Shifting Baselines in Coastal Ecosystem Service Provision

By:

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ABSTRACT

Coastal ecosystems provide vital suites of ecosystem services: food security, livelihoods, recreation, at global (e.g. climate regulation), regional (e.g. commercial fisheries) and local scales (e.g. recreation). The composition of these suites of services has clearly changed over time, as ecosystems have responded to natural and anthropogenic changes. Exploitation of these coastal ecosystems goes back centuries and many systems today are under stress from multiple sources including overfishing, pollution and climate change.

Management strategies and policies are now focused on reversing these kinds of adverse effects and on restoring systems back to their 'natural' state. However, many of the changes that have occurred predate environmental surveys. It is difficult to set reference points and to define management policies when baselines on how 'natural' the system are constantly shifting. These shifting baselines mean that what we consider to be a 'healthy' ecosystem, with 'optimal' levels of Ecosystem Service provision, often lack historical context. A historical approach provides one means to parameterise such relationships. In this study I use the Yorkshire Coast of the North Sea as a case study to understand the links between drivers of change, ecosystem and the services they have provided over time.

In this thesis, findings from interviews with stakeholders and from modelling long term data suggest that use of such historical data sources gives new insight into socio-ecological changes that occurs over time. It showed that there are shifting baselines and trade-offs in ecosystem services which can feed into management of future ecosystem services. It highlighted how fishermen's perspective on changes in species and ecosystem match scientific survey data for some species, but there are shifting baselines in perceived changes. Findings on role of biodiversity in cultural ecosystem service show that it serves more of a supporting role as part of the wider seascape, rather than as recreational value related to specific aspects of biodiversity.

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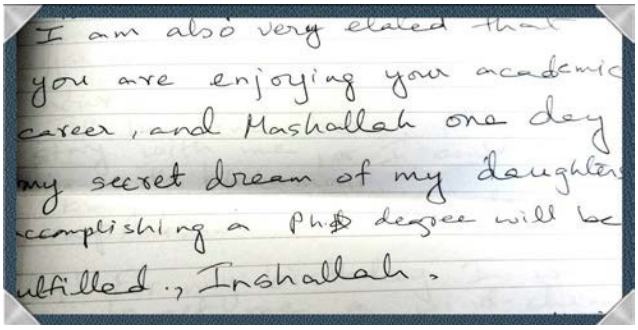
This is a small excerpt from my mother's last letter to me October 15th, 2004. I dedicate this to you Ammu. This has always been for you.


I am also very elated that
you are enjoying your academic
career, and Mashallah one day
my secret dream of my daughter
ccomplishing a PhD degree will be
ulfilled., Inshallah.

DECLARATION

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In chapter 5 I have used survey data using an online questionnaire on cultural ecosystem services administered by Yorkshire Wildlife Trust. I have their permission to use this data for analysis with due reference

In chapter 3 I reproduced images from two websites with prior permission from both sources - Amoret Tanner - fotoLibra and Callum Roberts – Unnatural History of the Sea

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CHAPTER 1 INTRODUCTION

1.1 Background

Daily et al. (1997) define ecosystem services as the "conditions and processes through which natural ecosystems, and the species that are a part of them, help sustain and fulfil human life". They are the benefits that human beings derive from the natural environment, both in terms of goods such as food and energy, and services such as climate regulation and recreation (Costanza et al., 1997). These services are categorized into four areas: provisioning, regulating, supporting, and cultural (MEA, 2005; Hein et al., 2006). This concept of ecosystem services has gained recognition over the last 15 years and is seen by many as a useful tool for valuation and conservation of biodiversity and sustainable management of ecosystems. Additionally, ecosystem services as a framework, has been a useful bridge and a common language to bring together the different disciplines of social scientists, ecologists and economists and address issues of ecosystem degradation, mitigation of biodiversity loss and environmental conservation (Granek et al., 2010; Chan et al., 2012). Marine ecosystems constitute the vast majority of Earth's living space and are potentially a considerable provider of ecosystem services. Human beings derive direct benefits from the marine ecosystem in terms of provisioning services such as food and energy, cultural services such as recreation and tourism, and regulating services such as climate regulation (MEA, 2005). One of the first comprehensive studies on marine ecosystem services highlighted how some marine goods and services are well defined (e.g. food provision) whereas others (e.g. recreation, tidal energy harvesting) are much harder to quantify (Beaumont et al., 2007). In addition, the scale at which humans depend on the marine environment ranges from global (e.g. climate regulation), to regional (e.g. commercial fisheries) to local (e.g. coastal defence, recreation).

Defining management strategies based on ecosystem services is complicated by the lack of understanding of the relationship between different services and how they are connected to the state of the ecosystem (Bennett et al., 2009). Relationships between different ecosystem services are not always well defined or even consistent, but both positive and negative correlations exist, such that it is impossible for any management strategy to maximize provision of all services concurrently. For example, commercial fishing interests may conflict with those of recreational fishing. Long-line fisheries targeting swordfish *(Xiphias gladius)* and yellowfin tuna *(Thunnus albacares)* caused 90% mortality in the popular sport fish white marlin *(Tetrapturus albidus),* costing the recreational fishing industry US$ 2Bn (Pikitch et al., 2004). More generally, the provisioning service of fisheries may have negative impacts on supporting services such as loss of habitat due to destructive fishing methods and decreased recycling of nutrients due to overfishing (Holmlund & Hammer, 1999). In the future, there might be a greater need for services such as carbon sequestration and renewable energy generation which might have to be traded off against recreation, fisheries and biodiversity. One possibility is that there exist multiple stable states of a system, each optimized for provision of a different set of ecosystem services (Petraitis et al., 2010).

Defining these different states will be essential to inform ecosystem-based management of coastal marine systems.

1.2 From biodiversity and 'ecosystem state' to ecosystem services

Although there have been many studies on the relationship between biodiversity and the functioning of ecosystems (e.g. Naeem et al., 2009; Loreau et al., 2001; Duffy, 2009), there has been much less research on how the relationship between biodiversity and ecosystem function in turn affects service provision. Most of the studies in marine systems on links between biodiversity and ecosystem function have been on small scales and in specific habitats, such as studies on rock pools, or on single species such sea grass (Duarte, 2000). There is therefore the need to study marine biodiversity and ecosystem functioning on a large spatial and temporal scale (Cardinale et al., 2010; Raffaelli and Friedlander, 2012). Past studies and experiments have shown links between biodiversity and processes/function but less on what happens to the loss or change in biodiversity and how that affects services (Worm et al., 2006). A study by Bennett et al. (2009) addresses this issue in relation to terrestrial ecosystems and highlights how services are impacted by human activities; and how this impact is related to the connection between services. This is applicable for marine systems where, for example, the impact of bottom trawling affects both provisioning services such as availability of food as well as supporting services such as those provided by sea grass meadows which act as habitats for many species (Moore and Jennings, 2000).

One of the criticisms of ecosystem services has been its focus on natural systems and the exclusion of human interaction and impact on these natural systems. It is now more widely recognized that we exist as part of a social-ecological system where human interaction with the environment shapes the ecosystem and the services provided (Huntsinger and Oviedo, 2014). Several conceptual frameworks have been proposed to describe these relationships, for instance those by the Resilience Alliance (Folke et al., 2004) and the Millennium Ecosystem Assessment (MA, 2005). In particular, the need to differentiate benefits, services, ecological functions, and ecological structures and processes, has been emphasized, with research focusing on how these individual processes underpin the links between natural capital and human well-being (Haines-Young et al., 2009). In recent years there have also been several studies using modified ecosystem service frameworks and developing new terminology such as ‘service providing units', ‘service beneficiaries’ and services as the ‘final products’, so that the evidence for links between ecosystem goods, services and human wellbeing becomes more useful for decision makers (Luck et al., 2009, Fisher et al., 2009, Mace et al., 2012). Modified versions of frameworks such as the well-established Drivers-Impact-Pressure-State-Response (DIPSR) have been used to define the impacts of environmental change drivers on ecosystem service provision and the policy and man-agreement responses that would result from such impacts (Rounsevell et al., 2010).

In this study I adapted the conceptual framework from Rounsevell et al (2010) as shown in figure 1.1. This framework includes different components within the socio-ecological system, and recognizes that a service is not only connected to the biological properties of the ecosystem but also connected to how people and society benefits from that service. This is a very important step in integrated social-ecological thinking (Rounsevel et al. 2010). Within this framework, we can also see that a socio-ecological system is impacted by multiple drivers such as climate change and human activities which then effects ecosystem service provision.

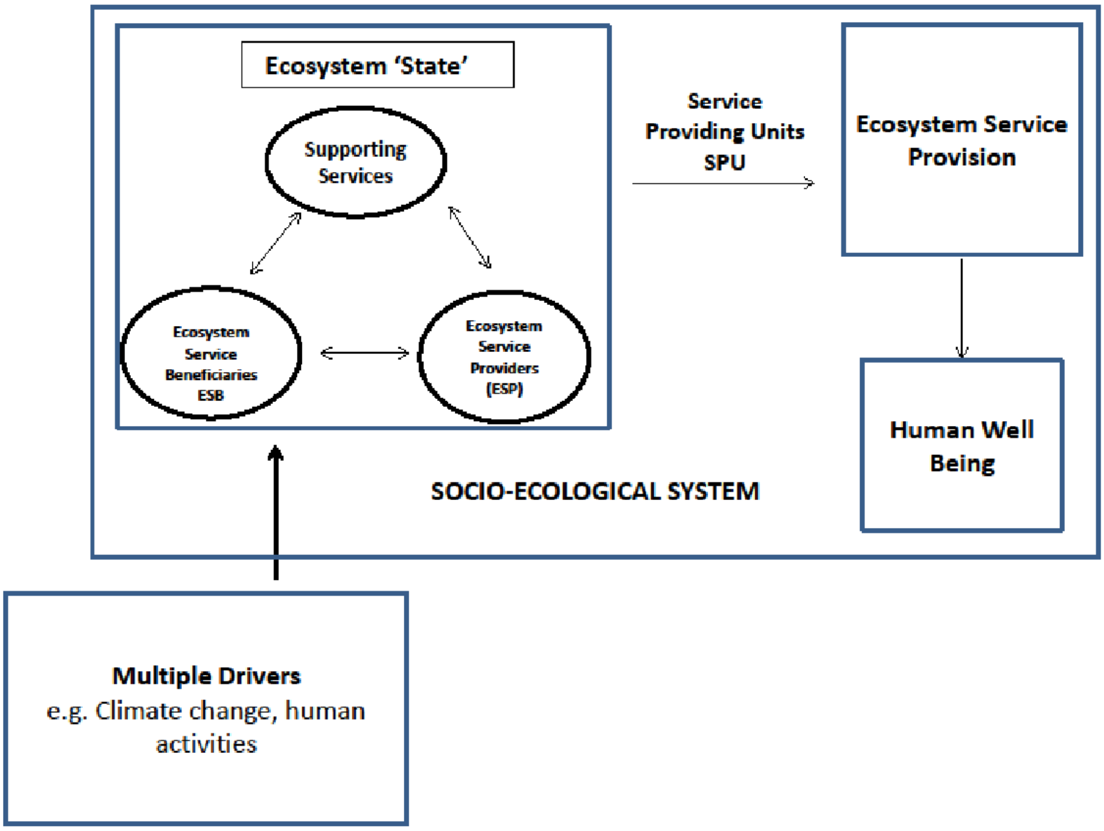

Figure 1.1 Schematic diagram, based on the framework of Rounsevel et al. (2010), showing how ecosystem state is defined by different components of the ecosystem – supporting services e.g. ESB and ESP which collectively can form SPUs that leads to ecosystem service provision. This in turn is valued for human wellbeing. Together this forms a socio-ecological system which can be affected by multiple drivers of change.

1.3 Long term changes in marine ecosystems

Human activities that can result in a loss of biodiversity and habitat also lead to the loss of many ecosystem services (Worm et al., 2006) such as a decrease in food production (fisheries), reduction of supporting services (nutrient cycling), and reduced resistance to damage from extreme events (e.g. due to loss of natural sea defences). Direct and indirect human activities include land-based activities, such as runoff of pollutants and nutrients, removal of salt marshes and estuaries, as well as ocean-based activities such as resource extraction, which lead to biodiversity reduction and loss of habitat (Halpern et al., 2008). Some species have declined from loss of shallow water habitats due to other anthropogenic activities such as clearing salt marshes for agriculture and development. A recent study on 'coastline hardening' (Gittman et al., 2015) showed that population growth and coastal development are primary drivers of marine habitat degradation. However, none of these anthropogenic changes have been as destructive and caused as much damage as overfishing (Jackson et al., 2001). Several studies have documented the impact of fishing on ecosystems, including the collapse of target species, and changes in food webs (Lotze et al., 2010; Donnan, 2001; Cardinale et al., 2010). Over-exploitation in fisheries has led to change in size and abundance of fish and reduction in total fish stocks (Pauly et al., 1998; Jennings et al., 2002; Pauly & Palomares, 2005). Jennings and Blanchard (2004) estimated that in the heavily exploited North Sea, the biomass of large fishes is 97.4% lower than it would be in the absence of fisheries exploitation. Fishing targets large sized fish, which tend to be the top predators in the food chain. Once these populations start declining or collapse, fishing efforts are moved down to the next trophic level until those species starts declining. This shift is commonly described as 'fishing down the food chain' and has several impacts on the structure of food webs and the ecosystem as a whole (Pauly et al., 1998; Jennings et al., 2002; Pauly & Palomares, 2005; Dobson et al., 2006).

Sometimes natural and anthropogenic disturbance causes the ecosystem to go into alternate states which may be less desirable for humans. An example of this is the collapse of cod *(Gadus morhua)* fisheries in New England and fisherman moving to shellfish fisheries (Roberts, 2007; MEA, 2005). Once depleted, populations such as the Atlantic cod may never recover to their previous levels of abundance. In some cases, the causes of significant changes in the marine systems remain unclear. For example it is still not clear why there was a sudden increase in Cod, Haddock *(Melanogrammus aeglefinus)* and Saithe *(Pollachius virens)*, commonly known as the 'Gadoid Outburst' in the North Sea during the 1960s (Hislop 1996). Although it is suspected that this is related to the decline in Herring stocks due to overfishing, it is still not confirmed whether there were other natural factors that contributed to this increase (Cushing 1978).

Besides fish abundance, baselines in other systems including widely regarded 'pristine' habitats such as coral reefs and seabed habitat have also changed tremendously due to human and natural activities. Many chain reactions have brought about changes in these systems such as the removal of oyster beds in Chesapeake Bay (Jackson et al., 2001). Mass eutrophication occurred here in the 1930s which was attributed to pollution and effluent discharge from agriculture and development. However, it was the overharvesting of oyster beds, which had previously acted as a filter for the water columns, which led to the decline in water quality and eutrophication (Jackson et al., 2001; Roberts, 2003; Raffaelli and Friedlander, 2012).

1.3.1 Shifting baselines and defining 'natural' ecosystem states

We know that coastal ecosystems have been exploited for centuries (Roberts, 2007) and many systems today are under stress from multiple sources including overfishing, pollution and climate change (Halpern et al., 2008). Such stresses have led to marked changes in the structure of many marine ecosystems, for instance in terms of the collapse of fisheries and changes in food webs (Jackson et al., 2001; Lotze et al., 2010; Donnan, 2001; Cardinale et al., 2010). With increasing awareness has come a strong drive from environmental policy to reverse these effects and to restore systems back to their 'natural' state. For instance, in the European Union (EU) the Marine Strategy Framework Directive commits signatories to achieve and maintain 'good environmental status' for all EU seas by 2020 as well as 15% restoration of degraded ecosystems (Secretariat of the Convention on Biological Diversity, 2005). Such a target clearly requires a definition of 'good environmental status', however many ecological changes in European seas predate systematic environmental surveys. This lack of information on 'natural' baseline states makes it difficult to set reference points, strategies and management policies. The 'shifting baseline syndrome' diagnosed by Pauly (1995) suggests that each generation of marine scientists "accept as a baseline the stock-size and species composition that occurred at the beginning of their career, and uses this to evaluate subsequent changes, often assuming that inadequate data exist for earlier periods". A study on 'shifting perspectives' was conducted by Bunce (2008) on coral systems in a small degraded island called Rodriguez, which lies in the inter-tropical zone of the south-western Indian Ocean. The study looked at the perception of 3 generations of fishermen and found evidence for 'shifting perceptions' on size and abundance of fish, where the older generation quoted more species depletion and higher catch rates than at present (Bunce 2008). Recognizing the difficulty of setting baselines when the exploitation of marine ecosystem goes back centuries, scientists have started to reconstruct past histories of marine food webs, populations and systems (Jackson et al., 2001; Pinnegar & Engelhard, 2007) to understand better the dynamics and state of marine ecosystems. A good example of the insights this historical approach can afford is the finding that the abundance of plaice *Pleuronectes platessa* was higher in pre exploited states and that fisheries on spawning grounds had greater negative impacts than had been assumed in the absence of historical data (Cardinale et al., 2010).

One of the ways to assess disturbance or negative changes caused by fishing or other activities is to identify metrics or indicators such as fish length or abundance (Rochet et al., 2010). Establishing these indicators requires prior knowledge of fish populations as the baseline is continuously shifting and it is useful to see time trends of the marine ecosystem and use these indicators to identify process changes (Trenkel & Rochet, 2010). For example, population biomass estimates commonly used for current management decisions (quotas, closures) are based on age, size-structured models and/or abundance of fish species from fisheries research surveys that took place in the 1970s; exploitation of some of these species go back decades and centuries (Mackenzie & Myers 2007). This lack of prior knowledge makes it difficult and sometimes inadequate to set 'benchmarks' and 'indicators' that can help to monitor ecosystems. There is the need to know what systems looked like before baselines can be set for service provision such as fisheries, and this led to the use of historical data to get a more holistic understanding of ecological processes.

1.3.2 Historical marine ecology and sources of historical data

Increasingly, researchers are turning to history to provide an idea of past ecosystem states (Jackson, 2001, Lotze et al., 2010) and understand human-nature interactions of the past (Szabo, 2010). It has the potential to provide a better understanding of current processes in nature and how they have been shaped by both natural (cyclones, floods) and anthropogenic changes (land use, fishing). According to Lotze et al. (2010: 199) “Knowing the magnitude of past changes is essential to judge the current state of marine ecosystems, and understanding past drivers and consequences of change is needed to mitigate current and future human impacts.” A study conducted by Cardinale et al. (2010) shows that there is a time lag of decades before we start seeing some of the ecological changes that have occurred due to human activities such as fishing. One example of such a study by Jackson et al. (2001) shows how removal of top predators such as sea otters results in population explosions of herbivores, which then results in deforestation of kelp forests and major reduction in trophic levels due to loss of kelp forests. These are all long term effects and the changes are sometimes not seen for decades. Studies incorporating this historical dimension have shown several trends that have shifted our existing perspective on marine systems (Roberts, 2007). A historical study by Lotze & Worm (2009) showed how large predatory species, such as whales, pinnipeds, large fishes and sea turtles, have decreased over the centuries, whereas several opportunistic groups such as gulls, polychaetes, green algae and exotic invaders increased during the 20th century. This study found that across 256 reviewed records, exploited populations declined 89% from historical abundance levels. Whilst such work has offered unique insights into lost ecological communities, such an approach has not previously been used to link the ecological state of historical ecosystems with the services provided to people.

Over the last 15 years, historical ecology has contributed to marine sciences and policy in several ways. On the conservation front, it has filled in several biological gaps and knowledge to deal with the issue of shifting baselines (McClenachan, 2012, Jackson et al. 2001, Lotze and Worm, 2009). On the policy front, it is being used in directives such as MSFD to aid in the benchmarks for achieving ‘Good Environmental Status’ by 2020 as well as in the assessments for the IUCN Red List of threatened species (Willis et al., 2007). It has been used in restoration conservation projects (Jackson and Hobbs, 2009) and even though it lags behind terrestrial ecosystem management using such historical records (McClenachan et al., 2012) there is a growing body of literature using novel approaches predating scientific surveys to tap into informal data sources such as archival and narrative records and zooarcheological remains. Marine historical ecology has also indirectly contributed to conservation through studies on life history traits. When there is missing data on abundance of species knowledge of the life history rates can help in predicting species vulnerability and extinction rates (Dulvy et al., 2003, Roberts and Hawkins 1999). Such studies have highlighted how traits like maximum size and age of maturity respond to exploitation. This can help in prioritization in conservation and management (Jennings et al., 1999; Dulvy & Reynolds, 2002).

The fact that exploitation of fisheries goes back centuries is richly illustrated through historical anecdotes, ship data analogues, fish landings and photographs. A study conducted by Chen et al. (2011) evaluated 100 years of environmental change in China via photography and found that repeating pictures taken from 50 years ago can help to detect vegetation change, temperature change, urbanization. Although this study was for terrestrial system, photography has been used to capture changes in marine ecosystems as well, in particular on size and types of fish. Pictures from fish markets, fish landings and from sports fishing catches have been used to highlight such changes.

Documentation of large trophy fish in Florida showed that the mean fish size declined from estimated 19.9 kg to 2.3 kg between 1956 and 2007; there was a major shift in species composition as well where it was common to catch large sharks which are now replaced by small snappers (McClenachan 2009). Besides gathering of physical evidence such as photographs, fish landings and ships' logbooks, more direct human knowledge through anecdotes (Pauly, 1995; Jackson et al., 2001; Bunce, 2008) and traditional and local knowledge of different stakeholders have also been used to collect historical marine knowledge. There is growing interest in using more socio-ecological methods in gathering such data and this is demonstrated in study carried out by Shackeroff et al. (2011) on using TEK (Traditional Ecological Knowledge) and LEK (Local Ecological Knowledge) of different stakeholders such as fisherman, diving shops, aquarium shops and marine experts. The study found data on about 271 species over a period of 80 years within a 50-mile region. There was consistency in the different stakeholders' observations of which species change in abundance or declined; however their perceptions on what they believe caused such change, varied much more. Another study goes back 200 years and coded Early Naturalists Accounts in long term fishing community changes in the Adriatic Sea. It used data collected by early naturalists and combined them with landing data to draw a picture of fish community structure indicators over 200 years (Fortibuoni et al., 2010).

1.4 Gaps in the knowledge

1.4.1 Historical knowledge and shifting baselines in ecosystem services

Literature on shifting baselines in ecological populations and communities are quite well developed and has been demonstrated in many marine communities (Hutchings & Baum 2005; MacKenzie et al., 2011; McClenachan 2009). However the human element in shifting baselines and how benefits and services have changed and adapted to these changes in ecosystem state has been explored far less. These shifting baselines that several studies have demonstrated mean that what we consider to be a 'healthy' ecosystem, with 'optimal' levels of ecosystem service (ES) provision, often lack historical context. But several of these shifting baselines have been reconstructed by leaving the human element out of marine nature, and as such the ecological baselines become the only ones of interest (Campbell et al., 2009).

1.4.2 Links between biodiversity and ecosystem services

The relationship between biodiversity and ecosystem services is complex and due to methodological challenges this complexity has been studied far more in provisioning, regulating and supportive (Harrison et al., 2014) and less in the role of biodiversity in cultural ecosystem services (Plieninger et al., 2013). According to the CBD, the Ecosystem Approach seeks to put human needs at the centre of biodiversity management and emphasizes the need to clearly identify the benefits from nature (Secretariat of the Convention for Biological Diversity, 2004). Recommendations from the studies that have been done on the relationship between biodiversity and ecosystem services, especially the intangible links between biodiversity and cultural ecosystem services calls for more novel methods to capture the values associated with biodiversity and how it benefits CES.

1.4.3 Socio-ecological coupling and future marine ecosystem services

Scientists and policy makers are looking at sustainable management of marine ecosystems in a more holistic way and incorporating all aspects – social, economic and ecological – in management of marine ecosystems. This is demonstrated in current UK legislation and policies such as the National Ecosystem Assessment, Ecosystem Approach and overall ecosystem-based fisheries management (UK NEA, 2011; Pikitch et al., 2004; Greenstreet & Rogers, 2006). According to the UK NEA (2011) some of the future uses of marine systems include offshore renewables, algal biomass, coastal defence and carbon sequestration in deep ocean waters, which add new challenges to marine and coastal sustainability. There is the need for socio-ecological adaptation to such changes and this is demonstrated in a study by Perry et al. (2011) on how societies and species have adapted to short term and long term changes to marine ecosystems. Interdisciplinary approaches of this kind on stakeholders' preferences for coastal zone management have widened perspectives on both ecological and human elements in management of marine ecosystems (Ruiz-Frau et al., 2011). There are still gaps in studying marine ecosystems using a socio-ecological perspective so that it can better feed into these legislations and policies. In this thesis, I ascertained different stakeholders' preferences for past, present and future services around the Yorkshire Coast, which can aid in identification what services can provided under future scenarios of the ecosystem.

1.5 Thesis aims

1. To identify shifting baselines in perception of different stakeholders on changes in the ecosystem and provision of ecosystem services (Chapter 4).
2. To characterize drivers of change on marine ecosystems and service change through time to inform future management and environmental change scenarios in a system (Chapter 2).
3. To explore linkages between biodiversity and less studied ecosystem services e.g. cultural services so that it can be used in marine spatial planning (Chapter 5).
4. To evaluate whether historical context adds value and informs range of ecosystem services scenarios considered for future management (Chapter 3).

Thesis objectives 1 and 4 directly link to both the conceptual framework outlined above as they address shifting baselines in perception of changes in ecosystems as well as in changes in services such as livelihoods and recreational services. Thesis objective 2 further shows how the different components within this framework – drivers, state and services – are connected and also how pathways between components can change over long periods of time. Thesis objective 3 links to the central conceptual framework more indirectly, as I wanted to address gaps in the study of ecosystem services – in particular, integration of cultural ecosystem services within the larger socio-ecological framework. When combined with the historical perspective presented in Chapter 3, however, this work is of clear relevance to the concept of shifting baselines as it highlights how interactions between visitors to the coast and coastal biodiversity have changed over the past century. Capturing the cultural values placed on biodiversity by current visitors to the coast also provides a baseline against which to assess future change with shifting use of our coastal ecosystems (e.g. from fisheries to renewable energy generation).

1.6 Thesis outline

1.6.1 Chapter 2 Drivers of change and their effects on fisheries

Changes in marine ecosystems can be both due to natural physical forces or human activities. Reconstructing history can help to show the extent to which changes are due to fishing, rather than to natural (or anthropogenic) climate change (Pinnegar & Engelhard, 2007). In chapter 2, I address the second aim of the thesis – to characterize how different drivers of change – both natural and anthropogenic – can bring about changes in ecosystem and on ecosystem service. I used an integrated modelling approach to assess how the final delivery of marine ecosystem services to coastal communities is influenced by the direct and indirect effects of changes in ecosystem processes brought about by climate and human impacts, using fisheries of the North Sea region as a case study. Partial least squares path analysis is used to explore the relationships between drivers of change, marine ecosystem processes and services (landings). A simple conceptual model with four variables—climate, fishing effort, ecosystem process and ecosystem services—is applied to the English North Sea using historic ecological, climatic and fisheries time series spanning 1924–2010 to identify the multiple pathways that might exist. This chapter highlights how path analysis can be used for analysing long-term temporal links between ecosystem processes and services.

