The inter-quartile ranges of the grazed areas varied visually to a higher extent than the ungrazed areas.

5.4 Invertebrates

5.4.1 Method

Surface invertebrate sampling took place at the end of July 2012 over a two week period. This period was selected as being an ideal period in which to ascertain a vibrant invertebrate assemblage (Ford et al., 2012a).

Invertebrates were sampled using pitfall traps which have been extensively used for similar research (Eglington et al., 2010). The method used here followed various approaches, all with the same theme of sunken cups, mesh to cover the traps to avoid unwanted captures, a rain lid, and a preservative-killing agent for invertebrates that fell into the cups (Natural England, 2007; Ford et al., 2012a). Plastic cups, 7.5 cm in diameter and 10 cm deep were filled with 70% alcohol and 30% glycerol up to about 2 cm. The traps were placed in the ground, so the top was in line with the top salt marsh sediment layer, and covered with a metal mesh (12 mm × 25 mm) to avoid non-target species such as small mammals falling in (Figure 30). In order to stop rain directly falling into the cups, longer nails were used to prop up ceramic tiles as ‘hats’ for the cups (Figure 31). The traps were checked, emptied and refilled every two to three days. Invertebrates were preserved using 70% alcohol and 30% glycerol, the standard University of Salford laboratory method.

Figure 28: Pitfall trap showing cup, mesh, and long nails to prop up the tiles. The mesh measures 12 mm × 25 mm.

Figure 29: A covered pitfall trap, the grass was replaced so that the trap and area was restored to its original state.

Four locations within each treatment were trapped over the two weeks; these are indicated and labelled as points in Figure 32. The locations of the traps were selected using a random number table generated in Microsoft ® Office Excel ® 2010. At each location, 4 pitfall traps were laid out at the corners of a 4 x4 m square. Therefore there were 16 pitfall traps in the grazed and the ungrazed treatments. As the timing of the sampling was not an experimental factor over the two weeks, the invertebrate samples were pooled for each pitfall trap. Invertebrates were identified to Order level; this was found to be a sufficient measure when comparing diets of Lapwing and Redshank by Ausden et al. (2003). Identification followed Tilling (1987).

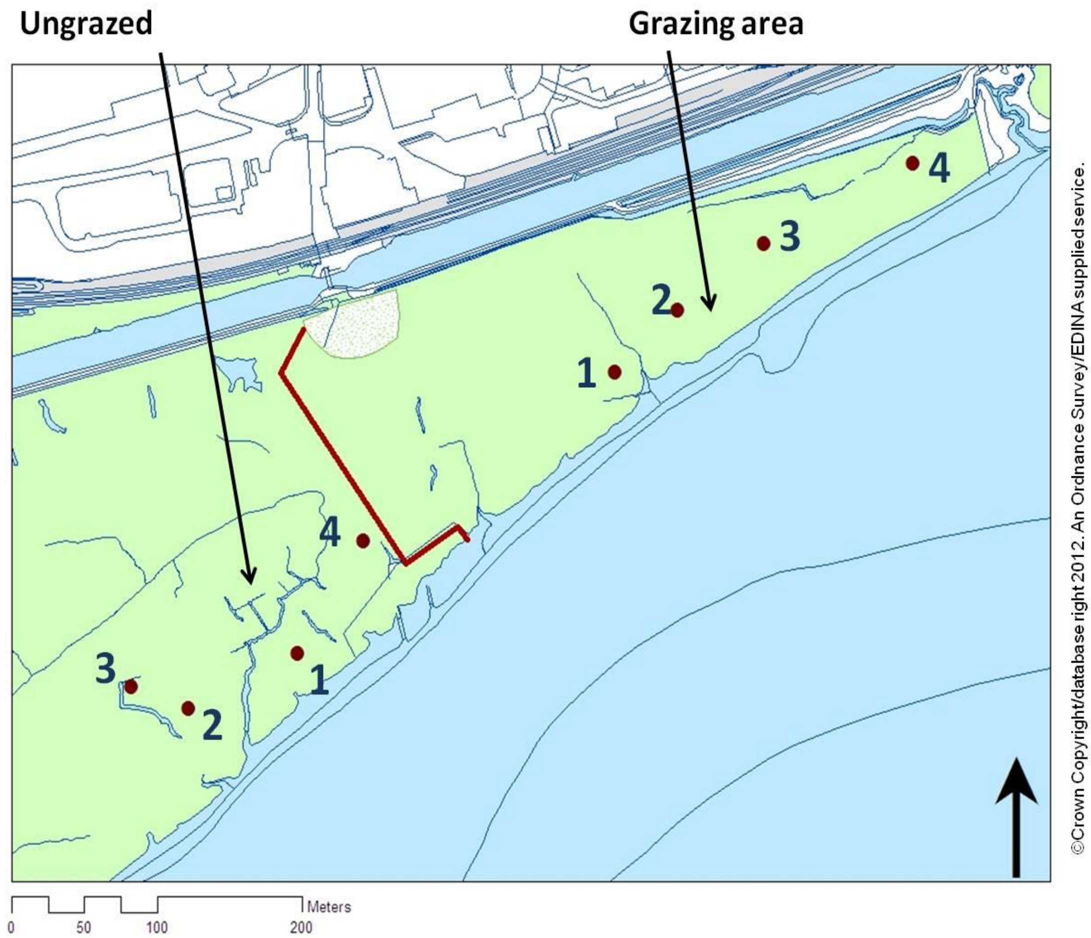

Figure 30: Map displaying the layout of the locations of the pitfall traps. Location of the traps was selected using random methods. The red line indicates the boundary between the grazed and the ungrazed area.

Statistical analysis

To examine for differences between grazed and control sites, the data were analysed using the Community Analysis Package V 4.1.3© (CAP) to establish whether the invertebrate assemblages differed significantly in an Analysis of Similarities (ANOSIM) test (Clarke, 1993). The CAP is a statistical software package which is used to analyse biotic communities and multi-dimensional relationships between them (Seaby and Henderson, 2007).

The pitfall trap data were transformed into a Bray-Curtis Similarity Index using the CAP. This index calculates similarities between all the replicates so that identical replicates have a similarity rating of 1 and replicates completely different in their composition have an similarity rating of 0 (Bray and Curtis, 1957). This transformed data therefore represents a set of data with the differences in the composition of the replicates (in this case pitfall traps) being able to be compared.

A non-parametric Analysis of Similarities (ANOSIM) statistical test was performed on the transformed data. An ANOSIM test allows the determination of whether or not community assemblage differs at a significant level (Clarke and Warwick, 2001). A Global R sample statistic and a probability statistic is calculated by the CAP software package, where $P < 0.05$ indicates significance (Seaby and Henderson, 2007). The ANOSIM was used to test the null hypothesis:

> H_0- There was no significant difference in the assemblage similarity of the invertebrate orders between the grazed and the ungrazed pitfall traps.

To show the relationship between the pitfall traps' assemblage as a visual representation both within and between the treatments, a multi-dimensional scaling (MDS) plot was created, using the CAP (Seaby and Henderson, 2007). The MDS plot places the pit fall traps with the highest similarity of order assemblage, closest together (Seaby and Henderson, 2007).

As a *post hoc* examination, Similarity Percentage Analysis (SIMPER) was performed on the raw data to indicate which orders, if any, contributed most to the dissimilarities between the groups (Seaby and Henderson, 2007). Using the transformed data within the Bray-Curtis similarity index, the CAP calculates mean dissimilarity contributions between the treatments and the contributions each variable makes to any dissimilarity (Seaby and Henderson, 2007).

5.4.2 Results

Overall, more invertebrates were recorded in the ungrazed section of the salt marsh. The highest number invertebrates by order was Diptera in the ungrazed area,797, compared to 277 in the grazed area. There were many more Amphipoda recorded in the ungrazed area, 755, than in the grazed, 239. In the grazed area, more Araneae were recorded than in the ungrazed area (grazed = 213; ungrazed = 169). In terms of number of orders, more orders were recorded in the grazed area than in the ungrazed area (grazed = 9; ungrazed = 7). These data are displayed in tabular form in Tables 23 for ungrazed, and Table 24 for the grazed area.

Table 23: Invertebrates recorded in the ungrazed section of the salt marsh.

Order/ Traps	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	Total
Amphipoda	41	37	43	41	67	91	14	57	74	115	59	0	49	25	10	32	755
Araneae	18	14	16	11	10	11	9	9	6	9	12	8	13	9	6	8	169
Coleoptera	3	11	7	9	2	13	1	1	4	3	1	3	0	6	2	7	72
Diptera	43	93	65	73	30	55	32	46	43	69	28	48	26	53	49	44	797
Hymenoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Collembola	9	13	7	8	8	7	1	3	12	3	10	16	3	12	6	5	123
Acari	0	0	3	1	0	0	0	0	0	0	0	1	0	0	0	0	4
Dermaptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemiptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

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Table 24: Invertebrates recorded in grazed section of the salt marsh.

Order/ Traps	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	Total
Amphipoda	33	15	34	10	14	19	11	20	7	14	4	5	12	5	17	19	239
Araneae	3	8	9	17	10	12	10	16	14	15	11	9	14	22	20	23	213
Coleoptera	5	2	7	9	3	12	5	9	0	0	0	0	6	0	0	0	58
Diptera	38	8	11	19	8	10	16	25	27	12	19	19	11	18	15	21	277
Hymenoptera	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Collembola	12	10	11	6	5	5	5	6	7	5	4	5	2	2	1	8	94
Acari	2	0	0	0	1	0	4	0	1	0	2	0	0	1	0	0	11
Dermaptera	0	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	4
Hemiptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1

At a statistical level, there was a significant difference in assemblage similarity between the grazed samples and the ungrazed plots (ANOSIM, Global R = 0.69, P< 0.001). Pairwise comparison of the sites revealed that both treatments were highly significantly different in terms of assemblage similarity in all cases (Pairwise comparison, P< 0.001). Figure 33 uses a multi-dimensional scaling plot to illustrate how the trap sites and treatments were similar and dissimilar, within and between different treatments.

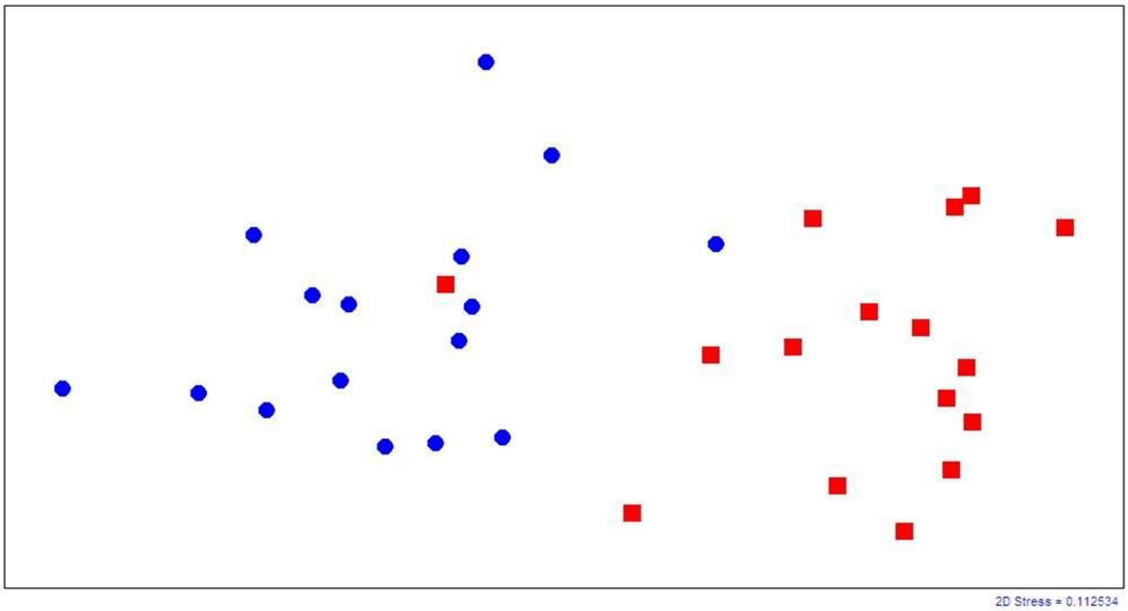

Figure 31: Non-metric, multi-dimensional Scaling (MDS) ordination, representing a visualisation of the differences between the community assemblage of the invertebrates between the grazed and the ungrazed area. Red squares represents grazed and blue circles represent the ungrazed pitfall traps. The layout of the quadrats in relation to one another clearly shows the similarities within treatments and differences between them as the ungrazed (blue) pitfall traps and the grazed (red) pitfall traps are generally clustered together.

The SIMPER analysis revealed that four Orders contributed 93.09% to the dissimilarity between the treatments. The order with the highest contribution to this dissimilarity was Amphipoda (40.88%), followed by Diptera (39.69%), Araneae (6.83%), and Collembolla (5.68%). The mean abundances of these were higher in the ungrazed pitfall traps for Amphipoda (ungrazed: 47.19 s.d.+/- = 30; grazed: 14.94, s.d.+/- = 8.88), Diptera (ungrazed: 49.81, s.d.+/- = 18.14; grazed: 17.31, s.d.+/- = 7.94), and Collembola (ungrazed: 7.69, s.d.+/- = 4.19; grazed: 5.88, s.d.+/- = 3.14) and was higher in the grazed treatment pitfall traps for Araneae (ungrazed: 10.56, s.d.+/- = 3.37; grazed: 13.31, s.d.+/- = 5.41). These results are displayed in tabular form in Table 25 with a visual representation of the mean abundances with standard deviations in Figure 34.

Table 25: Orders contributing to the dissimilarity between the treatments, with mean abundances of these and standard deviations.

Order	Mean abundance Ungrazed (+/- standard deviation)	Mean abundance Grazed (+/- standard deviation)	Percentage contribution to dissimilarity between the treatments
Amphipoda	47.19 (30.00)	14.94 (8.88)	40.88
Diptera	49.81 (18.14)	17.31 (7.94)	39.69
Araneae	10.56 (3.37)	13.31 (5.41)	6.83
Collembola	7.69 (4.19)	5.88 (3.14)	5.68

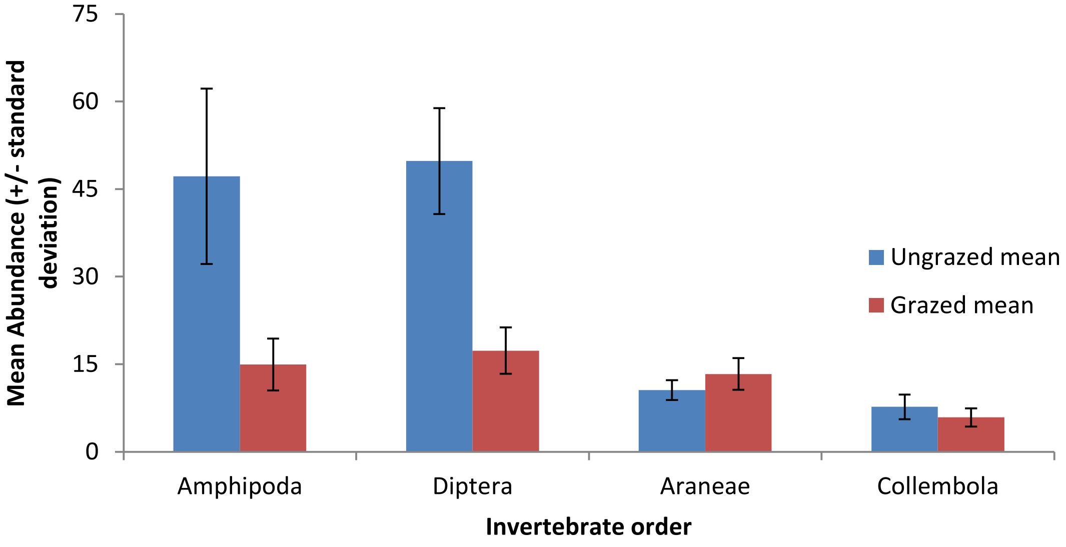

Figure 32: Mean abundance (+/-standard deviation) of orders of invertebrate species in pitfall traps, and standard deviation around the mean, for orders contributing to the difference between the grazed and ungrazed sections of salt marsh. Blue columns represent ungrazed traps and red represent grazed.

5.5 Discussion

The purpose of the chapter was to address Objective 3 (Chapter 2.6) relating to the effects of the management measure on the ecosystem service of wild species diversity as a cultural ecosystem service. In this regard: use of the habitat for song birds, breeding waders and wildfowl; vegetation structure as a determinant of breeding bird habitat selection; and invertebrates as a food supply for breeding birds and chicks was examined. The third component of Daily at al.'s (2009) model (Figure 8) requires that ecosystem services are measured as a result of management and changes in values are reported in the fourth component, this discussion aims to address these two components.

The song bird results revealed a decrease in breeding density in the grazing area and an increase in breeding density in the ungrazed area over the two years (Table 12). During 2012 the rainfall figures for this period were highly irregular compared with 2011 and recent years before this- R. Smith (2011) reports that this may have had an influence on breeding bird numbers as nests may have been flooded. It should also be noted that the grazing periods for

2011 and 2012 were different, for 2011 this was April to August and for 2012 – June – October. This may have added to the use of the grazing area by nesting birds; Hart et al. (2002) report trampling by cattle can decrease the chance of nesting success although the results described above show a higher density with a higher density.

The wader bird results showed two important facets. The first of these is the absence of any breeding or chick rearing behaviour in both the ungrazed and in the grazed area in 2011. This is in agreement with a large body of other research. Brindley et al., (1998) specifically point to the management of salt marsh using grazers as a step towards an increase in breeding Redshank. Brindley et al., (1998) showed a marked decline (22.9%) over eleven years in the abundance of breeding Redshank on British salt marsh with the recommendation that conservation management methods be introduced to reverse this decline.

The second important facet is the recording of two pairs of breeding waders on the grazed area in 2012. Stocking density plays a large part in the use of salt marsh for waterfowl. Intensively grazed marsh in the Wadden Sea has a higher level of use by Wigeon (*Anas penelope*) and Barnacle Geese(*Branta leucopis*) (Berg et al., 1997).

Breeding populations of Lapwing (Hart et al., 2002) and Redshank are linked to effective grazing management and the Elmley RSPB Reserve in Kent, UK, has provided three robust case studies on the relationship between water and wetness, typography and survival success of these two species (Hart et al., 2002; Milsom et al., 2002; Ausden et al., 2003).

The vegetation structure is a key component for breeding Redshank. Smart et al. (2006) identified a key characteristic for vegetation structure to be long grass close to or interspersed with short grass and water bodies. Increased stocking rates of grazing on salt marshes in the UK have resulted in the decline in the number of breeding Redshank as there is less cover for protection that Elymus grasses provide (Bakker et al., 2003). While the research site did not contain any major water bodies, the vegetation structure results certainly show a variation within the grazed area, especially in the boxplots for the second year

(Figures 26, 27,28 ,29) during the same period the breeding Redshank and Lapwing were surveyed in the grazing area in the current study. The variation in vegetation structure in the grazed area provides cover and protection for breeding waders.

Salt marshes support more breeding Redshank than any other habitat within the UK (Brindley et al., 1998) and therefore conservation management to improve the habitat for these waders, using conservation grazing management techniques, is of vital importance (Doody, 2008).

It should be recognised that vegetation structure also has important wider benefits to plant species community and wild species diversity. The dominant grass species (*E. x. drucei*) at the research site is in strong agreement with competitive exclusion/ interspecific competition (Olff et al., 1997; Kleyer et al., 2003), especially by tall plants capable of using height as a restrictor to other plants' establishment (van Wijnen et al., 1997). The 'intermediate disturbance hypothesis' (Connell, 1978) holds that with an intermediate time gap between disturbances of varying intensity, species with dispersal and growth limitations are favoured and, diversity increases (Kleyer et al., 2003). Connell (1978) further stipulates that if the gap between disturbances is too long, dominance will be achieved by the competitive exclusion capabilities of a species. Examples in plants include allelopathy (Kruse et al., 2000) or simply through height as a light competitor (Olff et al., 1997; van Wijnen et al., 1997). With Connell's (1978) hypothesis in mind, enhancing plant diversity on high salt marsh can be achieved through two integrated management methods: firstly, by controlling competitive species and secondly, creating gaps to promote the growth of less competitive species, especially halophytes (Loucougaray et al., 2004). With these two principles in mind and examining the effects of herbivores, it is possible to recognise the beneficial effects of grazers on Widnes Warth.

Further to grazing effects, in grazed salt marsh, an effect of grazing is the removal of the leaf litter layer, which composes much of the diet of salt marsh specialist invertebrate species (Andresen et al., 1990). Invertebrate availability and density is crucial to the survivability of breeding and nesting success for waders and wild fowl (Ausden et al., 2003).

The invertebrate results indicate there was a difference between the grazing invertebrate communities with greater mean abundance in the invertebrate orders Amphipoda, Diptera, and Collembola in the ungrazed area, and a higher mean abundance of Araneae in the grazed area. Although invertebrates were identified to order, all the individual invertebrates within the Amphipoda were a single species, *Orchestia cavimana* (Heller). *Orchestia* species are ubiquitous on salt marsh and coastal grazing land and form an important part of the diet of waders, wildfowl, and their chicks.

The results agreed with previous research showing higher abundance of invertebrates in ungrazed and abandoned salt marsh (Andresen et al., 1990; Ford et al., 2012a). Species numbers of Araneae, Carabids (Coleoptera), *Orchestia* species and Collembola increased in an abandoned area after eight years (Andresen et al., 1990). In research on surface dwelling invertebrates on north-west of England on grazing treatment started 40 years ago, Ford et al., (2012a) found a higher abundance of Coleoptera and *Orchestia gammarella* on an ungrazed salt marsh and a higher abundance of Araneae on a grazed section- in full agreement with the current study.

That the current study agreed with these eight year results is remarkable given the relatively short period of four months intensive grazing in 2011, and two months of lower density grazing in 2012. The effect on the grazing shown in the late months of 2011 showed a very low median height which could account for lack of habitat for the surface dwelling invertebrates found in the grazed area.

Further research to investigate the success of the management in terms of nesting and chick rearing through bird surveys and continuation of vegetation measurements is clearly recommended in the current study. While the two pairs of breeding waders do not allow for formal statistics to be carried out on breeding abundance, the descriptive statistics show a strong bias in favour of the grazing area for waders and wildfowl. Over two years no records were made of waders and wildfowl in any of the ungrazed areas and two sets of breeding pairs were found within the grazed area after a full year of grazing.

6. Ecosystem Service 2 - Environmental Settings

6.1 Introduction to the Chapter

Within the cultural theme of ecosystem services, Environmental settings as an ecosystem service was identified as relevant ecosystem services in the current study (Chapter 4.5). Objective 3 requires measuring the effects of management on relevant ecosystem services. The presence of the charismatic English Longhorn cattle, the effects of the grazing, and the conservation directives will produce or change the cultural ecosystem services visitors receive from the greenspace that existed prior to the management intervention. The aim of the research presented in the current chapter is to examine and identify these ecosystem services and goods manifested in the behaviour and perceptions of visitors and users of the area, as a result of the presence of the cattle and the grazing. In order to provide a practical answer to this objective with regards to the cultural ecosystem service of environmental settings, ethnographic participant observation was used. Collecting data in ethnographic research involves more than one technique to strengthen and solidify results (Angrosino et al., 2007). Ethnography was employed in two steps: participant observation and informal interview.