1.6.2 Chapter 3 - Characterizing historical changes in marine ecosystem services

Knowledge of past ecosystem services and how humans had extracted marine resources and benefited from the coastal environment can aid in having a better understanding of the wide range of values present within a seascape (Tengberg et al., 2012.) In this chapter, I addressed the fourth thesis aim and illustrated how a historical perspective of ecosystem services can be used in marine policy and management. I highlight a few case studies from the Yorkshire coast to show that simply projecting back a recent linear trend in a socio-ecological system does not capture non-linear shifts within that system. I present four case studies along the Yorkshire coast to characterize historical ES, and how they have disappeared, evolved and/or changed into different ecosystem services over the past 100 years. I used long term scientific monitoring surveys, records from newspaper clippings, video clips, films and historical books and early naturalists' data records to piece together selective snapshots of marine ecosystem services along the Yorkshire coast over a 100 year period. In the past, focus on historical studies in this region have been on commercial and non-commercial fish species (Kerby et al., 2013; Callaway et al., 2007) and whilst this is one of the most important ES in this region – fisheries – there are others that have been important throughout the span of the last 100 years.

1.6.3 Chapter 4 - Local ecological knowledge from Yorkshire fishermen over a period of 60 years

This chapter addresses the first thesis aim where I try to ascertain if there are shifting baselines in perception of different stakeholders on changes in the ecosystem and provision of ecosystem services. In this chapter I carry out in depth interviews with 46 fishermen where I combine unique data resource with new information on the LEK of fishermen from the Yorkshire coast of NE England to assess how well fishermen's perception of change in the size and abundance of key fish species is reflected in independent long term data. In addition, by interviewing fishermen who started fishing this system in different decades, including some who have more than 50 years of experience, I was able to test whether shifting baselines of fishermen's perceptions of change influence the utility of the LEK framework. I also asked them about future ecosystem services such as off shore windfarms and marine protected areas to gauge out perceptions on trade-offs between services.

1.6.4 Chapter 5 - Role of biodiversity in cultural ecosystem services as perceived by local visitors/tourists

In this study I attempted to address gaps in the literature on cultural ecosystem services, its valuation and integration in the general ES framework. It addresses the third thesis aim on exploring linkages between biodiversity and less studied ecosystem services - cultural services - so that be used in future marine spatial planning. I carried out face-to-face interviews supplemented with results from data collected via online questionnaire on people who have visited the Yorkshire coast. The aim was to investigate what people enjoy when they visit the seaside, what activities are important to them, and crucially what is the role of marine biodiversity in supporting these activities. I used a mixture of open and close ended questions to capture the kinds of CES that people value, whether these have changed in time, and importantly whether these CES are linked to marine biodiversity. I also gathered people's knowledge of marine biodiversity and opinion on marine conservation to see if the activities they enjoy related to their level of knowledge and perception on the state of marine ecosystems. By gathering such data on the ecosystem as perceived by people visiting the coast, I addressed issues of trade-offs between CES and other ES in this region.

1.7 Rationale for case study of the North Sea along Yorkshire Coast, England

The focus of this study is the North Sea which has been heavily exploited by the industrialized and densely populated nations surrounding it. It has been fished intensively since 1900 and fishing effort has increased consistently since that time (Rijnsdorp, 1996; Greenstreet & Rogers, 2006). This region has been the focus of numerous long-term and/or spatially extensive ecological surveys, including the Continuous Plankton Recorder survey (www.sahfos.ac.uk), UK government bottom trawl surveys of demersal fish (www.cefas.co.uk), the Seabirds at Sea programme (jncc.defra.gov.uk/page-1547), the North Sea Benthos Survey and North Sea Benthos Project (http://www.vliz.be/vmdcdata/nsbs/about.php). In addition, the North Sea ecosystem is well captured in models including ERSEM (European Regional Seas Ecosystem Model, www.meece.eu/library/ersem.html). In a historical context, North Sea food webs have been constructed from the 1920s using planktonic data (Tett & Mills, 1991) and various other studies have been conducted on long-term changes in individual species such as Sole *Solea solea* and Plaice

(Rijnsdorp & Van Beek, 1991). Besides studies on individual species, there have been studies that relate to the spatial distribution of species (Cardinale et al., 2010). Another such study on spatial distribution by Callaway et al (2007) on the epibenthos of the North Sea found more diversity and abundance of sessile species in the Northern part and less in the Southern Part. Ecological modelling was carried out in both the period 1980s and 1880s (Mackinson, 2001) and the study demonstrates that whilst species assemblages were similar among the fish groups in both periods, the relative biomass and distribution of flows was likely to have been considerably different.

This thesis focuses specifically on the Yorkshire coast of the North Sea. The Yorkshire coast is a suitable case study because it has seen major significant shift over this time period from intensive fishing, to tourism and recreational fishing and it is currently being explored for energy (offshore wind farms, tidal energy harvesting) and coastal defence. There are good records of the biological communities of this coastal region, which can be linked with existing information on their functional traits to build an understanding of how the biology of the system ultimately defines the provision of ecosystem services.

CHAPTER 2 DIRECT AND INDIRECT EFFECTS OF CLIMATE AND FISHING ON CHANGES IN COASTAL ECOSYSTEM SERVICES – A HISTORICAL PERSPECTIVE FROM THE NORTH SEA

2.1 Introduction

2.1.1 Drivers of change in coastal ecosystems

Coastal ecosystems have been exploited for centuries (Worm, 2006; Roberts, 2007; Lotze et al., 2010) and many today are under stress from multiple sources including overfishing, pollution and climate change (Halpern et al., 2012). Such stresses have led to marked changes in the structure of marine ecosystems, for instance in terms of the collapse of fisheries and changes in food webs (Jackson et al., 2001, Cardinale et al., 2012). Recent studies have shown the causal links between physical (climate) and social drivers (human impact), and changes in marine ecosystems (Link et al., 2009; Jennings & Brander, 2010; Sumaila et al., 2011; Heath et al., 2012). The relationship between direct exploitation and changes in the abundance of target and non-target species has been well documented (Hofstede & Rijnsdorp, 2011; Luczak et al., 2012; Kerby et al., 2013). Likewise, effects of rising temperatures on species and ecosystems are increasingly well understood (Perry et al., 2005; Dulvy et al., 2008). However, what is still lacking is an integrated approach to assess how these processes affect the delivery of marine ecosystem services to coastal communities; and how these changes are influenced by the direct and indirect links between ecosystem processes, climate, and human impacts.

2.1.2 Classification of coastal ecosystem services

Coastal ecosystems provide vital suites of ecosystem services to local communities, visitors, and wider society. For instance, they act as a source of food (fisheries), employment (fishing and tourism sectors) and recreation (tourism, water sports, wildlife-watching) (Beaumont et al., 2007). Mace et al. (2012) present a system for classifying these different services by considering separately ecosystem goods and final ecosystem services (benefits) as shown for coastal ecosystems in figure 2.1. The relative contributions of these different ecosystem services to the full suite of services provided by a given coastal system will clearly change over time, as both societal priorities and states of ecosystem change. We know that ecosystem services are linked to ecosystem function and processes (Solan et al., 2012). This implies that different suites of ecosystem services will be affected by the states of different ecosystem components. However, the relationship between different services and state of the ecosystem is poorly understood (Feld et al., 2009, Bennett et al., 2009; Cardinale et al., 2012). There is thus a crucial link to be made between ecosystem processes and potential ecosystem service provision.

One approach for linking anthropogenic drivers, ecosystem function and diversity, and services is to use the Driver-Pressure-State-Impact-Response (DPSIR) framework, but most implementations of this approach have been theoretical (Bowen & Riley, 2003; Chan & Ruckelshaus, 2010; Rounsevell et al., 2010) and empirical evidence and applications to real case studies are lacking. Overall, little applied research exists at large spatial and temporal scales on how these various factors are correlated and how they interact to bring about changes in ecosystem processes and service provision. There is thus a need to study marine processes on a large spatial and temporal scale (Cardinale et al., 2012; Raffaelli and Friedlander, 2012) to connect these variables to service provision.

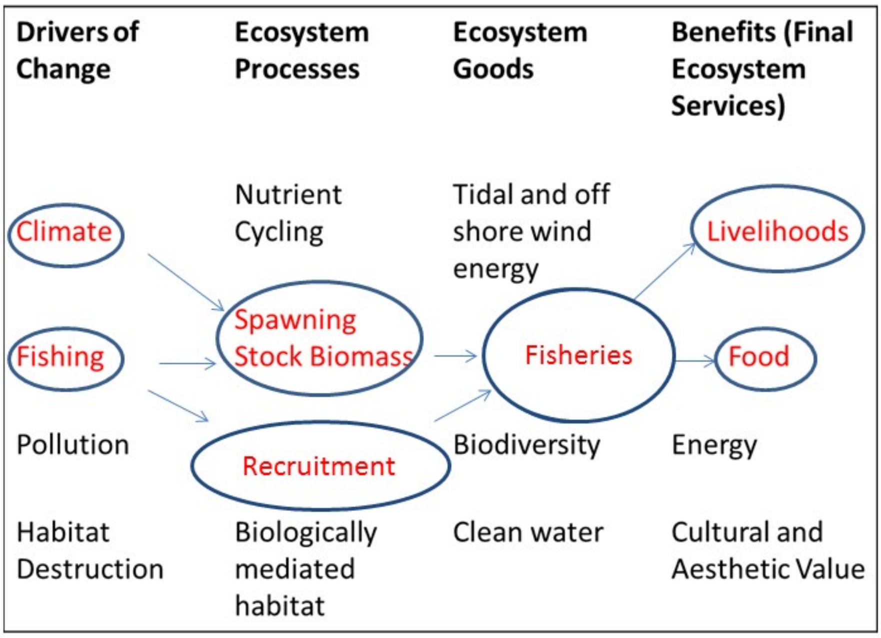

Figure 2.1 Schematic diagram, based on the framework of Mace et al. (2012), showing how a selection of drivers can affect various processes in coastal ecosystems, and how these in turn can affect ecosystem good and benefits (final ecosystem services). In this study Ilook at the highlighted pathway linking fishing and climate (drivers) to spawning stock biomass and recruitment of three demersal fish species (ecosystem processes) and the consequences for delivery of the ecosystem goods (fisheries) and ultimately on food provision and economic livelihoods (final ecosystem services).

2.1.3 Using history to understand the causal links between drivers, ecosystem and services

Increasingly, researchers are turning to history to understand past ecosystem states (Jackson et al., 2001; Lotze & Worm, 2009; Szabó, 2010), as it offers unique insights into lost ecological communities. This approach has the potential to provide a better understanding of current processes in nature and how they have been shaped by both natural climatic fluctuations and anthropogenic climate change, as well as human activities (e.g. land use change, fishing). Studies incorporating this historical dimension have shown several trends that have shifted our existing perspective on marine systems, such as the previously much higher abundances and larger individual sizes of several species and the rich diversity that existed in the past (Roberts, 2003). A long term perspective provides a means to understand these links, by analysing historic time series of physical and biological changes in a coastal ecosystem together with social changes in the provision of certain ecosystem services.

In this chapter, I illustrated how this historical perspective can be applied to long term time series, using a Partial Least Squares Path Modelling approach to show how climate and fisheries can affect ecosystem processes, and through this coastal ecosystem service provision. used the coastal region of North East England from Sunderland to Grimsby to quantify provision of an exemplar ecosystem service, the food provision and livelihoods supported by fisheries, over the course of most of the 20th Century, a period encompassing significant changes in environmental and socio-economic drivers of change. I used the excellent records of the biological communities and climatic history of this coastal region, as well as socio-economic data on fishing effort and fish landings, to examine how shifts in environmental drivers have affected fish populations and ultimately fisheries. In particular, I tested the hypotheses that fishing effort will negatively affect both indicators of fish populations (adult biomass and recruitment), despite being positively related to landings. In contrast, I had no clear expectation of the direction of the effects of climatic variables on either fish populations or fisheries landings. The objective of this chapter is to illustrate how path modelling can be used as a method to identify the direct and indirect pathways that can exist between drivers of change, ecosystem and service.

2.2 Methods and materials

2.2.1 Study region

This study focuses on the North Sea, covering the spatial range between 52°N and 60°N and between 2°W and 4°E (figure 2.2). The North Sea has been heavily exploited by the industrialized and densely populated nations surrounding it. It has been fished intensively since 1900 and fishing effort has increased consistently since that time (Rijnsdorp, 1996; Jennings et al., 2002). This region has been the focus of numerous long-term ecological surveys, including the Continuous Plankton Recorder survey (www.sahfos.ac.uk), UK government bottom trawl surveys of demersal fish (www.ices.dk/marine-data/data-portals/Pages/DATRAS.aspx), the Seabirds at Sea programme (jncc.defra.gov.uk/page-1547), and the North Sea Benthos Survey (NSBS; Craeymeersch & Duineveld, 2011). At present, the North Sea has regained importance in Britain's fisheries as, for example, in 2009 it provided 63% of the demersal fish landed by UK vessels into the UK and abroad (Marine Management Organization, 2009). I considered the coastline from Sunderland to Grimsby, focusing on a single set of ecosystem goods and the associated final ecosystem services, fisheries landings to the Yorkshire Coast – mainly into the ports of Scarborough, Whitby, Filey, Bridlington, Grimsby and Hull (figure 2.2).

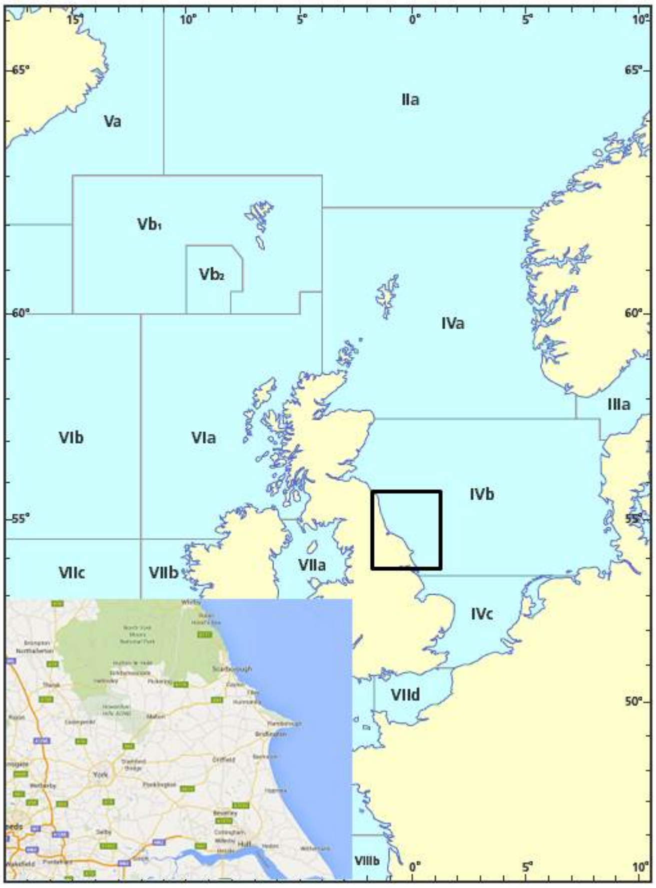

Figure 2.2 The study region consists of ICES rectangles IVa, IVb and IVc in the North Sea including the fishing ports of NE England highlighted in the black box. These include all ports from Sunderland in the north to Grimsby in the south.

2.2.2 Sources of data

Time series of fish abundance spanning the period 1924-2010 are shown in figure 2.3. Historic data on the Spawning Stock Biomass (SSB) and recruitment of three demersal species, cod *Gadus morhua*, haddock *Melanogrammus aeglefinus,* and whiting *Merlangius merlangus,* were obtained from Pinnegar (2007). These species are three key commercial species in term of landings and they also contribute >50% by weight of total species composition in the central North Sea demersal fish community (Harding et al., 1986; Sparholt, 1990; Hislop, 1996). The spatial resolution of this historical data set covered the entire North Sea, and the data is aggregated according to International Council for the Exploration of the Sea (ICES) areas IVa, IVb and IVc (figure 2.3). Further details of how these statistical rectangles are defined can be found on the ICES website (http://www.ices.dk/marine-data/maps/Pages/ICES-statistical-rectangles.aspx). This coarse resolution is typical of historical datasets, and dictated the spatial resolution of our study.

The environmental variables I used are Sea Surface Temperature (SST), to characterise long-term climatic trends, extracted for the study area from ICES Surface Data Source (http://ocean.ices.dk/data/surface/surface.htm) and averaged for each year; and the North Atlantic Oscillation (NAO) index, obtained from Hurrel et al. (2013), to characterise short-term climatic fluctuations. Monthly NAO data were averaged across summer months (April-September) and winter months (October-March) for each year.

I extracted data on fish landings to the English East Coast ports of Grimsby, Hull, Robin Hood's Bay, Scarborough, Filey, North Shields and Whitby for the three demersal fish from ICES areas IVa, IVb and IVc from 1924-2010 from ICES records (ICES, 2013). Fishing effort data were obtained from UK Sea Fisheries Statistical Archives (http://www.marinemanagement.org.uk/fisheries/statistics/annual_archive.htm). I digitized records of fishing effort in terms of number of hours in the North Sea by all sail, steam and motor trawls (beam and otter trawler >10m) from England & Wales for the period 1924-2010, and standardized effort into smack-units following Engelhard (2009). Briefly this is done by taking the fishing power of the original sail trawl as baseline and comparing all other types of trawls (steam and motor) to the fishing power of sail trawl, as recommended by Garstang (1900).

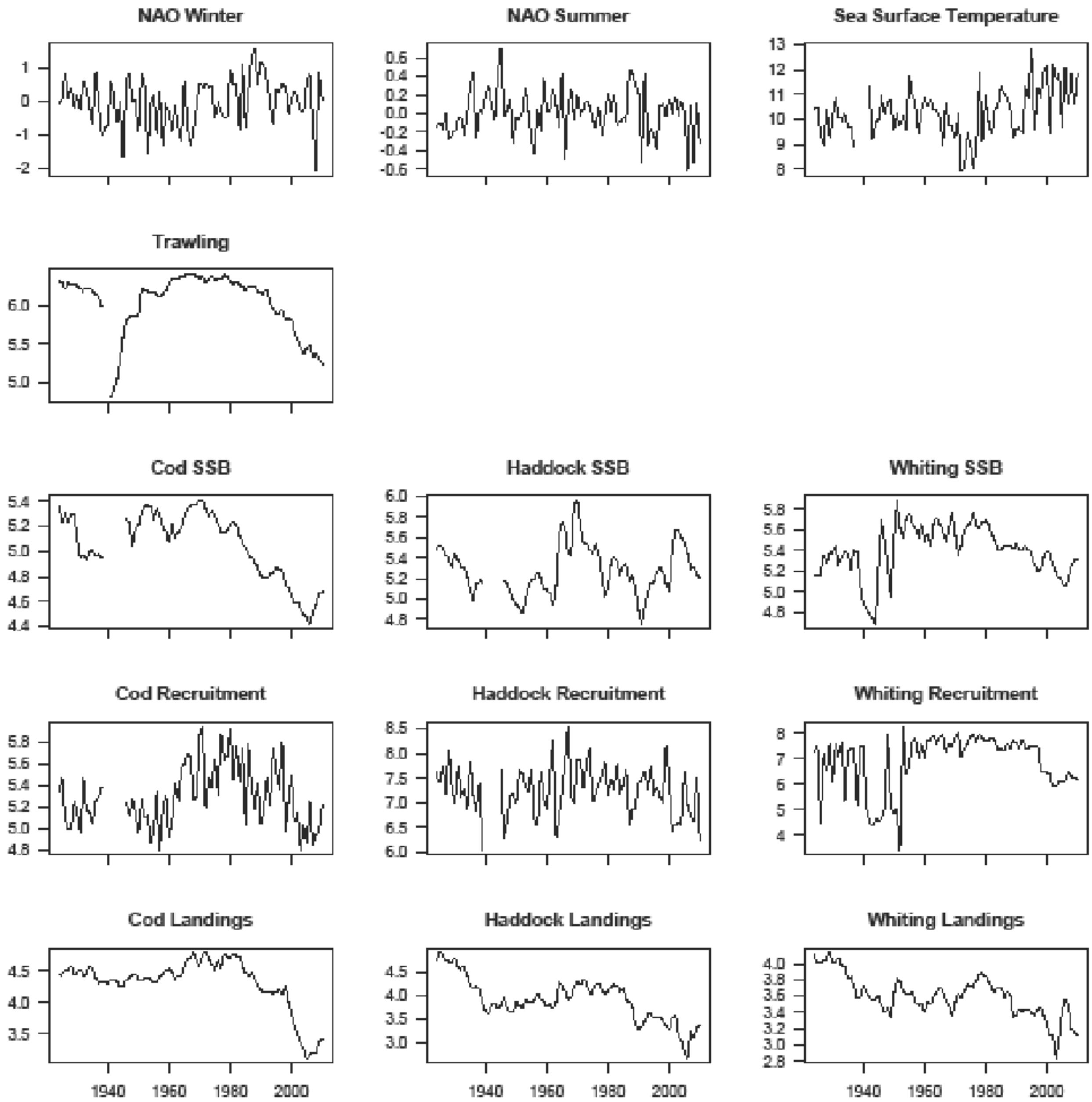

Figure 2.3 Time Series of the datasets used in this study. Climate is represented by the summer and winter NAO index and by Sea Surface Temperature. Fishing effort is represented by numbers of hours fished by different types of trawlers, standardised to constant power. Ecosystem processes are represented by spawning stock biomass (SSB) and recruitment of three commercial fish species – cod *Gadus morhua*, haddock *Melanogrammus aeglefinus, and* whiting *Merlangius merlangus*. Goods and services are represented by landings of these three species into ports on the east coast of England by British trawlers. All variables except the climate indices (NAO and SST) are log-transformed.

2.2.3 Statistical analysis

I used Partial Least Square Path Modelling, using the PLSPM package (Sanchez, 2013) in R version 2.15.3 (R Core Team 2013) to investigate the causal relationship between drivers of change (climate and effort), ecosystem processes (SSB and recruitment) and ecosystem services (fish landings). PLS Path Modelling is a variance-based form of structural equation modelling (SEM) (Tenehaus et al., 2005), allowing for the simultaneous modelling of relationships among multiple independent and dependent variables (Gefen et al., 2000). Path modelling is mainly used to measure both direct and indirect pathways between variables, as well Latent Variables (LVs) that are unobserved or hidden, and it can deal with issues of multi-collinearity when modelling complex systems, making no strong assumptions on distribution, sample size and measurement scale (Tenenhaus et al., 2005). It is a component-based estimation method (Vinzi et al., 2010) that contains an inner model (structural model) which measures the causal links between LVs (i.e. variables that are not directly observed) and an outer model (measurement model) which shows how blocks of indicator variables measure each LV (figure 2.4). This enables indicators to be aggregated, while taking into account both the impact of each indicator on its LV as well as the causal relationship between the unobserved LVs (Trinchera, 2010).

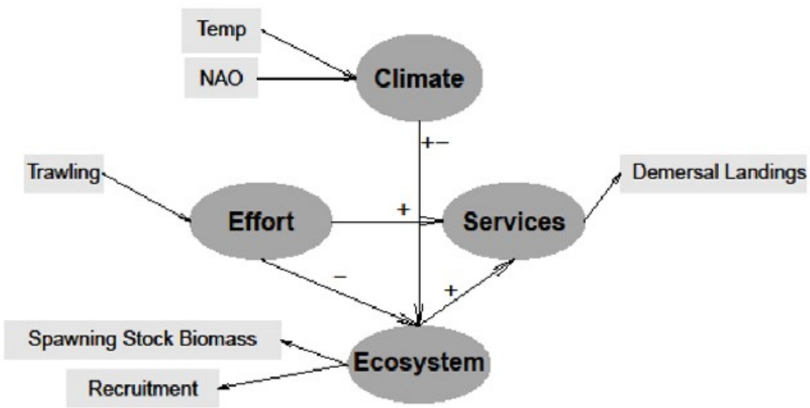

Figure 2.4 Conceptual path model linking drivers of change (climate and fishing effort), ecosystem processes and service (demersal landings). The inner model consists of 4 Latent Variables (LVs, dark grey ovals). Two of these, climate and effort, are exogenous variables (not affected by any external factors). These affect the endogenous variables (ecosystem processes and services) through different pathways. Each LV is measured by its own block of manifest variables, which form the outer model (light grey boxes). I hypothesised that climate can affect ecosystem processes directly and services indirectly, and that these effects can be positive or negative. Ecosystem processes are hypothesised to positively impact services, and fishing effort is hypothesised to impact ecosystem processes negatively and services positively.

Our path model is illustrated in figure 2.4, where four LVs (climate, fishing effort, ecosystem processes, and ecosystem services) are each measured by their own block of indicators, and the hypothesized directional flows of the impact of drivers on the ecosystem processes and ecosystem services are indicated. I hypothesized that the exogenous (independent) variables – fishing effort and climate – have four possible pathways linking them to the endogenous (dependent) variables, ecosystem processes and services. PLSPM Indicators can be constructed in reflective mode or formative mode. In our path model, climate and effort are represented by formative indicators (e.g. temperature and NAO "inform" the LV climate) whereas ecosystem and services are represented by reflective indicators (e.g. SSB and recruitment are shaped by the LV ecosystem). In reflective mode any change in the LV will cause a same directional change in the reflective indicators. Alternatively, in formative mode the direction of the indicator does not have to be the same within the LV. An example of this is the latent variable climate which is measured by SST and NAO, which are likely to be negatively correlated because a negative NAO is associated with mild winters. I further separated the two ecosystem processes, recruitment and SSB, into different LVs so as to better assess whether climate and fishing effort had different impacts on each. The LV services included landings of the three demersal fish into east England ports.

Both the inner and outer models were assessed using standard measures (Chin, 2007) of communality and redundancy, R^2 and Goodness of Fit (GOF). For the outer model (measurement model) I tested whether the chosen indicators represent and measure their LV effectively, taking a variable weight (for formative indicator) or loading (for reflective indicator) ≥0.7 to indicate a reliable construct of the indicators (Sanchez, 2013). This is equivalent to a communality (squared loading) >0.49, indicating that 50% of the variability in an indicator is captured by its LV. Itested for unidimensionality (i.e., that all indicators in a block act in the same direction) of LVs measured in reflective mode (ecosystem and services) using Dillon-Goldstein's ρ (Sanchez, 2013), which is considered a better indicator than Cronbach's α (Chin, 2007).

For the inner model, Iused R^2 to measure how much of the variance in the endogenous LV is explained by its exogenous LV (Sanchez, 2013), and average communality and redundancy to explain variability of the indicators in relation to the amount of variance due to measurement error (Sanchez, 2013). I used path coefficients to estimate the strength and direction of the relationship between the exogenous and endogenous LVs (Sanchez, 2013), and Goodness of Fit (GOF, the geometric mean of the average communality and average R^2 value) to assess the overall predictive performance of the model. Finally, I used bootstrapping as a final check of the validity of the model pathways and results, using the 95% bootstrap confidence interval to evaluate whether the parameters are significantly different from zero.

Ecosystem processes and services may not respond instantly to the effort and climate drivers, but instead show lagged responses. I therefore checked for lags of up to four years in the relationships between climate and fishing drivers and ecosystem processes and services.

Autocorrelation analysis revealed two year lags between NAO winter and both cod and whiting recruitment. I therefore included a two year time lag for NAO winter in our models.
Past research has shown that there might be strong temporal autocorrelation in climate time series (Sirabella et al., 2001).

When dealing with long time series, it is possible that the relationship between exogenous and endogenous variables has not been constant through time. In particular, in the North Sea the decline in fishing effort broadly coincides with an increase in SST, suggesting a possible shift from a regime dominated by intensive fishing, to one in which climatic effects are more significant. To test for the effects of this on our model, I first checked the fishing effort time series for changes in temporal trend. Broadly speaking (Fig 3), with the exception of the war years, effort increased until the early 1970s, and has declined thereafter. Modelling post-war (1946-2010) log-transformed trawling effort as a quadratic function of year produces an excellent fit ($R^2 = 0.96$) with an inflexion point in 1972, after which effort has declined markedly (Fig S1; see Appendix I). Trends in SST are less clear, however when I modelled this time series as a two-part linear breakpoint model, the optimal year for the breakpoint (lowest AIC, highest R^2) is also 1972, with a steeper slope (more pronounced warming) from 1972 to 2010 than in earlier years (Fig S1; Appendix I). Therefore Ire-ran our PLSPM under two different 'regimes' – a 'fishing' regime from 1924 to 1971 defined by heavy fishing effort, and a 'climate' regime from 1972 to 2010 defined by a stronger climatic influence.

2.3 Results

2.3.1 Full time series

The outer model results for the model using the full time series are shown in table 2.1. In our model all the LVs were measured effectively by only some the chosen indicators (table 2.1). In both SSB and recruitment, loadings were above 0.7 for cod and whiting but not for haddock. In the LV services, loadings was high for all landings (>0.7). Effort had only one indicator measuring its LV and therefore does not have a loadings score. The LV climate is formative and so I used weights rather than loadings for evaluation. I observed a high weight for the indicator SST (0.83) but not for NAO. Communalities were >0.5 for all the indicators with high loadings (>0.7) and as such more than 50% of their variance is shared with its corresponding LV. Values of Dillon-Goldstein's ρ were >0.7 for SSB, recruitment and services, so I considered the indicators to be homogenous and unidimensional in my model.

Table 2.1 Outer measurement results for all 3 models showing how well each indicator measures their individual latent variable. Formative indicator results are measured using weights (in italics) and reflective indicators are measured using loadings. Results that are significant (>0.7) are shown in bold.

Loadings and Weights	Full Time Series Model	Fishing Regime Model	Climate Regime Model
Climate			
NAO Winter	*0.37*	*0.49*	*0.23*
NAO Summer	*-0.29*	*-0.39*	*-0.11*
SST	***0.83***	***0.81***	***1.00***
Effort			
Total Hours Trawled	-	-	-
SSB			
Cod SSB	**0.93**	**0.78**	**0.96**
Haddock SSB	0.43	**0.91**	0.04
Whiting SSB	**0.77**	0.26	**0.95**
Recruitment			
Cod Rec	**0.75**	**0.89**	**0.76**
Haddock Rec	0.47	0.59	0.35
Whiting Rec	**0.82**	0.63	**0.9**
Services			
Cod Landing	**0.90**	**0.99**	**0.97**
Haddock Landing	**0.67**	0.01	**0.94**
Whiting Landing	**0.73**	-0.13	**0.93**

The overall GOF of our model using the full time series was 0.50, showing that the predictive performance of our model was 50%. The inner model (showing how well the LVs are related) has R^2 values of 0.21 and 0.31 for SSB and recruitment, and 0.55 for services respectively (table 2.1). In other words, >20% of the variance in endogenous variables SSB and recruitment, and >50% of the variance in services, can be explained by the exogenous variables climate and effort. All the endogenous indicators for which it could be calculated had an average communality >0.39 indicating that the indicators used to measure them are represented well in the model (table 2.1).

Path coefficients show the strength and direction of the pathways, and in our full time series model (figure 2.5A) fishing effort had a significant positive effect on both ecosystem processes SSB (0.65, bootstrapped CI: 0.54—0.79) and recruitment (0.63, CI: 0.43—0.78), and on ecosystem services (fish landings, 0.87, CI: 0.67—1.05). Climate had no significant impact on either SSB or recruitment (figure 2.5A). The impacts of SSB and recruitment on services were not significant either (figure 2.5A). PLSPM allows the total effects of LVs to be separated into direct and indirect effects. For our model, indirect effects were typically much weaker than direct effects.

Table 2.2 Reliability convergence of inner model showing the R^2 and the Average Communality for all the endogenous variables in the 3 models showing how much of the reflective block variability can be explained by the exogenous latent variables climate and fishing effort.

LV	Type	R^2 Full Model	Average Communality	R^2 Fishing Regime	Average Communality	R^2 Climate Regime	Average Communality
SSB	Endogenous	0.210	0.551	0.32	0.50	0.83	0.61
Recruitment	Endogenous	0.310	0.488	0.32	0.51	0.7	0.54
Services	Endogenous	0.551	0.394	0.48	0.34	0.87	0.89

2.3.2 'Fishing' vs 'climate' regimes

Modelling the 'fishing' (1924-1971) and 'climate' (1972-2010) regimes separately resulted in some of the path coefficients being different in the two regimes. The weights and loadings (table 2.1) show that the LV climate is still measured better by the formative indicator SST in both regimes (0.81, 1.00). In the 'fishing' regime, the LV SSB is measured well by cod and haddock SSB (0.78, 0.91) but not by whiting SSB (0.26). In the 'climate' regime, LV SSB is measured well by cod and whiting SSB (0.96, 0.95). The LV recruitment is measured well by cod recruitment only in the fishing regime (0.89) and by both cod and whiting in the climate regime (0.76, 0.90). LV services is measured well by only cod landing in the fishing regime and by all three indicators in the climate regime. R^2 and average communality of the two regimes are provided in table 2.2 which shows that the inner model of the ‘climate’ regime had higher R^2 and average communality than the fishing regime model. GOF was also higher for the climate regime model (0.69) than the GOF of the fishing regime model (0.39).

The path coefficients and their 95% bootstrapped CIs for the two regimes are shown in figure 2.5B and 2.5C. The pathways between climate and recruitment have the same directional trend in both regimes. The path coefficients for the pathways effort on ecosystem services was significant in the climate regime (0.47, CI: 0.19—0.73) but not in the fishing regime (0.31, CI: -0.31—0.79). SSB had a significant positive impact on services in the climate regime (0.50, CI: 0.27—0.76) but not in the fishing regime (0.10, CI: -0.68—0.69). The pathway from effort to recruitment was significant in both regimes (fishing regime: 0.55, CI: 0.29—0.76, climate regime: 0.89, CI: 0.70—1.04), that from effort to SSB was significant only in the climate regime (0.81, CI: 0.63—0.92), and additionally the SSB to services pathway was significant in the climate regime (0.50, CI: 0.27—0.76; Fig 5B, C).

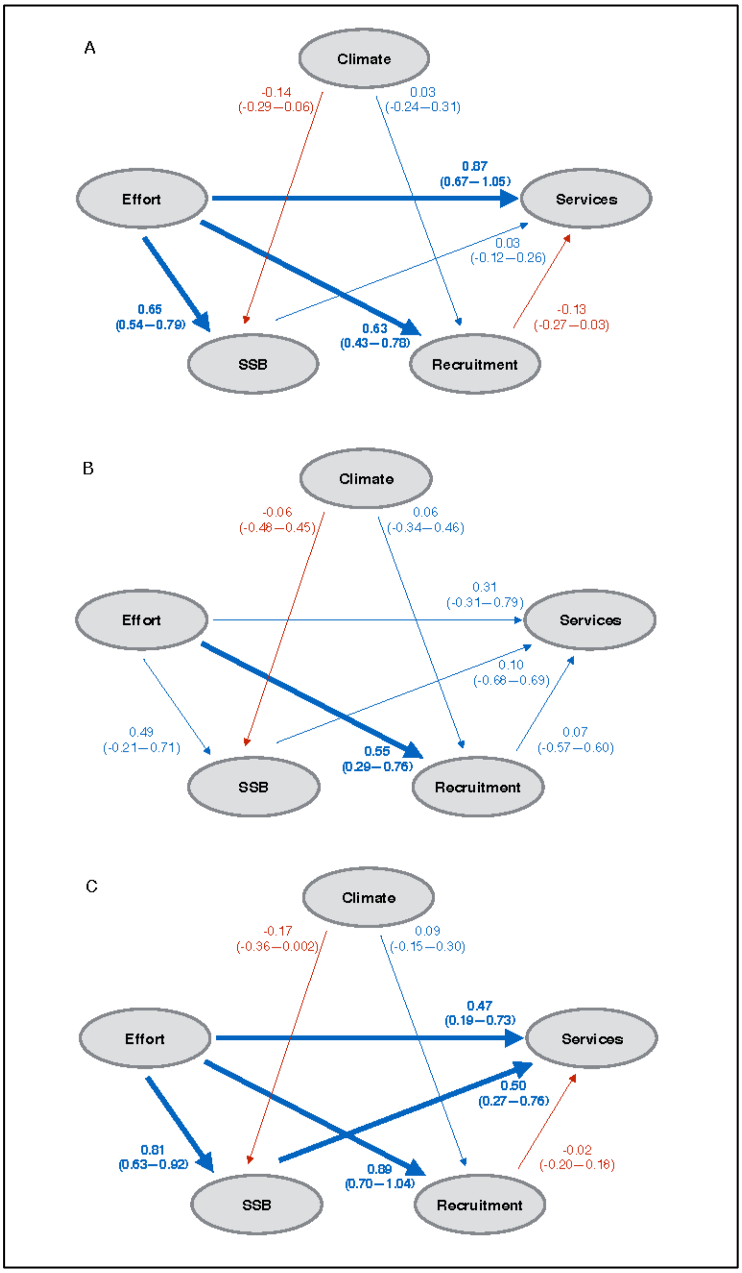

Figure 2.5 Path coefficients of the inner models for all three models showing the strength and direction of all the different pathways. Positive pathways are highlighted in blue and negative pathways in red. Bootstrap validation was carried out on all the models and the 95% confidence intervals (CI) are given below each path coefficient. A) Full time series model showing the significant positive effect of fishing effort on both ecosystem processes and services. The other pathways were not significant. B) 'Fishing' regime model showing the only significant effect was fishing effect on recruitment. C) 'Climate' regime model showing the significant positive effects that effort had on ecosystem processes and services, and SSB on services as well.

2.4 Discussion

The aim of this study was to illustrate how combining historical data with path modelling can inform our understanding of multiple drivers of marine ecosystem processes and ecosystem services. There is an inevitable trade-off between the data requirements of a model and the time period over which adequate data are available. In this initial implementation I aimed for maximum temporal coverage which has necessarily led to a simplified and partial representation of the multiple complex pathways between the physical, biological and social drivers of change in ecosystem service provision. Nonetheless I have demonstrated how a partial ecosystem pathway model can be used to test several hypotheses about the long-term change in a natural system. Our hypotheses were that effort would have a negative impact on both ecosystem processes, but a positive impact on services. Climate could have either negative or positive impact on ecosystem processes. Ifound that effort had a positive impact on both the spawning stock biomass (SSB) and the recruitment of three commercially important demersal fish species, and these results were significant in all the three models. SSB also had significant positive impact on services in only the 'climate' regime model, although the coefficient was positive in all three models. The additional pathways of climate on ecosystem processes and recruitment on services were not significant.

The fact that fishing effort had a positive impact on both SSB and recruitment could be explained by the fact that fishing effort increased during periods of high abundance and availability, such that effort responds to ecosystem processes as well as driving them. Over the 90 year period, as effort increased, especially after 1950s, SSB and recruitment also increased. The direction of causality is unclear here, however, as it could be that fishers were responding to the 'gadoid outburst' of the 1960s and 1970s, when cod, haddock, and whiting had some of the highest recruitment on record (Cushing, 1978; Hislop, 1996). Overall, the decline in fishing effort since the 1970s is mostly due to the implementation of quotas and Total Allowable Catches beginning during the 1970s and 1980s (Hatcher, 1997). As such the correlations between effort and landings are masked by other external factors such as implementation of management control and policies, which could be included in future models. Additionally I only had fishing effort data from British vessels fishing in the North Sea. As such I was unable to establish how total fishing effort in the North Sea (including effort from foreign vessels) impacted ecosystem processes and services.

The pathways between climate and recruitment, and climate and SSB were not significant. Past research has shown that climate affects fish communities and that certain species have shifted polewards or moved deeper due to rising temperatures (Brien et al., 2000; Perry et al., 2005; Kerby et al., 2013). However, the interaction between climate and ecosystem processes is likely to be more complex than the direct links between fishing effort and landings. Ecosystem processes might be affected by bottom-up forcing rather than top down control (Jackson et al., 2001; Beaugrand., 2004; Fauchald et al., 2011; Luczak et al., 2012); hence I would have had to include species at lower trophic levels such as zooplankton in the model to start seeing better interaction between change in climate and ecosystem processes. It would be possible to expand our approach to include individual species from each trophic level, as demonstrated for instance by Lauria et al. (2012) who analysed effects of changes in SST across trophic levels. Additionally, although climate is well represented in our models by a simple temperature variable (SST), future models might need to include other indicators to effectively measure climate, including temperature extremes, bottom temperature, or the Atlantic Multidecadal Oscillation (AMO).

Past studies have tried to disentangle the effects of fishing and climate on ecosystems (Rochet et al., 2010; Hofstede & Rijnsdorp, 2011). Running the model separately for the proposed fishing (1924 to 1971) and climate (1972-2010) regimes, showed that only the impact of effort on both SSB and recruitment were significantly different under the two regimes. Fishing effort had high positive correlation with both SSB and recruitment in the fishing regime but significantly higher in the climate regime. As outlined above, this can be explained in the fishing regime by effort tracking the rise in stocks due to 'Gadoid outburst' (Cushing, 1978; Hislop, 1996). In the climate regime the positive relationship between effort and stocks is likely due to both declining effort due to management instigated in the 1970s, partly in response to declining stocks (ICES, 2005). SSB had a stronger positive impact on services under the climate regime than in the fishing regime. However, recruitment had a positive impact on services under fishing regime but negative under climate regime, suggesting that these ecosystem processes might affect services in different ways, depending on how they themselves are affected by external factors. Similarly, in a study of path coefficients differ under different regimes, Cattadori et al. (2005) showed that climate impacted red grouse populations but it was the trophic interactions with parasites that differed under different regimes which indirectly affected the population.

Here I have shown how PLSPM can be applied to model the different drivers of change in a subset of the ecosystem (three commercially important demersal fish species) and for one particular type of provisioning service (fisheries). In future models, this could be extended to include interactions between different ecosystem components and processes (e.g. zooplankton, seabirds, and benthic invertebrates) as well as to other services (e.g. recreational fisheries, livelihoods, climate regulation). In addition, PLSPM has previously been applied successfully to marketing and management strategies through identification and measurement of LVs such as 'satisfaction' and 'image' (Hair et al., 2011). This is very pertinent to the field of valuation of ecosystem services, in particular cultural services which can be difficult to measure and which have been identified as a research priority (Chan & Ruckelshaus, 2010). Path analysis could also be applied to regulating services, for instance where different factors combine to provide one particular service (e.g. disturbance prevention, flood and storm protection), because several indicators can measure a single LV.

More complex models will necessarily require more comprehensive data, which will likely come at the expense of the unusually long time series I have used in this study. I believe this long-term historical context of ecosystem service provision can be useful for several reasons. First, by linking ecological and socio-economic time series we can establish functional relationships between ecosystem state and ecosystem service provision (Kremen, 2005; Nelson et al., 2009; Cardinale et al., 2012). Similarly, we can track changes in ecosystem state and ecosystem service provision, which for instance, enables the ease (or cost) of transitioning between different states to be estimated. Finally, documenting the past states of ecosystems and the services they provide can expand the range of scenarios considered for future management and definitions of ‘good environmental quality’ (Pinnegar et al., 2006; MSFD, EC 2008); MacKenzie et al., 2011). This might include quantitative changes in the current suite of ecosystem services, or qualitative changes, for instance prioritizing the recovery of ‘lost’ ecosystem services (Bullock et al., 2011).

This study adds to the growing research assessing human impact on landscapes and seascapes and its effect on biodiversity and ecosystem services (Bennett et al., 2009; Nelson et al., 2009; Chan & Ruckelshaus, 2010). It builds on previous studies by adding empirical analysis using complete time series of historical ecological and socio-economic data, to identify links between anthropogenic drivers, ecosystem process and ecosystem service. To reach any solid conclusion on the overall long-term impact of climate and fishing drivers on ecosystem processes and services it is clear that Iwould need to consider inclusion of additional variables. Future improvements to the model and integration of long term time series will help to develop these links further and allow better understanding of the complex nature of how ecosystem service provision are influenced by changes in both natural and anthropogenic factors.

CHAPTER 3 CHARACTERIZING HISTORICAL CHANGE IN MARINE ECOSYSTEM SERVICES ALONG THE YORKSHIRE COAST

3.1 Introduction

Historical ecology utilizes a wide range of discipline such as archaeology, anthropology and geology and attempts to understand past relationships between human beings and the environment. It differs from evolutionary ecology as it does not aim to study how living beings have evolved through history, but rather what past historical events had affected and shaped the state of the environment ((Balée and Erickson 2006). Historical ecology uses diverse data sources to try to understand past changes in ecosystems. These include anecdotes, photographs, and newspaper articles and they have helped to better understand past trajectories and changes that have taken place in particular ecosystems (Rick and Lockwood, 2012), before the onset of systematic ecological monitoring. Some of these studies have been on individual species that have been exploited for centuries but for which we have scientific data only going back a few decades. For instance, study by Alleway et al. (2015) used historical records to show how the collapse and extinction of native oyster (Ostrea angasi) reefs in Australia took place over a period of commercial fishing. Others have focused on using historical ecology to better understand the drivers of change such as increase in fishing effort and power of fleets (Thurstan et al., 2014).

Marine historical ecology is a relatively new field focused on bringing together historical records to better understand the ocean's ecological history (Jackson et al., 2011, Kittinger et al., 2015). As historical ecology has developed, scientists and practitioners have realized that it is not possible to study changes to the environment and ecological communities without considering the effects of human activities. We know that in many parts of the world, human extraction of marine resources had begun thousands of years ago (Thurstan et al., 2014). Even industrial fishing had begun as early as the 16th century and has had impacts on the ecosystem long before such ecological data was collected to assess these impacts.   Previously, researchers had used different ways to understand the magnitude of these impacts in different ways such as substituting space for time and studying species in remote areas which had little or no fishing pressure (Hawkins and Roberts, 2004), on the assumption that these unexploited communities would provide a useful indication of the pre-exploited state of currently overexploited systems. However such studies have several limitations as even the most pristine ecosystems have been impacted by global drivers such as climate change and ocean acidification, and also these systems are not necessarily similar to coastal ecosystems most impacted by human activities (Thurstan et al., 2014). Historical ecology attempts to address some of these issues by using whatever records are available to directly study the past state of exploited systems.

Historical ecology is not, however, without its critics. For instance, some restoration ecologists find the study of historical records stagnant and backward thinking (Martín-López et al. 2012, Buizer et al., 2012). They compared the use of historical data in restoration activities and preserving species that have not evolved to a 'living museum' (Buizer et al., 2012). Baisre et al. (2013) challenged the use of historical information to establish baselines for endangered species and called for more rigor when making such interpretations from mostly anecdotal data. Other studies have also shown that using anecdotal data for establishing geographical range of species is unreliable, leading to significant errors regarding the presence, population dynamics, and range of the species in question (McKelvey et al, 2008). Whilst the value of such anecdotal data is clearly important for bettering our understanding of past states of ecosystems – for instance, concerning their structure, function and processes (Boshoff & Kerley, 2010) – many scientists are of the opinion that historical population records are too fragmented and unreliable to be used to establish baselines. More generally, the limitations of historical data include issues such as poor records, discrepancies in how the data were collected, and the non linear dynamics between past events and how they have impacted the environment. This makes it hard to project back in time when the spatio-temporal trends are not linear.

Over the past two decades, historical ecology has contributed to marine science and policy in several ways. For instance, the Historical Marine Animal Population (HMAP) initiative, part of the Census of Marine Life (CoML, http://www.coml.org/projects/history-marine-animal-populations-hmap) has demonstrated how the past is relevant to the study of marine ecosystems (e.g. Pinnegar and Engelhard, 2014; Poulsen, 2010; Alleway & Connell 2015). In a conservation context, a consideration of history is essential to deal with the issue of 'shifting baselines' (Pauly, 1995; Jackson et al., 2001; Willis et al., 2007; Rick and Lockwood, 2012), that is, the tendency of people to consider the conditions of an ecosystem when they first encountered it to represent a 'natural' state. Such shifting baselines have been demonstrated in many marine communities (e.g. Hutchings & Baum, 2005; MacKenzie et al., 2011; McClenachan, 2009).

History is pertinent too in a policy context. For instance, there are strong policy drivers from the EU Marine Strategy Framework Directive to achieve and maintain 'good environmental status' for all EU seas by 2020 (EC 2008). This means that ecosystems should be protected and restored, and degradation prevented, while they continue to be used sustainably. However, this then raises the question, what should we restore to? The concept of 'sustainable use' suggests a focus on ecosystem services, which is seen by many as a useful tool for valuation and conservation of biodiversity and sustainable management of ecosystems (Mace et al. 2012, Granek, 2010). Even though the concept and definition of ecosystem services is relatively new, people have always derived benefits from nature and human activities have long affected and shaped the provision of these benefits. Knowledge of past ecosystem services and how humans have extracted marine resources and benefited from the coastal environment can thus aid in understanding the wide range of values present within a seascape (Tengberg et al., 2012). Yet although the provision and benefits of a marine diet through time have been studied, there are still major gaps on how economic and social changes have shaped how historical societies have used marine resources (Máñez et al., 2014). There is thus a need for better understanding of how these ecosystem services have changed over time to know what ecosystem restoration is possible that can provide an array of ecosystem services. Indeed, understanding how human societies have used different marine resources over time is considered to be one of the major priorities for future research in marine historical ecology (Máñez et al., 2014). This will require better collaboration between history and science ((Bolster

2006), including consideration of lost ecosystem services that had benefited humans in the past (Jackson et al., 2001, Roberts 2003, Saenz-Arroyo et al., 2006).

Figure 3.1 captures several issues that ought to be considered when planning any kind of management involving restoration (Jackson and Hobbs, 2009). First, there has to be redefinition of what is natural as there is hardly any system that has not been touched by human activity, even though impacts differ in scale and time. Secondly, natural and anthropogenic climate change mean that the ecosystems of even the recent past may be unsustainable under current climate. And thirdly, human impacts have sometimes caused the system to shift to other 'natural' or alternate states, beyond simple linear change within a system.

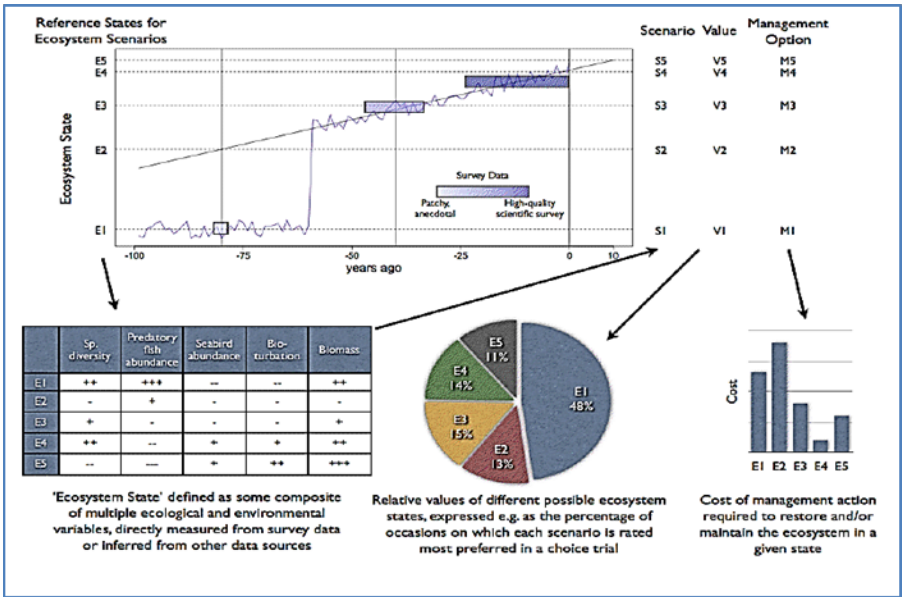

Figure 3.1 100 year timeline of the state of a hypothetical North Sea ecosystem illustrating how a historical perspective of ecosystem services might be used in marine policy and management. As shown for a hypothetical situation here, the current ecosystem state (E4) does not differ markedly from the average state over the previous 25 years of intensive sampling of the ecosystem. However, including knowledge gained from previous surveys, or other sources (e.g. contemporary reports, photographs, etc.) taken 40 years ago suggests that very different ecosystem states (E3) are possible; and looking further back still, records from 80 years ago suggest that a qualitatively different state (E1) is possible too in this ecosystem. Note that simply projecting back a recent linear trend does not capture this non-linear shift, and predicts an ecosystem state (E2) which may never have existed in nature.

To illustrate this further, in this paper I present three case studies along the Yorkshire coast to characterize historical ecosystem service (ES) provision. The objective of this chapter is to highlight

the fact that societal changes happening at a local, regional and sometimes even on international scales can bring about changes in demand for services irrespective of changes within an ecosystem.
Few regions can claim a longer history of fishing than this coastline. The productive waters of the North Sea coast have provided livelihoods for local people for centuries, encompassing the heyday of the herring fleets in early 19th century (Freethy, 2012), major industrial trawl fisheries for cod and haddock throughout the 19th century up until the 1980s (Frank, 2002), and at present Bridlington is the most important port in the UK for lobster landings and is one of the most significant in Europe (Holderness Coast Strategy, 2011). Previous historical studies in this region have focused on these commercial fisheries (e.g. Kerby et al.,2013; Callaway et al., 2007), but a range of other ES have also been important throughout the last 100 years. Here I show how some of these past ES have disappeared, evolved, and/or changed into different ecosystem services over the past century. As is typical in historical ecology, I use a range of different data types, including long term scientific monitoring surveys, records from newspapers, film archives, historical books, and records from early naturalists to piece together selective snapshots of marine ecosystem services along the Yorkshire coast. Today there is growing support for such opportunistic data with schemes in the UK like the garden bird watch scheme, and many other citizen science schemes that use public participation to capture biodiversity in local urban and rural spaces (Roy et al., 2015). Here I focus three groups of services: recreational angling, natural history, and the importance of seabirds for different types of ecosystem services.

3.2 Historical ecosystem services of the Yorkshire coast of the North Sea

The North Sea is among the best studied Large Marine Ecosystems in the world. Many long-term and/or spatially extensive ecological surveys have been carried out there, including the Continuous Plankton Recorder survey (www.sahfos.ac.uk), UK government bottom trawl surveys of demersal fish (https://datras.ices.dk/Home/Descriptions.aspx#NS-IBTS), the Seabirds at Sea programme (jncc.defra.gov.uk/page-1547), and the North Sea Benthos Survey and North Sea Benthos Project (http://www.vliz.be/vmdcdata/nsbs/about.php). In a historical context, North Sea food webs have been constructed from the 1920s using planktonic data (Tett & Mills, 1991) and various other studies have been conducted on long-term changes in individual species such as Sole *Solea solea* and Plaice *Pleuronectes platessa* (Englehard et al., 2011). This study found that shifts in distribution patterns in both species were attributed to climate change for plaice rather than to fishing, but that both climate and fishing affected the distribution shift of sole. In addition to individual species, the North Sea ecosystem is well captured in models including ERSEM (European Regional Seas Ecosystem Model, www.meece.eu/library/ersem.html), which can hindcast detailed estimates of environmental conditions several decades into the past. For instance, modelling the system under both 1880s and 1980s conditions, Mackinson (2001) shows that whilst species assemblages were similar among the fish groups in both periods, the relative biomass and distribution of flows was likely to have been considerably different. Besides studies on individual species, there have been studies that relate to long term spatial distribution of species (Cardinale et al., 2010) which showed that it was not only the abundance that was higher in the past, but that species richness was higher as well.