6.2 Method

The ethnographic method has been described as a holistic, multifactorial method using dialogue and inductive reasoning (Angrosino et al., 2007). Ethnography includes the description of the routine lives of humans by studying their behaviour and social issues (Grix, 2004; Angrosino et al., 2007). This process involves describing people in a collective sense (not as individuals), usually in the form of communities or societies (Angrosino et al., 2007).

Qualitative research in social science attempts to answer questions regarding perceptions and background interests which are unobtainable using quantitative methods (Holliday, 2002). Questions can be answered descriptively in a manner that addresses ‘what’ perceptions are, contrasted with ‘why’ these perceptions may exist (de Vaus, 2002). Such research allows open ended questions to be answered in, for example, interviews on attitudes to unknown and unexplored areas of social perceptions and values (Holliday, 2002).

Methods of collecting data in ethnography have been grouped into three categories by Angrosino et al. (2007): 1, documentary sources; 2, observation; and 3, interviewing. Using at least two of these methods together combines their strengths (Moser and Kalton, 1997) and is an aid to triangulation (Grix, 2004; Angrosino et al., 2007). Triangulation either reinforces assessed data, or builds a bigger picture (Angrosino et al., 2007; Blaikie, 2010). The current research has an active, on-going element in that the field site is under active conservation measures. This presents an ideal situation, using observation and informal interviews, to provide intensive data. Two methods were used:

1. Unobtrusive participant observation
2. Opportunistic informal interviews with content and thematic analysis

6.2.1 Unobtrusive Participant Observation

Participant observation is a style adopted by researchers in which studies are carried out using various methods within a community (Ellen, 1988; Angrosino et al., 2007), from total participation in the field to simple observation (Blaikie, 2010). These methods range from being heavily immersed in the study area, to being as detached as a surveyor of natural phenomena, as one would be in surveying birds for example (Ellen, 1988).

Participant observation is achieved by directly observing human behaviour. Ethical issues arise in social observational studies when surveys are carried out without the knowledge and consent of the subjects (Moser and Kalton, 1997). However, *proxemic* studies, in which the researcher observes people's behaviour in public settings and notes these behaviours, is a common method in ethnographic research, wherein justification rests if public (as opposed to private) behaviour is being monitored (Angrosino et al., 2007; EC, 2011b). The unobtrusive observation method of surveying human behaviour in an urban setting, used by Tzoulas and James (2010), examined how behaviour and use patterns are related to management intervention. Observational data is often insufficient and is supplemented by interviewing (Moser and Kalton, 1997) as part of triangulation (Angrosino et al., 2007).

At the research site, preliminary observation surveys carried out in February 2011 found the optimal survey point to be the main viewing area at the Carter House Bridge (Figure 35), either from one spot or walking along the Trans Pennine Trail in view of the main viewing area (between points 5,1, and 3, of the map displayed in Figure 35). There are three information boards with views of the salt marsh, these are found at the Carter House Bridge, the *Phragmites* Information Board, and the Eastern Information Board (Points 1, 3, and 2 respectively on the map in Figure 35). During the preliminary surveys it became obvious that when observing visitors from either the *Phragmites* or the Eastern Information Board, it was impossible to see the cattle holding pen and other associated amenities at the main area where three significant access points, Fiddlers Ferry, Spike Island, and Tan House Lane, converged. Therefore observations were carried out close to the Carter House Bridge at the point where the three approaches converge.

The main viewing, Carter House Bridge (Point 1 in Figure 35) area took on the natural role as a focal point for visitors taking an interest in the cattle as the information board here provided context specific information about the aims of the cattle grazing. The key features at the main viewing area are a holding pen for cattle, an information board with a brief description of the project, and access to the boardwalk (Figure 36).

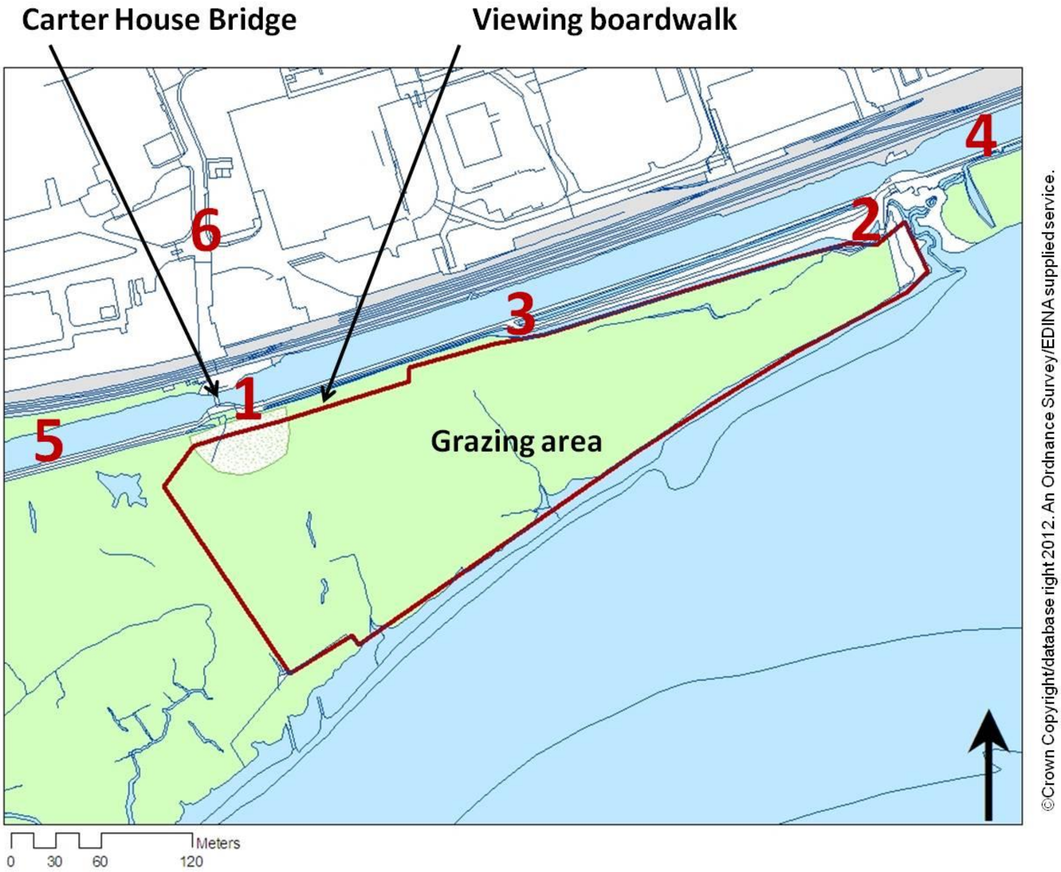

Figure 33: Visitor surveys, 1- Main viewing area, 2 – Eastern Information board, 3 – *Phragmites* board, 4 – towards Fiddlers Ferry, 5 – towards Spike Island, 6 – Tan House Lane. The Trans Pennine Trail travels through points 4 and 5. Grazing area indicated by red line, raised refuge area indicated by light green speckled area at point 1.

The view from the fence in the main viewing area, in Figure 36 encompassed the wide open vista of the estuary looking in a south-easterly direction and approximately 90% of the grazing area. This was also the access point for the boardwalk (Figure 37), which was installed in January 2011 as an added feature for visitors to access the salt marsh and grazing area for better viewing. This became a feature of later conversation as within two weeks of being installed, half of the original timber was stolen.

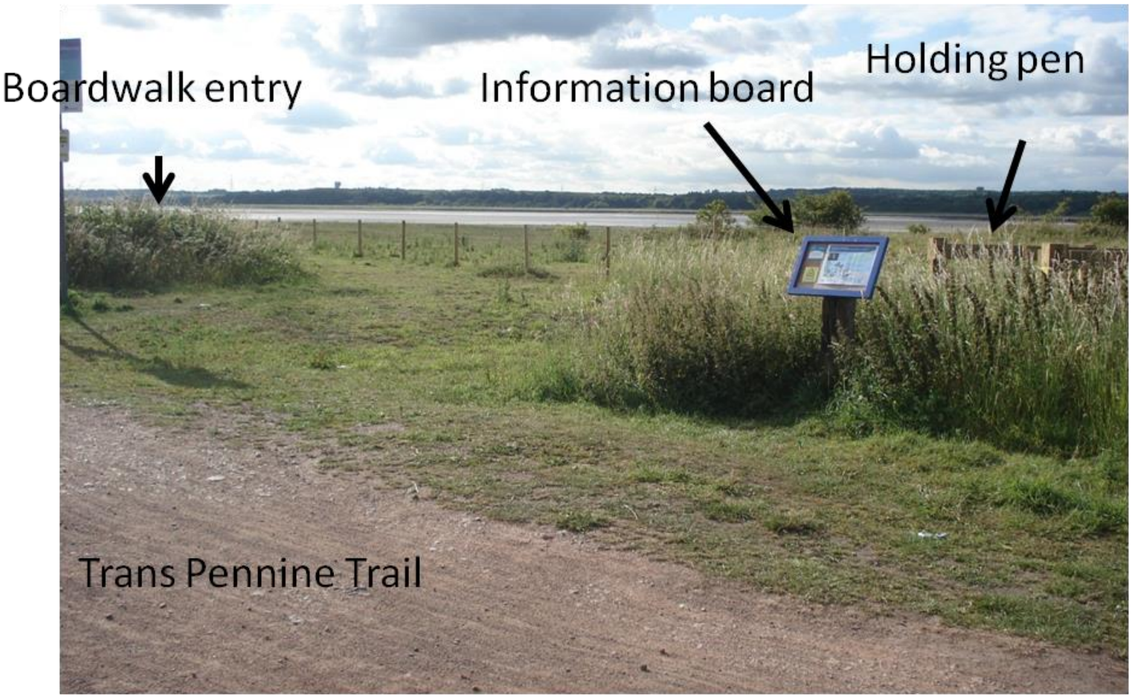

Figure 36: View of the main viewing area. This view in a south-easterly direction from Point 1 of Figure 35.

Figure 37: View of the boardwalk and grazing area. More than half of that shown here was stolen shortly after the boardwalk was installed.

Categorical observation surveys, using participant observation (Grix, 2004; Angrosino et al., 2007), were carried out to examine whether visitors stopped to look at the conservation grazing area. The observer's main task is to observe from a position or situation which is unbiased (Moser and Kalton, 1997). Using the unobtrusive observation method (*sensu* Tzoulas and James, 2010), the surveyor melded into the background as a bird watcher and recorded (making notes as a bird watcher or naturalist) users of the Trans Pennine Trail as they passed the grazing project. Visitors were ascribed categories: cyclist, dog-walker, walker, fisher, runner, bird-watcher, and motorbike. The visitor category, direction travelling to and from, and whether or not the user stopped to look at the cattle grazing project, was noted. Appendix 1 shows a data recording sheet.

Visitors were restricted to approaching the main viewing area on the Trans Pennine Trail from Fiddlers Ferry, Spike Island, or from Tan House Lane (points 4, 5, and 6 respectively in Figure 35). Figure 38, Figure 39 and Figure 40 contain photographs of the approaches from Fiddlers Ferry, Spike Island, and Tan House Lane respectively.

During the month prior to the introduction of the cattle, 12 hours of survey were carried out. On the 14 April 2011, the day after the cattle arrived, surveys with the cattle *in situ* began. During the four months the cattle were grazing, surveys took place at times to best reflect the spread of the week, including mornings and afternoons of both weekdays and weekends (Table 26).

Table 26: Times of surveys during weekdays and weekends.

Day of week	Times
Monday	08h00-10h00; 11h30-13h30
Tuesday	11h30-13h30; 13h30-15h30
Wednesday	16h00-19h00
Thursday	13h30-15h30; 16h00-19h00
Friday	08h00-10h00; 10h00-12h00
Saturday	10h00-12h00; 13h00-16h00; 16.00-17h30
Sunday	08h00-10h00; 10h00-12h00; 13h00-16h00

Surveys were discontinued or postponed in the case of persistent rain, or on one occasion when the surveyor deemed it unsafe to carry on due to personal safety issues (there were unsavoury characters nearby and no other visitors). There were 70.5 hours of surveys during this period. The cattle remained on the salt marsh until the 23 August 2011 when they were removed to more sheltered pastures and to re-join the main herd for the winter months. In the month after the cattle were removed, 21 hours of survey were carried out. The hours for each month are listed in Table 27. Dates of surveys were randomly selected (using the =RAND-between function in Microsoft ® Office Excel ® 2007) with days and times remaining the same for each week, except where new days were added to the month. Times were selected to represent a range of periods when visitors were expected to visit. It can be reasonably assumed that rain will restrict recreational use and activity in the area. If rain began during the survey and continued for longer than ten minutes, the survey was discontinued and repeated the next available weekday if a weekday survey or weekend day if the discontinued survey was a weekend day.

Table 27: Months and hours surveyed for the unobtrusive observation surveys during 2011.

	Date started	Date finished	Total hours
Prior	15/ 03/ 2011	13/ 04/ 2011	12.0
Month 1	14/ 04/ 2011	13/ 05/ 2011	12.0
Month 2	14/ 05/ 2011	13/ 06/ 2011	19.5
Month 3	14/ 06/ 2011	13/ 07/ 2011	18.0
Month 4	14/ 07/ 2011	13/ 08/ 2011	21.0
Post*	24/ 08/ 2011	24/ 09/ 2011	21.0

* The cattle were taken to sheltered pasture for the winter on the 23 August 2011.

Figure 38: View towards Fiddlers Ferry approach from the main viewing area. Grazing area to the right.

Figure 39: View towards Spike Island approach from the main viewing area

Figure 40: View towards the Tan House Lane approach from the main viewing area.

A key point of the observational data collection was the description of the behaviour of those visitors who stopped to look at the grazing area at the main viewing area. Whilst the action can be simply described by observation, the intentions cannot be determined by an unobtrusive observer; the visitor may be stopping to look at the river in the distance or may have noted another natural element such as a hovering kestrel for example. The use of the term 'stop and look' was used to describe the activity of a visitor doing this, even though it may have seemed apparently obvious the visitor was interested in the cattle; the case for arguing that visitors were stopping exclusively to look at the cattle and associated amenities would only have been accomplished by asking each visitor whether that was the case. Such an approach would have been obtrusive and therefore falls outside the method chosen. Therefore, the term 'stop and look' was used to describe the behaviour of visitors who performed this action whether or not an active interest in the grazing project may have seemed obvious to the observer.

During the primary surveys, it became apparent that many visitors were arriving from a particular direction, continuing on, and returning in the same direction from where they came (as one may expect of recreational walkers etc.). This creates an issue with visitors who approach from a particular direction, stop to look, continue on and return to their point of origin without stopping to look again, having already had a look. These visitors have then stopped to look 100% in their total visit but would be recorded as one ‘yes’ (on the first pass of the main viewing area) and one ‘no’ (on the way back) during their visit. Looking at the maps and urban nature of the area under study (as shown in Figures 9 and 10 of this document), it is clear that the closest urban area is West Bank, from the Spike Island direction. The area north of Tan House Lane has elements of brownfield and industrial units up to Halton View, and the nearest residential area from the Fiddlers Ferry direction is from west Warrington. In terms of distance, West Bank is ~ 1.5 km, Central Widnes and Halton View are ~ 1 km, and the closest part of Warrington, Penketh, is ~ 4 km. Accepting that many more visitors and regular users are arriving from the closest access points of Spike Island and Tan House Lane, this issue was investigated by examining the number of visitors from each origin that stopped to look.

To show descriptive results of the visitors’ ‘stop and look’ data, the categorical results were tabulated using pivot tables in Microsoft ® Office Excel ® 2010. Results of the following data were described:

1. The total number of visitors, the number of visitors in each category, the number in each category which stopped to look, the percentage of the total visitors that each category constituted, and the percentage of each category that stopped to look. These results were collated during the grazing period.
2. Recognising that the origin of visitors that stopped to look influenced whether a visitor stopped, the number of visitors from each origin that stopped to look, during the grazing period.
3. Stop and look behaviour by month, including the month prior to the grazing, the grazing period, and month post grazing, to examine whether the absence of cattle and period since grazing could have influenced visitor stopping behaviour.

6.2.2 Informal interviews, Content and Thematic Analysis

Part of the inductive approach previously described in the methodological approach of this document (Chapter 3.2), refers to the investigation of how humans interpret, or attach meaning to, situations (Pathirage et al., 2008). Using informal interviews, or open-ended interviews, data can be extracted from which interpretations are made to inform research (Ellen, 1988). Thematic analysis of comments extracted during informal interviews searches for themes and patterns derived from, *inter alia*, feelings, vocabulary, conversation topics, ideas, and experiences (Ellen, 1988; Aronson, 1994).

Informal interviews were carried out with visitors who stopped to look at the main viewing point and who were close enough to be amicably and amiably approached at the time. Care was taken to maintain uniformity in the initial approach to the visitor(s). This consisted of the question and statement; 'Are you interested in the cattle? I am part of the research team from the University of Salford looking at the effects of the cattle grazing.' Or 'Are you interested in the cattle, I am studying the effects of the cattle on the salt marsh.' Given that the interview maintained an informal approach (no clipboard or luminous tabard), the conversation was allowed to flow as the visitor either engaged in conversation or not. For visitors who showed an interest, it was explained that the cattle were being used as a natural conservation instrument that improve the ecology of the salt marsh as they engineered a habitat that would be favourable to avifauna and flora. Care was taken to use lay terms such as 'nature' instead of 'ecology' or 'biodiversity' and 'a mixed environment with lots of variety' instead of 'heterogeneity'. Of those with whom informal interviews took place, salient comments regarding their opinions, viewpoints, and any relevant information were transcribed for later content and thematic analysis.

Content analysis of texts and documents using a content cloud (aka. a tag cloud) has been used to visualise and summarise text within documents (Cidell, 2010; White, 2013). Content clouds have been in practical use since a 'mental map' of Paris was created by Stanley Milgram, a social scientist, who used the frequency of words used by interviewees' responses to geographical questions related to that city in the early 20th century (Crown, 2013b). Based on the frequency of words used, content clouds allow visualisation of text, to create an overview which hierarchically displays common words (White, 2013). Words within documents with a higher occurrence are presented in a larger font through a series of algorithms so that interpretation of the text is carried out in a participatory visualisation technique (Viegas et al., 2009). Content clouds are used intensively in social internet media to indicate main themes of discussion in social media interfaces (Mishra and Mishra, 2012).

Transcribed comments made by visitors were entered into a document and a tag cloud was created using the Wordle™ software (Wordle.net, 2011). Wordle™ is freely accessible on the internet and has recently been used as a tool to generate a consensus of the understanding of 'sustainability' (White, 2013). Other well-known use of tag clouds for content analysis has been carried out on United States presidential speeches (White, 2013).

Comments were first manually 'stemmed' to disengage any letters which could alter the frequency count by the Wordle™ program (Wordle.net, 2011; White, 2013), especially with possessives and plurals for example. Examples of this include 'river's' to 'river' and 'chemicals' to 'chemical'. Colloquialism was also taken into account and words removed which may skew results; the word 'like' is often used by locals as a suffix to a sentence to add weight to the statement, an example would be;

> 'Any problems with the cattle? What with it being down here and all like'*.*

The 'like' replacement occurred on six occasions. Plural form was replaced in 'chemical' to 'chemicals' and from 'cow' to 'cows' on two occasions each.

An initial overview of content clouds showed 'used' and 'to' as separate high incidence words, this overview revealed these to be part of comments pertaining to the history of the personal experiences and observations around research area, for example;

> 'There **used to** be Lapwing when the cattle were here, maybe they'll come back.*'*

The words ‘used’ and ‘to’ were joined using the tilde symbol, ‘~’, to show this phrase as one element within the comments. This occurred on twenty occasions.

For clarity and ease of visualising, the Wordle™ program automatically removes common English words including all pronouns and articles. This creates an issue where comments have naturally included pronouns to replace the cattle or another facet, examples of this were;

‘Have you seen the size of the horns on **them**?’

In this example the visitor is using the pronoun ‘them’ to refer to the cattle.

Or another example;

‘There’s a few dinners in there. **They’ve** been here all week.’ (Referring to the geese).

In this case the visitor is referring to a flock of Canada Geese, in ‘They’ve’, on the salt marsh.

The comments were individually analysed and pronouns describing nouns were replaced where necessary. In the above two examples, ‘them’ was replaced by ‘cattle’ and in the second example, ‘They’ve’ was replaced by ‘geese’ (Table 28).

Table 28: Pronouns replaced from informal interview comments with number of times this occurred.

Word	Number of pronouns replaced
cattle	55
people	5
council	3
farmer	2
geese	2
drugs	2
kids	2
birds	1
merlin	1
redshank	1
widgeon	1
corncrake	1
lapwing	1

The number of words to be displayed in the content cloud was set at 33, this figure was derived by compiling a frequency table and observing where natural breaks took place (Figure 41).This was found to be more or equal to seven occasions. This process also aided in engaging further with the text to extract themes for later thematic analysis.

Thematic analysis of interviews follows a funnelled approach to discerning themes (Blaxter et al., 2010). This begins with an overall view of the text to begin understanding themes and ideas which may be flowing from them, an initial start is made on coding text, based on the texts' common aspects, these are refined as the process goes on to a point where the results can be strongly backed up with examples from the text (Blaxter et al., 2010).