The Yorkshire coast is bounded to the north by the River Tees and in the south by the Humber. The first settlers who came here were seafarers (Frank et al., 2002). It encompasses a mixture of sandy beaches, rocky coves and rugged cliffs and is home to a wide range of wildlife including iconic species such as the puffin (*Fratercula arctica*) and minke whale (*Balaenoptera acutorostrata*). The Yorkshire North Sea coast is particularly interesting because of the long (and well documented) relationship of its communities with the sea, together with recent shifts in the way that people have exploited and enjoyed its marine environment, including changes in the species targeted by large- scale commercial fishing and recreational angling, different activities preferred by tourists to the region, and different industries dependent on the coast (Robinson, 1989; Frank, 2002; Roberts, 2007). In the pre-railway period Yorkshire was known for its ship building and alum extraction industry (Robinson 1989, Frank, 2002). But fishing was always central to these communities, in particular the fishery for herring *Clupeus harengus*. By the 1870s and 1880s, the Yorkshire harbours were packed with vessels that had come in for their share of the herring harvest, with more than 200 boats fishing for herring out of Whitby alone (Freethy, 2012). Widespread introduction of trawling in the 19th century had a revolutionary impact on fishing, with major fisheries for cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, ling *Molva molva*, plaice *Pleuronectes platessa* and other demersal species in addition to herring (Frank, 2002). The herring brought predators too: bluefin tuna *Thunnus thynnus* was present in the region between the 1900s-1970s, where they are known as 'tunny' (Ross, 2010). Indeed, Scarborough was the centre of a sport fishing industry from the 1930s to 1950s (Berry, 2010) see Case Study 1 below. The sport fishery for tunny also dwindled with the last certified fish caught in 1954; it is still not clear whether this fishery collapsed from overfishing or from long term weather or climatic change (Fonteneau, 2009).

MR. T. O. M. SOPWITH AND HIS PARTY'S RECORD CATCH OF TUNNY CAUGHT OFF SCARBOROUGH

Figure 3.2 Fishing boat party record catch of tunny caught off Scarborough. Photo credit: Roberts, 2007 http://www.york.ac.uk/res/unnatural-history-of-the-ea/images/content/gallery/gstb8large.jpg

Tourism has also long been very important in this region, especially after the railway transportation had started in 1860. Scarborough was the first seaside resort in England and large numbers of working class people flocked here during the months of April to September to visit the coast, with its cliffs, rocky shores, sandy beaches, resort towns and fishing villages (Walton 2000). Coastal tourism here is generally associated with activities such as boating, fishing, bird watching, rockpooling and recreational use of beaches for walking and enjoying day excursions. A study carried out by Usher et al. (1974) on the impact of tourism on the coastal area of Spurn Point, Yorkshire gives an overview on some of the concerns and issues, such as disturbance of wildlife and pollution, associated with increasing number of people visiting the coasts. Seaside tourism is still very important in this region supporting 11,400 jobs and producing an estimated Gross Value Added (GVA) of £65 million (Beatty & Fothergill, 2010). In Chapter 5 I focus on recreational ecosystem services along the Yorkshire coast where I assessed which activities are still important to local visitors.

3.3 Case study 1 - changing species composition leads to provision of different ecosystem services: sport fishing for tunny

British zoologist and sea captain Wolfe Murray observed that in the 1920s and 1930s there were large schools of bluefin tuna *Thunnus thynnus* - known locally as 'tunny' - feeding on herring which fell from the herring nets hauled aboard or thrown back out to sea (Wolfe Murray, 1932). From Murray's observations we know that these schools of tunny were present in the North Sea for an average of 71 days during the period 1923-1931. They were major predators and most of this prey (ca. 75%) was probably herring (Tiews, 1978). Beginning in the early 1930s methods and equipment were developed to enable these enormous fish to be hooked and landed on rod and line (Ross, 2010). Prior to that, in 1928 and 1929, English anglers had travelled to Denmark to participate in Danish bluefin sport fisheries (Svendsen, 1949). There are no known landings of tunny from English waters prior to 1930, but the well-known angler Mr Stapleton-Cotton had hooked two large fish estimated at well over 270 kg and almost certainly bluefin, off Scarborough, Yorkshire, in 1929, but he was not able to retain either (see http://www.fileybay.com/tunnyfish/). 1930 was the year that fishing for tunny from Yorkshire became prominent, and the burgeoning popularity of this sport, together with the consequent founding of the British Tunny Club has left us with a rich documentation of the size and location of all tuna caught during the heyday of Scarborough sport fishery (Berry 2010; Ross 2010). There is even a short film clip stored at the Yorkshire Film Archive about a sport fishing expedition for tunny and what they caught that day (http://www.yorkshirefilmarchive.com/film/tunny-action). Most fish were caught off the Yorkshire coast between Scarborough and Dogger Bank, with detailed records where each was landed (Ross, 2010), and they tended to be extremely large. Figure 3.3 shows records for each individual tunny caught and recorded by the British Tunny Club between 1930 and 1955. The mean size was 269 kg and the maximum size was 386 kg for an individual caught in 1949 (figure 3.3).

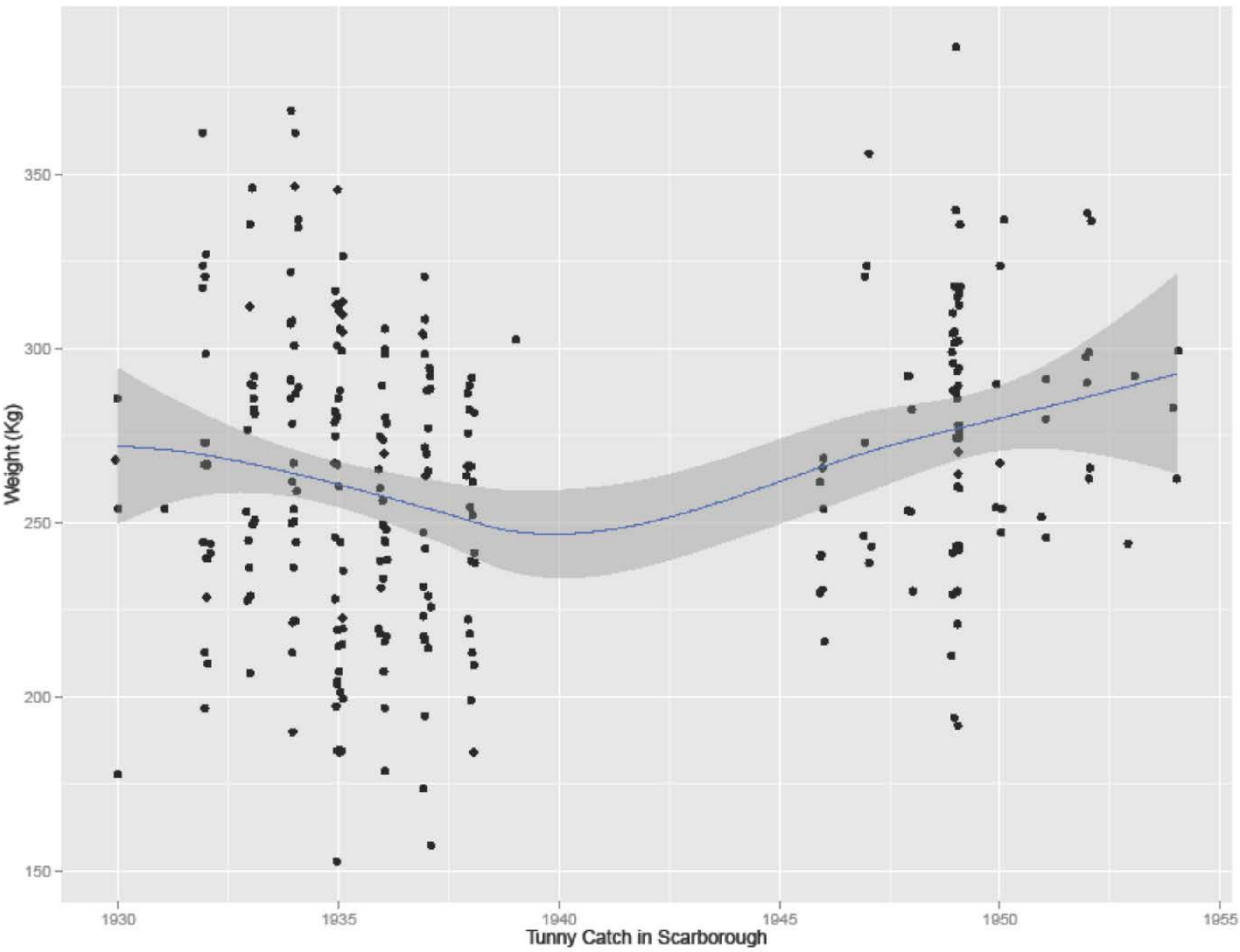

Figure 3.3 The British Tunny Club record of certified catches 1930-1954 taken from Appendix I, Ross (2010)

There have been a few studies of the North Sea bluefin tuna population and fishery, and speculations over why they had disappeared. Mackenzie and Myers (2007) document the rise and fall of the bluefin tuna fishery in European waters from 1900-1950 and mention how there is poor documentation on landings and gear data and the overall general development of the fishery for this species. The Bluefin tuna came to North Atlantic waters during their annual migration to feed on herring and mackerel (Tiews, 1978). Arrival was usually in late June–July and departure around late autumn (Mackenzie and Myers 2007) Whilst fishing for tunny was primarily a recreational sport in UK waters, this was not the case in other neighbouring countries (Fontaneau, 2009). For instance, commercial fishing of bluefin tuna developed in neighbouring countries such as Denmark, Germany and France in the 1920s and in Norway after World War II (Mackenzie and Myers 2007). It is still not clear why the tunny stopped visiting the Yorkshire coast during their migration, resulting in the end of the fishery. According to (Tiews, 1978), it is not due to overfishing of the bluefin stock, but most likely as a result in environmental changes which led to their changing patterns. This view that even though commercial exploitation had a role in the disappearance of this species, the weather patterns were inconsistent during this time has been stated elsewhere too (http://www.worldseafishing.com/more-fishing/angling-history/history-british-tuna-fishing/). There were also social changes that occurred, for instance, the demography of people with free time and disposable income to chase tunny every summer had become rarer in the 1950s (Berry 2010). Even though this ES was specifically local to Yorkshire coast, in particular to Scarborough, the people benefitting from it were not local and mostly rich aristocrats from other parts of Britain: "Attracted by tales of the huge fish, high society turned its attention to Scarborough where sport was available only a few miles offshore. Special trains were run from London to bring the luminaries. Magazines published many sensational stories covering the personalities and the yachts that sailed to Scarborough" (Taylor, 1934).

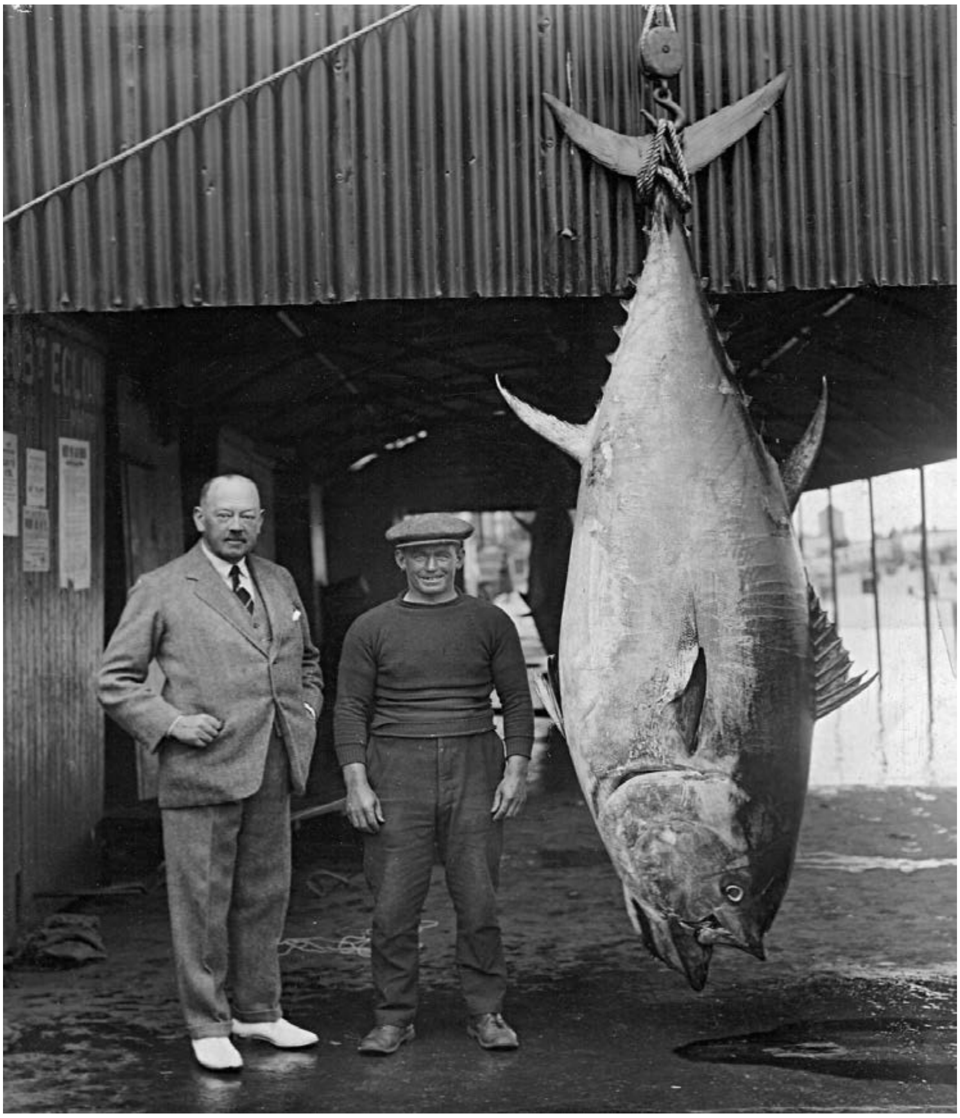

Figure 3.4 Photo of Lorenzo Mitchell Henry with his 851 pound (386 kg) tunny catch taken in 1933. Image reproduced with permission from Roberts, 2007

Recreational fishing is still popular along the piers of fishing villages around Yorkshire but it is mainly for demersal fish species such as cod, sea bass and whiting (http://britishseafishing.co.uk/yorkshire-and-humberside/). There is even an annual Scarborough competition which had been running since 1890 and is still a popular event today. Therefore, although recreational angling remains popular in this region, the exact nature of this important ES has changed markedly, with few people alive today lamenting the loss of the tunny. Recently however bluefin tuna have been cited and caught around the coast of Wales (http://www.mirror.co.uk/news/uk-news/two-monster-tuna-fish-weighing-6429004) and Ireland, with the possibility that tunny might return to Yorkshire as well (http://www.yorkshirepost.co.uk/yorkshire-living/health-family/monsters-of-the-north-sea-1-5054002).

3.4 Case Study 2 - Changing attitudes lead to different benefits from the same ecosystem resources: from climmers to twitchers and from whalers to wildlife tour operators

An interesting observation from studying ecosystem services over a long period of time is the fact that certain aspects of an ecosystem (sometimes certain species) can provide a different suite of ecosystem services at different periods of time regardless of changes in the abundance or diversity within that ecosystem. To demonstrate this, I observed the services provided by seabirds on Bempton Cliffs in the 1920s and now. Bempton Cliffs is a popular nature reserve run by the RSPB (Royal Society for the Protection of Birds) and is situated on the north side of the Flamborough peninsula, just west of North Landing (Map in Chapter 5, figure 5.1). The reserve is home to the largest seabird colony in England with large breeding aggregations of charismatic species such as puffins *Fratercula arctica* and gannets *Sula bassana*. There are eight key species of seabird inhabiting the cliff face through the spring and summer months: gannet, puffin, kittiwake *Rissa tridactyla*, razorbill *Alca torda*, guillemot *Cepphus grylle*, fulmar *Fulmarus glacialis*, herring gull *Larus argentatus* and shag *Phalacrocorax aristotelis*. This area is mainly visited by birdwatchers today as well as by people who come to enjoy coastal walks. Tourism statistics show that 46-66,000 people visit Bempton Cliffs annually to see the 250,000 seabirds that flock here to find mates and lay eggs (Keith Clarkson, Bempton Cliffs Site Manager, pers comm).

From the 18th to the early 20th centuries, Bempton Cliffs was visited for different reasons then it is now. During the 1920s there was high demand for seabird eggs. Some were bought by egg collectors, others used for sugar refining and manufacture of patent leather. But mostly they were eaten by local people. In other words, seabirds, which now provide recreational ecosystem services, were in the recent past a source of provisioning services. The men who collected eggs on the cliffs were known as egg climbers or just ‘climmers’. The process involved being lowered down on ropes anchored at the top by their fellow climbers. They collected mostly guillemot eggs, with up to 130,000 guillemot eggs taken each year (see http://www.hulldailymail.co.uk/Daredevils-Bempton-Cliffs-Climmers-collected/story-20342022-detail/story.html). The collectors did not really see it as damaging to the birds because when one egg is stolen, the guillemot would just lay another and when that is stolen they would lay a third. What they did not know was that the second or third egg was unlikely to be fertile (see http://www.hulldailymail.co.uk/Daredevils-Bempton-Cliffs-Climmers-collected/story-20342022-detail/story.html). The sheer number of guillemots on those cliffs made egg collecting a prosperous occupation, even though the whole process of dangling on a rope over the sea with rocks below is very dangerous. Climmers collected the eggs of the gannets and razorbills as well (http://www.hulldailymail.co.uk/Daredevils-Bempton-Cliffs-Climmers-collected/story-20342022-detail/story.html). There are several stories http://www.scarboroughsmaritimeheritage.org.uk/abempton.php, newspaper clippings and there are two short film documentary that can be seen in the Yorkshire archives of the egg collectors http://www.screenonline.org.uk/film/id/514132/index.html and http://www.yorkshirefilmarchive.com/film/egg-harvest-cliff-climbing-flamborough. Changing attitudes towards birds, enshrined in The Bird Protection Act of 1954, put a stop to this practice and this ended a 200 year old industry.

Figure 3.5 Image of Cliff Egg Gatherers at Flamborough Head, 1910 credit © Amoret Tanner / fotoLibra Reproduced with permission.

Climmers were not the only people to seek food from the cliffs. In the mid 19th century there was a lot of bird shooting on the Bempton Cliffs for sport carried out by Victorian shooting parties in boats sailing out from Scarborough and Bridlington (http://www.rspb.org.uk/news/details.aspx?id=tcm:9-

228954). This suggests that yet another benefit – this time a recreational service – was also provided by the seabirds. However this conflicted with the egg climbers and once the Seabird Preservation Act of 1869 was passed, it put a stop to the hunting. Today the benefits we derive from Bempton's seabirds are entirely different: Bempton Cliffs is one of the UK's most popular sites for birdwatchers who flock here to see the thousands of seabirds. Throughout the British Isles, some seabird populations have increased in size over the last century for a number of reasons, including increased protection from hunting and persecution (Mitchell, 2004). Others have decreased over the last 30 years. The common guillemot, which was exploited the most for the bird egg collection, is now the most abundant seabird in Britain and Ireland and studies show that these numbers are double what they were in 1969-70 across UK (Mitchell, 2004).

Not everyone welcomes the shift in attitudes towards seabirds, however. For instance, the fishermen interviewed in Chapter 4 present another side of the story. They feel that the abundance of birds at Bempton Cliffs, especially the gulls, clashes with provisioning services – fisheries. Although certainly there have been increases in some species, other factors are also at play. For instance, one of the reasons people might perceive an increase in gulls (both fishermen and tourists believed gulls had increased; chapters 4 and 5) was that the number of some species such as the herring gull and lesser black-backed gull roosting on rooftops in towns and cities increased during the 1980s and 1990s. However, these birds represent a small portion of the total herring gull population which nests mainly on coastal cliff tops, and this population has declined by 50% since 1969-70 (Mitchell et al., 2004). The decline in commercial fishing around the British Isles over the past 30 years, together with less discard and retention of offal for conversion to fish meal, has led to a reduction in food available to scavengers such as the herring gulls (JNCC, 2014). Even though kittiwakes are also one of the most abundant seabirds in the British Isles, there has been a decline in its numbers since the 1985-88 survey. The number of greater black-backed gulls breeding in Britain has changed little over the last 30 years whereas the number of lesser black-backed gulls has increased over the last 30 years by 77% (JNCC, 2014). The public perception of gulls in general seems to be that they have increased and it is very probable that most people, both local visitors and people visiting from outside this region are not aware of past ecosystem services provided by the sea bird population of Bempton Cliffs.

Besides the high abundance and diversity of seabirds, the Yorkshire coast is also visited by several marine mammals. We know from survey records, sightings and strandings that a variety of cetaceans such as minke whale *Balaenoptera acutorostrata*, harbour porpoises *phocaena phocoena*, white beaked dolphin *Lagenorhynchus albirostris* and grey seal *Halichoerus grypus* are present in this region of the North Sea and seen frequently off the coast (Walday and Kroglund 2011.) Whitby was a popular whaling station and one can still see the jaw bones of a whale along the west cliffs of Whitby, kept as a monument to the whales caught by Whitby fishermen. During the period 1753-1833, there were 55 whaling ships that operated from the harbour (http://www.whitbyonline.co.uk/whitbyhistory/whaling.php). Further remnants of this part of Whitby's whaling history can be seen at the local museum there, including the provisioning services (oil, food) that whales provided earlier part of this century. But it is only in the last 20 years or so that marine mammals, besides being an important part of the rich biodiversity in the North Sea, started providing recreational services locally here as well when small boat operators started offering whale watching tours. Many of these operators were previously fishermen who did not find it feasible to make money from fishing due to quotas and restrictions implemented in the 1980s. During fishermen interviews (chapter 4), several of these tours in Whitby for whale watching as well as seal watching tours in Flambourough Head and Scarborough could be seen. Furthermore, as part of The Living Seas project run by Yorkshire Wildlife trust, the Flamborough Head Living Centre works with some of these fishermen I interviewed in chapter 4 and provides marine wildlife viewing boat trip around the chalk headland of Flamborough. What is interesting is that the fishermen who are working with conservation agencies such as the YWT come from a long line of fisherfolk going back 6 generations. They have adapted to changes in the socio-economic system and adjusted their fishing patterns seasonally to supplement their income with provision of wildlife tour as there is high demand for it during the summer months.

3.5 Case Study 3 - Consequences of changes in the ecosystem or a change in societal need? Shift from whitefish to shellfisheries

As outlined above, Yorkshire's fishing communities were built on major fisheries for herring, initially, with whitefish such as cod and haddock becoming more important through time. Considerable focus has been placed on the causes and consequences of declines in these fisheries, with historical data playing a key part (Kerby et al., 2012). This narrative is echoed in other studies of the loss of ecosystem services as a result of loss or decline in species (Worm et al., 2006). However, although much reduced in scale, there remains a thriving inshore fishing industry in Yorkshire's fishing ports, centred primarily on shellfish (mainly lobster *Homarus gammarus,* crab *Cancer pagurus* and nephrops *Nephrops norvegicus*). Bridlington is the largest lobster landing port in all of Europe and brings in £5 million annually (Holderness Coast Strategy, 2011). It also supports 85 individual businesses as well as auxiliary activities such as marketing and processing (http://www.fishupdate.com/nffo-plays-key-role-in-saving-bridlington-shellfish-industry-fishupdate-com/).

Similar shifts have been seen elsewhere, for example in New England and Newfoundland where fishermen also shifted to shellfish following the collapse of cod *Gadus morhua* fisheries (Roberts, 2007; MEA, 2006; Howarth et al., 2013). It has been argued that this represents a regime shift from fish-dominated to shellfish-dominated and that once depleted populations of fish such as cod may be unable to fully recover (Hutchings 2005). However, because there are few robust, long term surveys of the abundance of key shellfish species, it is often hard to tell whether existing shellfish fisheries were dependent on the collapse of whitefish stocks, or were simply unexploited previously due to a lack of market demand. In other words, perhaps fishermen just adapted to higher demand for shellfish, alongside reduced quotas on whitefish such as cod, and so started increasing effort on targeting shellfish rather than whitefish (Perry et al., 2010). Again, the longer, historical perspective is useful here, emphasizing the cyclical nature of Yorkshire's fisheries: "…the region's fisheries have been dominated by the pursuit of different species in different ages. During Medieval times the Yorkshire coast summer herring fishery was a major source of revenue to rich and poor alike, whilst for centuries hand lining or netting of species such as cod and haddock was a mainstay of the industry. Crabbing became increasingly important from late Victorian times and today the lobster fishery forms a crucial element of the region's fish trade. Throughout the centuries, however, whatever the species pursued or the method of capture deployed, the sea and the sea fisheries have always occupied a significant and distinctive position in the economic, social and cultural life of the region." (from: *http://nffo.org.uk/news/the-fortunes-of-fishing-in-yorkshire.html*).

3.6 Conclusion

These three case studies are presented to highlight the fact that societal changes happening at a local, regional and sometimes even on international scales can bring about changes in demand for services irrespective of changes within an ecosystem. Conservation efforts such as restoration, rewilding, and identifying what to preserve need to incorporate this aspect of changing societal needs. The purpose of restoration ecology is not only to reverse habitat loss and damage done, but also to discover and when possible, recover ecosystem services that are associated with the coastal environment (Kittinger et al. 2015). In this chapter, I use the first two case studies to highlight the loss of such past ecosystem services.

The concept of 'shifting baselines' is now well-established in study of ecosystem conservation and management. I use our case study of the North Yorkshire Coast to extend the concept to economic and cultural ecosystem services, and show that it applies equally in this context. This can help to address the 'intergenerational amnesia' experienced with shifting baselines in ecosystem states (Alleway, 2015, Roberts, 2003, Pauly, 1995). The issue of trade-offs between services has been highlighted in several studies (Maes et al., 2012, Martin-Lopez et al., 2009) and adding such historical anecdotes on how one service (e.g. fisheries) has previously affected another (e.g. tourism) can aid in our current understanding of marine ecosystem and how best to manage use its resources. Referring back to figure 3.1, and knowing about trade-offs between services, one can see that there is unlikely to be some 'optimal' ecosystem state in which all features of value are maximized. However, by presenting stakeholders with a range of ecosystem scenarios, based on known past, current, and projected future states, it will be possible to generate a relative preference for each defined state.

These three case studies are presented to highlight two important points in the study of marine historical ecology. Firstly, they demonstrate that societal changes happening at a local, regional or sometimes even international scale can bring about changes in demand for services irrespective of changes within an ecosystem. The Seabird Preservation Act of 1869 was implemented nationally and it had long term local effects on changes in ecosystem services at Bempton Cliffs, independent of any change in the state of the ecosystem (e.g. in terms of the population sizes of seabirds).

Secondly, marine historical ecology recognizes the importance of harnessing the types of narrative stories and anecdotes presented here to understand past changes within an ecosystem. For instance, Bolster (2006) argues that harnessing such storytelling helps to keep people and culture connected to nature. Improving accounts of the changes in marine environments where human values and behaviours play a central role, such as those I present here, is therefore important.