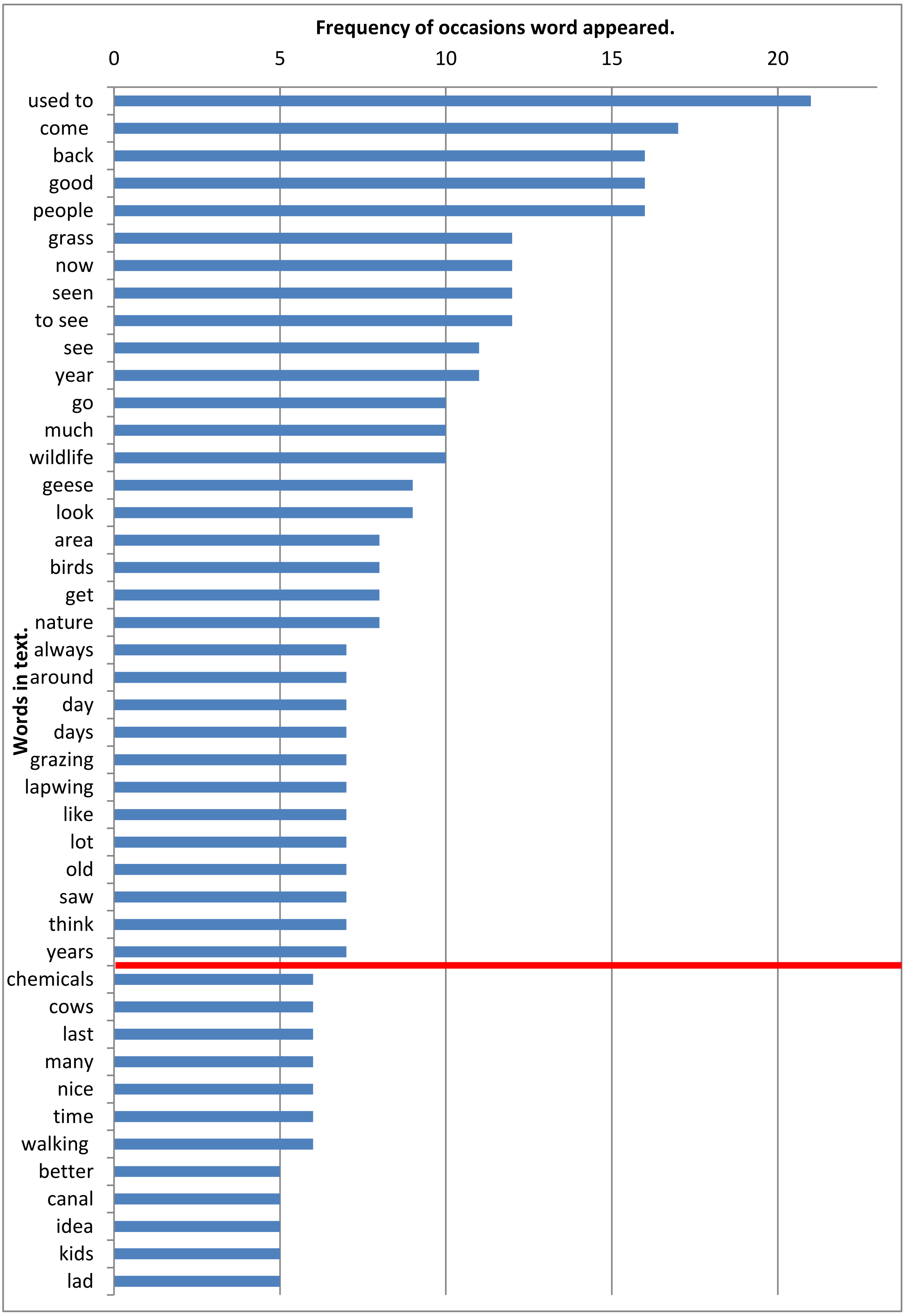

Figure 4134: Frequency of appearance of words in informal interviews. The word ‘cattle’ has been removed for clarity. The frequency of ‘cattle *n* = 101. Red line indicates the cut-off for words included in the wordle image.

Informal interviews were carried out during the grazing period of 2011 and 2012. During the grazing period of 2011 these coincided with the unobtrusive observation surveys described in Section 8.2.1. During 2012, informal interviews were carried out in a similar opportunistic manner although the categorical observations had ceased for this period as these data had generated sufficient results for the case study. The timing of the observations was determined by a random number table generated in Excel selected (using the =RAND (between) function in Microsoft ® Office Excel ® 2007). In addition to the 70.5 hours of opportunistic interviews carried out in 2011, a further 32.0 hours were completed in 2012.

The survey schedule for the 2012 grazing period was severely altered by precipitation. The Met Office reports that the summer of 2012 showed the highest level of rainfall for the UK for 100 years. For June, July and August of 2012 the total rainfall was 371mm of rain equating to 154% of the average for 1981-2010 (Crown, 2013b). For the months between April and September for the two years, the mean precipitation for the periods was 76.79mm (s.d.+/- = 29.96) and 123.58mm (s.d.+/- = 40.53) respectively; these data are displayed in tabular form in Table 29.

Table 29: Precipitation data for the summer period (to include September) for North Western England and Wales, supplied by the Met Office Hadley Centre, shown in millimetres. (Crown, 2013b).

Year	April	May	June	July	August	Sept	Total	Mean	s.d
2011 (mm)	28.0	79.9	72.7	77.7	97.1	105.3	460.7	76.78	26.96
2012 (mm)	98.8	59.5	174.4	131.9	124.3	152.6	741.5	123.58	40.53

Comments recorded following informal interview were examined to discern recurring ideas and themes (Aronson, 1994; Kim and Kaplan, 2004). These comments and interviews supplemented the observations and allowed the examination of any possible motives and feelings that visitors to the conservation area experience. Kim and Kaplan (2004) used interviews to augment observations in a similar fashion. Comments were grouped and analysed to derive main themes (Aronson, 1994). These themes were then matched with ecosystem goods related to the final ecosystem service of Environmental Settings.

As the process of thematic analysis was refined, comments were viewed using four basic questions:

1. What, if any, are the obvious underlying themes of the comment?
2. What are visitors deriving from the visit?
3. What constituent perception (benefit or detriment) is the intention from what is said?
4. What ecosystem service aspect of environmental settings is being engendered or highlighted?

The comments were viewed through these questions both from a hierarchical level (1 to 4) but also holistically so as not to limit or constrict the interpretation.

Patterns and themes were viewed from an *emic* perspective, that which seeks to understand how people understand things at the ground level, in case studies for example, as opposed to an *etic* perspective which seeks to link results to studies conducted in other environments (Angrosino et al., 2007). The *emic* perspective of the analysis was entered into with no pre-conceived ideas as to the results or with reference to other case studies.

6.3 Results

6.3.1 Visitors who Stopped to Look

During the grazing months of 2011, 70.5 hours of ethnographic surveys were carried out. In that period a total of 1890 individuals were observed, of whom 16.77% (317) stopped to look at the main focal area of the grazing project.

In examining the categories of visitors, the following results were found. Of bird watchers, 100% of the 10 bird watchers stopped to look, although this category comprised just 0.53% of the total visitors. For dog walkers, 40.54% and 39.50% of walkers stopped, these categories comprising 5.87% and 17.67% of the total visitors respectively. Cyclists were the highest number of visitors, 1256, comprising 66.46% of all visitors, although this category was the fifth in terms of those who stopped to look, 9.16%. The 42 runners comprised 2.22% of total visitors, of whom 4.76% stopped to look. None of the 35 motorbikes, 1.85% of the total, illegal users of the path, stopped to look over the grazing area. Table 30 contains these results in tabular form.

Table 30: Summary of total visitor activity at the main viewing area over 70.5 hours for the grazing period of 2011. Showing number of visitors, number who stopped to look, the percentage of the total visitors by category, and the percentage of each category that stopped to look.

Category	Total *n*	Total *n* stop and look	% of total visitors	% of category that stopped and looked
Bird watcher	10	10	0.53	100.00
Dog walker	111	45	5.87	40.54
Walker	334	132	17.67	39.52
Fisher	102	13	5.40	12.75
Cyclist	1256	115	66.46	9.16
Runner	42	2	2.22	4.76
Motorbike	35	0	1.85	0.00
Total	1890	317		16.77

For origin, the highest percentage who stopped to look were from Tan House Lane (21.28%) followed by Spike Island (18.98%), with Fiddlers Ferry having the least percentage of visitors who stopped to look (12.26%) (Table 31).

The percentage of visitors who stopped to look originating from Tan House Lane and Spike Island was higher than the total of all three (16.77%). The percentage of visitors from Fiddlers Ferry was lower than the total.

Table 31: Origin of users and associated stop and look behaviour.

Visitor Origin	Total	stop and look	% stop and look
Tan House Lane	329	70	21.28
Spike Island	827	157	18.98
Fiddlers Ferry	734	90	12.26
Total	1890	317	16.77

In examining the stop and look data by month, the results in Table 32 reveal a higher percentage of stop and look in the first two months than during the second two months. The lowest month for percentage of visitors was during the month after the cattle had been translocated to more sheltered pastures for the winter months.

Table 32: Percentage of interest shown during the survey period. During the month prior to the grazing introduction, months 1-4, and the month post grazing, when the cattle had been removed for the winter months.

Month	Hours surveyed	Total visitors	Total stop and look	% stop and look
Prior	12.0	190	24	12.63
1	12.0	212	51	24.06
2	19.5	493	124	25.15
3	18.0	538	59	10.97
4	21.0	647	83	12.82
Post	21.0	454	31	6.83
Total	103.5	2534	372	

6.3.2 Content and Thematic Analysis of Comments

6.3.2.1 Content cloud

A content cloud of all the comments recorded following informal interviews with visitors is displayed in Figure 42. By far the most common used word was 'cattle' (*n*= 101), this word was removed as this would have overshadowed the remaining words due to its prominence (*n* = 101 versus *n* = 21 for the next most popular). Prominent words are 'used to', 'great', 'people', 'see', 'good', and 'wildlife'. Noticeable too are 'nature' and 'wildlife' and nature associated words such as 'birds', 'lapwing', and 'geese'.

Figure 42: Tag cloud showing the prominence of words taken from comments during the grazing period, *n*= 33. Content cloud produced using Wordle™. Content cloud excludes ‘cattle’ (*n*= 101) as this would have obscured the other words.

6.3.2.2 Thematic analysis

There were 104 comments transcribed from informal interviews. From these, eleven ecosystem goods were elicited relating to cultural environmental settings. In total 154 ecosystem goods were elicited from the comments, indicating that, in some comments, more than one was elicited. Ecosystem goods derived from the comments are as follows.

Natural history interest

The most common was a Natural History Interest with 33 occurrences. Visitors were interested in and pointed out the elements of wildlife and natural surroundings. This ecosystem benefit was recognised when visitors made comments pertaining to aspects of nature such as birds, wildlife, or the physical effects of grazing. Examples of the Natural History Interest benefit include:

‘I’ve seen a lot more lapwing this year’

‘We need more wildlife.’

‘It’s well down that grass.’

‘It’s about time we had some nature.’

Educational benefits

The next most common ecosystem good was the value of education from the conservation grazing; there were twenty three comments from which Educational benefits could be recognised. Visitors were interested in the grazing and were inquisitive as to the reasons for grazing and the effects the grazing was expected to have. This ecosystem benefit was primarily recognised where people asked questions relating to the conservation grazing. Examples of these included:

‘The cattle are good for diversity, how many do you need? What happens when the tide comes in?’

‘How do the cattle survive with the salt?’

‘…so why are you doing this?’

‘What are the fenced off areas for?’

A Sense of History

There were 22 instances where the conservation grazing elicited or manifested comments relating to the visitor’s Sense of History, showing the area had a historical value accentuating and resonating in the grazing management. The grazing evoked memories of times before and reignited memories of when the visitor was young or when previous grazing had taken place. Examples of these included:

‘I remember the old days when this was a mess.’

‘When I was a lad.’

‘It was awful back in the day.’

‘It’s cleaned up fantastic, it used to be disgusting.’

A Sense of Ownership

The cattle grazing conjured a sense of ownership in 19 of the comments. Comments indicated that visitors took responsibility for the management or welfare of the cattle, the cattle grazing objectives, or the salt marsh. Examples of these included:

‘I always check on them when I come down.’

‘I’ve come to check on my ladies.’

‘We couldn't see them for a while, we thought they were swimming.’

‘I've been keeping an eye on them; I've seen them on the top area; they’re nice to look at when you're walking along.’

‘They should have put more cattle on, three's not coping.’

Anti-social concerns

Anti-social concerns were raised by visitors in 16 of the comments, these related to various fears or feelings that crime could be committed or had been committed in the case of vandalism of the boardwalk for example. The management raised aspects of the area that indicated people expected anti-social behaviour to occur or that it was occurring. Examples of these comments included:

‘I always check on them when I come down, it's night time when the yobbos come.’

‘This is bandit country down here, when we go fishing at Sankey Valley and tell them where we are from they say we wouldn’t go down there, that’s bandit country.’

‘They must go through some bloody grass them. I thought they'd been nicked. They'd be in the butchers the next day.’

‘They'd pinch your eyeballs while you were sleeping round here I'm telling you.’

A sense of Pure Enjoyment

There were 15 comments that indicated a pure sense of enjoyment as a result of the grazing. The management evoked physical and, or psychological well-being relating to visitors simply enjoying the grazing project. Examples include:

‘Will they stay all year? It's nice to see, they're nice to look at.’

‘Is there only three? I didn't know the cattle were back, oh it's brilliant.’

‘I was made up when the cattle arrived. That marsh looks well better now.’

‘It's perfect, we didn't even know and we live close by, it's great.’

A Sense of Place

The grazing evoked a sense of place in 13 of the visitor comments. A Sense of Place is an abstract idea that comes from a general feeling of positivity about a place or an area.

'Are there only two? It's great isn't it, it adds a touch to the area, makes it a lot more interesting.'

'It's a lot better down here than it used to be.'

'It's great to come out from the centre of town, people don't realise what's on their doorstep.'

'They're keeping it down aren't they, I saw a flock of pheasant the other day, it was very unusual. I come all the time when the weather is good.'

Health benefits

This ecosystem good was assigned to comments where visitors made explicit reference to their health at both physical and psychological levels. There were five comments where this was elicited. Examples include:

'Brilliant, dead good (the cattle), we walk everywhere, I used to have disc troubles in my back but since I started walking a massive improvement has happened.'

'Relaxation and quiet, it's just good down here now, really good.'

'I'm not sure what I get, it's just a feeling of being out here, it makes me feel good inside. I hate being stuck indoors.'

Immobilisation of pollutants

Other aspects of this ecosystem good is addressed in Chapter 8 of this thesis. Here, knowledge of the existence of pollutants in the salt marsh raised four comments surrounding this, either being connected with environmental fear or questioning the effects of the grazing. Examples include:

‘…There are very big problems with contamination after all the chemicals we put into here, I'm dreading the new bridge because it will release all the chemicals buried in there.’

‘…Before they changed the law they used to dump horrendous amounts of chemicals in here.’

‘Isn't it all toxic around here? I thought the Mersey was bringing it all down. Is it bad for the cattle?’

Recognising food supply

Visitors commented on food availability on two occasions, once in relation to Canada Geese grazing in the cattle grazing area, and once relating to the cattle themselves. These were as follows:

‘There's a few dinners in there (referring to the Canada geese), they've been there all week.’

‘I've never seen them here before; you wouldn't expect to see them down here. Man - they would look better on a plate. I didn't know they were here.’

Tragedy of the commons

The concept of open spaces being a victim of their open and free access, means detrimental results occur as more and more users exploit their openness. This theme was perhaps most starkly explored in Hardin’s (1968) seminal Tragedy of the Commons. The two examples here were:

‘…there is a conflict of interests between the fishers and the cyclists in the area because the cyclists could crash into the rods.’

‘Well, if you're wanting to get more people down here, hmmm, not sure you want more people; there'll be more cans and rubbish. It's a shame there's not more people though.’

The number of occurrences for each ecosystem good described above is displayed in Table 33 for clarity.

Table 33: Ecosystem goods and their occurrence derived from the 104 comments transcribed during the informal interview process.

Ecosystem goods	Number of instances
Natural History Interest	33
Educational benefits	23
Sense of History	22
Sense of Ownership	19
Anti-social concerns	16
Sense of Pure Enjoyment	15
Sense of Place	13
Health benefits	5
Immobilisation of pollutants	4
Recognising food supply	2
Tragedy of the Commons	2
Total	154

Table 34, contains a list of all the comments recorded with an explanation of how each ecosystem good was derived or concluded from the comment. The subject matter of each comment was examined and ecosystem goods were derived from these. The justification in the table is made clear where the words have been formatted in bold or an explanation is provided in italics where this would be more appropriate.

Table 34: Comments recorded and the ecosystem goods derived from each. The justification for the derivation or how the ecosystem good was assigned is illustrated in the comments where the text is in bold format **or a justification is written in *italics* after the comment.**

Comment Number	Comment	Ecosystem Good derived.
1	**Fabulous, excellent!**	Enjoyment
2	They're settling down nicely now. *Evidence of previously checking on cattle.*	Sense of Ownership
3	There **used to be** Lapwing when the cattle were here, maybe they'll come back.	Sense of History
3	There used to be **Lapwing** when the cattle were here, **maybe they'll come back**.	Natural History Interest
4	**The river's much cleaner now.**	Sense of place
5	That's terrible, can't have nothing. *Regarding theft of boardwalk.*	Anti-social
6	It's a lot better down here than it **used to be**.	Sense of History
6	**It's a lot better down here** than it used to be.	Sense of place
7	I loved it down here with my lurchers **when I was a kid**. It's awful the boardwalk being vandalised.	Sense of History
7	I loved it down here with my lurchers when I was a kid. **It's awful the boardwalk being vandalised.**	Anti-social
8	**Swallows are back**, motorcycles very bad as the birds are not able to nest.	Natural History Interest
8	Swallows are back, **motorcycles very bad** as the birds are not able to nest.	Anti-social
9	**I didn't even know** the cattle were here!	Sense of Ownership
10	The **lapwing** are back.	Natural History Interest
11	**What are they mate**? I thought some bloody gypsies had shoved them on there.	Educational benefits
12	Brilliant, dead good, we walk everywhere, I use to have disc troubles in my back but since I started **walking a massive improvement has happened**. I was taking loads of drugs from the doctors like but they made me drowsy, I don't take them as much no more.	Health benefits
12	**Brilliant, dead good**, we walk everywhere, I use to have disc troubles in my back but since I started walking a massive improvement has happened I was taking loads of drugs from the doctors like but they made me drowsy, I don't take them as much no more.	Enjoyment
13	It's great to come out from the centre of town, people don't realise what's on their doorstep, great	Anti-social

	to come out from the centre of town to this nature**, the anti-social** behaviour could be sorted out.	
13	**It's great to come out from the centre of town**, people don't realise what's on their doorstep, great to come out from the centre of town to this nature, the anti-social behaviour could be sorted out.	Sense of Place
14	I've come to check on **my ladies**.	Sense of Ownership
15	It's **nice** to see them here, **great** to see.	Enjoyment
16	The cattle are good for diversity, **how many do you need? What happens when the tide comes in?** I think it's great, that's why a lot of people come down here, and they're an unusual breed of cattle down here.	Educational benefits
17	**I always check on them when I come down**, it's night time when the yobbos come.	Sense of Ownership
17	I always check on them when I come down, it's night time when the **yobbos** come.	Anti-social
18	Can't you get them on Wigg Island? It's nice the way they've done it. You get plenty of wildlife over there (Wigg). **I've lived on West Bank 50 years.**	Sense of History
19	ICI stopped the cattle all **them years ago** when the owners stopped the farmer using the land. Grazing is good for wild geese because the geese like the shorter grass, wildfowling is as old as the Tudor days and people are the same now as they were then, there is a conflict of interests between the fishers and the cyclists in the area because the cyclists could crash into the rods, the whole area is getting redeveloped there will be recycling plant close to the Carter House bridge, the Saffil plant makes your throat burn some days. There is an unexploded bomb in the slurry next to the power station**, it was dropped** during WW2 and it was never recovered. Back in the day **kids used to** swim in the river and then clean themselves off in the canal, both were equally disgusting. Before ICI there was the United Alkali Company. **Back in the day** there was no nature in the area like there is now.	Sense of History
19	ICI stopped the cattle all them years ago when the owners stopped the farmer using the land. **Grazing is good for wild geese because the geese like the shorter grass**, wildfowling is as old as the Tudor days and people are the same now as they were then, there is a conflict of interests between the fishers and the cyclists in the area because the cyclists could crash into the rods, the whole area is getting redeveloped there will be recycling plant	Educational benefits

	close to the Carter House bridge, the Saffil plant makes your throat burn some days. There is an unexploded bomb in the slurry next to the power station, it was dropped during WW2 and it was never recovered. Back in the day kids used to swim in the river and then clean themselves off in the canal, both were equally disgusting. Before ICI there was the United Alkali Company. Back in the day there was no nature in the area like there is now.	
19	ICI stopped the cattle all them years ago when the owners stopped the farmer using the land. Grazing is good for wild geese because the geese like the shorter grass, wildfowling is as old as the Tudor days and people are the same now as they were then, **there is a conflict of interests between the fishers and the cyclists** in the area because the cyclists could crash into the rods, the whole area is getting redeveloped there will be recycling plant close to the Carter House bridge, the Saffil plant makes your throat burn some days. There is an unexploded bomb in the slurry next to the power station, it was dropped during WW2 and it was never recovered. Back in the day kids used to swim in the river and then clean themselves off in the canal, both were equally disgusting. Before ICI there was the United Alkali Company. Back in the day there was no nature in the area like there is now.	Tragedy of the Commons
19	ICI stopped the cattle all them years ago when the owners stopped the farmer using the land. Grazing is good for wild geese because the geese like the shorter grass, wildfowling is as old as the Tudor days and people are the same now as they were then, there is a conflict of interests between the fishers and the cyclists in the area because the cyclists could crash into the rods, the whole area is getting redeveloped there will be recycling plant close to the Carter House bridge, the Saffil plant makes your throat burn some days. There is an unexploded bomb in the slurry next to the power station, it was dropped during WW2 and it was never recovered. Back in the day kids used to swim in the river and then clean themselves off in the canal, both were equally disgusting. Before ICI there was the United Alkali Company**. Back in the day there was no nature in the area like there is now.**	Natural History Interest
20	**When I was a lad**, at the beginning of each school year there was always at least one desk empty because a child who had been swimming was	Sense of History

	drowned in the Mersey.	
21	**Are they still there**? *Looking for the previously seen cattle.*	Sense of place
22	**How do the cattle survive with the salt?**	Educational benefits
23	The **lapwings** are picking up.	Natural History Interest
24	Have you seen the size of the horns on them? They come down with bales of hay. **They should** put the cattle on the other side of the fence so they can eat the grass on that side.	Sense of Ownership
25	**We saw an otter** along the canal, it was great to see, I'm responsible for the chemical mess around here and it's all coming back. It was awful back in the day It's great to see it like this now.	Natural History Interest
25	We saw an otter along the canal, it was great to see, I'm responsible for the chemical mess around here and it's all coming back**. It was awful back in the day** It's great to see it like this now.	Sense of History
26	I'm amazed how much they've eaten, you can see by looking at the fenced area how much grass they've eaten. We **used to** bring heffers here. It was common grazing land back then.	Sense of History
26	I'm amazed how much they've eaten, **you can see by looking at the fenced area how much grass they've eaten**. We used to bring heffers here. It was common grazing land back then.	Educational benefits
27	**I could only see five but the one was hidden**. I've been meaning to ask Ste to go and clean up the mess in there because the cattle will hurt themselves walking around at night. I've seen all sorts of mammals, mink, weasel, stoat, ferret.	Sense of Ownership
27	I could only see five but the one was hidden. I've been meaning to ask Ste to go and clean up the mess in there because the cattle will hurt themselves walking around at night**. I've seen all sorts of mammals, mink, weasel, stoat, ferret**.	Natural History Interest
28	Looks like every other cow I've seen **so why are you doing this?**	Educational benefits
29	I've seen **a lot more lapwing** this year.	Natural History Interest
30	**I remember the old days** when this was a mess, I was speaking to a birder at Pickerings who was saying the grazing will bring back groppers (Grasshopper warbler, *Locustella naevia*) and then Merlin will follow as that's what they eat.	Sense of History
30	I remember the old days when this was a mess, I was speaking to a birder at Pickerings who was	Natural History Interest