Finally, studying historical interactions between humans and nature also helps us to understand past socio-ecological systems. Globalization is a central feature of coupled human–environment systems (Young et al. 2006) and studying these patterns of changes can thus give us new insight on resilience and adaptability. In case study three, I highlight how local and global societal changes can bring about shifts in ecosystem services and this theme is picked up again in chapter 4 when fishermen discuss the trade-offs in the shift from targeting whitefish to fishing primarily for shellfish.

The three case studies demonstrated here highlight socio-ecological coupling on a local scale where fishermen adapt to changes in socio-economic situations but also benefiting from different species within the same ecosystem. Using such socio-ecological historic data can also help us to project likely ecosystem provision scenarios under different future ecological regimes and it can expand our conception of what services are possible from a given environment, depending on what the socio- ecological system looked like at different periods in time. In other words, it enables a full discussion of what 'good environmental status' means to different stakeholder groups, leading to more informed decisions about future management targets.

CHAPTER 4 SHIFTING BASELINES IN LOCAL ECOLOGICAL KNOWLEDGE: CONFRONTING FISHERMEN'S PERCEPTIONS OF LONG-TERM CHANGE IN A MARINE ECOSYSTEM WITH ECOLOGICAL DATA

4.1 Introduction

Long term exploitation of marine ecosystems has resulted in loss of marine biodiversity and habitat destruction, analogous to the effects of agricultural intensification on land (Swartz et al., 2010). This in turn has resulted in reduced supply of many ecosystem services (Worm et al., 2006) such as change in food production (fisheries), reduction of supporting services (nutrient cycling) and resistance to damage from extreme events (e.g. due to loss of natural sea defences). For example, over-exploitation by fisheries has led to changes in the composition, size, and abundance of fish stocks (Pauly et al., 1998; Jennings et al., 2002; Pauly & Palomares 2005), with the tendency of fisheries to target large, high trophic level species leading to substantial declines in the biomass of large fishes in some ecosystems such as the North Sea (Jennings & Blanchard 2004). Recovery from an over-exploited state is not always possible, as some ecosystems have been shifted into alternate states which may provide different suites of services to those previously exploited. For example, the collapse of Cod *(Gadus morhua)* fisheries in New England was followed by the development of shellfish fisheries (Roberts, 2007; MEA, 2006).

Although the intensification of fisheries at a global scale is a relatively recent phenomenon (Watson et al., 2013), some marine ecosystems such as the North Sea have been exploited for centuries (Kerby et al., 2012). With increasing awareness has come a strong drive from environmental policy to reverse negative effects of exploitation and to restore systems back to their 'natural' state. For instance, in the European Union (EU), there is the Water Framework Strategy Directive (WFD, 2000/60/EC) which aims for 'good environmental status' of all surface and ground water by 2015 and the Marine Strategy Framework Directive which commits signatories to achieve and maintain 'good environmental status' for all EU seas by 2020 as well as 15% restoration of degraded ecosystems (EC, 2008). The target according to MSFD is to achieve "ecologically diverse and dynamic oceans and seas in the EU which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations". Such a target clearly requires a definition of 'good environmental status', however many ecological changes in European seas predate systematic environmental surveys (Mee et al., 2015). This lack of information on 'natural' baseline states makes it difficult to set reference points, strategies and management policies. There is also the debate of what is considered natural and how far do you go back to define a state that is undisturbed by human activities. Some systems have had marine resources extracted for millennia whereas in others significant exploitation dates back only decades. This leads to subjectivity amongst ecologists on deciding what a pristine system looks like (Campbell et al. 2009). At the same time, there is also uncertainty over describing what a past ecosystem was like, and the possibility of past regime shifts may mean that it is not straightforward to return to a past state simply by removing some specific pressure. Further, (Paetzold et al. 2010) suggest that attaining 'the undisturbed reference state' is only one aspect of an ecosystem and it is also important to look the value that people and society places on provision of ecosystem services.

In the light of all these problems and issues, scientists have started to reconstruct past histories of marine food webs, populations and systems to understand better the dynamics and state of marine ecosystems (Jackson et al., 2001; Pinnegar & Engelhard, 2007). Alongside this has been a growing appreciation of the utility of historical data to study past human-nature interactions (Lotze & Worm, 2009, Szabó, 2010, McClenachan et al., 2012, Palmieri et al., 2014, Máñez et al., 2014). As Lotze et al. (2010: 199) put it, "Knowing the magnitude of past changes is essential to judge the current state of marine ecosystems, and understanding past drivers and consequences of change is needed to mitigate current and future human impacts." Historical data can thus provide a better understanding of current processes in nature and how they have been shaped by both natural (cyclones, floods) and anthropogenic changes (land use, fishing). Such long term changes pre-date systematic ecological surveys, and so historical ecology relies on less formal data such as historical anecdotes, ships logs, records of fish landings, and photographs.

Photographs have been used to document multi-decadal vegetation change, temperature change, and urbanization in China (Chen et al., 2011), and in a marine context photographs of fish markets, fish landings, and trophy fish have been used quantify changes (McClenachan, 2009). For instance, clear changes in the species composition (from large sharks to small snappers) and mean size (from c. 19.9 kg to 2.3 kg) have been documented in a Florida sports fishery between 1956 and 2007 (McClenachan, 2009). Such data have been compiled in global initiatives such as the Census of Marine Life's History of Marine Animal Populations (HMAP) project, and have shifted our existing perspective on marine systems (Roberts, 2003, Rosenberg, 2005). For instance, Lotze & Worm (2009) showed how large predatory species, such as whales, pinnipeds, large fishes and sea turtles, have declined by an average of 89% over historical timescales, whereas several opportunistic groups such as gulls, polychaetes, green algae and exotic invaders increased during the 20th century. More specific examples include the use of historical records to show how the collapse and extinction of native oyster (*Ostrea angasi*) reefs in Australia occurred over a period of commercial fishing but before formal record keeping began (Alleway & Connell, 2015); and that the abundance of plaice *(Pleuronectes platessa)* was higher in pre-exploited states and that target fisheries of spawning grounds had greater negative impacts than had previously been assumed (Cardinale et al., 2010).

An alternative source of historical data, besides documentary evidence from photographs, fisheries landings, and ships' logbooks, comes from direct human knowledge through anecdotes (Pauly, 1995; Jackson et al., 2001; Bunce, 2008) and Local Ecological Knowledge (LEK), typically obtained from different stakeholders using socio-ecological surveys. Morrill (1967) was one of the first to highlight how fishermen's knowledge can be used to gather information on the feeding habits, movement, population size and other ecological traits of fish species. Morrill (1967) observed that fishermen are constantly discussing the ecology of fish, a trend seen among many artisanal fishermen in coastal and inland waters around the world (Silvano et al., 2008). Silvano and Begossi (2012) found that fishermen's knowledge of habitat use and trophic interactions of nine coastal fishes in Búzios Island, south eastern Brazil, agreed with the scientific literature. At other times, the discrepancies and disagreements between fishermen's LEK and scientific biological data can produce new information (Johannes *et al*., 2000; Silvano & Valbo-Jørgensen, 2008) and so add to conventional science through an increased diversity of knowledge sources. This was seen in a study by Begossi & Silvano (2008) where there was disagreement on spawning season for whitemouth croacker *Micropogonias furnier*i along the Brazilian coast. New data using fishermen's LEK suggests that perhaps the fish may have changed its spawning season since the 1990s or that within that particular region, this species might have specific spawning seasons that is different than the wider literature from previous scientific studies suggest (Silvano & Valbo- Jørgensen, 2008). In a management context, Ballard et al. (2008) showed that using LEK can increase the participation of local people in the implementation of management decisions. In a recent review, Thornton and Scheer (2012) conclude that as well as improving conservation planning and practice, and resolving management disputes, LEK can provide historical and contemporary baseline information on the ecological status of marine environments. For instance, Shackeroff et al. (2011) tapped into the LEK of stakeholders including fishermen, divers, aquarists, and marine experts to assess the trends of 271 marine species over a period of 80 years within a Hawaiian coral reef ecosystem. Stakeholders agreed over which species had increased or declined, although their perceptions on what they believe caused such change varied much more.

This growing literature using LEK in marine ecosystems (Coll et al., 2014; Bunce, 2008, Lozano-Montes et al., 2008, Baum and Myers, 2004) has demonstrated that it can be useful in gathering baseline data on specific species and ecosystems, especially for places where there is lack of scientific data collection through systematic surveys. However, relying on the knowledge of the current generation of marine stakeholders does not guarantee an accurate picture of the historical state of the ecosystem. This is due to the 'shifting baseline syndrome' (Pauly 1995), which proposes that "each generation of fisheries scientists accepts as a baseline the stock size and species composition that occurred at the beginning of their careers, and uses this to evaluate changes. When the next generation starts its career, the stocks have further declined, but it is the stocks at that time that serve as a new baseline." Pauly (1995) originally conceived of this syndrome applying to generations of fisheries scientists, but the idea of 'shifting perspectives' applies equally to those who make their livelihoods from fishing in a system. For instance, on coral systems in Rodriguez, an island in the inter-tropical zone of the south-western Indian Ocean, Bunce (2008) showed that older fishermen perceived greater species depletion and greater declines in catches than their younger colleagues, LEK that will be lost as this older generation of fishermen dwindles. There is now substantial evidence of such "collective intergenerational amnesia" (Alleway and Connell, 2015), with shifting baselines documented for many species and ecosystems (Rosenberg et al., 2005, Máñez et al., 2014, Alleway and Connell, 2015).

Thus, although the value of LEK in understanding marine ecosystem change is clear, shifting baselines and intergenerational amnesia may still result in the magnitude of such changes being underestimated. Matching stakeholder perceptions with independent long term scientific data on the state of an ecosystem will potentially add further insight into understanding the changes. This is rarely possible, especially as LEK is typically applied to systems that are otherwise rather data poor. The written records of early naturalists have been compared to fisheries landings data to track changes in fish community structure over 200 years in the Adriatic Sea (Fortibuoni et al., 2010), and direct comparisons of LEK of living fishermen with independent fisheries records have been documented in the Adriatic Sea (Coll et al., 2014). In the North Sea, this has been done for a particular species – megrim *Lepidorhombus whiffiagoni* – where fishermen's perspectives were compared to two sets of independent survey data in the northern region (Macdonald et al., 2013). The study showed that the distribution and relative abundance of megrim was comparable between fishermen's knowledge and the two sources. Here, I combine LEK with independent survey and fisheries landings data for 7 commercial species for a different region of the North Sea.

In contrast to previous studies where LEK was used to better understand the effects of fishing in regions that are data poor (e.g. Lozano-Montes et al., 2007, Bunce, 2008), the history of exploitation of the North Sea ecosystem has been well documented. It has been fished intensively at least since 1900 and fishing effort has increased consistently since that time, peaking in the 1980s (Rijnsdorp, 1996; Greenstreet & Rogers, 2006). This region has also been the focus of numerous long-term, spatially extensive ecological surveys such as fisheries-independent trawl surveys of the demersal fish communities (http://ocean.ices.dk/Project/IBTS/) which has been running annually since around 1970; in addition, detailed records of fisheries landings are available since the early 20th century, giving an indication of benefits from this provisioning ecosystem service.

Here, I combined this unique data resource with new information on the LEK of fishermen from the Yorkshire coast of NE England to assess how well fishermen's perception of change in the size and abundance of key fish species is reflected in independent long term data. In addition, by interviewing fishermen who started fishing this system in different decades, including some who have more than 50 years of experience, I was able to test whether shifting baselines of fishermen's perceptions of change influence the utility of the LEK framework. This adds to previous analyses attempting to link physical and biological changes in this system with social changes in the provision of ecosystem services (Selim et al., 2014; see Chapter 2), by refining estimates of perceived changes in provisioning and cultural services from some of the most knowledgeable and important stakeholders in this system. The main objective of this chapter is to identify if there are shifting baselines in Yorkshire fishermen's perspective of changes in abundance and size of North Sea commercial species.

4.2 Methods

4.2.1 Study system

The North Sea Large Marine Ecosystem is a mid-latitude, relatively shallow continental shelf sea covering approximately 570,000 km^2 (Jones, 1982), bounded by the coasts of Norway, Denmark, Germany, the Netherlands, Belgium, France and Great Britain (McGlade, 2002). The North Sea has been heavily exploited by these industrialized and densely populated nations, and has supported the fishing industry for centuries, with considerable intensification since 1900 (Rijnsdorp, 1996;

Greenstreet & Rogers, 2006). This study focuses on the south-western North Sea, specifically ICES region IVb and on the fishermen fishing out of eight ports of the Yorkshire coast (figure 4.1). Few regions can claim a longer history of fishing than this coastline. The productive waters of the North Sea coast have provided livelihoods for local people for centuries, encompassing the heyday of the herring fleets in the early 1900s, intensive trawling for cod and haddock throughout the 20th century until the 1980s when new quotas and tariffs came in (Frank, 2002, Kerby et al., 2012), and more recently major shellfish fisheries, with Bridlington now one the most important ports in the UK (Holderness Coast Strategy, 2011) and one of the most significant in Europe for lobster landings.

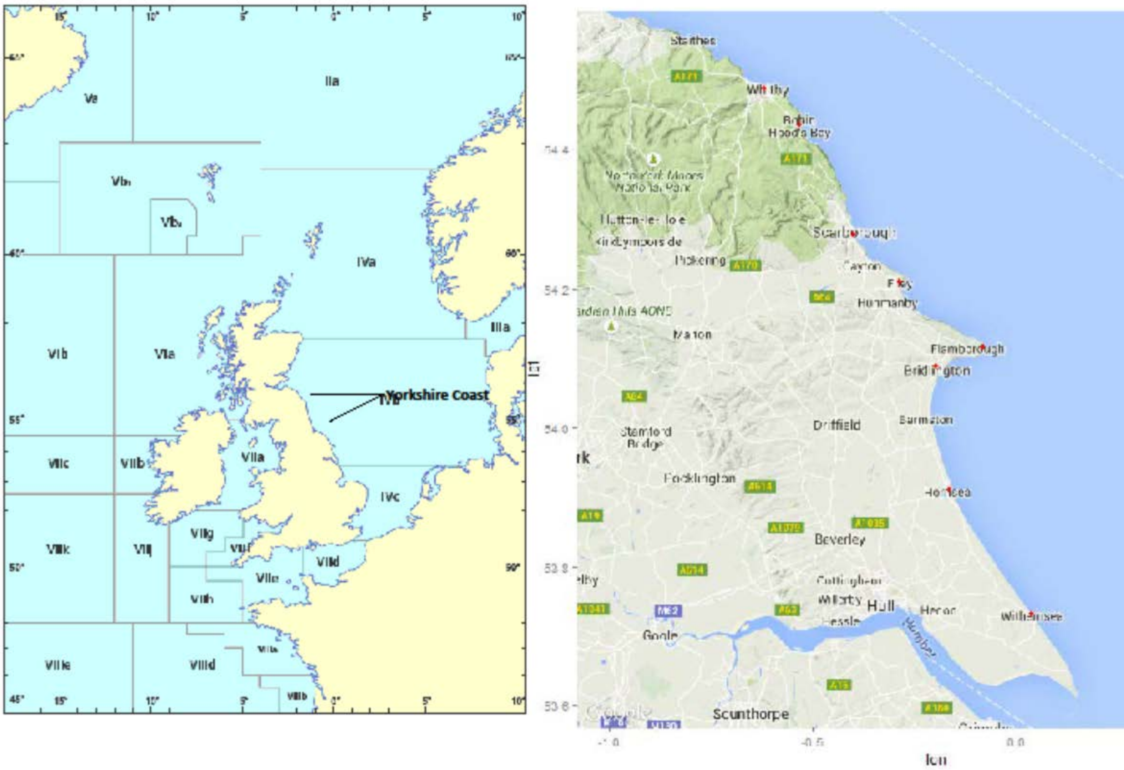

Figure 4.1 Map of study area showing ICES rectangles surrounding United Kingdom and the 8 Yorkshire ports where interviews with fishermen took place. Fish landings into England from area IVb is used to compare with fishermen's perception of changes in ecosystem.

4.2.2 Local ecological knowledge

A total of 46 fishermen were interviewed between June and December 2013. They were aged between 20 and 70, with between 5 and 61 years of fishing experience, and based in eight focal ports: Whitby (n = 7), Robin Hood's Bay (1), Filey (3), Flamborough Head (5), Bridlington (14), Scarborough (9), Hornsea (4), and Withernsea (3) (see figure 4.1). The oldest fisherman aged 70 did not officially start fishing till he was 16 years old but had been going out fishing with his father since the age of 9. Their perceptions of changes in commercial and non-commercial species were captured using semi structured interviews.

For the first round of interviews (June to September 2013), 26 fishermen were recruited. Most were recruited opportunistically while walking along the pier waiting for boats to come in or at the harbour as they were repairing gear or working in their garages. These interviews lasted about 20-30 minutes. The remainder were pre-arranged interviews. The second round of interviews in November

2013 was held in Bridlington at the Holderness Fishing Group Office where fishermen dropped by for other work purposes, and 22 agreed to a short (10-15 minute) interview. 2 fishermen in this second group had been interviewed previously so I didn't use their second round of answers. Most interviews were recorded with permission and later transcribed. To ensure that there was wide representation of people, I made sure that all age groups were represented well. Figure 4.2 shows the age distribution of fishermen and when they had started fishing. For data analysis I combined the age group 20-30 and 30-40 as there were only two individuals in the latter group. I collected details on when they first started fishing, number of years fished and in some cases when they had retired or moved onto a different profession. I also collected details on the main species they fished and which months of the year they fished. Additional information was collected on whether they were from generations of fisherfolk or were new in the industry, what kind of gear they used, and whether they fished on shore or offshore (see Appendix II for details). The study was completed with ethics approval from the University of Sheffield. The participants all signed consent forms allowing permission of the information they provided, quotes, as well as audio recordings of the interviews. They were all given information sheet describing the project and what their interviews will be used for.

Initially I tested out the questionnaire on 8 fishermen where we included a larger subset of species and based on their answers narrowed it down to the seven commercial species included in the questionnaire. I also asked them about to give specific size of fish and shellfish but left this out in future questionnaires due to time restraints.

Table 4.1 Questionnaire used for conducting semi-structured interview with 46 fishermen from 8 Yorkshire ports

Section 1. Background Information	
What year did you start fishing?	
Do members of your family fish(ed) for a living?	1 YES, my sibling(s) 2 YES, my parent(s) 3 YES, my grandparent(s) 4 YES, my great grandparent(s) 5 YES, my child(ren) 6 NO
What kind of boat do you skipper? (Can tick multiple answers here)	1 <10m 2 >10m 3 Inshore 4 Offshore
What is the main type of fishing gear you currently use on the boat you skipper? (tick the one most appropriate box)	1 Beam trawl – Stonemat gear 2 Beam trawl – Open gear 3 Otter trawl 4 Twin otter trawl 5 Triple otter trawl 6 Scallop dredge 7 Gill nets 8 Seine nets 9 Pots 10 Other, specify:
For each month, please list the main species you target.	Month Target Species
Section 2. Perception of changes in 7 species of commercial fish and shellfish	
How has the abundance of cod, haddock, plaice, sole, whiting, lobster and crab changed over your time fishing?	Much Less Less More Much More No Change
Has the typical size of cod, haddock, plaice, sole, whiting, lobster and crab changed over the course of your time fishing?	Bigger Smaller No Change
Section 3. Perception of changes in other species and state of ecosystem	
Have you observed changes in abundance or size of the following species? Gulls Other sea birds Seals Porpoises Whales and Dolphins Sea Star	Yes No I do not know

Crustaceans Other	
If Yes to any of the above species, how have they changed	
How would you describe the current condition of the fishery stocks of the North Sea	Underfished Sustainably fished Unsustainably fished Depleted
How would you describe the sustainability of fish stocks in - **5 years time** **10 years time**	Sustainable Unsustainable Not Sure
Are there any places in the North Sea that were once productive fishing grounds but are now depleted?	Show on Map
Do you know of any species that were once important in commercial or sport fisheries but are no longer or very rarely caught?	List of Species mentioned
Do you know of any species that are seen now that did not used to be here during your time fishing?	
Section 4. Opinion on conservation and management	
What do you think of the following measure to manage the North Sea fishery **Limited Licence** **Closed Season** **Closed Area** **Quotas** **MPAs** **Other policies**	Open ended answers which have been transcribed

4.2.3 Questionnaire

The questionnaire around which the interview was structured was divided into four sections: background information, perceptions of change in commercial species, perceptions of change in other species and wider ecosystem changes, and opinions on long term sustainability, future ecosystem services and management practices (table 4.1). These sections are described in detail below.

Background information

This included demographic information (where from, age, education and family background), Number of years fished, vessel size, gear type, and target fish. Since fishing in this area goes back hundreds of years, there have been distinct changes in the types of boats and gears used. Yorkshire is known for its wooden 'cobble'- a type of boat only used in this region. Initially I gathered the data on all the fish that were caught by fishermen in this region. I then focused on the 7 most commercially caught fish and shellfish as these were caught by majority of the 46 fishermen interviewed.

Perceptions of change in commercially fished species

Individuals were asked to assess changes in the abundance and body size of the seven commercial species most fished in the study area. I arrived to this list of species after the first day of trial interviews where I asked several fishermen on the most commonly caught fish in this area. The larger list of all the fish caught is captured in figure 4.3. I then narrowed down to this list once I established what is fished the most. They were asked to do this based on their experience over the time they had been actively fishing. This was to differentiate between what they experienced during their time working as fishermen compared to what they know now about species after they had retired. The species were cod *Gadhus morhua*, haddock *Melanogrammus aeglefinus*, plaice *Pleuronectes platessa*, whiting *Merlangius merlangus*, sole *Solea solea*, lobster *Homarus gammarus*and crab *Cancer pagurus*. For each species, the respondents marked their perception of changes in abundance based on a 5 point Likert scale (-2 = Much Less, -1 = Less, 0 = No Change, +1 = More, +2 = Much More). For choices on size the options were give as -1 = Smaller, 0 = No Change, +1 = Bigger.

Perceptions of change in the wider ecosystem

To understand how fishermen perceived wider ecosystem changes, respondents were also asked to assess changes in seabirds, mammals, and invertebrates, in particular identifying species that have decreased or disappeared as well as species that they believe to have increased.

Perception of sustainability and changes in non-commercial fish species

Respondents were asked for their views on the overall sustainability of North Sea fisheries, including the current status of North Sea fish stocks (under-fished, sustainably fished, unsustainably fished, or depleted), and their opinion on whether the stocks will be sustainable or unsustainable in 5 and 10 years. They were further asked about the locations of fishing grounds that used to be productive before but are not now. For knowledge and views on sustainability of species, they were asked to list species that used to be present more frequently but are not seen anymore and vice versa. The latter was to see whether new species are now present in these fishing grounds that might have moved northwards due to climate change. If they said yes to either and listed which species, they were then asked for their views on what might have brought about these changes.

4.2.4 Independent data on North Sea fish stocks

I used two sources of data to compare with the fishermen's perceptions of change. First, I used fisheries-independent survey data from the North Sea International Bottom Trawl Survey (NS-IBTS). The data were downloaded from the website datras.ices.dk. These data had been collected since

1967 for each ICES statistical rectangle (0.5º latitude x 1º longitude) across the North Sea. I specified which survey (NS-IBTS), which area and extracted data for quarter 1 which runs from January to March. The samples are collected using the Grande Ouverture Verticale (GOV) trawl and the method for collecting the sample has been standardized since early 1980s. Before 1977 all the ships used bottom trawls with a small mesh cover but there was no standardization of gear. Nets are shot and trawled across the bottom for ideally 30 minutes with the minimum allowable time being 15 minutes. All individuals are identified to species and measured in cm. Data are converted to standardized units of catch per unit effort (CPUE) per length per haul. Further details of how these surveys are carried out can be found on https://datras.ices.dk/Home/Descriptions.aspx#NS-IBTS.

To increase the temporal coverage of data, and to include data on shellfish as well, I also used data on fisheries landings. This includes commercial catch data from 20 ICES member countries collected since 1904. The figures represent the nominal commercial catch (live weight equivalent of landings, discards excluded) of finfish, invertebrates, and seaweeds (http://www.ices.dk/marine- data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx). I extracted data for the 7 commercial species in our study and their landings into England from the rectangle IVb as this is the region that most of the fishermen had fished in for the all or the majority of their time fishing (see figure 4.1). There are several limitations to using landings data for estimating abundance, one of them being that just England landings do not represent total landings from this part of the North Sea as a significant amount will be landed in Scotland too. But I wanted to compare different things – an estimate of abundance in the environment (IBTS) and an estimate of actual 'ES provision' (landings), for which I consider the trend of landings into English ports to best reflect the Yorkshire fishermen's experience .

4.3 Analysis

I analyzed fishermen's perception of 7 commercial species using ordinal logistic regression models (function "polr") in the MASS package (Venables & Ripley 2002) in R. "Polr" stands for "proportional odds logistic regression" and fits a logistic or probit regression model to an ordered factor response (Agresti, 2013). As in ordinary logistic regression, effects here are described by proportional odds ratios. I ran regression models for all seven species against the continuous variable: the year fishermen started fishing. I also compared these results against changes in landings, and changes in abundance. For changes in fish landings and abundance, I took the average of the 1st 1/3 of the number of years any one fisherman had fished and divided that by the last 1/3 of the number of years that he had fished. This was used as the change during each fisherman's time period for landings and abundance. Firstly I wanted to see if their perceptions matched with actual changes in both abundance and landings data. And secondly, to see if there was a shifting baseline in fishermen's perceptions where fishermen who had fished for longer had different perspectives that ones who had started fishing recently. For lobster and crabs, there are no survey data for abundance; hence I could only compare perception against changes in landings. I tested for strength of association between perceptions and changes in survey and landings data using Spearman's ρ.

4.4 Results

4.4.1 Fishermen's demography

I interviewed 46 fishermen in total of which there were 8 in the age group 20-30, 2 in the age group 30-40, 14 in the age group 40-50, 13 aged 50-60 and 9 aged 60+. The period when each of these fishermen started fishing differed, for example there were some in the older age group who only started fishing 10 years ago. Hence I categorized them into groups of time period of when they started fishing against the age group as shown in figure 4.2.

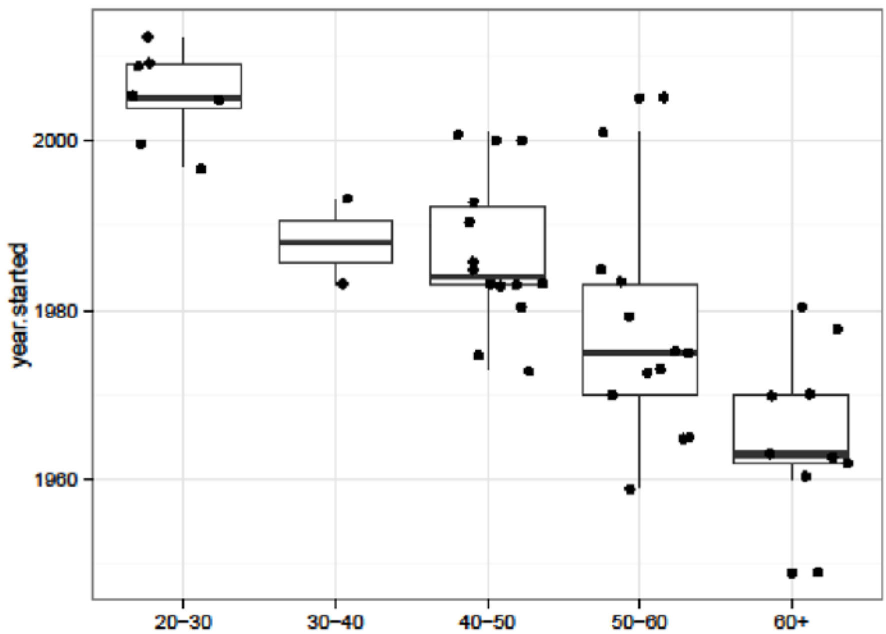

Figure 4.2 Demographic information showing the age range and the year when the 46 fishermen interviewed had started fishing.