	saying **the grazing will bring back groppers and then Merlin will follow** as that's what they eat.	
31	**Is this university research?** I think it's brilliant, brings back my geography research days; this area attracts a wide array of people.	Educational benefits
32	They're dead good, they look really gentle, **will they stay all the seasons? Aren't they too hot?** They're huge.	Educational benefits
33	**Lots of mammals in the canal including an otter** in the last two months, the bridge is a great idea. It's a pity about the social problems around the canal with the littering fishermen.	Natural History Interest
33	Lots of mammals in the canal including an otter in the last two months, the bridge is a great idea. It's a pity about the **social problems around the canal with the littering fishermen.**	Anti-social
34	They're looking great and keeping that grass down, **there was an owl** on Saturday and someone picking up cow dung and taking it home.	Natural History Interest
35	**I've been keeping an eye on them**; I've seen them on the top area they're nice to look at when you're walking along.	Sense of Ownership
36	They're keeping it down aren't they, **I saw a flock of pheasant** the other day, it was very unusual. I come all the time when the weather is good.	Natural History Interest
36	They're keeping it down aren't they, I saw a flock of pheasant the other day, it was very unusual. **I come all the time when the weather is good.**	Sense of place
37	Cattle are looking good, **we couldn't see them for a while**, we thought they were swimming.	Sense of Ownership
38	There **used to be** railway sleepers for their food in the old days, they've settled in alright.	Sense of History
39	It's perfect**, we didn't even know and we live close by**, it's great.	Sense of place
39	**It's perfect**, we didn't even know and we live close by**, it's great**.	Enjoyment
40	There **used to be** cattle here, they must drink salty water, you don't get many birds, **in the old days** the cattle used to graze all the way up to the big ditch, there's not many birds anymore some are extinct.	Sense of History
40	There used to be cattle here, they must drink salty water, you don't get many birds, in the old days the cattle used to graze all the way up to the big ditch, there's **not many birds anymore, some are extinct**.	Natural History Interest
41	It's wonderful, **the place would be poorer without the cattle**, people need to get their kids down here instead of them all sitting around watching telly, we	Sense of place

	think it's good.	
41	It's wonderful, the place would be poorer without the cattle**, people need to get their kids down here** instead of them all sitting around watching telly, we think it's good.	Educational benefits
42	**There's a few dinners in there** (referring to the Canada geese), they've been there all week.	Recognising food supply
43	**The geese** won't be there after the shooting starts, they want culling all them geese.	Natural History Interest
44	I've never seen them here before; you wouldn't expect to see them down here. Man **- they would look better on a plate**. I didn't know they were here.	Recognising food supply
45	Loads of **geese, they like to graze the salt marsh**, shame about the motorbikes.	Natural History Interest
45	Loads of geese, they like to graze the salt marsh, **shame about the motorbikes**.	Anti-social
46	It's great to see, **what happens with the tide? How long will they be here?**	Educational benefits
47	Good to see, **we need more wildlife**, I used to work here, do you have to check on them? How many, I like coming down here.	Natural History Interest
47	Good to see, we need more wildlife**, I used to work here**, do you have to check on them? How many, I like coming down here.	Sense of History
47	Good to see, we need more wildlife, I used to work here, **do you have to check on them?** How many, I like coming down here.	Educational benefits
48	It's cleaned up fantastic, what with all the chemicals **it used to be** disgusting around here with dead cats and dogs in the canal, there are very big problems with contamination after all the chemicals we put into here, I'm dreading the new bridge because it will release all the chemicals buried in there.	Sense of History
48	It's cleaned up fantastic, what with all the chemicals it used to be disgusting around here with dead cats and dogs in the canal, there are very big problems with contamination after all the chemicals we put into here, I'm dreading the new bridge because it will release **all the chemicals buried in there**.	Immobilisation of pollutants
49	Are they bulls, it's about time **we had some nature**.	Natural History Interest
50	**What are the fenced off areas for?**	Educational benefits
51	I've seen a **lot more wildlife** since the cattle have arrived.	Natural History Interest
52	It looks great, walking gets my chest going as **I have a breathing disorder**.	Health benefits

52	It looks great, walking gets my chest going as **I have a breathing disorder**.	Enjoyment
53	**It's well down that grass.**	Natural History Interest
54	**What's the story here then?** I worked at Liverpool university when we took core samples from the salt marsh.	Educational benefits
55	Really interesting, will you graze the other area? **I remember the transporter bridge.**	Sense of History
55	**Really interesting, will you graze the other area?** I remember the transporter bridge.	Educational benefits
56	**I always check there's six,** there's a stoat, the cattle are grazing a lot, the grass is getting shorter, good to see no motorbikes, how long is the project? How long are the cattle there? The motorbikes are wrecking the nature, I come here from Halton View.	Sense of Ownership
56	I always check there's six, there's a stoat, the cattle are grazing a lot, the grass is getting shorter, good to see no motorbikes, **how long is the project?** How long are the cattle there? The motorbikes are wrecking the nature, I come here from Halton View.	Educational benefits
56	I always check there's six, there's a stoat, the cattle are grazing a lot, the grass is getting shorter, good to see no motorbikes, how long is the project? How long are the cattle there? **The motorbikes are wrecking the nature**, I come here from Halton View.	Anti-social
57	**We come down here often and saw them last weekend and couldn't believe it,** how long are they here for? What's the idea?	Sense of place
57	We come down here often and saw them last weekend and couldn't believe it, **how long are they here for? What's the idea?**	Educational benefits
58	**Will they stay all year?** It's nice to see, they're nice to look at.	Educational benefits
58	Will they stay all year? **It's nice to see, they're nice to look at.**	Enjoyment
59	**Oh look there's bulls!**	Enjoyment
60	Fantastic, what's the idea? **Great for birds.** Are there bird hides?	Natural History Interest
60	Fantastic, **what's the idea?** Great for birds. Are there bird hides?	Educational
61	I'm not sure what I get, it's just a feeling of being out here, **it makes me feel good outside**. I hate being stuck indoors.	Health benefits
61	I'm not sure what I get**, it's just a feeling of being out here**, it makes me feel good inside. I hate being	Enjoyment

	stuck indoors.	
62	**This is bandit country down here**, when we go fishing at Sankey Valley and tell them where we are from they say we wouldn't go down there like, that's bandit country.	Anti-social
63	People come here for dog walking and fishing but they don't come here for the nature. **They go to Sankey Park for the nice walks and that**.	Anti-social
63	**People come here for dog walking** and fishing but they don't come here for the nature. They go to Sankey Park for the nice walks and that.	Health benefits
64	I tell you what though**; they aren't half bringing the wildlife back**. Up near Pickering's there's loads of lapwing. I think it's doing well the grazing. I don't think three would make a difference but I mean a few more would. How about them posts? What are they telling you? **It's getting better here for the wildlife** but the fishing kids leave a mess everywhere. There used to be loads of sheep and cattle when I was a lad. We used to chase the cows away so we could pick mushrooms for the pot. I was always up and down the marsh when I was a lad. I think it's brilliant they're back. It's definitely good for people to look at. They need to sort out the young people that damage the place. It's surprising the pheasants you get here now.	Natural History Interest
64	I tell you what though; they aren't half bringing the wildlife back. Up near Pickering's there's loads of lapwing. I think it's doing well the grazing. I don't think three would make a difference but I mean a few more would. **How about them posts? What are they telling you?** It's getting better here for the wildlife but the fishing kids leave a mess everywhere. There used to be loads of sheep and cattle when I was a lad. We used to chase the cows away so we could pick mushrooms for the pot. I was always up and down the marsh when I was a lad. I think it's brilliant they're back. It's definitely good for people to look at. They need to sort out the young people that damage the place. It's surprising the pheasants you get here now.	Educational benefits
64	I tell you what though; they aren't half bringing the wildlife back. Up near Pickering's there's loads of lapwing. I think it's doing well the grazing. I don't think three would make a difference but I mean a few more would. How about them posts? What are they telling you? It's getting better here for the wildlife but the fishing kids leave a mess	Sense of History

	everywhere. There used to be loads of sheep and cattle when I was a lad**. We used to chase the cows away so we could pick mushrooms for the pot. I was always up and down the marsh when I was a lad.** I think it's brilliant they're back. It's definitely good for people to look at. They need to sort out the young people that damage the place. It's surprising the pheasants you get here now.	
65	We weren't sure how many there were. **Get them other three cows back** we'll be alright.	Sense of Ownership
66	**Where** are they from? **Why** are they here? **Where** do they go in winter?	Educational benefits
67	**Where** are they now? **What** would happen if you went in there? **What** would happen if someone shot one? **What** happens when they eat too much grass? **What** are those birds that hover? **What** are those birds? **What** are the ones that just glide?	Educational benefits
68	**They were right up here the other day**, up against the fence.	Sense of Ownership
69	The cattle aren't spending much time at the top end. The cattle have been coming up to the high bit lately. *Taking notice of cattle's movements.*	Sense of Ownership
70	Is there only three? I didn't know the cattle were back, **oh it's brilliant.**	Enjoyment
70	Is there only three? **I didn't know the cattle were back,** oh it's brilliant.	Sense of place
71	I don't see the cattle often, **I always have a look**. Is there much more wildlife this year like? Before they changed the law they used to dump horrendous amounts of chemicals in here.	Sense of Ownership
71	I don't see the cattle often, I always have a look. **Is there much more wildlife this year like?** Before they changed the law they used to dump horrendous amounts of chemicals in here.	Natural History Interest
71	I don't see the cattle often, I always have a look. Is there much more wildlife this year like? Before they changed the law they used to dump **horrendous amounts of chemicals** in here.	Immobilisation of pollutants
72	**I've been to the other side but couldn't see the cattle**. It doesn't look any greener than before.	Sense of Ownership
73	We saw the cattle from the other side so we came down. **It's wonderful to see them.** You don't have to come far. We were here last year looking at the other six cattle.	Enjoyment
73	We saw the cattle from the other side so we came down. It's wonderful to see them. **You don't have to come far**. We were here last year looking at the other six cattle.	Sense of Place

74	What did the cattle do last year? So there's lots of knock on effects from the grazing. Are you not worried about what happens at night? Are you a ranger? **So, the grazing opens it up then?** Fascinating how it works. We come from Liverpool. Where do they go in winter?	Educational benefits
75	It looks great doesn't it? **I always have a look** and see where they are.	Sense of Ownership
75	**It looks great** doesn't it? I always have a look and see where they are.	Enjoyment
76	How many this year? **It's great to see them** isn't it?	Enjoyment
77	I really enjoy coming down here to see them and all that, **it's peaceful down here**.	Sense of Place
78	That's boss isn't it? It's great seeing **all the wildlife** and all that. See how everything works together? Any problems with the cattle, what with it being down here and all? Can't have nothing.	Natural History Interest
78	That's boss isn't it? It's great seeing all the wildlife and all that. See how everything works together? Any problems with the cattle, what with it being down here and all like? **Can't have nothing.**	Anti-social
79	Ten years ago it was awful because of the chemical works, it's great how they're doing it now. **There's otters here now**.	Natural History Interest
79	**Ten years ago** it was awful because of the chemical works; it's great how they're doing it now. There's otters here now.	Sense of History
80	You can't really see them, oh there they are on the edge. Well, **we love walking down here.** We just saw a kingfisher, it was great.	Enjoyment
81	Yep, **there's short eared owl here**, You can definitely see what the cattle have done like. **There's more birds**. When we were young we used to walk up the salt marsh. When the cattle were here back in the old days there were lots of partridges which you don't see nowadays.	Natural History Interest
81	Yep, there's short eared owl here, You can definitely see what the cattle have done. There's more birds. **When we were young** we used to walk up the salt marsh. When the cattle were here back in the old days there were lots of partridges which you don't see nowadays.	Sense of History
82	**They should put more cattle on**, there's only three this year, they aren't getting through the grass much. They spend a lot of time at the top end.	Sense of Ownership
83	Who's done that? Pillocks, can't have nothing. *In reaction to vandalism.*	Anti-social

84	Well, if you're wanting to get more people down here, hmmm, **not sure you want more people;** there'll be more cans and rubbish. It's a shame there's not more people though.	Tragedy of the Commons
85	They were up here last time. There never used to be any fishermen along here. **We used to play on the marsh when we were young**. Nature is a wonderful thing. There's more wildlife down here than there ever was. There was none of this when they brought the sugar barges **when I was a lad**.	Sense of History
85	They were up here last time. There never used to be any fishermen along here. We used to play on the marsh when we were young. **Nature is a wonderful thing**. There's more wildlife down here than there ever was. There was none of this when they brought the sugar barges when I was a lad.	Natural History Interest
86	**I was made up when the cattle arrived**. That marsh looks well better now. There are three pairs of Harris hawks up near the power station. Corn crake used to nest here, we used to steal their eggs. It's much better for wildlife. There's goshawk now here, a male and female. The council has no idea what they're doing, they keep on making decisions about everything but they haven't got a clue that lot. The cattle bring more skylark, there's been no skylark for years but there was some this year.	Enjoyment
86	I was made up when the cattle arrived. That marsh looks well better now. There are three pairs of Harris hawks up near the power station. Corn crake used to nest here, we used to steal their eggs. It's much better for wildlife. There's goshawk now here, a male and female. **The council has no idea what they're doing**, they keep on making decisions about everything but they haven't got a clue that lot. The cattle bring more skylark, there's been no skylark for years but there was some this year.	Sense of Ownership
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86	I was made up when the cattle arrived. That marsh looks well better now. There are three pairs of Harris	Sense of History

	hawks up near the power station. Corn crake used to nest here, **we used to steal their eggs**. It's much better for wildlife. There's goshawk now here, a male and female. The council has no idea what they're doing, they keep on making decisions about everything but they haven't got a clue that lot. The cattle bring more skylark, there's been no skylark for years but there was some this year.	
87	Are there only two? It's great isn't it, **it adds a touch to the area, makes it a lot more interesting.**	Sense of Place
88	Bloody-hell have you seen them cows? They **used to** be here years ago. I didn't know they were here. **When I was a lad** we used to hunt around here. **This is my old hunting ground.**	Sense of History
89	They must go through some bloody grass them. **I thought they'd been nicked**. They'd be in the butchers the next day.	Anti-social
90	I saw them right up against the fence the other day, real close they were, and they were at the very end down there and all. *Visitor is keeping an eye on them.*	Sense of Ownership
91	**Relaxation** and quiet, **it's just good down here** now, really good.	Health benefits
92	No, I've not seen them for a while. That's smashing news the **lapwing are breeding.**	Natural History Interest
93	**Years ago**, there was loads of Frisian cattle here but you never saw anyone down here**, it was a tip in those days**. I've not seen as much wildlife this year as there was last year.	Sense of History
93	Years ago, there was loads of Frisian cattle here but you never saw anyone down here, it was a tip in those days. I've not seen as much **wildlife** this year as there was last year.	Natural History Interest
94	**They'd pinch your eyeballs** while you were sleeping round here I'm telling you.	Anti-social
95	Was there **any problems with contamination**? It wouldn't surprise me if there was; it's a dirty old town.	Immobilisation of pollutants
96	**It's good if it keeps the grass down.**	Natural History Interest
97	**Isn't it all toxic around here**? I thought the Mersey was bringing it all down. Is it bad for the cattle? Can you eat them? What happens if you go in there? Would they chase you?	Immobilisation of pollutants
97	Isn't it all toxic around here**?** I thought the Mersey was bringing it all down. Is it bad for the cattle**?** Can you eat them**?** What happens if you go in there**?** Would they chase you**?**	Educational Benefits

98	Whenever I come down here with my lad they're always up here. *Knowledge of where they are while walking son.*	Enjoyment
99	**Years ago there used to be** cattle up that end (west) and sheep down here. The grass had tufts, there were tons of breeding redshank. They like the open spaces so they can see predators. The cattle don't go in the water. The cattle don't go into the water pools so the redshank can feed there. Have you seen all the widgeon? They're only meant to be here in October.	Sense of History
99	Years ago there used to be cattle up that end (west) and sheep down here. The grass had tufts, there were **tons of breeding redshank**. They like the open spaces so they can see predators. The cattle don't go in the water. The cattle don't go into the water pools so the redshank can feed there. Have you seen all the widgeon? They're only meant to be here in October.	Natural History Interest
100	**They should have put more cattle on**, three's not coping.	Sense of Ownership
101	They were shooting here yesterday. They shouldn't call it a nature reserve if they shoot ducks. **I've seen a lot of stoats and weasels lately**. They should have the cattle all over the marsh.	Natural History Interest
102	Are they alright? **We used to worry** about them being down here.	Anti-social
103	I **think it's a great idea** but I worry that some of the other locals could come down here at night and cause them harm. I work over at the factory there.	Enjoyment
103	I think it's a great idea but **I worry that some of the other locals could come down here at night and cause them harm**. I work over at the factory there.	Anti-social
104	I don't bring the dogs down here that often but it's good if it's **doing some good for nature like.**	Natural History Interest

6.4 Discussion

The purpose of the ethnographic study reported in this chapter was to identify and examine the effects of the conservation grazing on cultural ecosystem services; this was done using unobtrusive observations and informal interviews.

The results of the unobtrusive observations found that, after bird watchers, walkers and dog-walkers had the highest percentage rate of stop and look for visitors to the area while the cattle were *in situ*. Although cyclists were overwhelmingly the highest in terms of numbers, their stop and rate percentage was much lower than the bird watchers, walkers and dog-walkers.

Although all bird watchers who came into the area stopped to look, they form a low percentage of the number of visitors, indicating that this area is not a local hotspot for birders. Generally, estuaries and salt marshes are known as significant areas for bird watching (Everard, 2009; Natural England, 2009b; Tiziana Luisetti et al., 2011; UK-NEA, 2011d). The absence of conservation management to benefit bird species could explain the fact that there were very few bird watchers as visitors to the area. This indicates that by ‘voting with their feet’ the bird assemblage is not of ecosystem service value for recreational local birders watchers. Future observational studies may indicate higher levels of stop and look behaviour as the conservation grazing continues, with longer term effects on the bird assemblage especially, thereby attracting more bird watchers to the research site as a result of increased and more diverse bird use and knowledge thereof.

Walkers and dog-walkers’ behaviour is perhaps the most significant here; unlike cyclists it is much easier simply to stop and look at areas of interest. Walkers and dog-walkers are more likely to be out for relaxing pursuits whereas cyclists may be en route to a specified destination, between Widnes and Warrington for example.

The results of the stop and look data from the place of origin indicate a high likelihood that more people stopped to look during their individual visits. If it is accepted that more visitors are originating from the local areas of Widnes, as opposed to the much further Warrington, then stop and look behaviour was higher than when the point of origin was factored, indicating that the grazing affected behaviour to stop and look at the cattle, as a feature of the landscape.

Over the six months of unobtrusive observational surveys, the incidence of stop and look was much higher during the first two months of the grazing than the month prior to the introduction of the cattle. This strongly suggests they affected behaviour of visitors; visitors were stopping at a higher percentage when the cattle arrived because a new (and perhaps interesting) feature had been introduced. During the second two months of the grazing, the lower levels of stop and look behaviour is highly suggestive of, and could be related to the fact that regular users of the area were familiar with the presence of the cattle, and interest had been satisfied during the first two months. Although not measured using the current method, anecdotal evidence by the surveyor suggests a high proportion of visitors were regular users from local areas. Proximity to local greenspace is known to be a factor in how often visitors walk (Bell et al., 2008), especially in men, but not women due to safety concerns (Foster et al., 2004). The low level of stop and look percentage of visitors in the month after the cattle were removed is in line with the month prior to the introduction of the cattle and supports the contention that they had a material effect on visitors' behaviour.

The tag cloud and thematic analysis has provided new analytical data regarding the environmental settings. Not shown in the tag cloud, the highest incidence word, 'cattle' was unsurprising as they were the main focal point. The term 'used to' showed that the Sense of History was being evoked. Positive words, 'good', great' indicate the grazing project was highly appreciated by visitors, although it could be argued those who stopped are a self-selecting group of people who would positively associate the grazing objectives, there were no specific complaints to the grazing *per se*, although concerns were raised. Words associated with nature featured strongly, in particular the word 'wildlife', showing that a generalisation of what this word consists of (birds, mammals and other animals) was often mentioned.

The informal interviews provided what can be described as a pure data set, not biased by a formal expectation from either interviewer or visitor. Natural

History Interest featured the strongest; this could be strongly influenced by the survey method in explaining aims of the research by the surveyor. Nevertheless, many respondents made comments supporting the effects of grazing and making their own observations, indicating they took an active interest in local nature and made their own, informal observations. The ecosystem service value of Natural History Interest and the value of nature to people were accentuated.

Educational benefits in landscapes were described in formal terms previously by Natural England, (2009a) where bush craft courses, for example, were given in natural environment settings. The thematic analysis showed that there is a strong thirst for learning and the educational benefits of why the management was taking place with questions such as ‘why’, ‘what’, and, ‘how’ the grazing project and the cattle affected the environment and or how they were managed

Previously, in formal, structured interviews of respondents’ attitudes to landscapes, a Sense of History was attached to places where historical artefacts, ruins, or buildings were found (Natural England, 2009b). The sense of history in the research here was mostly highly personal to each interviewee when pointing out aspects of the salt marsh and close area, ‘When I was a lad...’ was a common theme and brings about an evocative feeling that the interviewee is reliving a personal experience that is unable to be experienced in that place by others who do not have a history there. The grazing management evoked a Sense of History in the visitors because there is a historical record of grazing in the area, the management choice here reignites memories for local visitors and the Sense of History ecosystem good was enhanced.

The thematic analysis further revealed a Sense of Ownership was engendered by the grazing. Promoting a sense of ownership has been reported to be a contributor to reduction in crime levels within communities in the UK (Bacon et al., 2010). The respondents in the current study were primarily concerned with the management of the area, the welfare of the cattle, and how best this could be done. This Sense of Ownership has strong links to pride, a positive reinforcement mechanism where land management is concerned. A Sense of Ownership as an ecosystem good received from the area promotes the future secured management of the area because ownership of land creates instilled obligations for the protection and efficient use of the land (Barthel et al., 2005).

Anti-social concerns were raised and highlighted the fear that interviewees' held regarding the local area and the welfare of the cattle. This ecosystem good can be seen closely, and adversely related to a Sense of Ownership, the more visitors enjoy a Sense of Ownership, more the fear and concern could be raised of anti-social concerns. 'I always check on them when I come down, it's night time when the yobbos come.' is a good example of this; the visitor has a Sense of Ownership, but fears the anti-social behaviour of night time vandalism and theft. Unmanaged and over-grown areas are known to induce fear of crime (Tzoulas, et al., 2007) although the area in the current study is clearly now under management; this concern may be reduced as the grazing management continues over the years. The anti-social behaviour experienced through theft and vandalism (of the boardwalk and a sign) increased this aspect for visitors.

A Sense of Pure Enjoyment was elicited from those comments where this was highly obvious. This ecosystem good can be closely related to a Sense of Place and Health Benefits as these are intrinsically related to positive emotions. A Sense of Place was described as a local area that was, or contributed to, the landscape, especially at a local level (Natural England, 2009b). Maas et al., (2006) found that perceived green space had a positive effect on mental health on urban residents. The Health Benefits derived from the informal interview analysis showed that people were receiving this from experiencing the local area. The low number of examples in the current study (five out of 104 comments) is highly mitigated by the fact that although respondents were in no way prompted to reveal any health benefits, they were provided through general discussion of the grazing project. A view of greenspace has strong links to physical health (Maller et al., 2006). Available green space has been shown to extend the lives of people living in cities in Japan (Takano et al., 2002) and has been found to have strong associations with moderating stress levels in adults (Payne et al., 1998). Contact with nature has been experimentally shown to increase happiness (Nisbet and Zelenski, 2011). These received ecosystem goods contribute positively to visitors' lives.