The fish caught varied between the different areas. Lobsters, crab and cod were the most common amongst all the fishermen. Whiting, sea bass, plaice, sole, salmon were less common and were caught by some fishermen at different times of the year. Figure 4.3 shows the kind of fish caught each quarter, where fish such as sea bass and cod were caught in specific season. On the other hand, lobster and crabs were caught all year long. This is representative of what they catch now in present times. Many of the fishermen mentioned how before they used to catch lobsters and crabs only in the summer, but as abundance and price increased, so did fishing effort all year round.

In addition to the 7 commercial species analysed in this study, the fishermen also caught red gurnard *Chelidonichthys cuculus*, salmon *Salmo salar*, sea bass *Dicentrarchus labrax*, scallops *Placopecten magellanicus* and prawns *Crangon crangon.*

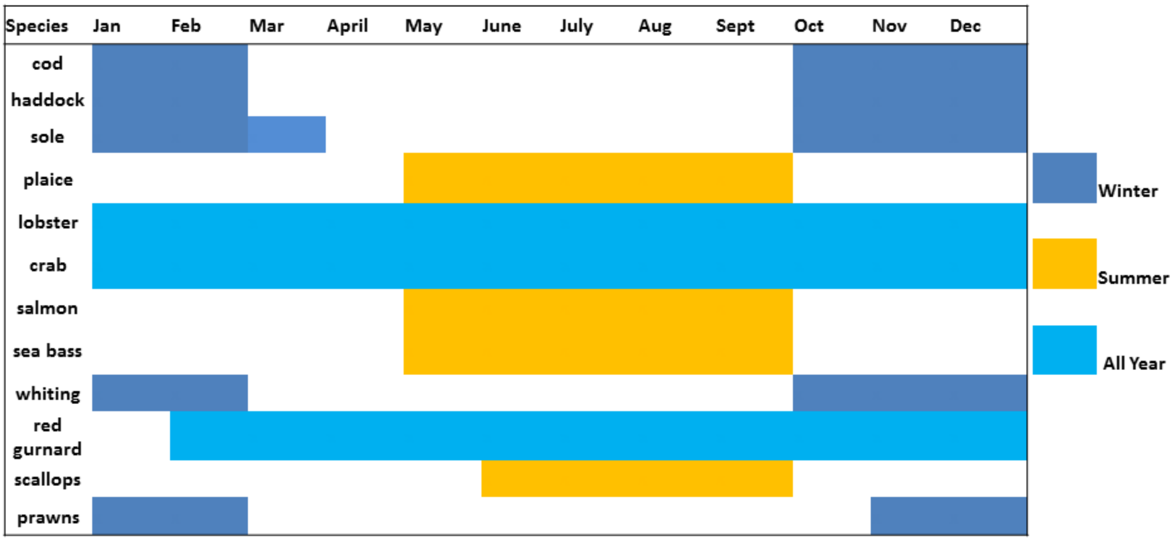

Figure 4.3 The different species caught by the 46 fishermen interviewed and the fishing period during the year for each species.

Fishing gear included pots, gillnets, tram and line, twin otter trawl, beam trawl, cobble, single rig trawlers, siene and long lines. 31 of the 46 fishermen used pots and gillnets. Only 8 still used otter trawls. Whitby and Robin Hood's Bay fishermen used more mixed gears including siene and trawling, whereas down south in Bridlington, it was mostly pots and gillnets. Again, this is only representative of current times in the last 30 years or so. Most of the fishermen who had fished for 30 years or longer only moved to pots in recent years and used to operate trawlers mainly. The areas they fished were all within ICES rectangle IV (figure 4.1). However, 6 fishermen also used to fish in area VII (figure 4.1) and to go further offshore for haddock in the 1970s.

The background of these fishermen varied where some came from generations of fishermen going back 200 years. Others only joined in the last 10 years or less. Some also used to work in big trawling ships and now catch lobsters locally. In Filey and Flamborough, they still use horses and tractors to get the boats to shore. These fishermen caught sea bass mostly during the months between May and September. There were 5 retired fishermen, and two of them now own a fish bait shop.

4.4.2 Perceived changes in abundance and size of 7 commercial species

On average the fishermen perceived cod, haddock, and plaice to have decreased, whereas whiting, lobsters and crabs had increased. 43% (n=20) of the fishermen perceived no change in sole (figure 4.4) Cod and haddock were perceived to have decreased the most where 84% (n=32) and 67% (n=7) respectively stated abundance of both these species were 'much less.' Only 12 of the 46 fishermen had fished for haddock. This perception is the average for all fishermen, without regard to age or when they started fishing.

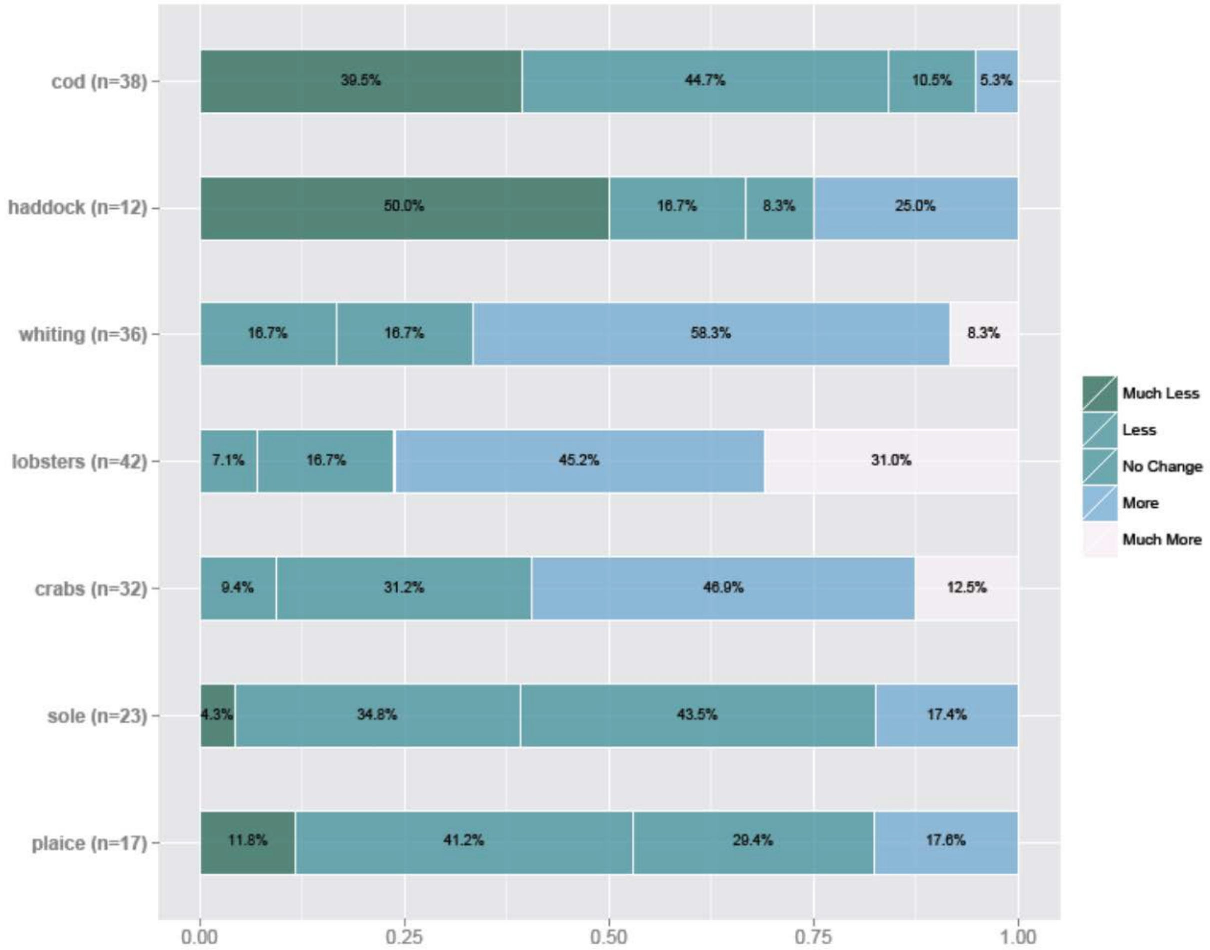

Figure 4.4 Perception of change in abundance of 7 commercial species – cod *Gadhus morhua*, haddock *Melanogrammus aeglefinus*, plaice *Pleuronectes platessa*, whiting *Merlangius merlangus*, sole *Solea solea*, lobster *Homarus gammarus*and crab *Cancer pagurus* by 46 fishermen who had fished along the Yorkshire coast over the period 1960-2010. The number following each species name is the number of fishermen who had fished for that species, and bars represent the percentage of these fishermen perceiving different degrees of change.

The perception was generally that cod and haddock had decreased in size: 64% (n=21) perceived cod to have decreased and 75% (n=3) perceived haddock to have decreased in size. On the other hand, 38-84% said that there had been no change in plaice, sole, lobster and crab size (figure 4.5). Whiting and plaice were perceived to have increased in size the most (44% (n=12) and 38% (n=3) respectively) across all seven species. The response rate was too low to calculate individual trends in size change over the period 1950-2010. According to 23 % (n=7) fishermen, the lobsters have also decreased in size. As one of them quoted “fishermen move to new ground and start catching all the big ones then they tend to get smaller ones afterwards.”

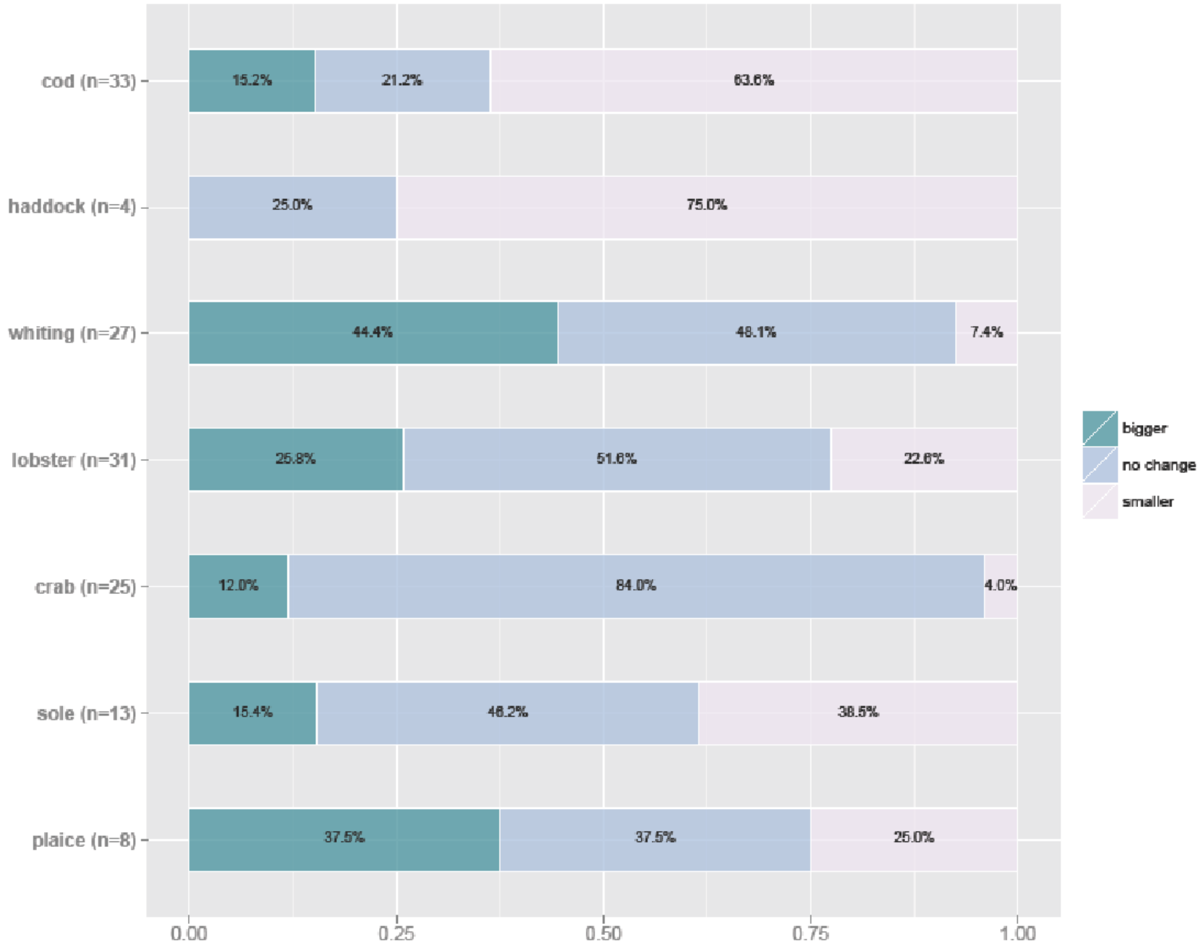

Figure 4.5 Perception of change in size (%) of 7 commercial species – cod *Gadhus morhua*, haddock *Melanogrammus aeglefinus*, plaice *Pleuronectes platessa*, whiting *Merlangius merlangus*, sole *Solea solea*, lobster *Homarus gammarus*and crab *Cancer pagurus* by 46 fishermen who had fished along the Yorkshire coast over the period 1960-2010.

4.4.3 Perception of changes against when started fishing

When I separated out the fishermen according to when they started fishing, the perceptions changed for some of the species where fishermen who had fished longer perceived certain species such as cod to have decreased more than fishermen who had fished in recent years (figure 4.6). The perceived change for plaice is similar where the fishermen who had fished longer perceive plaice to have decreased more than ones who had been fishing for fewer years (figure 4.7).

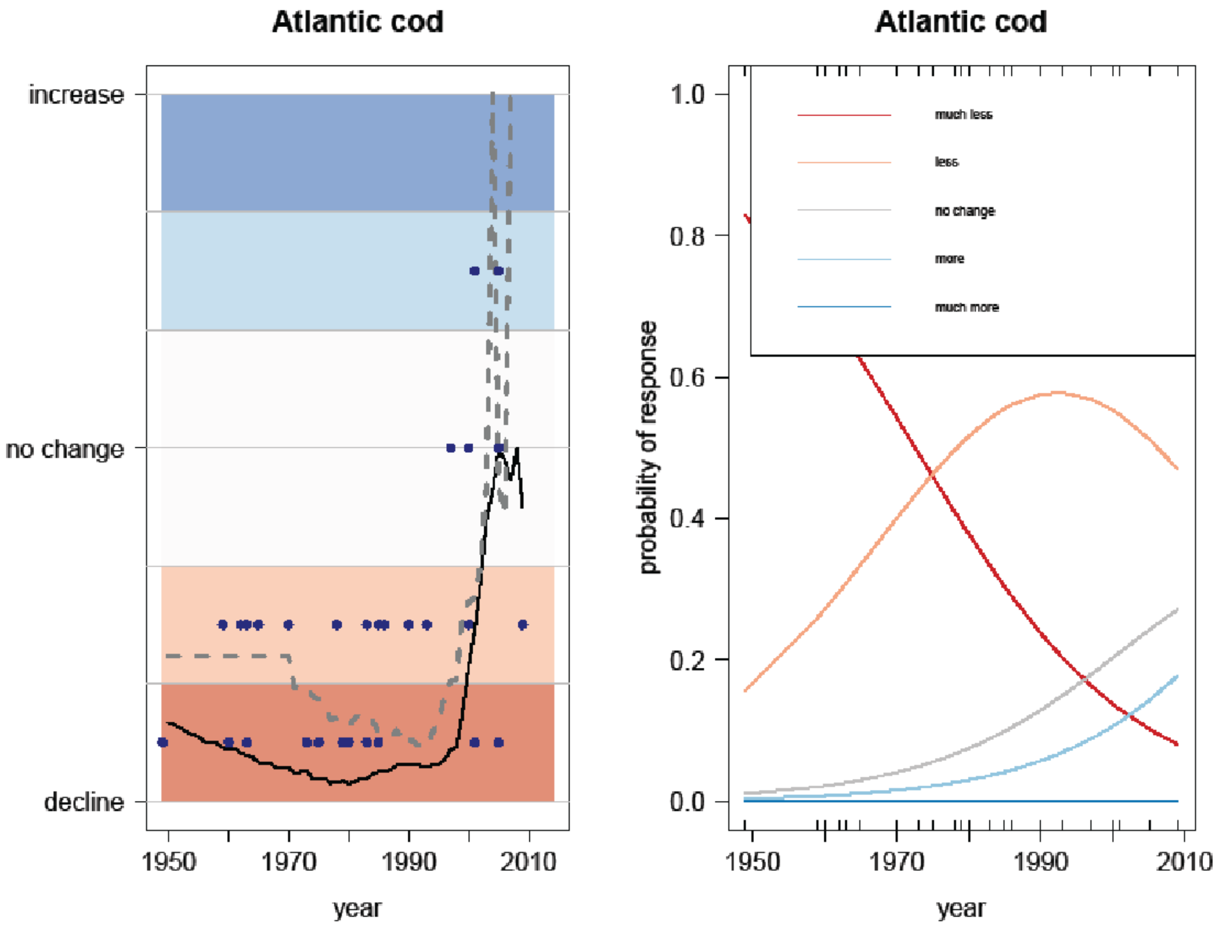

Figure 4.6 Fishermen's perception of change in abundance of cod (points) against year when they started fishing (left hand panel). Changes in abundance based on survey data (grey dashed line) and landings (solid black line) calculated over the relevant period are also shown. The right hand panel shows the results of the polr model fitted to perceptions of change against year started fishing.

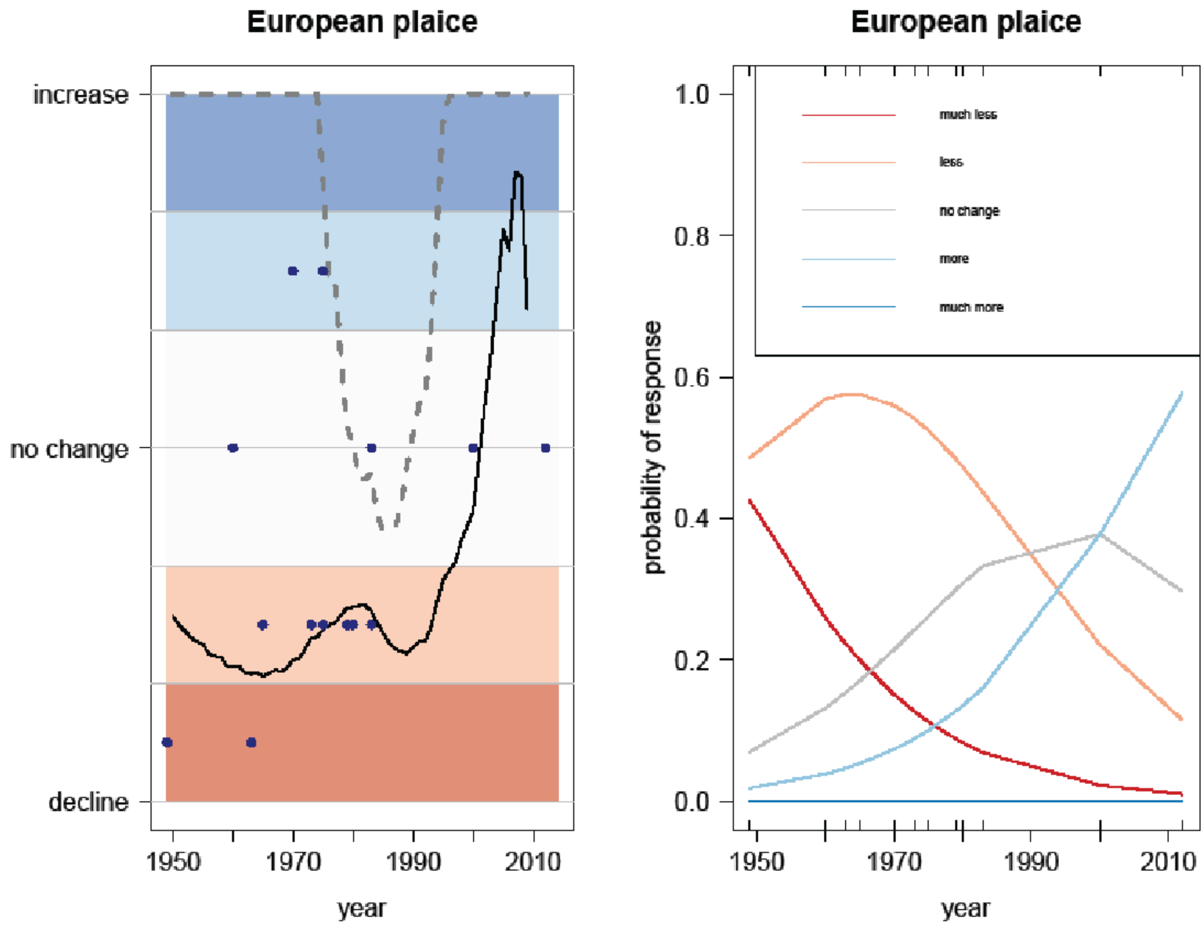

Figure 4.7 Fishermen's perception of change in abundance of plaice (points) against year when they started fishing (left hand panel). Changes in abundance based on survey data (grey dashed line) and landings (solid black line) calculated over the relevant period are also shown. The right hand panel shows the results of the polr model fitted to perceptions of change against year started fishing.

Ordinal regression analysis was carried out using polr and the results on response probability shown on the right side in figures 4.6 and 4.7 supported the perceptions of cod and plaice. The probability of response for cod and the response 'much less' goes down from 0.8 to 0.2 as the number of years fished decreases (figure 4.6). On the other hand the probability of responding 'no change' and 'more' increases if fishermen had started fishing more recently. The model fit for all the species – coefficients, confidence intervals and proportional odds ratio are shown in table 4.2. The proportional odds ratio is obtained by exponentiating the ordered logit coefficients and is interpreted as the following – for one unit change in the predictor variable, the resulting change in the observed variable is multiplied by the proportional odds ratio. The odds ratio for cod, plaice and crab are higher than 1 indicating that for each unit of change in year started fishing, the response for 'more' is likely to increase (table 4.2, figures 4.6 and 4.7) On the other hand, for species such as sole and whiting, the proportional odds ratio are less than 1 and so for each unit of change in year started, the response of 'more' is likely to decrease. The probability of responses from the models (figure 4.6 4.12) clarifies the result further and details on these results for the different species models can be found in the next section. For plaice, the probability of a response of 'much less' or 'less' goes down as length of time fishing goes down. Probability for responding 'less' and 'no change' increases over time for fishermen who had been fishing for shorter period of time. Some of the fishermen who had agreed that cod had decreased mentioned that they were coming back: *"Decline in cod populations over the 40 years but they are coming back, in Scotland they can't sell it there is that much"; "cod is coming back, better catch size this winter. They are coming back slowly as the trawling stopped 10-15 years ago, cod population therefore rejuvenating".*

Table 4.2 shows the results of all 7 models. Coefficients give the change in mean response (i.e. average perceived change) with an increase in the year that a fisherman started fishing. They are best interpreted in terms of the proportional odds ratio, using cod as an example: for every unit of change in year started, the odds ratio of cod perception moving from one unit to the next is multiplied by 1.10 (table 4.2). In other words, the odds of perception changing from 'much less' to
'less', or from 'less' to 'no change', increases in fishermen who started fishing more recently.

Models	Coefficient	2.5%, 97.5% CI for	Proportional Odds Ratio
Cod ~ year started	0.0956	0.0952, 0.0960	1.1003
Whiting ~ year started	-0.0239	-0.0243, -0.0234	0.9764
Sole ~ year started	-0.0395	-0.0405, -0.0385	0.9612
Plaice ~ year started	0.0681	-0.0029, -0.0018	1.0705
Haddock ~ year started	0.0167	0.0160, 0.0173	1.0168
Lobster ~ year started	-0.0024	-0.0029, -0.0018	0.9976
Crab ~ year started	0.0046	0.0040, 0.005	1.0046

For sole, fishermen who had been fishing longer were more likely to perceive that this species had increased than fishermen who had started fishing more recently (figure 4.8). For every unit of change in year started, the odds ratio of sole perception moving from one unit to the next is multiplied by 0.96 (table 4.2).

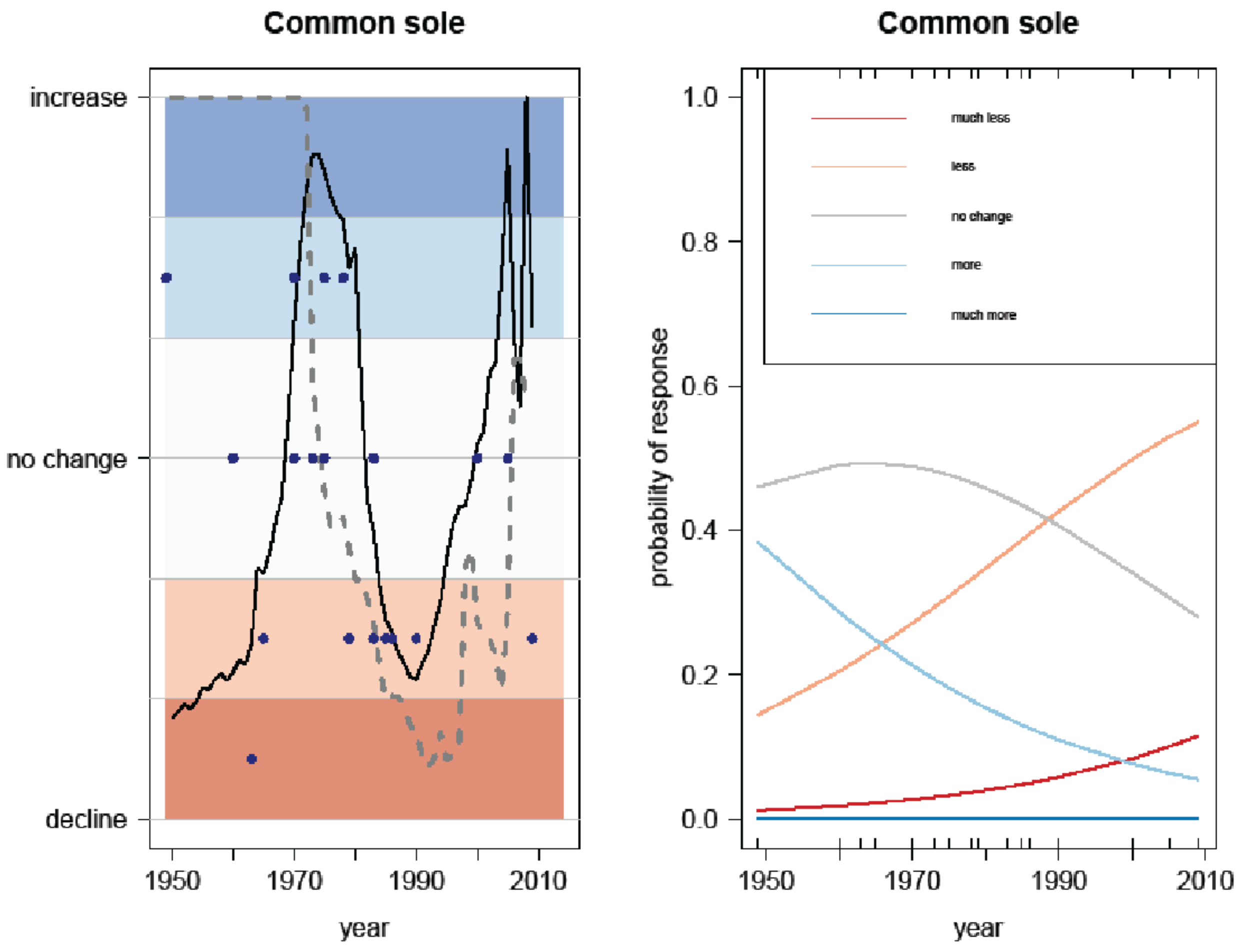

Figure 4.8 Fishermen's perception of change in abundance of sole (points) against year when they started fishing (left hand panel). Changes in abundance based on survey data (grey dashed line) and landings (solid black line) calculated over the relevant period are also shown. The right hand panel shows the results of the polr model fitted to perceptions of change against year started fishing.