The Immobilisation of Pollutants ecosystem good has been described with empirical evidence in the current study (Chapter 8). However, the comments reveal a knowledge base and a fear related to the history and the future of the research area. Although there were only six instances, it is interesting that this is a concern of users' because the immobilisation of pollutants is relatively understudied in the ecosystem service approach. That this is a significant concern for the visitors to Widnes Warth concerning the current store of pollutants there, suggests this is a significant area of research to be expanded within the ecosystem service approach.

Hardin's (1968) seminal Tragedy of the Commons was written with great foresight, and 45 years later remains relevant to the provision of ecosystem services. The expanding population and straining of resources influenced two comments from visitors. This indicates that as management in greenspace is expanded, people have concerns about sharing these resources where they may come for their own personal health and enjoyment.

The unobtrusive nature of the survey restricts certain data from being collected, for example how often people visit the site or where they come from. This would have added to the dataset but removed the 'naturalness' of visitors behaviour. If visitors know they are being surveyed, their behaviour may have changed to what they think is correct and to match the survey aims (Angrosino et al., 2007). The survey method used here provides 'pure' data, where it can be accepted that the results are not skewed by peoples' perceptions of what their behaviour 'should be' under surveyed conditions. Formal surveys with structured interviews change the perception of those being observed and interviewed where subjects may provide answers they deem to be correct. The methods used here don't allow this to happen although a system of structured interviews may add to the knowledge of the extensive use of the area.

Participant observation creates difficulties in presenting an objective view because this method is highly individual to each observer (Moser and Kalton, 1997). In the current study this was overcome by maintaining the same methods and the same interviewer for each person who was being interviewed.

This approach to valuing the management of an area and the effect on cultural ecosystem services has shown strong evidence that these intrinsic services are being enhanced using a conservation improvement method. This necessity was recognised as a key element of valuing ecosystem services by the UK's DEFRA (Defra, 2007).

7. Ecosystem Service 3 - Carbon storage - Sediment

7.1 Introduction to the Chapter

Carbon storage was found to be a relevant ecosystem service in the current study as detailed in Chapter 4.5. Carbon stored in soils and sediment regulates the atmosphere by retaining carbon in terrestrial habitats as opposed to it being present in the atmosphere (Chan et al., 2006). Carbon stored in soils accounts for between 66% and 75% of the global terrestrial carbon store (Frogbrook et al., 2009). Land use changes can affect the carbon storage capacity of soils (Batjes, 1996; Eigenbrod et al., 2011) and has resulted in large emissions of carbon dioxide into the atmosphere (Chan et al., 2006). Salt marsh sediment is known to be a significant store of carbon within regulating services (as described by the UK-NEA, 2011) and was taken into consideration as a potential benefit in a managed realignment study in Poole, UK (Defra, 2007).

In terrestrial grazed grasslands, carbon storage is dependent on the intensity of grazing (light, moderate, or high) (Ford et al., 2012b). In a review of differing land management methods (fertilisation, earthworm introduction, irrigation, managing grazing intensities, introduction of grasses and legumes), Conant et al. (2000) found an increase in carbon storage in all cases.

Economic metrics in calculating the value of the ecosystem service of carbon stored have been calculated by Andrews et al. (2006), Tol et al. (2000), and Pearce (2003). Monetary values are estimated by avoided costs. These are financial costs incurred in the absence of the ecosystem service (TEEB, 2010c). In carbon storage, the cost is calculated where the cost of carbon dioxide released into the atmosphere and damaging the environment is avoided by storing the carbon (Pearce, 2003). In a study investigating the managed retreat of an estuary to create an area of salt marsh on the Humber Estuary in the north-east of England, Andrews et al. (2006) used avoided costs of carbon dioxide released into the atmosphere to estimate the financial value of carbon stored in future scenarios.

Balvanera et al. (2006) identified the need for further quantification and experimental developments for carbon storage within the ecosystem service framework. Large scale data sets (Egoh et al., 2008; Eigenbrod et al., 2009) have been used to quantify carbon storage metrics but these did not consist of detailed, specific land use. The stable condition of sediment can be linked with carbon storage, a final ecosystem service within regulating services of the UK-NEA (Figure 6). This chapter will address Objective 3: to examine whether ecosystem services are increased by conservation management methods, in this instance - the carbon storage ecosystem service. This relates to the third and fourth parts of Daily et al.'s (2009) framework (Figure 8) wherein the services and the value, or change in the ecosystem service output, is translated through empirical research and investigation.

7.2 Method

A wide ranging survey of soil in the UK showed carbon stock to be a useful and relevant measure of carbon storage as an ecosystem service (Emmet et al., 2010). The simple and effective methods in Emmet et al. (2010) have been successfully used to show carbon stock rates in an area of grazed versus ungrazed salt marsh in the north-west of England (Ford et al., 2012b).

Three components are required in order to calculate the soil carbon stock: a known volume of soil, soil bulk density, and loss on ignition value as a percentage (Ford et al., 2012b; Moore and Hunt, 2012). A previous example of this was in a survey of carbon sequestration in storm-water wetlands and ponds; Moore and Hunt, (2012) measured percentage of total carbon in sediment using a standard method of loss on ignition at 550°C in an oven to gain a measurement of carbon as $g\ C\ m^3$ (Duke et al., 2012).

7.2.1 Field collection

Soil sample extraction took place, following the second year of grazing, in the autumn of 2012. This was to allow the maximum period in the current study for soil to display any effects related to the grazing regime in relation to carbon stored. In line with Emmet et al. (2010), samples were extracted to a depth of

15 cm. This depth was selected as a commonly used measurement because land use changes are most reflected in the top horizon of the soil. Commercially available hard plastic tubing (internal diameter of the tubes was 34 mm) was cut to a length of 15 cm and the tubes were used to extract the samples. Samples were extracted within the 6 exclosures and the paired quadrats which had been established on site to examine changes in vegetation (described in detail in Section 5.3.1); these locations provided a random representative spread across the grazing area (Figure 43). In the field, the tubes were pushed into ground so the top of the tube was flush with ground level and then carefully removed to include all sediment. Where necessary, a sharp knife was used to cut through thick roots which impeded the tubes' intrusion into the soil. The samples were kept in the tubes and then transferred to labelled bags for transport to the laboratory at the University of Salford.

For the grazing area, a sample was extracted at each of the twelve permanent quadrats and in each of the six exclosures two samples were extracted. Therefore, 12 samples were obtained from the grazing treatment and 12 from the ungrazed area.

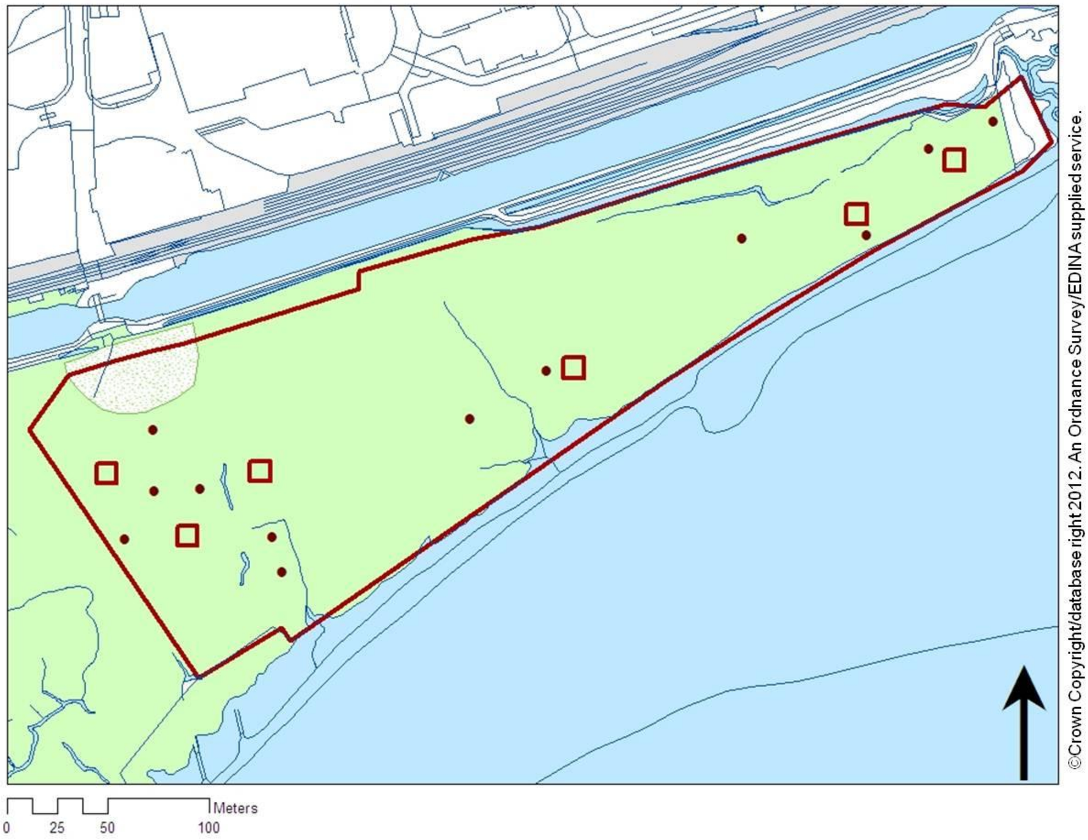

Figure 43: Position of extraction locations for carbon storage samples. Squares represent 10 m × 10 m exclosures, dots represent extant quadrats used in vegetation surveys. Two samples were extracted within each exclosure. The red line indicates the edge of the grazing area.

Calculating carbon stock

The calculation of carbon stock is determined using three components:

1. Bulk density in kg ha^{-1} to 15 cm
2. Organic content calculated by % loss on ignition
3. A conversion factor to ascertain true carbon, established during the 2007 Countryside Survey (Emmet et al., 2010) which translates organic content derived from loss on ignition to true carbon content, the conversion factor being 0.55.

7.2.2 Bulk Density

The first parameter to establish was bulk density. Bulk density is used to convert organic carbon percentage (found by loss on ignition) by weight to content by volume (Batjes, 1996; Emmet et al., 2010). Methods to determine bulk density follow Rowell (1994). The sediment was extruded from the tubes and placed in pre-weighed, pyrex glassware. The sediment was oven dried for at least 48 hours at 105°C; oven dry sediment and glassware were then weighed to ascertain the dry weight of the sediment. Calculation of bulk density (BD) (Rowell, 1994; Emmet et al., 2010) was as per equations 2, 3 and 4 (mass was measured in grammes):

$$Dry\ weight\ = (mass\ \ Pyrex\ glass\ ware + oven\ dry\ sediment)\ \ - mass\ Pyrex\ glass\ ware$$ **Equation 2**

- $Volume\ of\ cyclinder\ = \pi r^2 L$ **Equation 3**

  Where $\pi = 3.14$, *r* = radius of plastic tubing in cm (1.72 cm), *L* = length of tube (15cm)
- Therefore the volume of cylinder $= \pi \times 1.72^2\ \times 15\ \ =\ 139.34\ \ \mathrm{cm3}$
- $BD\ g\ cm^3 = \frac{dry\ weight\ (g)}{volume\ of\ cylinder\ (cm^3)}$ **Equation 4**

To extrapolate this to bulk density in kg ha^{-1} to 15 cm the following conversion was performed (1 ha = 10 000 m^2):

Equation 5

$$BD\ g\ m^3 = BD\ g\ cm^3 \times 100\ 000$$

Equation 6

$$BD\ kg\ m^2 = \frac{BD\ g\ m^3}{1000}$$

Equation 7

$$BD\ kg\ ha^{-1}\ to\ 1m\ depth = BD\ kg\ m^2 \times 10\ 000$$

$$BD\ kg\ ha^{-1}\ to\ 15\ cm = BD\ kg\ ha^{-1}\ to\ 1m\ depth \times \frac{1}{0.15}$$ **Equation 8**

7.2.3 Loss on Ignition

Methods to establish organic matter content in soil and salt marsh sediment using loss of organic matter due to ignition are varied (Olsen et al., 2011; Ford et al., 2012a). Rowell (1994) provides a standard method (Gwynne, 2004) which is used here.

Approximately 5g of soil was placed in crucibles and oven dried overnight at 105°C, these were then placed in desiccators to allow the samples to cool to room temperature without absorbing atmospheric moisture; following this, mass in grammes was recorded using a Mettler® AT400 scale. Oven dried sediments were placed in a Carbolite ® OAF 11/1 furnace at 500°C for four hours then re-weighed after being cooled in desiccators for at least 30 minutes. Loss on ignition results are expressed relative to oven dried soil (Rowell, 1994). The difference between the mass of the oven dried samples and the post furnace samples provides loss on ignition. To calculate the loss on ignition and determine the grams of organic carbon content per 100 g, Rowell's (1994) equation (Equation 9) was used:

% Loss on ignition =

$$(100\ x\ (mass\ of\ oven\ fried\ soil - mass\ of\ ignited\ soil))/(mass\ of\ oven\ dried\ soil)$$ **Equation 9**

7.2.4 Tonnes of carbon stock per hectare to 15 cm

To calculate carbon stock in the grazed and ungrazed sediment, Equations 10 and 11 were used to arrive at tonnes of carbon stock per hectare at a 15 cm depth.

Proportion of carbon per grammes = **Equation 10**

$$(percentage\ loss\ on\ ignition\ x\ carbon\ conversion\ factor)/100$$

The equation to establish soil carbon stock as t C ha^{-1} is as follows:

t C ha^{-1} = **Equation 11**

$$(Bulk\ density\ (kg\ per\ ha\ to\ 15\ cm)\ \ x\ \ True\ carbon\ per\ gram)/1000$$

The results of the equations above are displayed in tabular form in Appendices 2 and 3.

Statistical analysis

The differences in bulk density and loss on ignition were not tested for statistical significance as these values were only required to input into the equation to determine the carbon stock in tonnes per hectare.

The carbon stock in tonnes per hectare data showed no significant departure from a normal distribution (Kolmogorov Smirnov, $P > 0.15$) and the variances could be considered equal (F-test, test statistic = 0.47, $P > 0.05$). Therefore, to establish if there was a significant difference in the carbon stock between the grazed and ungrazed area, a Student unpaired T-test assuming equal variances was performed between the two treatments (Dytham, 2003) to test the null hypothesis:

H_0 - There is no significant difference between the grazed and ungrazed areas in terms of mean carbon stock of tons per hectare to 15cm.

Statistical analyses were performed using Minitab ® 15.1.0.0 © 2006.

7.2.5 Avoided costs

Using metrics derived from the Kyoto Protocol and established by Pearce (2003) and Tol et al. (2000), the managed realignment of salt marsh research described by Andrews et al. (2006) used a value per tonne of £7, set in 2000. To calculate the value per tonne in 2012, this figure was adjusted for inflation using Gross Domestic Product (GDP) deflators of the UK Government (Crown, 2013a). Following Andrews et al. (2006) and Thompson (2009), the effects of price changes due to inflation (and therefore to establish the value of carbon at the current time) were adjusted using the following formula:

Equation 12

$$Target\ year\ value\ per\ tonne = base\ year\ value\ \ x\ \left(\frac{target\ year\ index\ number}{base\ year\ index\ number}\right)$$

Where the target year in the current research is 2012, when the samples were extracted. The base year is the original year from which the price is adjusted, in the current research this is 2000 - using Tol et al. (2000). The index numbers were derived from data available from the UK Government's Her Majesty's Treasury (Crown, 2013a). Index numbers were obtained from publically available data via Office of National Statistics and calculated using the published consumer price index (Crown, 2013a). Index numbers show the effects of inflation over a period of time and allow the calculation of prices at their historical cost.

Having established the current value of carbon stored per tonne using Equation 12, the value of avoided costs through carbon stored in the grazed and ungrazed samples was established using the following formula:

$$Avoided\ cost = 2012\ carbon\ value \times mean\ tonnes\ of\ carbon\ per\ hectare\ stored\ to\ 15cm$$

Equation 13

7.3 Results

7.3.1 Bulk density results in cm^3

The bulk density of the sediment in the grazed area was higher than the ungrazed (grazed mean = 0.79 , +/- s.d = 0.059; ungrazed = 0.68, +/- s.d = 0.052) (Figure 44).

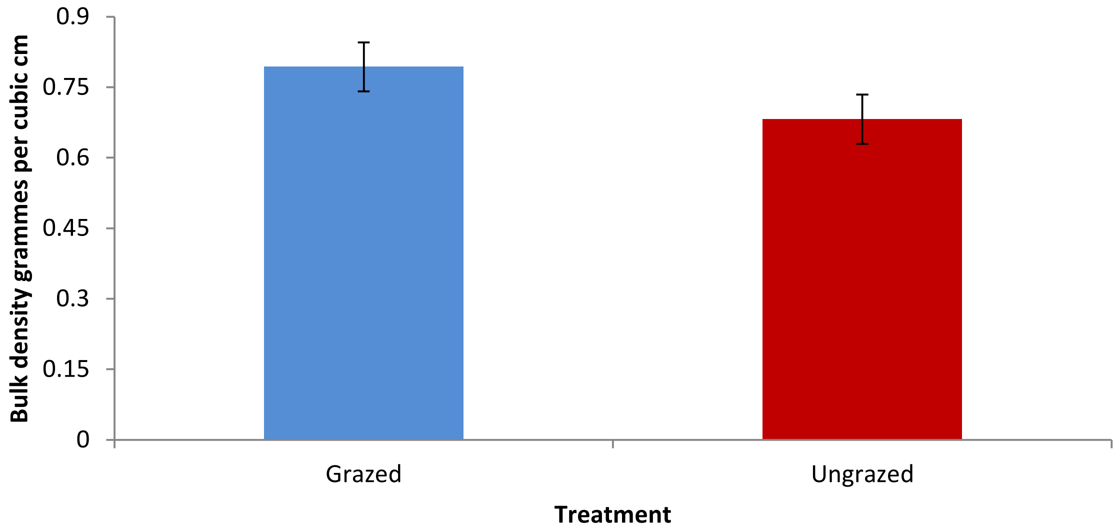

Figure 44: Mean bulk density of sediment in cubic centimetres (+/- s.d) between the grazing area permanent quadrats and the exclosure quadrats.

7.3.2 Loss on ignition

Mean loss on ignition of organic carbon for the grazed area was slightly higher than the ungrazed samples (grazed = 13.21 %, +/- s.d = 2.26; ungrazed = 13.184 %, +/- s.d = 2.41). (Figure 45).

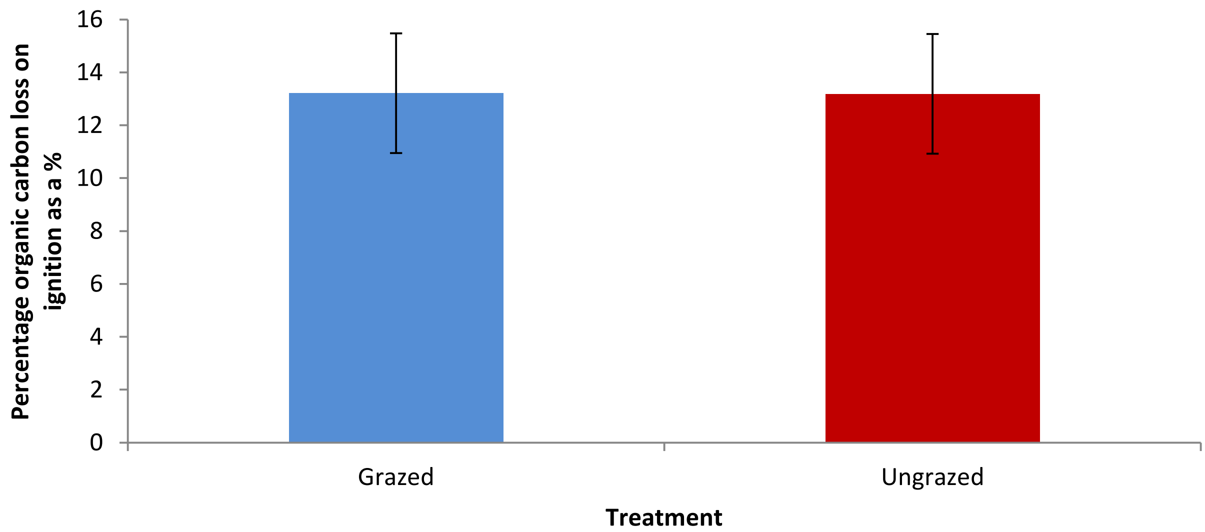

Figure 4535: Mean percentage (+/- s.d) loss on ignition as a percentage between the grazing area permanent quadrats and the exclosure quadrats.

7.3.3 Tonnes of carbon stock per hectare to 15 cm

The difference in the mean tonnes of carbon stock per hectare to 15cm was found to be not significantly different between the grazed and the ungrazed treatments (Student unpaired T-test, t = 1.68, df = 22, P=0.106). Mean tonnes of carbon per hectare to 15cm depth in the grazed area (mean = 85.12 T C ha^{-1} 15 cm; s.d.+/- = 12.5) was greater than the mean tonnes of carbon per hectare to 15cm in the ungrazed samples (mean = 74.39 T C ha^{-1}, s.d.+/- = 18.2) (Figure 46).

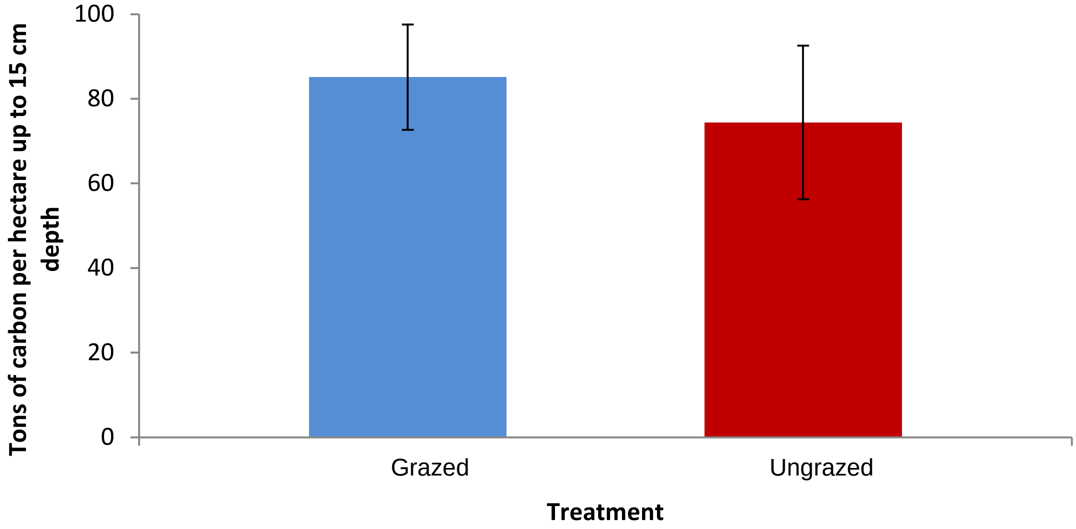

Figure 4636: Mean tonnes of carbon stock per hectare to 15 cm depth between the grazing area permanent quadrats and the exclosure quadrats. Error bars indicate standard deviation around the mean.

7.3.4 Avoided costs

Using the equation (Equation 12) provided by Thompson (2009), the avoided cost for storing carbon in the grazed and the ungrazed areas, is as follows:

$$\textit{Current value of carbon per tonne} = 7\ x\ \left(\frac{100}{77.313}\right)$$

$$= £9.05\ t^{-1}$$

Using this figure and multiplying it by the mean tonnes of carbon stored per hectare (Equation 11), the current study provides avoided costs of carbon dioxide emissions of £770.69 ha^{-1} (s.d.+/- = £113.13) and £673.27 ha^{-1} (s.d.+/- = £164.71) for the grazed and ungrazed areas respectively (Figure 47).

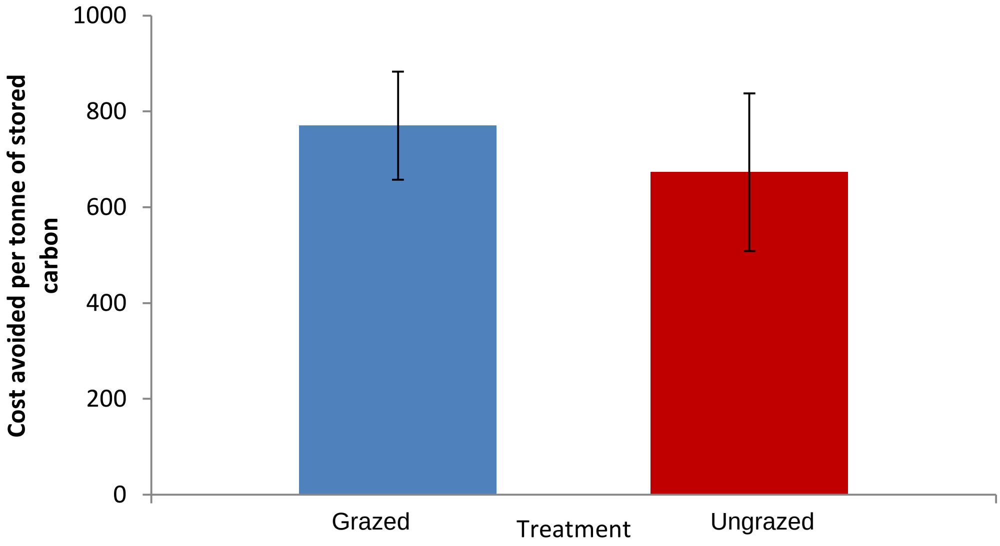

Figure 4737: Avoided costs in pounds sterling of carbon dioxide emissions for the grazed and ungrazed treatments. Error bars indicate standard deviation around the mean.

7.4 Discussion

The main purpose of the research reported in this chapter was to establish whether the soil in the grazed regime area had a different carbon stock than the ungrazed treatment after two years of grazing and to establish whether the ecosystem service of carbon storage was affected in any way. The null hypothesis, that there was no significant difference, could not be rejected in this case. Whilst the differences were not significantly different, the grazed area nevertheless had a higher carbon store in terms of tonnes per hectare to 15 cm, than the ungrazed area. The avoided costs of carbon emissions was higher in the grazed samples, indicating that grazing provided more value as an ecosystem service. An advantage of the measuring of carbon stock as an ecosystem service is the relative ease at which the study is carried out. This gives an empirical, quantifiable measure to be provided to planners, policy makers, and land owners to aid decision making on land management for ecosystem services.

There are potential limitations to the current study. Few studies have measured carbon storage capacity after only two years of management; this could be a reason that the difference was not significantly different, although the means showed grazing as having a higher amount of tonnes per carbon stored.

Previous empirical research in the north-west of England showed that after *circa* 40 years of grazing, the grazed area contained significantly higher levels of carbon stored in the soil (Ford et al., 2012b). It is, therefore, possible that the absence of a significant difference in the current study could be due to the fact that the grazing regime was in place for a much shorter period, in the study reported by Ford et al. (2012b) the vegetation communities had become different within the study.

It should be further noted that in the UK-NEA, peat is treated as the main national carbon store, simply by the order of magnitude that peat persists in the terrestrial sphere (Emmet et al., 2010). Although the salt marsh sediment is clearly not peat, salt marsh has been shown to sequester and store higher levels of carbon than peat (Chmura et al., 2003).

Land use changes resulting in higher emissions of carbon into the atmosphere found by other research (Batjes, 1996; Eigenbrod et al., 2009) has not been found in the current research. Clearly the research would benefit from more time and continuation of the sampling regime, should the current grazing practice continue. While the ecosystem service of carbon storage has not been shown to be negatively affected there has been a slight increase.

8. Ecosystem Service 4 - Immobilisation of Pollutants

8.1 Introduction to the Chapter

In estuaries, salt marshes can be significant sinks of heavy metals, other inorganic and organic chemicals derived from a range of sources including atmospheric deposition, and upstream and adjacent industrial processes (Adam, 1990; Gwynne, 2004). These chemicals are known as contaminants as they are not expected in this habitat; if and when the contaminants become harmful to the environment, they are known as pollutants (Kebbekus and Mitra, 1998). As heavy metal contaminants enter an estuarine environment they are absorbed onto sediment particles, a proportion of which will be stored as sedimentary deposits. Stored in the sedimentary particles, heavy metals are potentially less harmful than if they were in a suspended state in the water column (Environment Agency, 2005). Andrews et al., (2008) estimate that hundreds of tonnes of heavy metals would have been stored in sediments in the Humber Estuary during the 1960s, rather than being released into the water column; thus the sediments provide an ecosystem service. Immobilisation of pollutants was identified as a relevant ecosystem service with the in Chapter 4.5 which established contextual ecosystem services for the study reported in this thesis. The investigation into the change in the ecosystem service is within the third and fourth components of Daily et al.'s (2009) model (Figure 8).

Widnes Warth is known to contain harmful levels of inorganic contaminants below the surface layer, due to historical industrialisation in the Upper Mersey Estuary and the region as a whole (Fox et al., 1999; Fox et al., 2001; HBC, 2008a). Figure 4838 is a historical photograph depicting the extent of this legacy.

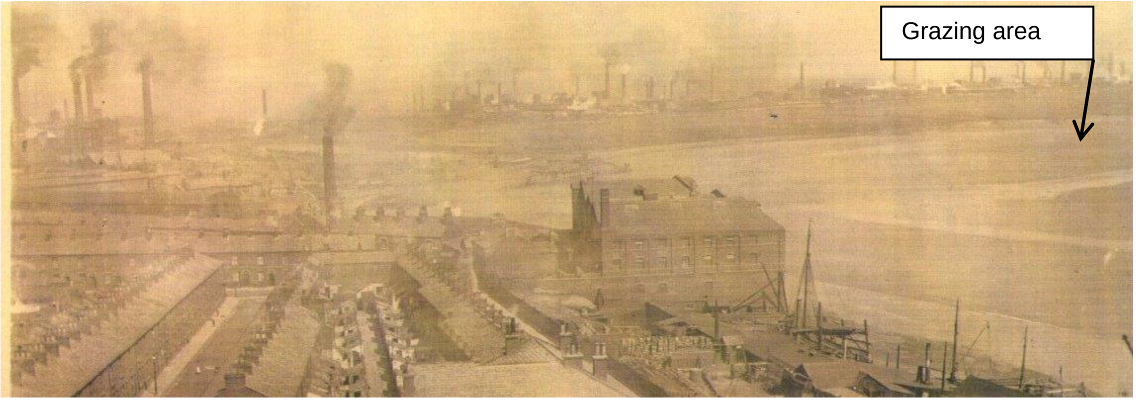

Figure 4838: Widnes Warth photograph, *circa* 1880's showing the factories and atmospheric effects of the chemical factories. The area to the right of the image is the northern bank of the Mersey River. The picture is taken in a north-westerly direction from Spike Island across the northern edge of the river. Copyright Halton Borough Council.

Previous studies show that in a stable form a non-significant risk is posed as the heavy metals are bound with organic matter and are present in an insoluble form (HBC, 2008a).

This ecosystem service of the immobilisation of pollutants serves two functions:

1. Prevents heavy metals being washed into the river with knock-on effects for fish, other aquatic species, and trophic levels, and/ or

2. Prevents dust being raised in the wind, potentially causing health problems for recreational users and passers-by.

Cattle disturb the sediments through tramping with their hooves or tearing the vegetation out during grazing (Jensen, 1985; Doody, 2008). The current study investigates the effects, if any, of introducing cattle to the salt marsh and if there are any attendant knock on effects from any resuspension of these heavy metals.

8.2 Method

8.2.1 Field collection

In order to establish the baseline sedimentary characteristics in relation to heavy metals a series of sediment samples were extracted in August 2010 and January 2011. To examine any effects of the cattle grazing on the grazed area, a series of repeated measures sampling (Dytham, 2003) was carried out. Repeated measure sampling (also known as matched samples) is a method for 'before, during and after' sampling (Dytham, 2003). A series of surface samples were extracted in November 2010, prior to the commencement of the grazing. Data from these tests were compared with paired sets after one year, and after two years of grazing to examine the effect, if any, of cattle grazing on the level of heavy metals on the surface of the salt marsh. Five transects of five samples were randomly placed across the salt marsh at equal distances apart (using a random number table generated using the =RAND function in Microsoft ® Office Excel ® 2007). The equal spacing, from front to back was selected so that the front to back spatial aggregation of the area was served within the randomness of the placement of the five transects. The end points of each transect were extracted at least 1.5 m away from either the edge of the salt marsh or the fence line so that any edge effect could be discounted (for example cattle frequently using the fence line as a walk way).These points were marked using a Garmin Etrex® global positioning system (error +/- 4 m) in order that the same position could be sampled in the following visits (Figure 49).

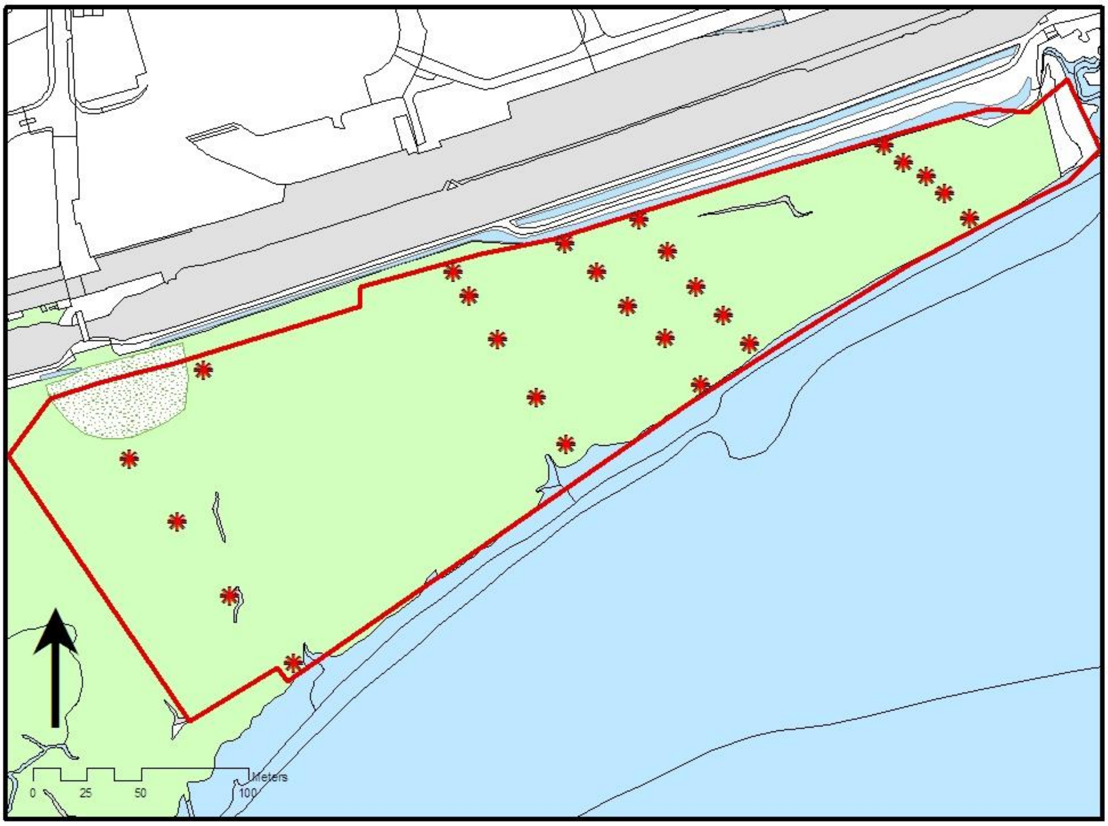

Figure 49: Image of grazing area showing location of sampling for the surface samples in red asterisks. The red outline represents the border of the grazing area. The light green speckled section in the west of the grazing area is the raised area.

At each point, three surface samples (roughly half a trowel) were taken within 60 cm of each other, to create a representative sample of the sampling point. The samples were transferred to labelled plastic bags for transport to the sediment laboratory at the University of Salford.

8.2.2 Laboratory processing of samples

Samples were dried in a fan drying oven set at 40 °C for at least 48 hours or until the samples were dry, ascertained visually and by gently breaking up the sample to ascertain that the sample was brittle with no visual evidence of any moisture. Preparation of samples consisted of homogenisation to best offer a representative sample of the sample point. A pestle and mortar was used to grind the sediments to a fine texture. To create a sub-sample for analysis a sample splitting method, coning and quartering, was used (Gerlach et al., 2002). In coning and quartering, the ground samples were poured onto a piece of paper, forming a cone. A thin piece of metal was driven through the apex of the cone and dragged approximately 1cm so that the cone was split into two. The cone was then rotated 90° and the piece of metal was driven through the cone again, thereby creating four quarters. The first and third quadrant was removed for the analysis. This new sample was subject to coning and quartering twice more (Gerlach et al., 2002) prior to being bagged and available for analysis. Sediment not used was archived and stored.

Analysis was performed using a Thermo Scientific Niton XL3t XRF Analyser®, a wavelength dispersive field portable X-ray fluorescence (FPXRF). Although other laboratory techniques, for example Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES), are available, FPXRF is a relatively quick method to provide effective results (Melquiades and Appolini, 2004; Kilbride et al., 2006). FPXRF has previously been used to provide analysis of contaminant metals, on Humber Estuarine salt marsh (Andrews et al., 2008).

FPXRF produces an array of heavy metal results. For the purposes of the current study, lead and arsenic were selected as valuable and reliable proxies for the elements within the area because they are known to be stable in sediment samples (Dudka and Miller, 1999) and salt marsh in particular (Cave et al., 2005), the Widnes Warth salt marsh had previously been found to be a stable marsh, without major historical perturbation (Fox et al., 1999). The results were validated with a certified reference material and the error margin within the samples during measurement was less than 10%. To validate the results, Chinese stream sediment (NCS DC 73308) was used as a certified reference material, the reference material was tested prior to each measuring session as the first sample to be measured after the FPXRF was switched on. The mean of the recovery rates throughout the sampling process was 93.39% (s.d.+/- = 3.89) for lead and 98.3% (s.d.+/- = 3.67) for arsenic. Appendix 4 contains a table of the recovery results for validation purposes.

8.2.3 Descriptive and Statistical analysis

Boxplots have been previously described in Section 5.3.1 of this thesis and are used here to display the results.

The data were subjected to normality tests using a Kolmogorov-Smirnov test (Dytham, 2003). Results to the normality tests are summarised below in Table 35. All statistical tests were performed using Minitab ® 15.1.0.0 © 2006.

Table 35: Results of statistical tests to examine departure from normal distribution for measurements of lead and arsenic across the grazing area.

Sample	Test statistic	Level of significance
Lead Prior	0.191	0.03
Lead Year 1	0.147	>0.15
Lead Year 2	0.136	>0.15
Lead Prior Log N	0.229	<0.01
Arsenic Prior	0.435	<0.01
Arsenic Year 1	0.370	<0.01
Arsenic Year 2	0.148	>0.15
Arsenic Prior Log N	0.324	<0.10
Arsenic Year 1 Log N	0.245	<0.01

The data for lead in the Prior data set did not conform to normality using both the raw and Log transformed data as the results précis shows in Table 35. A similar result for normality exists with the arsenic data for the Prior and the Year 1 data sets.

In the absence of the data conforming to a normal distribution, the non-parametric test Wilcoxon Signed Ranks test was performed for both heavy metals so that the median of the Prior sample was compared with the end of year 1, and end of year 2 samples individually. Wilcoxon Signed Ranks tests subtract the control from the matched measures and tests whether the median of the differences is significantly different from zero (Dytham, 2003). The null hypotheses of the statistical tests for lead and arsenic were as follows:

- H_0 - The median of the differences between the Prior and Year 1 samples was not significantly different from zero.
- H_0 - The median of the differences between the Prior and Year 2 samples was not significantly different from zero.

8.3 Results

Examining the change in lead levels at the surface during the duration of the grazing.

Between the Prior and Year 1 levels of lead, the median of the differences was not significantly different from zero (Wilcoxon Signed Ranks test, W = 170, P= 0.851). The median lead prior to the introduction of grazing was 134.97 µg g^{-1} (1st quartile = 128.23 µg g^{-1}, 3rd quartile = 146.99 µg g^{-1}). The median lead level for the end of the first year of grazing was 139.70 µg g^{-1} (1st quartile = 121.46 µg g^{-1}, 3rd quartile = 147.57 µg g^{-1}). The boxplot (Figure 50) shows this in graphical form.

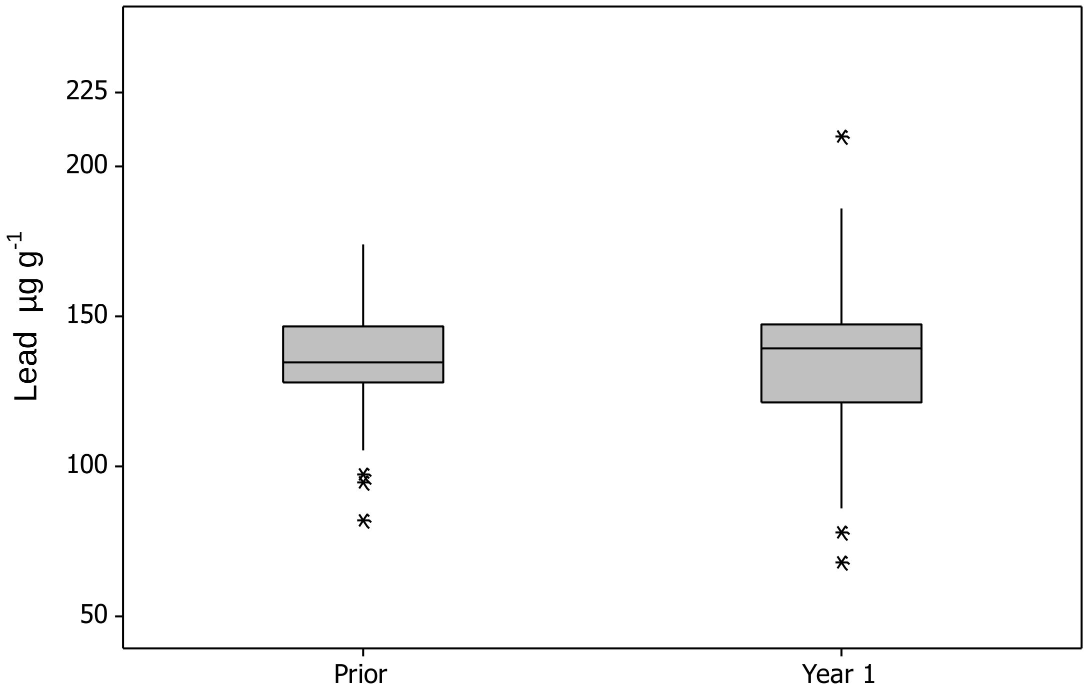

Figure 50: Boxplot showing lead recorded prior to and at the end of the first year of grazing. Asterisks refer to outliers in the data set. *N* = 25 for each series.

Between the Prior and Year 2 levels of lead, the median of the differences were not significantly different from zero (Wilcoxon Signed Ranks test, W = 196, P= 0.375). The median lead prior to the introduction of grazing was

134.97 µg g^{-1} (1^{st} quartile = 127.38 µg g^{-1}, 3^{rd} quartile = 147.64 µg g^{-1}). The median lead level for the end of the second year was 137.49 µg g^{-1} (1^{st} quartile = 109.66 µg g^{-1}, 3^{rd} quartile = 145.42 µg g^{-1}). Figure 5139 shows this result in a boxplot.

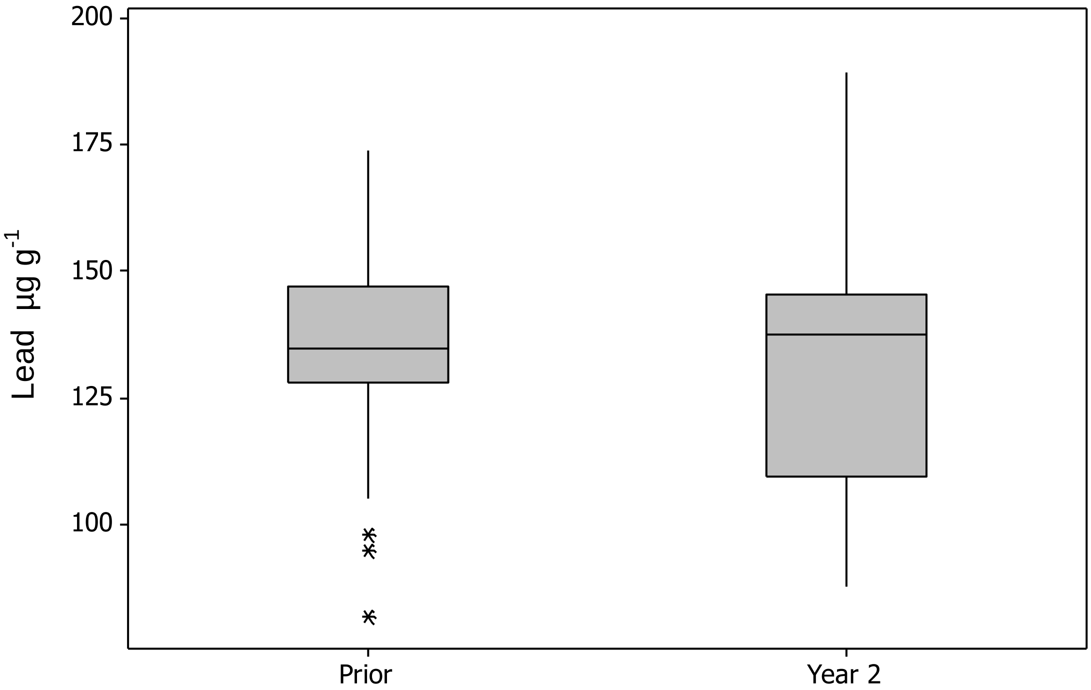

Figure 5139: Boxplot showing lead recorded prior to the implementation of the grazing management and at the end of the second year of grazing. Asterisks refer to outliers in the data set. *N* = 25 for each series.

Change in arsenic levels at the surface during the duration of the grazing.