The majority of fishermen perceived whiting, crab and lobster to have increased, regardless of when they started fishing, although some did perceive no change or even a decrease decreased (figure 4.9 – 4.11). There is some indication that fishermen who had fished longer perceived an increase in whiting whereas ones who had fished for shorter period perceive no change or decrease as shown by the response probabilities of the model (figure 4.9). Some of the comments on whiting showed that whiting is often caught as bycatch making it hard to gauge changes. In addition, it may have been the case that they were catching more whiting due to restrictions on other commercial fish. Most of the fishermen, irrespective of when they started fishing, perceived an increase in abundance of crab and lobster. The model fit showed no indication that perceived abundance was related to when they started fishing (figure 4.10 and 4.11). Very few fishermen fished for haddock and only 3 perceived haddock to have increased (figure 4.12). Most of them answered that they had stopped fishing for haddock for many years even though they were still fishing inshore waters. They perceived that haddock had decreased.

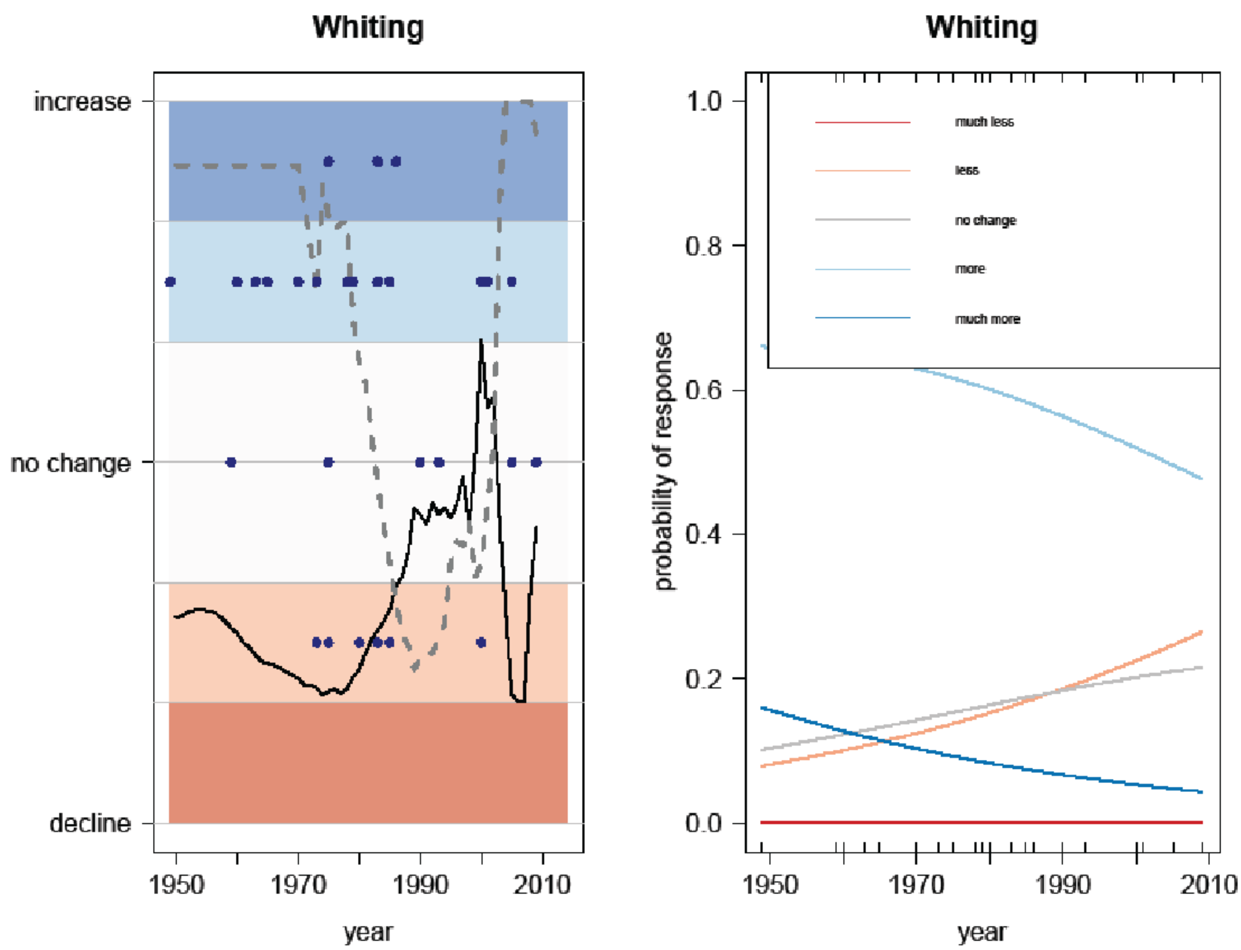

Figure 4.9 Fishermen's perception of change in abundance of whiting (points) against year when they started fishing (left hand panel). Changes in abundance based on survey data (grey dashed line) and landings (solid black line) calculated over the relevant period are also shown. The right hand panel shows the results of the polr model fitted to perceptions of change against year started fishing.

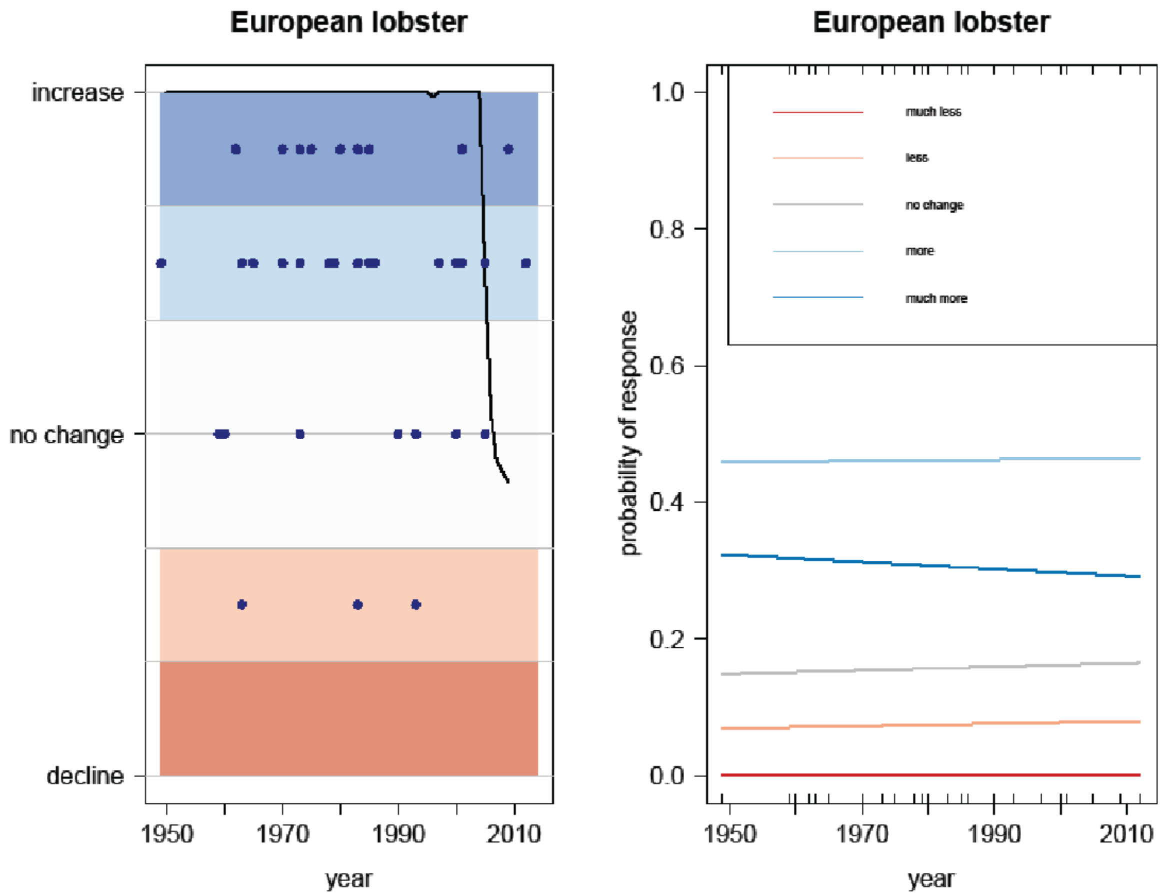

Figure 4.10 Fishermen's perception of change in abundance of lobster (points) against year when they started fishing (left hand panel). Changes in abundance based on survey data (grey dashed line) and landings (solid black line) calculated over the relevant period are also shown. The right hand panel shows the results of the polr model fitted to perceptions of change against year started fishing.

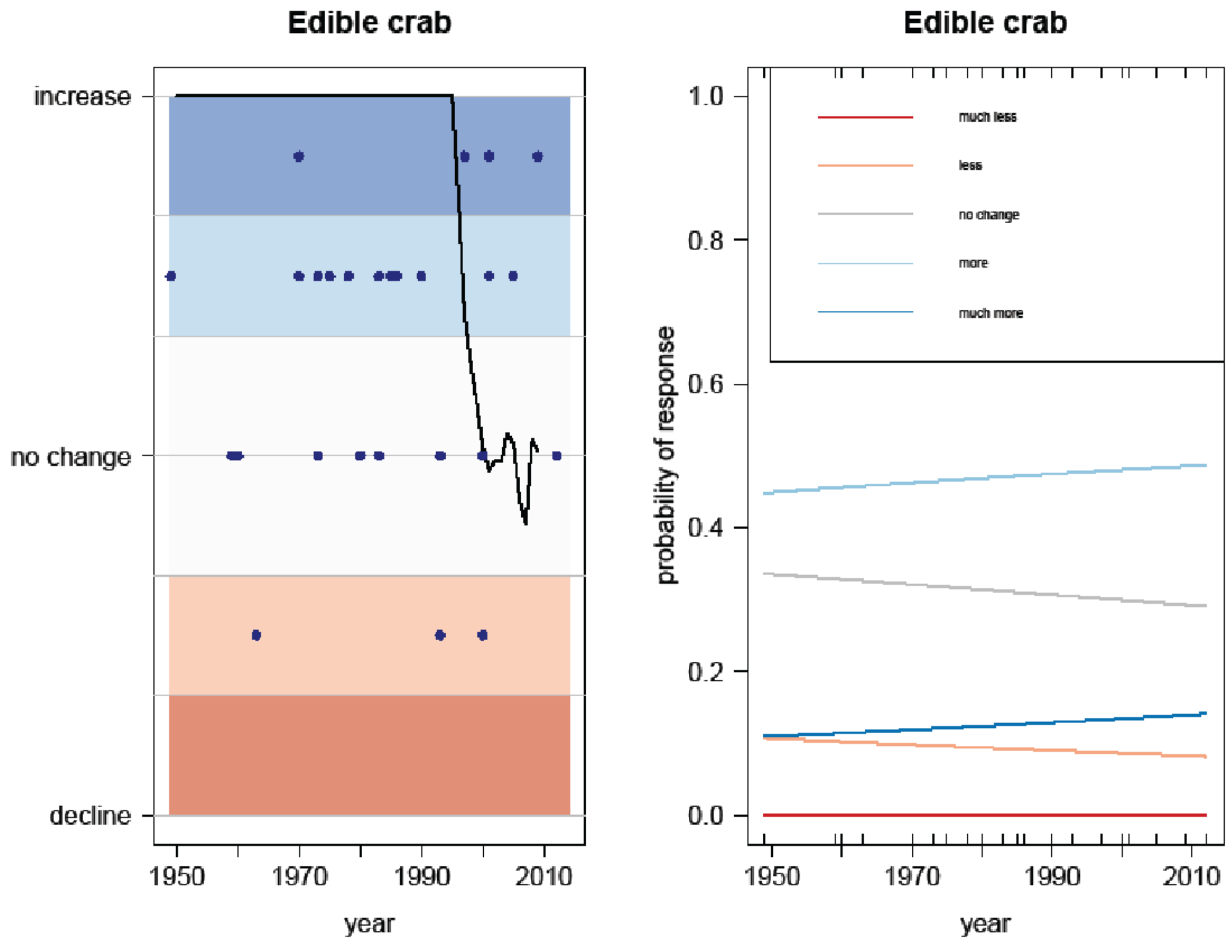

Figure 4.11 Fishermen's perception of change in abundance of crab (points) against year when they started fishing (left hand panel). Changes in abundance based on survey data (grey dashed line) and landings (solid black line) calculated over the relevant period are also shown. The right hand panel shows the results of the polr model fitted to perceptions of change against year started fishing.

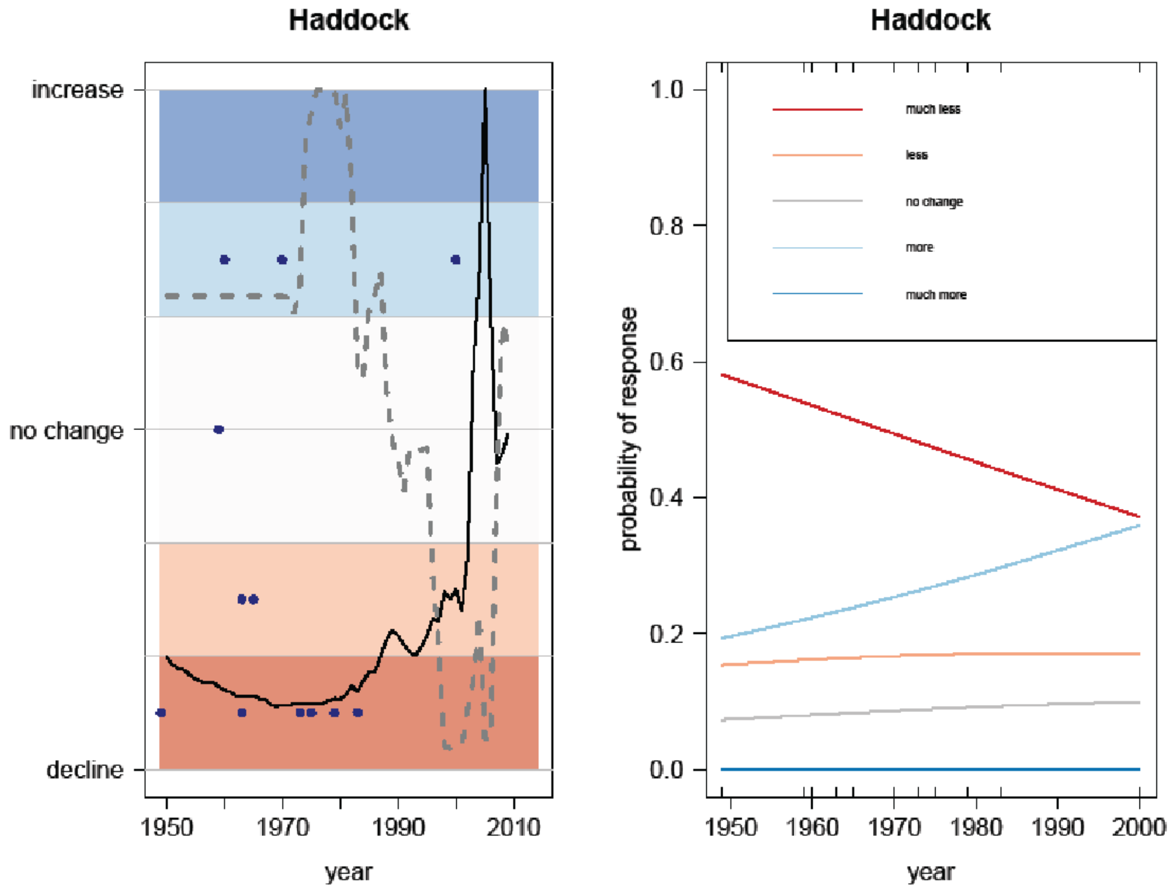

Figure 4.12 Fishermen's perception of change in abundance of haddock (points) against year when they started fishing (left hand panel). Changes in abundance based on survey data (grey dashed line) and landings (solid black line) calculated over the relevant period are also shown. The right hand panel shows the results of the polr model fitted to perceptions of change against year started fishing.

4.4.5 Fishermen's perception of change in species against changes in abundance from survey and landings data

Cod perception against landings and survey data shown in figure 4.6 indicated that perception of changes in cod correlated with changes in both landings and surveys. Fishermen who had been fishing the longest perceive cod to have decreased whereas those who had fished in recent years perceive cod to not have changed or increased. The correlation between perceptions of change in cod abundance and change in landings was significant ($r_s = 0.37$, $p < 0.05$; table 4.3), but there was no significant relationship between perceived change and change derived from surveys. Changes in both landings and survey data indicate that a certain amount of experience is needed (i.e. starting fishing pre-1990) before a decline is perceived. During the period 1990-2000 the difference between the first 1/3 of the data is the same as the last 1/3 of the data hence the difference is 'no change'.

Table 4.3 Correlations (Spearman's rho) of fishermen's perceived change in abundance of each species and change estimates from landings data, and from survey data. * indicates statistical significance at $p < 0.05$

Species	Numbers for each species (N)	perception vs landings data	Perception vs survey data
Cod	38	0.370 * (p=0.022)	0.102
Haddock	12	0.158	-0.467
Whiting	35	0.016	0.066
Plaice	17	0.068	0.106
Sole	23	0.320	0.323
Lobster	42	0.299	NA
Crab		-0.035	NA

None of the other correlations between perceptions and either landings or survey trends are significant (table 4.3), although 6/7 landings correlationships and 4/6 survey correlations are positive, indicating some degree of agreement between fishermen's perceptions and independent data. The lack of stronger agreement may be due to complex temporal changes in abundance, whereby an experienced fisherman may have witnessed both declines and increases in a species. In addition, low sample sizes for some species limit the statistical power of these tests.

4.4.6 Perception of changes in other species and sustainability

Half of all the fishermen interviewed (n = 23) perceived that the number of gulls had increased and 16 of them did not know if they had changed. Only 4 thought they had decreased and 3 said there was no change. Given how vocal the ones were who had said gulls had increased, it was surprising to see that they represented only half of all the fishermen interviewed. Survey data for gulls in this region show that population of some gulls had increased, whereas others are stable (Mitchell et al., 2004).

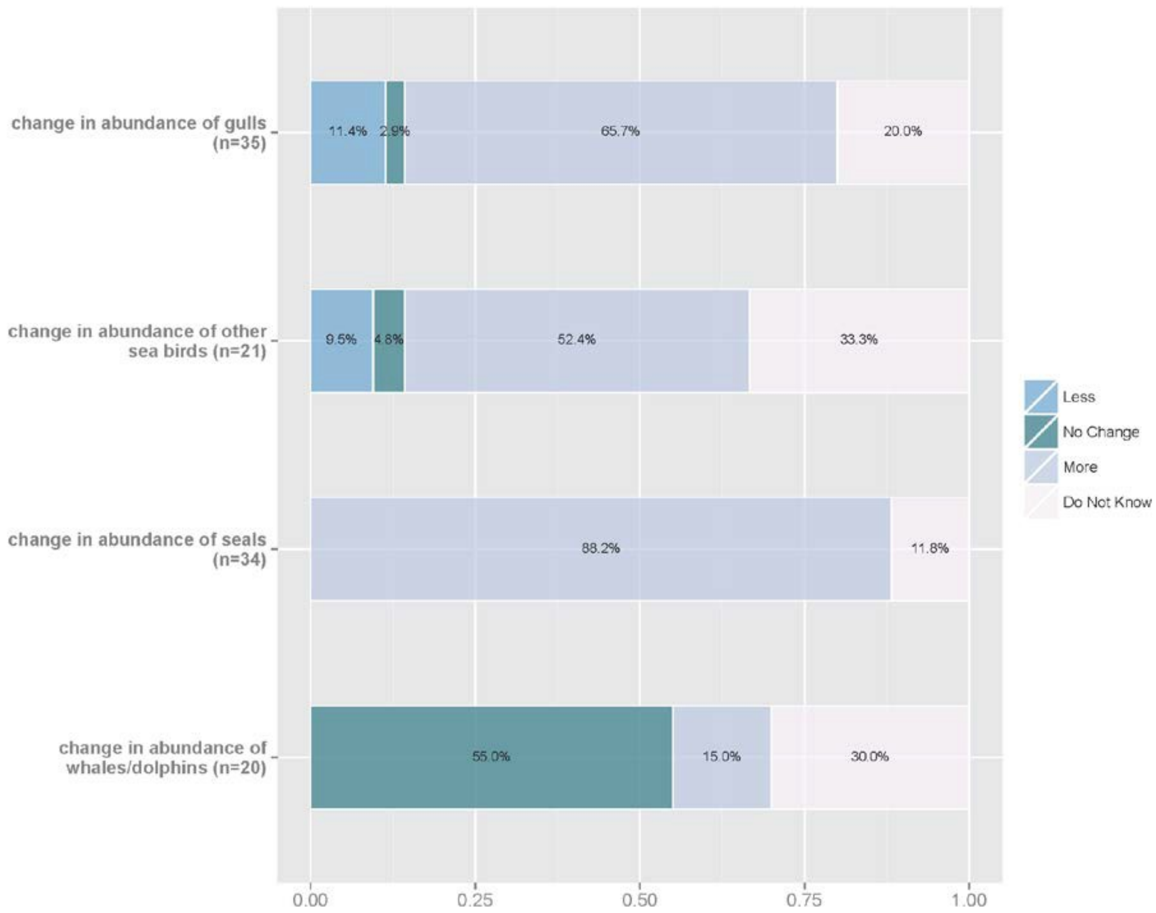

Figure 4.13 Fishermen's perception of changes of other species besides commercial fish.

Most (n=30) of the fishermen thought that grey seals *Halichoerus grypus* had increased. Many mentioned that there was a need for introduction of culling again. No one thought there were fewer seals and they all perceived that seal populations negatively affected fisheries. Scientific surveys carried out show that there was an increase in seal population after the culling had stopped in the 1970s. However that increase had started to level off and the population was stabilizing, mostly as a result of density dependent population factors, and in some populations, decreasing because of disease outbreak (Thompson et al., 2010).

76% of the fishermen (n=35) said the North Sea was still unsustainably fished. However, within this group, 30% percent said that it is not as bad as people make it out to be. They mentioned that certain areas were still depleted but cod is now making a comeback in many areas. Several fishermen mentioned about the unfairness of the quotas where other surrounding countries like France and Belgium were allowed to fish for species that are depleted but UK is not. Hence that makes North Sea overall unsustainable even if UK fishermen caught less fish. 20% percent said it was sustainable due to the lucrative business of the lobsters and crabs.

Fishermen were questioned about other species of fish besides the commercial ones they fished. Several species were mentioned, some of which have decreased and some are now seen but were not previously. The five fish most commonly mentioned as previously present but now absent were dogfish *Centroscymnus coelolepis*, skates *Raja clavata*, haddock *Melanogrammus aeglefinus*, dab *Limanda limanda*, and turbot *Scophthalmus maximus*. Species that are frequently seen now that were not present before include velvet crab *Necora puber,* red mullet *Mullus surmuletus,* sun fish *Mola mola,* tunas (family *Scrombidae*)*,* and smaller plaice *Pleuronectes* spp.

To bring together all the different threads of data collected and analyzed from interviews with fishermen, I have summarized the results according to perception of change in abundance and size and perception of sustainability and other species. The average perception of all the fishermen regardless of when they started fishing show that they perceive cod, haddock, and plaice to have decreased, whereas whiting, lobsters and crabs had increased. But when the data is separated out according to when each fishermen started fishing, the results show that there is shifting baselines in the perception of changes in cod and plaice (figure 4.6 and 4.7) Perception of changes against survey and landings data show that there is a positive correlation between cod perception and landing data but none of the other correlations between perceptions and either landings or survey trends are significant (table 4.3). Perception of sustainability and other species show that majority (73%) of the fishermen think that the North Sea is fished unsustainably and that the population of seals and gulls have increased.

4.5 Discussion

This study highlights the use of LEK for gathering long term socio-ecological data on fisheries and the results show that fishermen have good recollection of catch but this only extends as far back as their personal experience. This is shown in figures 4.6-4.12 where perception of cod and plaice (figure 4.6 and 4.7) show that fishermen who had been fishing a shorter period of time perceived both species to have increased. On the other hand, fishermen who had started fishing more recently had perceived sole and whiting to have decreased (figure 4.8 and 4.9.) The trends in the other three species did not change depending on their fishing experience. Results from ordinal regression analysis showed that only the result of the cod model is significant. Their perceptions of abundance do not always reflect catch data (figure 4.6-4.12) but this issue of whether catch is a useful measure of abundance is strongly debated (e.g. Pauly et al., 2013). We know that historical knowledge has provided a wealth of knowledge in understanding changes in marine ecosystems and the impacts of long term human exploitation in these systems (McClenachan et al., 2012). LEK has shown to be a useful method in collecting data on fish species, behaviour, feeding patterns and changes in fish populations and the wider ecosystem (Silvano & Valbo- Jørgensen, 2008). Whilst this has been crucial in gathering information in tropical regions where there is poor data, it has also been important in adding new information that complements scientific survey data in existing data rich areas such as the North-Atlantic. The North Sea has been heavily exploited by the industrialized nations surrounding it and use of its marine resources go back a long time.

Firstly, conducting LEK in such regions allow us to test hypothesis on how accurate fishermen's knowledge and perception are. From this study I have seen that whilst accurate for some species, the knowledge has also been filtered for some species depending on when fishermen had started fishing. Secondly, gathering long term LEK data highlights the issue of shifting baselines which has already been shown (Silvano & Begossi 2012; Bunce 2008) when it comes to species and ecosystem but rarely shown when it comes to shifting baselines in services. A few studies (McClenachan, 2009) that have highlighted this has shown that even though people are still benefiting from 'ecosystem services' provided by the same ecosystem, the services themselves have vastly changed and now provide different services (see Chapter 3). On the other hand, sometimes it is the same service that's benefitting people but at a vastly reduced scale – both in terms of quantity and size. For example Maine lobsters are considered abundant and well managed by local cooperatives but historical catches show a different story where in 1887 Maine lobstermen had an average of 2000 pounds in a trap and in 2005 this averages about 20 pounds per trap (Jackson, 2011). Even though trap limits were put in place, the effort going into catching lobsters is much higher. Along the Yorkshire coast, effort for catching shellfish had gone up but it is not evident that it was the case of shifting from whitefish to shellfish or a combination of societal changes and higher demand for shellfish. This is seen in the findings from part 4 of the survey where fishermen were asked about long term sustainability, management options and future ecosystem services.