Between the Prior and Year 1 levels of arsenic, the median of the differences were not significantly different from zero (Wilcoxon Signed Ranks test, W = 165, P= 0.957). The median arsenic prior to the introduction of grazing was 27.99 µg g^{-1} (1^{st} quartile = 24.72 µg g^{-1}, 3^{rd} quartile = 29.8 µg g^{-1}). The median arsenic level for the end of the first year was 26.82 µg g^{-1} (1^{st} quartile = 23.84 µg g^{-1}, 3^{rd} quartile = 31.52 µg g^{-1}). The spread of the results is illustrated in boxplot form (Figure 2).

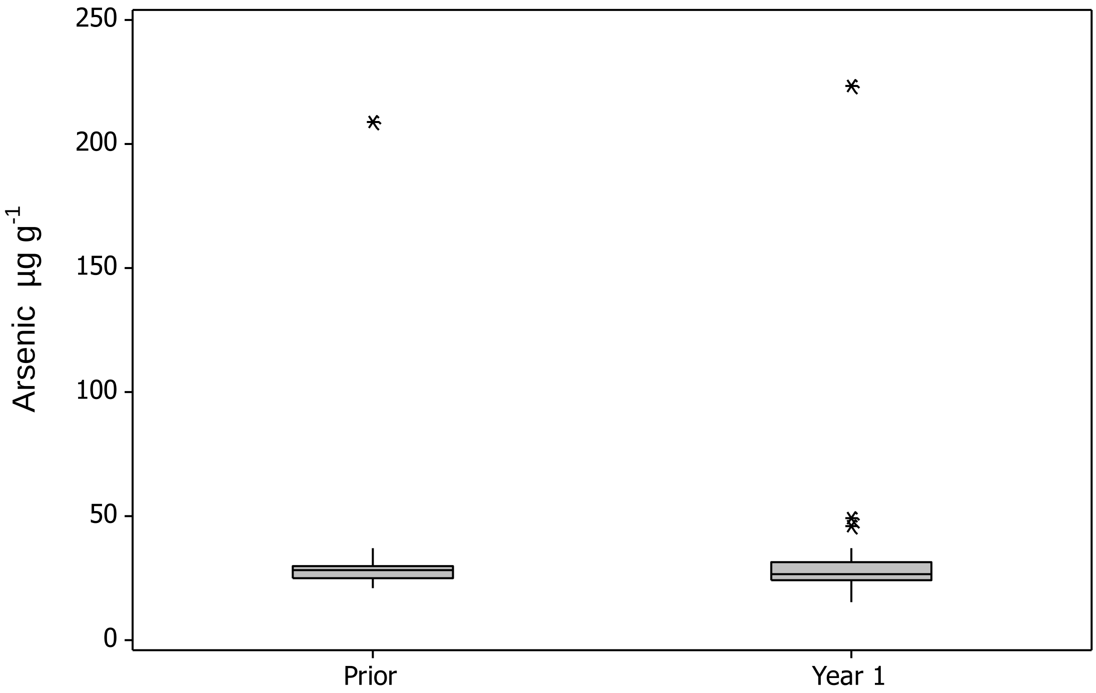

Figure 52: Boxplot showing arsenic recorded prior to, and at the end of, the first year of grazing. Asterisks refer to outliers in the data set. *N* = 25 for each series.

In order to illustrate the results without the outliers in the Prior and Year 1 data set, Figure 53 shows these in boxplot form.

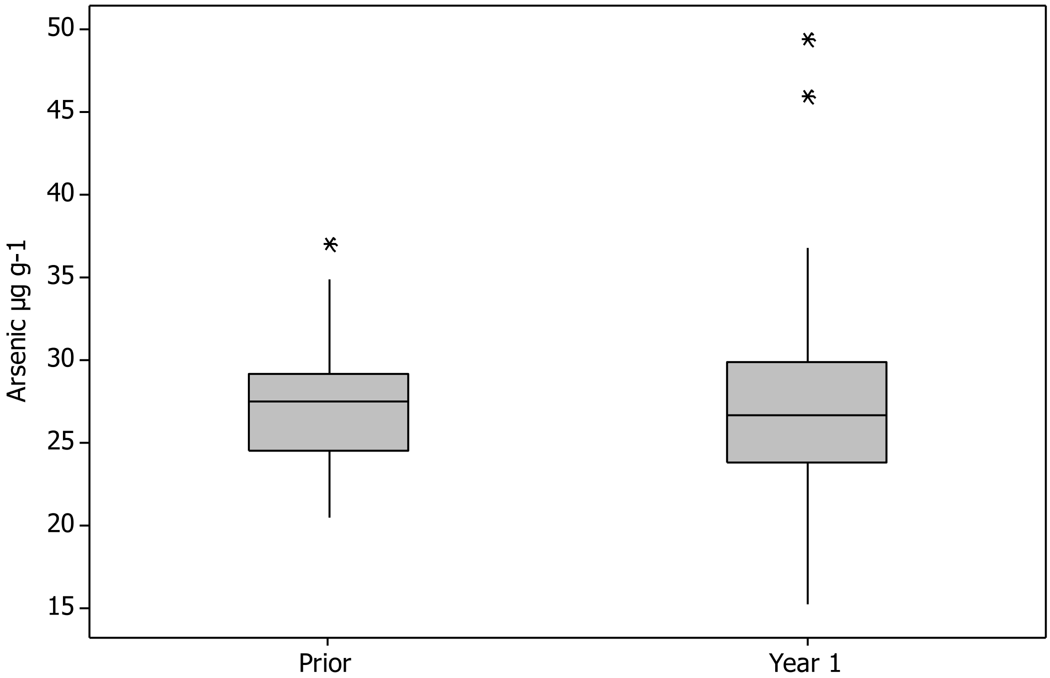

Figure 5340: Boxplot showing arsenic recorded prior to, and at the end of the first year of grazing, with outliers removed. *N* = 24 for each series.

Between the Prior and Year 2 levels of arsenic, the medians of the differences were significantly different from zero (Wilcoxon Signed Ranks test, W = 251, P= 0.018). The median arsenic prior to the introduction of grazing was 27.99 µg g^{-1} (1^{st} quartile = 24.72 µg g^{-1}, 3^{rd} quartile = 29.8 µg g^{-1}). The median arsenic level for the end of the second year was 25.87 µg g^{-1} (1^{st} quartile = 21.90 µg g^{-1}, 3^{rd} quartile = 30.35 µg g^{-1}). The high outlier found in the Prior data set was not found in the end of the second year (Figure 5).In order to illustrate the spread without the outlier. Figure 54 shows the spread of the results in boxplot form.

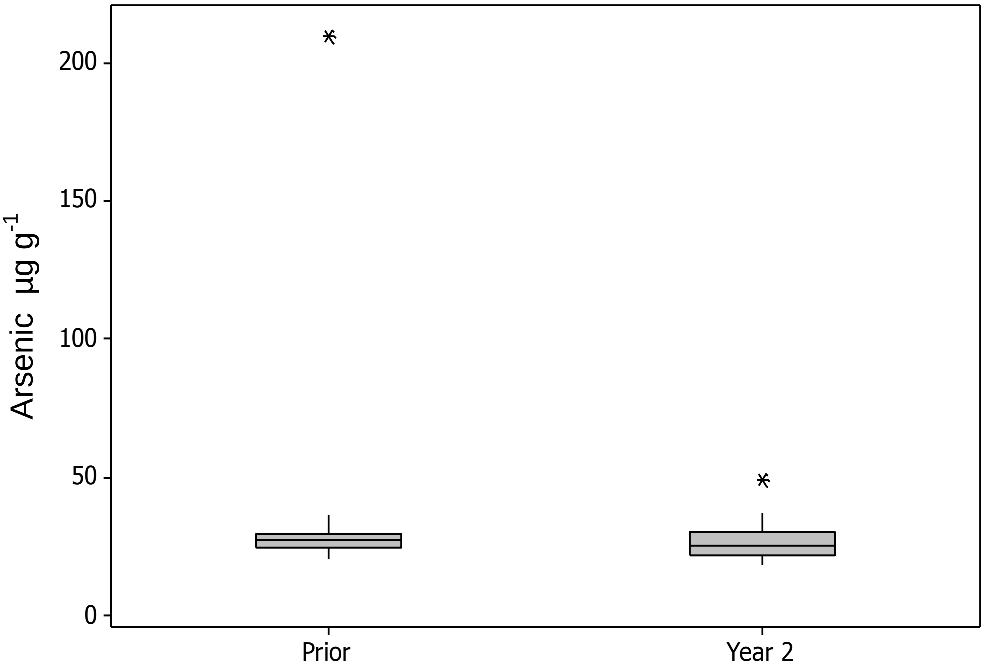

Figure 54: Boxplot showing arsenic recorded prior to the grazing management and at the end of the second year of grazing. Asterisks refer to outliers in the data set. *N* = 25 for each series.

In order to illustrate the results without the outliers in the Prior and Year 1 data set, Figure 55 shows these in boxplot form.

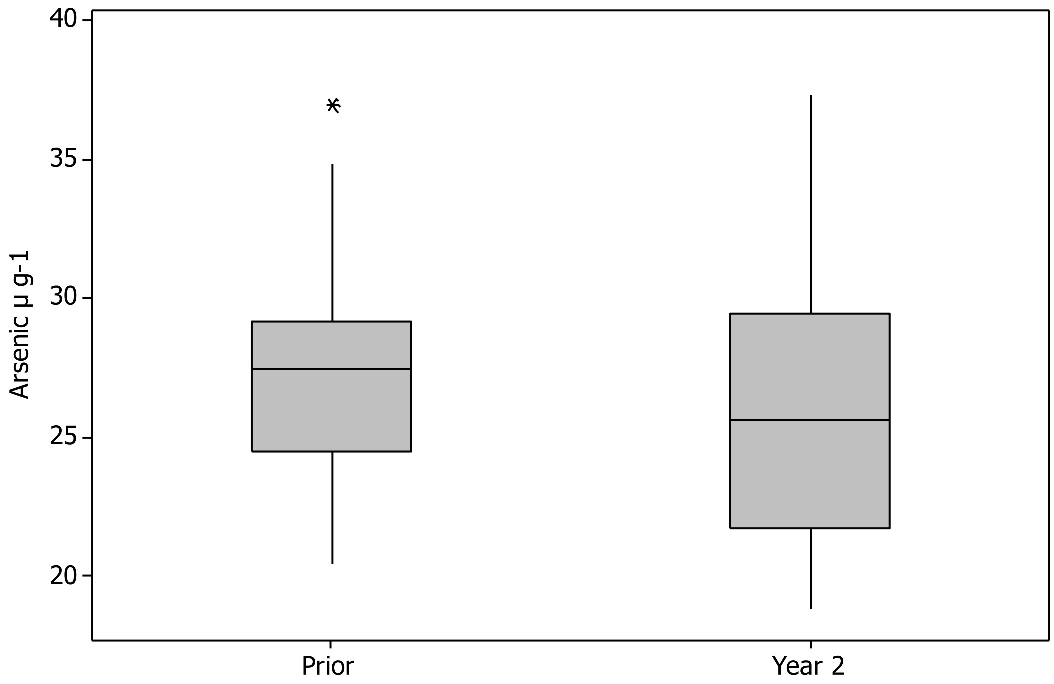

Figure 5541: Boxplot showing arsenic recorded prior to, and at the end of the second year of grazing, with outliers removed. *N* = 24 for each series.

8.4 Discussion

The overall purpose of this chapter was to present an examination of whether the ecosystem service of pollutant immobilisation was altered by the grazing. The salt marsh has deposits of heavy metals stored below the surface and the grazing could influence whether or not these are brought to the surface, increasing the potential for them to be spread into the river during high tides, or to be raised as dust, potentially harming passers-by and recreational users.

The difference between the base line data and that following one and two years of grazing did not differ significantly for all lead measurement and between the prior data collected for arsenic and the end of year 2. This indicates the ecosystem service was not affected by the grazing regime.

Between the arsenic data set extracted prior to the grazing and after two years, the boxplots (Figure and Figure 5) show a high outlier. Examination of the raw data shows this to be the same point on the salt marsh, close to and east of the raised area. The outlier in the data set after two years, although much lower than the prior and after 1 year was also the same sampling point. There is no historical published information available as to the reason for this. However, anecdotal evidence from local residents with a historical knowledge of the area suggests that the raised area was used as a convenient dumping area for the nearby factories producing chemicals. This anomaly could therefore have been a simple result of the direct tipping of a solution containing high arsenic levels. The sampling points for years 1 and 2 are within 3-4 m of the previous points due to GPS capability, therefore this high level datum point could be very isolated and was not sampled for the post second year of grazing. The high levels recorded for this point (Prior – 209.36 µg g^{-1} , +/- 4.71 µg g^{-1}; Year 1 – 223.49 µg g^{-1}, +/- 5.4 µg g^{-1}; Year 2 – 49.02 µg g^{-1}, +/- 3.82 µg g^{-1}) far exceed the soil guideline values described by the UK Environment Agency of 32 µg g^{-1} for domestically based soil and 43 µg g^{-1} for soil used in allotments but not for areas with commercial status, 640 µg g^{-1} (EA, 2009).

Further research requirements naturally tend towards a continuation of the paired samples as the grazing continues annually. In addition, but beyond the remit of the current study, the potential for pollutants to enter the cattle through their grazing action, either from eating grass or contact with sediment during the grazing action of tearing and ripping (Jensen, 1985), is an area of opportunity for further research as cattle potentially enter the food chain.

There have been few previous studies of a similar nature which have investigated grazing effects on contaminant stability. In the UK, salt marsh in Essex was investigated where lead levels of 36 µg g^{-1} (range 22-51 µg g^{-1}), 55 µg g^{-1} (range 27-80 µg g^{-1}), and 50 µg g^{-1} (6-76 µg g^{-1}) and for arsenic 20 µg g^{-1} (range 16-25 µg g^{-1}), 26 µg g^{-1} (22-35 µg g^{-1}) and 14 µg g^{-1} (4-24 µg g^{-1}) were found for vegetated areas where deposition occurred via historical mining and industrial deposition (Wiese et al., 1995). This is in broad agreement with the current study although these results are not comparable with any treatment processes such as the current study, thereby indicating the importance of this work.

Salt marsh sediments act as important sinks of heavy metal contaminants although extreme weather events, damaging the structure of salt marsh, could spread contaminants into the water column (Gedan et al., 2009). This research indicates that the ecosystem service of immobilisation of pollutants has not been affected by the grazing activity. Referring to Daily et al’s (2009) model, the management decision within the salt marsh ecosystem has not affected the ecosystem service and the value thereof.

9. Summary

9.1 Introduction to the Chapter

The work presented in this thesis has addressed gaps highlighted in the critical literature review of extant knowledge in this field (Chapter 2) and provided new insights and knowledge. Using social-ecological systems thinking as a perceptive framework has allowed humans and ecology to be integrated. The social-ecological system has all the elements required for management: experts, governance bodies, ecological processes, the biotic and abiotic processes, and urban actors. The interdisciplinary nature of the research and the results add to the joining up of science and policy-making as called for by Alberti et al. (2003).

Themes identified in the literature reviewed in Chapter 2 related to holistic environmental management options and including humans as an integral part of managed ecosystems. Urban areas are ecosystem sinks (MA, 2005a); therefore it is important that ecosystem service output should be monitored in these habitats and to identify those management practices which increase the localised output of ecosystem services, thereby reducing ecological footprints of these areas, as called for by Gaston et al. (2013). The aim and objectives of this thesis were drawn from gaps found in the available literature. The discussion presented here draws together the implications of using the ecosystem approach (CBD, 2000) and Daily et al.'s (2009) framework (Figure 8) for implementing this holistic framework.

Findings of the deductive and inductive research relating to management decisions using ecosystem services (Chapter 4) and the impacts of the grazing management on four ecosystem services (Chapters 5- 8) were discussed individually in each chapter. The implications of these findings and new insights into practical application of the ecosystem approach and ecosystem services are related in the current chapter. The implications reported in this thesis present an opportunity for a novel relationship between humans and the natural environment and new ways of understanding the benefits nature provides.

9.2 Implementing the Ecosystem Approach – lessons learnt from this study

A theme that the ecosystem approach emphasises, and which was discussed in the literature review (Chapter 2.2) is that humans rely upon and induce major changes in nature (Holt and Hattam, 2009). The 12 principles of the ecosystem approach (Chapter 2.4) lay out specifically what the approach entails and encompass those areas of environmental management which relate to this holistic framework. New insights in the current research, which can be drawn from the research in relation to implementation of the 12 Principles of the ecosystem approach, have been found. These are addressed individually below. For ease of reference, the text for each is displayed in italics font.

Principle 1: *The objectives of environmental management are a societal choice*, was addressed through the local experts' forum (Chapter 4.3) and was further informed by the data collected from the unobtrusive observations (Section 6.3.1 and Section 6.3.2) The results of the local experts show a management option was derived from societal choice which is based on knowledge, this decision making process coincides with the first stage of Daily et al.'s (2009) model (Figure 8). In the case study, local experts used ecosystem services to indicate the optimal management option to be grazing by cattle (Table 8 and Table 9).

Principle 2: *Management should be decentralised to the lowest appropriate level*. This principle has been addressed because management has been decided in conjunction with (but not limited to) local experts (Chapter 4).

Principle 3: *Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.* The effects of management on adjacent or other ecosystems, was addressed specifically through the wild species diversity comparison with ungrazed treatment (Chapter 5). In addition, the investigation into two regulating ecosystem services, carbon storage (Chapter 7) and immobilisation of pollutants (Chapter 8) related to adjacent and other ecosystems. In carbon storage, carbon stored is beneficial to the atmosphere in that there is less harmful carbon dioxide in the atmosphere; in the immobilisation of pollutants, pollutants remain in the sediment and not in the water column where they may go into the food chain.

Principle 4: *Recognising potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context.* This principle relates to the economics of ecosystem services, this has been served in the avoided costs mechanism in the carbon stored (Chapter 7). Other than the avoided costs of the carbon stored; economic indices are outside the remit of the research described here.

Principle 5: *Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.* This has been a mainstay of the environmental management described here, ecosystem services have driven decision making (Chapter 4) and have been recorded in the subsequent chapters (Chapters 5-8).

Principle 6: *Ecosystems must be managed within the limits of their functioning.* How ecosystems are managed within the limits of their functioning was addressed in Chapter 4.2. The methods available for managing salt marsh habitat were identified and then they were eliminated where necessary and finally, two remained – grazing or mowing.

Principles 7: *The ecosystem approach should be taken at the appropriate spatial and temporal scales*; and 8: *Recognising the varying temporal scales and lag-effects that characterise ecosystem processes, objectives for ecosystem management should be set for the long term.* In the current thesis, a case study is used to inform and aid a future management scenario for the Upper Mersey Estuary, an appropriate scale (Principle 7 of the Ecosystem Approach) was used as this informs the future management of the area and provides a mechanism under which future management under the ecosystem approach can be identified and future decisions made. The case study lasted two years; clearly in the ecosystem service effects on environmental features, further years are needed. This presents a limitation in that more time is needed to establish patterns and trends. This also leads to opportunities for further research. At the time of writing, continuation of the grazing treatment by The Mersey Gateway Environmental Trust during 2013 is being continued using the same methods employed in the current research (Chapter 4.6) and the management has been set for the long term- in accordance with Principle 8.

Principle 9: *Management must recognise that change is inevitable*. Change took place and was highly expected to take place with such a highly interventionist management technique such as introducing grazing an abandoned salt marsh (Adam, 2002; Bakker et al., 2003).

Principal 10: *The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.* The integration of social and ecological scientific methods and the drawing together of the management of the salt marsh in the case study represent the ideal of this principle whereby an appropriate balance between conservation and biological diversity has been aimed at.

Principle 11: *The ecosystem approach should consider all forms of relevant information, including scientific and indigenous, and local knowledge, innovations and practices*. The local expert knowledge (Chapter 4.3), rapid assessment using academic literature (Chapter 4.3), and informal interviews of visitors (Chapter 6.2.2) provided insight from scientific, indigenous, and local knowledge.

Principle 12: *The ecosystem approach should consider all relevant sectors of society and scientific disciplines.* The research took note of all relevant sectors of society in that experts, academics and local users were involved in the research; an unanswered question here is where one draws the line at all relevant sectors and what these may be. If all sectors include those within a social-ecological system, in other words local users and decision making bodies, then this principle was met.

Within the new style management of ecosystem services, new perspectives are provided when using an ecosystem services approach. When land owners or practitioners decide on changing a landscape feature to improve the area for a particular ecosystem addition or function, there can be both positive and negative effects on ecosystem services. An appreciation of the ecosystem services approach can provide a new perspective on previous unintended ecological and social consequences. This was highlighted by

Bennett et al. (2005) in a series of interviews with expert respondents across the globe. In that study, of primary concern was the affinity that people have with local places, juxtaposed with a desire for a global cosmopolitan culture (Bennett et al., 2005). Human management of natural resources to increase ecosystem services can simplify or homogenise ecosystems (Vitousek et al., 1997). An example of this simplification leading to losing ecological diversity is when a farmer converts a diverse grassland area into a crop land, thereby increasing the ecosystem service output of food provision but decreasing the ecological complexity and wild species diversity provided by the area (Bennett et al., 2005).

This translation of management aims and objectives into ecosystem services is part of the 'Kuhnian' paradigm shift described by Potschin and Haines-Young (2011b), wherein a shift in perception of the sciences is produced by new approaches and experiential changes in scientific research (Kuhn, 1970). This shift in perspective in the research described here has established itself through a social-ecological system. This system enabled the division between social and ecological approaches, described by Liu et al. (2007), to be unified. The interdisciplinary nature of the research showed that environmental management can move away from a single, narrow approach to a wider ranging one by incorporating humans and the human perspective – a mainstay of the ecosystem approach (CBD, 2000). This is especially true in the urban environment, where the share of the population living in these areas continues to rise (Eigenbrod et al., 2011; Gaston et al., 2013).

Using the ecosystem approach and ecosystem services within such a social-ecological system creates hitherto unavailable opportunities which reflect and answer the growing demand for anthropocentric values and benefit, and using expert knowledge may go a way to avoid the dilemma facing land managers and land owners when deciding how to manage land and being unaware of ecosystem services available. This was an issue highlighted by Bennett et al. (2005).

The ecosystem service approach started as a 'humble metaphor' to describe the benefits to nature and has moved to being a complex arena of ideas in recent years (Norgaard, 2010, p.1226). The idea that the term ‘ecosystem services’ is confusing to those outside the academic and policy debate (who probably include all of the natural resource users) has been discussed (Fish, 2011). This was bought into stark relief by the author whilst interviewing a resource user in the case study - when the author described the benefits which were being freely discussed at a lay level of language, the visitor displayed behaviour that can only be described as ‘glazed over’. Therefore, translating the ecosystem service approach and ecosystem services to local user appropriate language is a challenge. The human component research wherein human behaviour and thematic analysis of comments provided new insight into people’s perceptive benefits (Section 6.3.2.2, Table 33). While the inductively led research displayed clearly the ecosystem service benefits being received by the urban actors, translating these to show local users is an area for future research that has been presented with an opportunity here.

The importance of ecosystem services to humans has been answered by the current research, especially in an unmanaged urban environment. The framework described by Daily et al. (2009) to deliver the ecosystem approach has been completed. The framework used in this thesis is used to examine four ecosystem services that were relevant to the habitat in the case study. The implementation of the framework has been shown to be feasible and could be used in other habitats, for example rainforest, coasts, and moorland.

The UK Government published a White Paper in 2011, ‘The Natural Choice: securing the value of nature’, which pushed forward the recommendations of the Lawton Review (Crown, 2011). The White Paper made significant statements regarding the important health benefits of contact with nature (Crown, 2011). The ecological management of the research area in the current thesis, by using the decision triangulation described in Chapter 4, led to an increase in the ecosystem services relating to mental and physical health. The research described in Chapter 6 showed strong evidence that this was the case through the ecosystem goods derived, *inter alia*: Health benefits, Sense of History, and Sense of Ownership (Table 33). The interpretation of comments to extrapolate ecosystem services showed benefits for both mental and physical health. Pride in the local environment was engendered by the cattle grazing, as seen in the results in Chapter 6 - Sense of Pure Enjoyment and Sense of Place (Table 33), relating to cultural ecosystem services.

9.3 Integrating environment decisions and ecosystem services using a cyclical framework

The ‘call to deliver’ on ecosystem services by Daily et al. (2009) was made in response to the increasing literature and theory on ecosystem services juxtaposed with the lack of practical application. In response to this, Daily et al. (2009) proposed a cyclical framework (Figure 8) starting with environment decisions, secondly to the ecosystems affected, next recording the changes in ecosystem services and moving onto values of the ecosystem services and, finally, the results are provided to institutions (ranging from committees to international governing bodies). The cycle is completed when the institutions use the results of the decisions to begin the next cycle, on the next occasion with more knowledge (Figure 8).

Decisions: the research surrounding the management options, local experts, and the rapid assessment were accomplished here. A critical overview of options to manage salt marsh revealed five techniques; three of these were discounted by a practical walkover of the research site. The remaining two (grazing and mowing) were presented to local experts (Chapter 4.3) who discussed these in relation to the effect they would have on a set of ecosystem services drawn from the MA (MA, 2005b). The system using a set of arrows determined clearly that grazing be the preferred option (Table 8 and Table 9). To triangulate these results a rapid assessment using extant literature revealed grazing to be the preferred option (Table 10 and Table 11). The implication of the results of this research is that the triangulation of experts’ knowledge and a rapid assessment provided new insight into a decision making process on environmental management using ecosystem services.

The second iteration within the cyclical framework (Figure 8) was addressed in the review of literature related to grazing of the salt marsh (Section 4.4.2). It should be noted that in order to arrive at the management option, a range of options had to be discovered. This is a shortcoming of the cyclical framework because there are two stages to this literature review; the first prior to the decision making process (to decide on the options), and the second to present best practice options on the decision. The implication of the results of the literature search is that grazing management was described and the results acted upon in the case study area (Chapter 3.3).

The third component of Daily et al.'s (2009) framework introduced the quantification and measuring of the effects of the management decision on ecosystem services. The ecosystem services were investigated separately, reflecting the ecological or social research approaches (Chapter 5-8), a brief summary of each shows how the results addressed this component of the cyclical framework.

The choice of wild species diversity as an ecosystem service to be studied in this investigation (Chapter 5) reflected the aim of the grazing: to improve the ecological diversity. Grass structure as a proxy showed encouraging results (Chapter 5, Figures 22-29) for the desired effect of optimal habitat for nesting birds; this was complemented by the two pairs of nesting wading birds appearing in the grazing area in the second year of grazing (Chapter 5, Figure 17). The breeding bird results between the grazed and the ungrazed area were similar over the two years (Chapter 5, Figure 15). The implications of these results are that clearly more time is needed. A cross reference here is to Principle 8 of the Ecosystem Approach relates to this in that lag effects exist in managing natural environments and management objectives should be long term (CBD, 2000).

The study on cultural ecosystem services, Environmental Settings, described in Chapter 6, has perhaps been the most crucial aspect of the current research which delineates ecosystem services and traditional, reductionist environmental management approaches. The behaviour of visitors in relation to the presence of the cattle showed strong evidence that people stopped to look at the cattle, in particular walkers and dog walkers (Table 32). The interpretation and analysis of comments showed new and novel insights into cultural ecosystem services and goods derived from the management intervention (Section 6.3.2). The implications of the data interpretation in the social research are clearly that the management intervention provided a range of ecosystem benefits and concerns, the benefits included a Sense of Pure Enjoyment and a Sense of History, whereas the concerns included Anti-social Concerns and a Tragedy of the Commons (Table 33). By working with local experts and deriving the needs, emotions, and concerns of users and local residents relating to the management through the unobtrusive observations and analysis of comments (Chapter 4 and Chapter 6), the local governing body of Halton Council can identify and use these to inform their decisions on environmental management. This aspect provides the last link in Daily et al. (2009) framework (Figure 8); wherein institutions utilise information for future scenarios in decision making for environmental management. Further research to this would be to extend the research through explicit questionnaires and local residents' workshops. This would allow researchers to delve deeper into the classifications of ecosystem services found in the current study and identify means and methods which would extend them.

The carbon sequestration and immobilisation of pollutants aspects of this thesis are good examples of relevant ecosystem services being missed when just managing for 'ecology' or 'biodiversity'. Carbon storage was unaffected by the grazing treatment at a statistical level but there was a higher carbon capacity recorded in the grazed treatment (Chapter 7, Figure 46) The higher value of the grazed area in terms of avoided costs of carbon dioxide in the atmosphere provides a new insight into the economic value of grazing a salt marsh, that managing a greenspace on an urban area in this way can be a source of ecosystem service, and not an ecosystem service sink, as described by Millennium Assessment (MA, 2005a). The implications of the interpretation of the results are that there are missed opportunities for providing policy makers with aspects of environmental management that may otherwise have been missed without the study of ecosystem services.

The immobilisation of pollutants as an ecosystem service was highlighted by the UK-NEA to be exclusive to salt marsh (UK-NEA, 2011d) but as far as is known at the time of writing, there has been no prior empirical research into this on grazed areas. The results and discussion to the research on the immobilisation of pollutants have confirmed that the salt marsh is a store of pollutants and the action of the grazing, in a repeated measures test, had little effect of the surface, exposure area, of this ecosystem service pertaining to the immobilisation of pollutants (Chapter 8.3). The implications of these results are that the action of cattle grazing did not affect the ecosystem service, except where localised concentration of arsenic was found and an outlier affected the statistical significance of the results (Figure 53, p. 175).

The penultimate iteration of Daily et al.'s (2009) framework relates to the interpretation of changes in values of ecosystem service output. The changes in value of the ecosystem service was provided in the interpretation of the results and therefore this component of the framework does not add to what Haines-Young and Potschin (2013) describe as a function of frameworks – to make concepts as simple as needed. The research into the ecosystem services and this framework has provided new insight so that eliminating this phase would allow a simplification of addressing the integration of ecosystem services into environmental management.

The final component of the conceptual framework aims to provide institutions with the data, results, and knowledge required for the continuation of the process. The challenge identified in the introduction to this thesis (Chapter 1) (Daily et al., 2009) related to the circular, iterative nature of the integrating ecosystem services and the ecosystem approach. The research here has shown how this can be achieved in a practical way. This is a good example of 'consilience', the bringing together of knowledge between and across knowledge bases (Alberti et al., 2003). In the case study reported here, the results have been acted upon by the governing body, The Mersey Gateway Environmental Trust to extend the grazing into the future, recognising the ecosystem services provided.

9.4 Impact of the research

The current research was conducted within the framework of a large scale construction project, the Mersey Gateway, a bridge crossing the Upper Mersey Estuary to meet the high and increasing road traffic requirements between Merseyside and north Cheshire and the south of England. At present the project works robustly within existing environmental legislative requirements as provided by the UK Government (HBC, 2008b). There has been a shift within environmental legislation through the new National Policy Planning Framework (NPPF), White Papers and European Union (EU) strategies and policies. The new NPPF was published by the UK Government in March 2012, in this framework ecosystem services are mentioned as part of the necessity to recognise these benefits for the conservation of the natural environment (Crown, 2012). Carbon storage, wildlife, and recreation are prominent examples provided in the NPPF (Crown, 2012).

Notably, the EU has adopted a 'Biodiversity for 2020 Strategy' which explicitly includes the preservation of ecosystem services (EC, 2011a). In the 2020 strategy, the European Parliament accepted that the previous target to halt the decline in biodiversity and the degradation of ecosystems by 2010 had failed (EC, 2012). The new 2020 strategy has ecosystem services at the heart of its requirements because it recognises a strong link between biodiversity and the delivery of ecosystem services (EC, 2012). The core message emanating from the 2020 strategy is that by the year 2020, the loss of biodiversity and ecosystem degradation is halted (EC, 2011a).

The Mersey Gateway Environmental Trust was established in 2011 as a conduit to which the Mersey Gateway offers a mitigation platform to formulate, monitor, and implement ecosystem benefits to the Upper Mersey Estuary. The Trust has far reaching opportunities as a governance body to implement some of the recommendations of the Lawton Review (Lawton et al., 2010). In particular those related to localism and Recommendation 3 of the Lawton Review related to extension zones in which ecological processes are restored. Restoring these ecological processes results in an increased output of ecosystem services. Creating ecological restoration zones to be managed by local governance is a key tenet of the Lawton Review, in the research described in the current investigation; this local governance was achieved through a local expert forum. The local expert forum represented of the governance component in the social-ecological system (Figure 3). Using the ecosystem approach and Daily et al.'s (2009) framework (Figure 8) has allowed this to have been achieved in the current research.

The introductory paragraphs in Chapter 1 of this thesis exposed the issues the environment faces in regards to the state and delivery of ecosystem services at a global level and the pressures faced as a result of the expanding urbanisation due to population rise. The case study reported in this thesis has shown how these issues and pressures can be reversed through the practical implementation of the ecosystem approach using a compact decision making process - such as the one proposed by Daily et al. (2009) - and the use of both social and natural scientific research techniques. Social-ecological systems exist throughout the globe; these can be defined and managed using the ecosystem approach and an iterative framework such as the one used in the current research.

The case study reported here has provided a conceptual working model (Figure 56). This model has been adapted from the methodological framework of the case study reported in this thesis. The model has three stages (Figure 56). Stage 1 uses local experts and extant literature to decide on management methods of habitats and ecosystems, and establishes ecosystem services (Chapter 4). Stage 2 investigates the effects of the management on the relevant ecosystem services (Chapters 5-8). Stage 3 reports these effects results to inform future management and to highlight the impacts the management has made on the selected ecosystem services (discussion within Chapters 5-8). This framework can be used in multiple habitats and on multiple scales.

For the ecosystem approach and the ecosystem services approach, interdisciplinary teams would be able to expand on the empirical work for ecosystem services. This author agrees with Ostrom et al. (2007) and de Groot, et al., (2010) in that single and simple models should be treated with caution as pure panaceas to problems. The ubiquity, success, and pervasiveness of ecosystem services in environmental management means that current and future management of nature through this new lens cannot be ignored (Robinson et al., 2013).This research has addressed questions related to integrating humans into nature. The author agrees with Wang et al. (2013, p. 1) that ‘Human beings are the stewards of this planet and it is time to adopt this integrative ecosystem services management concept’.

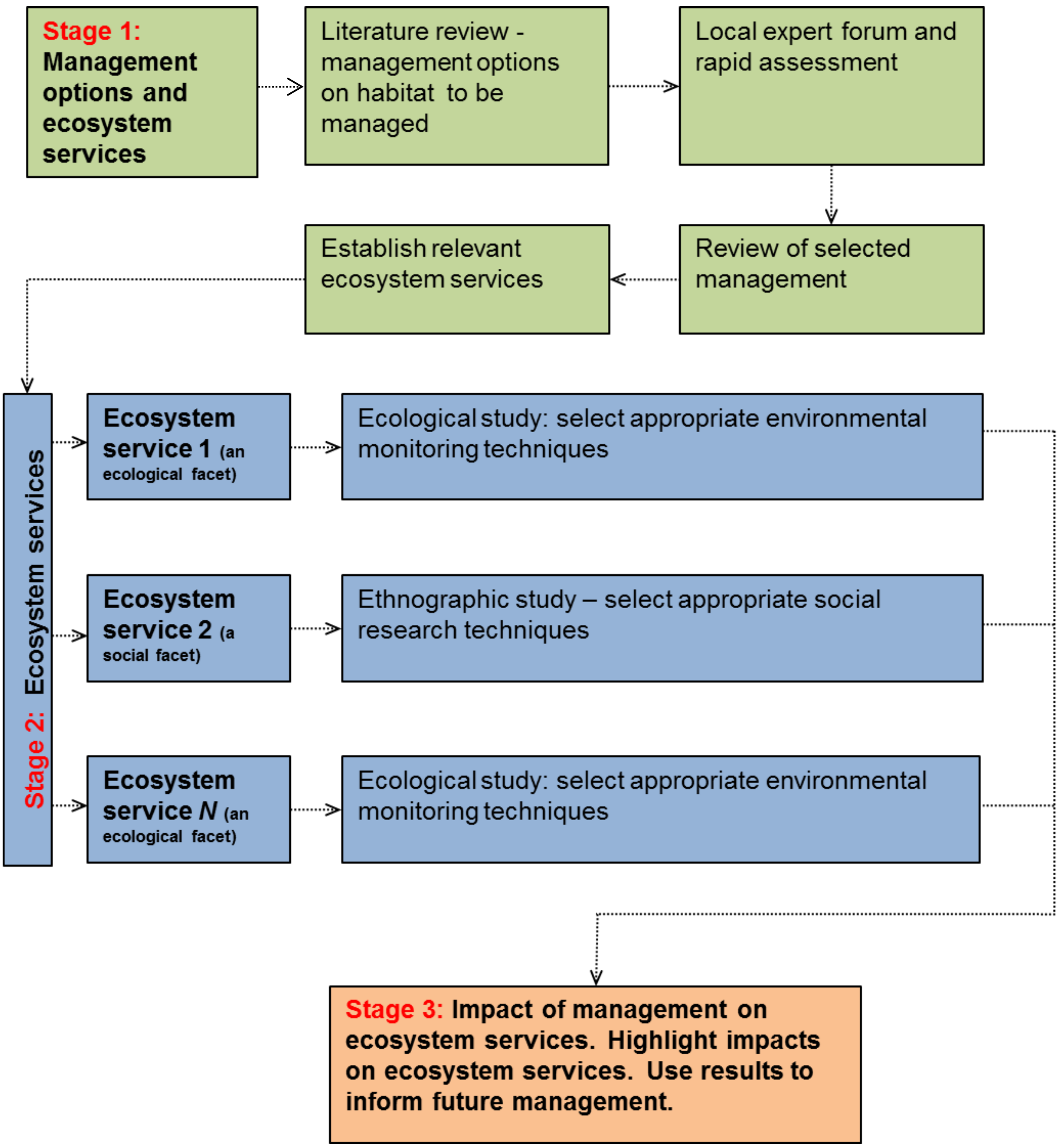

Figure 56: The model used in the case study reported in the current thesis. The number of ecosystem services to be measured is contextual to each study.

9.5 Future Research

Although beyond the scope of the present research, organic compounds stored in the sediment are subject to half-life degradation. The half-life of organic compounds ranges from months to years based on whether degradation is abiotic or biotic (Minnich, 1993). In sediments, degradation is likely to be primarily biotic due to the presence of microbial processes through soil bacteria (Minnich, 1993). In laboratory experiments Anderson et al. (1991) examined half-life times for 15 common organic compounds and found times of between <2 days to up to 11.3 days for half-life degradation (Anderson et al., 1991; Minnich, 1993). Therefore, a key ecosystem service extension of immobilisation of pollutants is through inorganic compounds, they are degraded within sediments; this is an important ecosystem service and an opportunity for further research.

Recommendations for future research for each of the ecosystem services have been made discretely in the relevant chapters' discussion, a summary is provided in Table 36.

Table 36: Summary of recommendations for future research as per individual ecosystem services.

Chapter	Ecosystem service	Future research recommendation
5	Wild species diversity	Continuation of bird and vegetation surveys. Bakker et al.'s (1990) research continues over nine years.
6	Environmental settings	Structured interviews
7	Carbon storage	Continuation of grazing regime and yearly measurements of carbon stored.
8	Immobilisation of pollutants	Continuation of grazing regime and yearly measurements of surface lead and arsenic.

Appendices

Appendix 1: Data recording sheet for unobtrusive observations

Data recording sheet: Direct observation surveys. Widnes Warth Cattle Grazing Project- general page. Date:				
Time	Number	Category	Direction	Stop and look (Y/N)
Notes: (date, time and duration, weather conditions, points of relevance, salient comments following informal interview – ensure comments are referenced to time).				

Appendix 2: Calculation steps to reach tonnes of carbon stored in sediment to 15 cm depth in Grazed (G) samples.

Treat†	% LOI‡	% C (0.55)	prop C	BD (g cm^3)	BD (g m^3)	BD (kg m^{-2} to 1m)	BD (kg ha^{-1} to 1m)	BD (kg ha^{-1} to 15cm)	Soil C stock (kg C ha^{-1} to 15cm)	Soil C stock (t C ha^{-1} to 15cm)
G 1	9.96	5.48	0.05	0.95	945373.87	945.37	9453738.69	1418060.80	77665.08	77.67
G 2	13.40	7.37	0.07	0.71	708755.89	708.76	7087558.95	1063133.84	78324.76	78.32
G 3	11.00	6.05	0.06	0.90	897615.37	897.62	8976153.69	1346423.05	81422.60	81.42
G 4	13.48	7.42	0.07	0.92	922283.69	922.28	9222836.93	1383425.54	102583.47	102.58
G 5	13.41	7.37	0.07	0.79	788862.46	788.86	7888624.60	1183293.69	87244.30	87.24
G 6	13.57	7.46	0.07	0.85	847614.88	847.61	8476148.81	1271422.32	94857.70	94.86
G 7	12.12	6.67	0.07	0.74	744462.63	744.46	7444626.35	1116693.95	74458.69	74.46
G 8	10.16	5.59	0.06	0.86	858401.40	858.40	8584013.97	1287602.10	71972.00	71.97
G 9	13.01	7.16	0.07	0.82	819530.47	819.53	8195304.69	1229295.70	87977.27	87.98
G 10	17.80	9.79	0.10	0.73	733620.14	733.62	7336201.41	1100430.21	107711.60	107.71
G 11	15.73	8.65	0.09	0.51	511382.03	511.38	5113820.35	767073.05	66367.04	66.37
G 12	14.85	8.17	0.08	0.74	740084.87	740.08	7400848.74	1110127.31	90684.33	90.68
Mean	13.21	7.26	0.07	0.79	793165.64	793.17	7931656.43	1189748.46	85105.74	85.11
Stdev	2.26	1.24	0.01	0.12	118300.40	118.30	1183004.00	177450.60	12458.81	12.46

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Appendix 3: Calculation steps to reach tonnes of carbon stored in sediment to 15 cm depth in Ungrazed (UG) samples.

Treat†	% LOI‡	% C (0.55)	prop C	BD (g cm^3)	BD (g m^3)	BD (kg m^{-2} to 1m)	BD (kg ha^{-1} to 1m)	BD (kg ha^{-1} to 15cm)	Soil C stock (kg C ha^{-1} to 15cm)	Soil C stock (t C ha^{-1} to 15cm)
UG 1	11.86	6.52	0.07	0.47	470129.17	470.13	4701291.74	705193.76	46009.39	46.01
UG 2	11.86	6.52	0.07	0.68	683000.31	683.00	6830003.08	1024500.46	66808.54	66.81
UG 3	11.92	6.55	0.07	0.70	700857.98	700.86	7008579.84	1051286.98	68911.27	68.91
UG 4	11.89	6.54	0.07	0.56	564118.98	564.12	5641189.82	846178.47	55354.81	55.35
UG 5	11.16	6.14	0.06	0.68	681702.05	681.70	6817020.50	1022553.08	62758.91	62.76
UG 6	11.18	6.15	0.06	0.77	766676.54	766.68	7666765.42	1150014.81	70730.88	70.73
UG 7	12.08	6.65	0.07	0.58	582162.53	582.16	5821625.33	873243.80	58031.12	58.03
UG 8	13.96	7.68	0.08	0.73	733388.34	733.39	7333883.35	1100082.50	84473.57	84.47
UG 9	11.90	6.54	0.07	0.86	862923.41	862.92	8629234.08	1294385.11	84688.87	84.69
UG 10	14.69	8.08	0.08	0.78	776549.47	776.55	7765494.69	1164824.20	94142.23	94.14
UG 11	17.81	9.79	0.10	0.67	674474.44	674.47	6744744.39	1011711.66	99079.46	99.08
UG 12	17.89	9.84	0.10	0.69	689167.93	689.17	6891679.27	1033751.89	101741.07	101.74
Mean	13.18	7.25	0.07	0.68	682095.93	682.10	6820959.29	1023143.89	74394.18	74.39
Stdev	2.42	1.33	0.01	0.10	104751.25	104.75	1047512.54	157126.88	18158.70	18.16

Appendix 4: Percentage recovery rates for Certified Reference Material: NCS DC 73308

Recorded CRM by FPXRF during Prior sampling				NCS 73308				Recovery rate	
Lead	Lead Error	Arsenic	Arsenic Error	Lead	Lead Error	Arsenic	Arsenic error	Lead Recovery as %	Arsenic Recovery as %
23.50	2.01	25.43	1.96	27	2	25	3	87.05	101.72
23.50	2.01	25.43	1.96	27	2	25	3	87.05	101.72
25.75	2.05	24.93	1.99	27	2	25	3	95.37	99.72
27.10	2.07	22.73	1.97	27	2	25	3	100.37	90.92
25.00	2.03	25.46	1.98	27	2	25	3	92.58	101.84
25.00	2.03	25.46	1.98	27	2	25	3	92.58	101.84
26.01	2.05	23.78	1.97	27	2	25	3	96.33	95.14
26.01	2.05	23.78	1.97	27	2	25	3	96.33	95.14
24.53	2.03	24.83	1.97	27	2	25	3	90.84	99.34
24.49	2.03	25.25	1.98	27	2	25	3	90.69	101.00
24.69	2.03	23.96	1.97	27	2	25	3	91.43	95.84
Recorded CRM by FPXRF during Year 1 sampling				NCS 73308				Recovery rate	
Lead	Lead Error	Arsenic	Arsenic Error	Lead	Lead Error	Arsenic	Arsenic error	Lead Recovery as %	Arsenic Recovery as %
25.87	2.05	23.37	1.97	27	2	25	3	95.81	93.48
26.74	2.07	24.33	2.00	27	2	25	3	99.04	97.32
25.50	2.06	25.37	2.00	27	2	25	3	94.44	101.48
23.80	2.02	25.88	1.98	27	2	25	3	88.15	103.52
Recorded CRM by FPXRF during Year 2 sampling				NCS 73308				Recovery rate	
Lead	Lead Error	Arsenic	Arsenic Error	Lead	Lead Error	Arsenic	Arsenic error	Lead Recovery as %	Arsenic Recovery as %
25.94	2.06	23.84	1.98	27	2	25	3	96.07	95.36
25.26	2.06	23.95	1.99	27	2	25	3	93.57	95.78
Mean recovery rates								93.39	98.30
Standard deviation around the mean								3.895863468	3.673563409

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