Location seemed to play a key role in the difference of fishermen's attitude towards increase in shellfisheries over the past 20-30 years. Whereas most fishermen in the north of the region, in Whitby, Robin Hood's Bay and Filey were hopeful that cod and other white fish species were making a comeback, there were many in Bridlington, Scarborough, Withernsea and Hornsea who made comments about being happy with just having an abundance of shellfish and business being good; they would rather the cod not make a comeback. This is also reflected in the shift from fishing for cod to fishing for shellfish in Newfoundland following the collapse of cod stocks in 1992 (Roberts, 2007). It highlights this trade-off in services where change in the ecosystem that causes in the crash of one provisioning services (finfisheries) can result in another more lucrative service (shellfisheries). Besides the monetary value gained from a change in service, there are other examples of how trade-offs occur where people are still happy with that service unaware that the ecosystem underpinning that service has changed dramatically. For example, sport fishers in the Florida Keys have continued to derive similar benefits from fishing (both in terms of the satisfaction of clients and economic returns to providers) despite the marked decline in size of trophy fish landed between the 1950s and the 2000s (McClenachan 2009). In other words, overfishing has resulted in a quantitative shift of ecosystem state from one with many large fish to one dominated by smaller-bodied fish, which has had a measurable effect on actual ES provision (anglers catch smaller fish); yet this has had minimal effect on perceived ES provision (anglers remain happy with their catch; boat owners have not seen a decline in income).

The phenomenon of shifting baselines in fishermen's perception is highlighted when I separated out perceptions on changes in abundance and size of fish. This is most evident in perception of cod and plaice (figure 4.6 and 4.7). True to the classic description of 'shifting baselines' the older fishermen who had been fishing longer perceived cod and plaice to have decreased whereas fishermen who had started fishing in the 1990s perceive both species to have had no change in abundance or to have increased. I did not see this shifting baseline in perception in the other species. Most fishermen perceived whiting, crab and lobster to have increased. Haddock were fished by too few people to pick up any trend. Fishermen's perception of some of the species matched trends in actual changes in abundance measured from both landings and scientific survey data. But looking at this data (figure 4.7 to 4.12) it can be seen that these trajectories are not linear, there is no single upwards or downward trend and the time series have sharp peaks and dips. This coincides with what many of the fishermen had said verbally about these species that in some years they have seen an increase, other years were not so good. Many answered 'no change' to these species but had said it fluctuated over the years.

The in depth interviews with these fishermen highlighted their local knowledge of species that are not as well documented as the commercial species. Interviews with the fishermen also highlighted adaptation strategies such as changing to wildlife tour operators on weekends over the summer, or combining fishing as well as acting as local guides for guided wildlife tours. Two of the fishermen had also retired from fishing early and opened tackle and bait shop. One of the families who had been fishing for generations had diversified and was now working with conservation agencies like the Living Seas Centre. Other strategies adopted following the decline in fisheries and the use of quotas was to a shift to shellfisheries. It is not established how much of this change is more a result of changes in the ecosystem, whereby there was an increase in abundance of lobsters and crabs or whether due to restriction in other fish species, fishermen have just turned to shellfisheries. Globalization was also fueling this change as there was more demand for shellfish – not by British consumers, but by neighbouring European nations. One of the fishermen shared a unique story of globalization – before they would use salmon heads as bait and it was cheap to get, but due to demand from China for salmon heads, the price of this bait had risen, hence they know had to turn to other sources of cheaper bait so they could catch lobsters and crab for export to France and Spain.

It has been evident for a while now that historical overfishing did damage to coastal ecosystems and led to reduction in fish stocks well before scientists had started measuring the effects of such destruction. Scientists and fisheries managers acknowledge this and have started to construct historical baselines using data from a variety of sources, including fossils, photographs and anecdotes. At present most of this historical data have come from archives and archaeological data sets, but there is scope for using LEK for gathering such historical data. According to Campbell et al (2009) there is a wealth of literature from human-ocean interaction which can enable better understanding in the study of shifting baselines syndrome. LEK allows us to add in the socio-ecological changes that have taken place along with ecological construct of a changed system. It helps to highlight shifting baselines, not just in the ecosystems itself but in ecosystem services. There is the need to document such socio-ecological adaptation to changes and this is demonstrated in a study by Perry et al., (2011) on how societies and species have adapted to short term and long term changes to marine ecosystems. A study by Stutton and Tobin (2009) had also used proportional odds ratio logistic regression to understand recreational fishermen's attitude to rezoning of the Great Barrier Reef Marine Park. This study showed that there was a strong relationship with between fishermen's support of the rezoning plan and their perception of the necessity of the plan and its values.

The more general open ended questions on management and sustainability yielded a variety of answers that suggests that few of the fishermen were in approval of management. Rather, most were cynical and mistrustful of local authorities and higher government intervention and their management strategies regarding quotas, discards and total allowable catch (TAC). Several fishermen mentioned the problems with discards as well as the unfairness of the allocation of quotas – how the French vessels and Danish vessels are allowed to land sole and plaice, whereas British boats are not. The fishermen who had been fishing for a long time, since the 1960s, talked about the unfairness of the allocation of quotas between the EU countries. Some of these fishermen used to work offshore on large trawlers that targeted cod and haddock in Icelandic waters. They mentioned that back in the 1970s, there were more fishermen working offshore than in nearer waters and as such when the quotas were allocated, British fishermen did not get a large proportion as they constituted a smaller percentage of inshore fishermen. But now they can neither fish in Icelandic waters, nor make a living with the smaller quotas they are restricted to.
Some common comments made by fishermen include views on quotas, open/closed seasons and discards:

- "quotas don't work, targeting bigger fish as more valuable. Throwing away small fish. Would be sustainable if properly managed"
- "no to closed seasons/areas, which areas do you shut ?"
- "Under 10m can't make a living, if potting collapsed there would be nothing left"
- "lobster crab netting sustainable"

What was interesting was the conflict between fishermen who did mixed fishing in the north of our study region and shellfishermen based mainly in Bridlington. Many of the fishermen who thought that the North Sea was being sustainably fished mentioned how the waters were full of lobsters and crab and their businesses were profitable. A few of them mentioned that even though cod populations had been low for a number of years, it was starting to recover now and there were hotspots across the region where cod populations were sustainable. The fishermen from Whitby, Scarborough and Filey wanted a more mixed fisheries quota rather than just for shellfish. One person quoted:

- "So if the potting collapses, then you would have no 'less than 10 fleet'. If they gave a percentage quota, then they would start netting, giving shellfish stocks a rest for a bit"
- "Too much potting- too much gear found and too concentrated around here"
- "Limitations of pots needed- compromise needed, 1st June till August no lobsters landed at all"

The fishermen from Bridlington who were primarily shellfishermen complained more about having to use escape latches to let smaller size lobsters escape. But in general they were happier with management plans than the fishermen up north. On a local scale, the fishermen also seemed to have additional knowledge of other non-commercial species that can aid in understanding of changes in data poor species and the wider ecosystem.

Scientists and policy makers now look at fisheries and marine ecosystem management in a more holistic way and incorporating all aspects – social, economic and ecological – in management of marine ecosystems. This is demonstrated in current UK legislation and policies such as the National Ecosystem Assessment, Ecosystem Approach and overall ecosystem-based fisheries management (UK NEA, 2011; Pikitch et al., 2004; Greenstreet & Rogers, 2006). As mentioned earlier, there are also the European framework directives – WFD and MSDF – both which have introduced novel legislations following ecosystem based approaches (Borja et al, 2010). According to Hering et al (2010) there are several lessons that one can learn from the Water Framework Directive that can be implemented into the Marine Framework Strategy Directive, in particular, in the context of setting the good environmental status (GEnS) criteria and making sure that the objectives of these European strategies are comparable across the regional seas. Borja et al (2010) also discusses how there are conflicts between the two directives, such as spatial overlap and difference in defining biodiversity. This study also highlights how the WFD takes a 'deconstructing, structural approach' whereas the MSFD takes a 'holistic, functional approach' (Borja et al, 2010.)

Use of LEK can help gather such socio- ecological data required for the implementation of the MSDF, and feed into such current policies in managing for future ecosystem services on what we want from our seas. Returning to shifting baselines and the issue of identifying a 'natural state', it is important to note that it is not possible to use just the state of the ecosystem to define 'good environmental status' as stated in the MSFD. In this study, I gathered local knowledge of species and ecosystems, but at the same time, I also identified tradeoffs in service (e.g. whitefish to shellfish, provisional to recreational) which suggests that there is a need to include the value people place on the use of multiple ecosystem services when measuring ecological quality and management strategies (Paetzold et al., 2010).

There were a few limitations to the study starting with the small sample size (n=46). Secondly, even though I had in depth interviews with more than half the fishermen, there were several that were restricted due to time and the busy schedules of the fishermen. I didn't get to collect enough information from the open ended questions to carry out content analysis, where I could use key words picked up from the interviews and use them to objectively make inferences about the interviewees . I also have few results for some of the species e.g. haddock as well as on size of most species to run quantitative analysis to see if perceptions changed with when fishermen had started fishing. However, from this small sample, I could show that fishermen's perception of changes in ecosystem and services are limited by their own experience of fishing and for some species these compare well to independent data. Here I considered a specific provisional service – fisheries – which provides both food and livelihoods. But it can be seen how it is also linked to cultural services – recreation – as a result of such long term changes in the ecosystem. To make up for a decrease in livelihoods when fishing became restricted (e.g. introduction of quota system) fishermen turned to become wildlife tour operators. The rise in seal populations helped increase in such recreational activities, although this could just be that there are such tours available now and hence chance of seal sighting is higher. This subject of tradeoff in ecosystem services is brought up again in chapter 5 where I interview a different set of stakeholders and highlight what values they associate with Yorkshire coast, specifically on the cultural ecosystem services of this coastal region.

CHAPTER 5 ROLE OF COASTAL BIODIVERSITY IN PROVISION OF CULTURAL ECOSYSTEM SERVICES

5.1 Introduction

Coastal ecosystems provide a variety of ecosystem services which range from provisioning (e.g. fisheries) and regulatory (e.g. carbon sequestration), to supporting (e.g. coastal defence) and recreational (e.g. angling) (Beaumont et al., 2007). In recent years there has been much work to identify, characterise, and value coastal ecosystem services (Guerry et al., 2013; Barbier 2012; Beaumont et al., 2007; De Groot et al., 2002). Several of these studies have informed and have been integrated into management practices and policies such as the Millennium Ecosystem Assessment (MEA, 2005), Ecosystem Based Management (EBM) (Granek et al., 2010) and the Marine Strategy Framework Directive (MSFD) (Directive 2008/56/EC). Whilst provisioning, regulatory and supporting ecosystem services have been largely integrated into ecosystem approach (EA) frameworks, there has been much less integration of cultural ecosystem services (Chan et al., 2012, Daniel et al., 2012).

Cultural ecosystem services (CES) are defined as ecosystem services that provide recreational, aesthetic, and spiritual benefits to human beings (MEA, 2005), or more specifically that "combine with built, human, and social capital to produce recreation, aesthetic, scientific, cultural identity" (Costanza et al., 2011, p2). In this study I specifically refer to the cultural ecosystem services provided by coastal ecosystems. These can loosely be put in two categories. The first one includes aesthetics, spiritual benefits, and wellbeing – the often intangible benefits that people get from being near the coast or other 'blue' spaces. White et al. (2010) found that both natural and built scenes containing water were associated with higher preferences, greater positive affect and higher perceived restorativeness than those without water. Depeledge and Stone (2011) also found that being near the sea encourages people to be outdoors more and overall increases wellbeing. Delving deeper into this relationship, Halkos and Matsiori (2012) showed that the value people place on blue spaces depends on the characteristics of different coastal sites – including good water quality (e.g. blue flag status), number of recreational activities and other amenities.

The second broad category of CES is recreational benefits, including sea angling, spending a day by the beach, rockpooling, and other seaside activities which can be measured in monetary or other quantifiable ways. In a study of the leisure and recreational services provided in the Lyme Bay region, England, Rees et al. (2010) found that activities such as SCUBA diving, sea angling and wildlife watching depended on a diversity of sites and preservation of marine resources to provide such benefits. Rees et al. (2010) used both monetary and nonmonetary valuation of CES to provide evidence to support the sustainable use and protection of marine biodiversity as opposed to unsustainable exploitation. However, quantification and mapping of the full range of CES, in particular the aesthetic value that people place on different parts of the ecosystem and landscapes, remains a challenge. For instance, in a review of 107 publications considering methods, scales, drivers of change and trade-offs between CES and other ecosystem services, Milcu et al. (2013)

identified gaps in the literature mainly related to improving methods for CES valuation, being clearer about how CES can be included in policy and management, and incorporating and studying CES in the context of ‘bundles’ of ecosystem services. This last point is further emphasised by Daniel et al. (2012), who suggest including CES in socioecological models together with a larger set of ES thus highlighting trade-offs and synergies between ES.

Most studies measuring the benefits of CES have tended to be based on valuation in terms of economic or monetary estimation of nonmarket benefits and have included methods such as random utility models and the contingent valuation method (CVM). Halkos and Matsiori (2012), for example, used CVM to understand what people would be willing to pay to improve the quality of a beach. However, a range of methods may be needed to accurately capture the value of CES. Daniel et al. (2012) suggest measuring CES by differentiating between monetary assessments, non-monetary quantitative assessments, and comprehensive studies of the human–nature interaction. For example, Chhun et al. (2014) used choice experiments as a type of valuation method to assess biodiversity and ecosystem services with the aim of improving spatial management of near-shore marine areas in New Zealand. They found that combining monetary and non-monetary methods was a useful way to learn about social preferences for the use and allocation of marine resources. More generally, non-monetary valuation of cultural ecosystem service values can be easier for the general public to interpret than monetary valuations (Chan et al., 2012). Several studies have identified the need for novel methods to capture CES in a meaningful way to enable them to be integrated into management and policy (Chan et al., 2012, Poe et al., 2014). One such method involves uploading aerial photos to Google from different natural sites to map spatial distribution of goods and services, but with the added benefit of integrating CES and how it overlaps with other goods and services (Casalegno et al., 2013). Jobstvogt et al. (2014) present a case study on the importance of CES to divers and anglers. This study emphasizes the need to understand stakeholders’ CES values so that this can inform sustainable management of marine resources. Plieninger et al. (2012) conducted a study of CES at a community level incorporating spatial scales and utilizing both social survey methods and GIS.

Current evidence indicates links between biodiversity and provisioning, regulatory and supporting services (Cardinal, 2012). A systematic literature review on links between biodiversity and 11 ecosystem services by Harrison et al. (2014) found that the majority of the relationships were positive. In marine systems, biodiversity loss has been shown to affect marine ecosystem services (Worm et al., 2006). However our understanding of how CES will be affected by biodiversity loss, and in turn how this could impact upon well-being, remains limited (Clark et al., 2014). Sandifer et al. (2015) reviewed perhaps the best known CES link, that between biodiversity and health and wellbeing. Much of this CES research considers the health benefits of living near urban green spaces (e.g. Brown & Grant 2005). For instance, Fuller et al. (2007) found that the psychological benefits of green spaces increased with biodiversity in Sheffield, England, and that people can identify differences in species richness of some the better known taxa such as birds and plants. On the other hand, Dallimer et al. (2012) showed that whilst people do benefit from exposure to nature, the wellbeing factor comes from perceptions of biodiversity which may not be closely linked to the actual diversity of species in the area. In the context of coastal ecosystems, however, such studies are lacking. For instance, there is very little literature on the extent to which tourists care about the ecology of the system they are visiting, including features such as the composition of demersal and pelagic fish communities or the health of the food web, compared to general concerns about aesthetic value derived from clean water and beaches. There is also limited information on how disturbances such as vegetation trampling, litter or pressure on resources affect marine systems, and on what people enjoy about the seaside and their perceptions of biodiversity (Hall, 2001).

The objective of this study is to address this gap and explore the role of biodiversity in cultural ecosystem services. I do this by using the Yorkshire coast as a case study to investigate what people enjoy when they visit the seaside, what activities are important to them, and crucially what is the role of marine biodiversity in supporting these activities. The Yorkshire coast provides an ideal test case. Stretching 70km from Saltburn-by-the-Sea in the north to Spurn Point in the south (figure 5.1), it encompasses a mixture of sandy beaches, rocky coves and rugged cliffs and is home to a wide range of wildlife including iconic species such as the puffin (*Fratercula arctica*) and minke whale (*Balaenoptera acutorostrata*). The rocky shores are also popular for rockpooling, with the opportunity to see a variety of marine creatures such as brittle stars (*Ophiothrix fragilis*) and edible crabs (*Cancer pagurus*). Tourism has long been important in this region, especially following the arrival of the railway in 1845. Scarborough is recognised as the first seaside resort in England and large numbers of working class people flocked here during the months of April to September to visit the coast, with its cliffs, rocky shores, and sandy beaches (Walton 2000). Coastal tourism here is generally associated with activities such as birdwatching, rockpooling and recreational use of beaches for walking and enjoying day excursions. However the increasing number of people visiting the coasts has long given cause for concern about factors such as disturbance of wildlife and pollution (Usher et al., 1974). In this study I use a mixture of face-to-face interviews with visitors to the Yorkshire coast, and results from an online survey, to capture the kinds of CES that people value, whether these have changed in time, and importantly whether these CES are linked to marine biodiversity. I also gathered people's knowledge of marine biodiversity and opinions on marine conservation to see if the activities they enjoy related to their level of knowledge and perception on the state of marine ecosystems. By gathering such data on the ecosystem as perceived by people visiting the coast, I also address issues of trade-offs between CES and other ES in this region.

5.2 Methods

5.2.1 Study site

I conducted face-to-face interviews at 5 sites along the Yorkshire coast: Bempton Cliffs, Flamborough Head, Robin Hood's Bay, Whitby and Scarborough (figure 5.1). I grouped these sites into 'cliffs' (Bempton Cliffs and Flamborough Head) and 'seaside' (Robin Hood's Bay, Whitby and Scarborough) for analysis. This categorization is based on the assumption that people visiting different kinds of sites are likely to have different interests and levels of knowledge about biodiversity. For example, both of the cliff sites are well known sites of natural history interest (see below) and are likely to attract different kinds of visitor than the seaside sites, where people are more likely just out at the beach for a seaside holiday and might not have any interest in biodiversity at all.

Bempton Cliffs is a popular nature reserve run by the RSPB (Royal Society for the Protection of Birds) and is situated on the north side of the Flamborough peninsula, just west of North Landing. The reserve is home to the largest seabird colony in England with large breeding aggregations of charismatic species such as puffins and gannets *Sula bassana*. There are eight key species of seabird inhabiting the cliff face through the spring and summer months: gannet, puffin, kittiwake *Rissa tridactyla*, razorbill *Alca torda*, guillemot *Cepphus grylle*, fulmar *Fulmarus glacialis*, herring gull *Larus argentatus* and shag *Phalacrocorax aristotelis*. This area is mainly visited by birdwatchers, and people enjoying coastal walks. Tourism statistics show that 46-66,000 people visit Bempton Cliffs annually (Keith Clarkson, Site Manager at Bempton Cliffs, Pers Comm).

At Flamborough Head, interviews were conducted near the Flamborough Head Living Seas Centre which is located at South Landing, Flamborough. Right next to it is South Landing Local Nature Reserve which is 14 hectares of woodland, meadow and cliff top. There is a nature trail which runs through wooded areas, wild flower meadows, sea cliffs and a beach. I interviewed people who had been visiting the centre as well as those that had walked down to the beach and along the trail. This site is popular for people interested in nature and/or coastal walks as well as for people who enjoy activities by the sea. Flamborough Head is designated as a Marine protected area by OSPAR Commission (http://mpa.ospar.org/home_ospar/mpa_datasheets/an_mpa_datasheet_en?wdpaid=555556998&gid=1536&lg=0) as well as Special Areas of Conservation (Habitats Directive) due to the species associated with its hard chalk cliffs. The site includes around 14% of the UK's coastal chalk cliffs.

The rest of the interviews were conducted on the beaches and piers at Scarborough, Whitby and Robin Hood's Bay. According to the Scarborough Tourism Strategy 2011-2014, 53% of visitors to the area come from within the Yorkshire region. Visitor survey results show that repeat visitors are very common and people usually tend to stay for relatively long periods of time. Overall in this region people tend to visit the North York Moors National Park, the Borough's Heritage Coastline, traditional seaside towns and the area's large caravan parks. Tourism supports at least 21.7% of jobs in Scarborough (Scarborough Borough Council, 2011). In 2010 Scarborough was identified as the third most important destination in England for domestic tourism, just behind London and Blackpool (Scarborough Tourism Strategy 2011-2014). Across the Yorkshire region Scarborough Borough hosts the highest proportion of staying visitors, accommodating 22% of all overnight visitors. Whitby is known nationally and internationally as a quaint seaside town, rich in culture and heritage history and also famous for its unique geological features. Robin Hood's Bay is a combined bay and village situated about six miles south of Whitby. Taken together, the bay and the village form part of the Heritage Coast of the North Moors National Park.

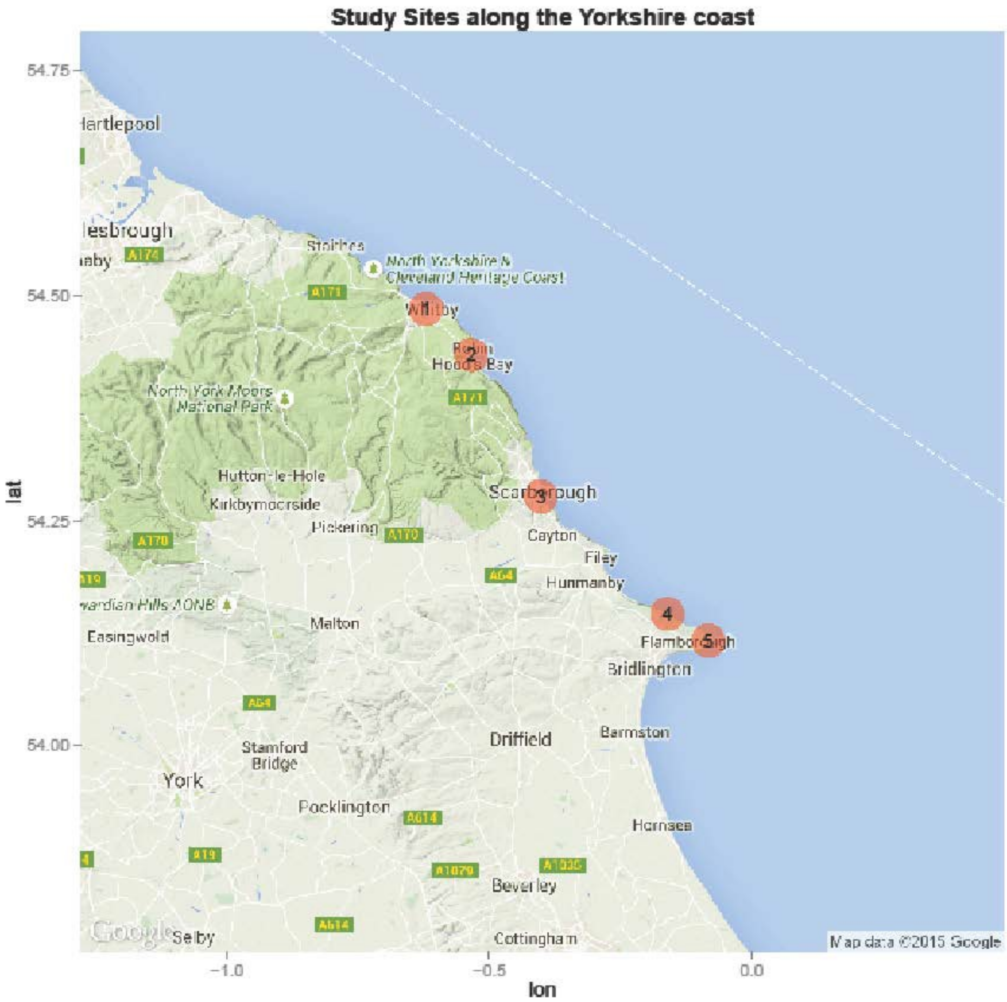

Figure 5.1 Five sites along the Yorkshire coast of the North Sea at 1) Whitby, 2) Robin Hood's Bay,
3) Scarborough, 4) Bempton Cliffs and 5) Flamborough where I carried out 82 face-to-face interviews over the period June-September 2014

5.2.2 Face-to-face interviews

I conducted 82 face to face interviews where respondents were targeted opportunistically at each of the sites. Each interview lasted about 10-15 minutes. Background information was collected on age, gender, where respondents had travelled from, when individuals had first travelled to the Yorkshire coast and how frequently they visit the coast. The objective was to gauge whether they were infrequent tourists or those visiting for the first time, or regular visitors who had been coming here often. This was followed by ticking areas that they visited the most from a range of choices along the Yorkshire coast. Following this, respondents were asked, What do you like to do by the seaside along the Yorkshire Coast? They were then asked to rate a series of activities. They rated each reason on a Likert scale of 1-5 (1-unimportant, 2-slightly important, 3-some importance, 4-very important and 5-main reason for visiting). The activities were: rockpooling, sun-bathing, building sandcastles, birdwatching, wildlife tours, water sports, angling, coastal walks, visiting historic sites, natural history (general), and fossil hunting. They were given additional reasons not related to activities for choosing the Yorkshire coast – near to home, cheap, friends nearby and/or any other reasons that the questionnaire did not cover. I then delved deeper into specific activities that relate to biodiversity. I considered three different types of seaside activities that are closely related to biodiversity – rockpooling, birdwatching and wildlife tours. I wanted to see if different aspects of biodiversity affected how much people enjoyed from any of these activities. Was it just the activity itself that was enjoyable or were factors like richness, abundance, rarity of species or presence of charismatic species also important? Full details of the questionnaire are included in Appendix III.

Following the questions on links between marine biodiversity and the various activities, I asked respondents questions about their knowledge of change in species and ecosystems. I asked whether the abundance of gulls, seals, crabs and lobsters had changed over the time period they had visited the Yorkshire Coast. Finally I offered a series of options on what the respondents think could improve their seaside holiday in this region. These suggested options were guided birdwatching tours, guided rockpooling activities, cheaper accommodation, better public transport to destinations, cleaner beaches, more water sports, more wildlife tours, more information on all the above activities, and guided coastal walks. Respondents could tick four responses: yes, no, makes no difference, not sure. At the end I asked them a series of questions to gauge in an indirect manner their affinity for environmental conservation. I asked them whether they were members of RSPB and/or any other environmental charity such as the National Trust or one of the Wildlife Trusts. I further asked their views on marine protected areas (MPAs) and offshore wind farm development – whether they think it will harm seabirds, marine mammals or invertebrates. For each of these questions they were asked to respond yes, no, or not sure.

This last set of questions was identical to the ones I asked fishermen in chapter 4. I wanted to capture how knowledge of changes in species found in the Yorkshire coast differed across a range of different stakeholders, as well to explore whether different stakeholders benefit from different ecosystem services along the same coast.

5.2.3 Online questionnaire

To supplement the face-to-face interviews, I also analysed data collected by Yorkshire Wildlife Trust as part of their Living Seas Project scheme (http://www.ywt.org.uk/news/2014/06/05/how-do- you-interact-north-sea). An online survey was carried out across 12 North Sea Wildlife Trusts from Northumberland to Suffolk. The objective was to gain a better understanding of how people interact with the North Sea coast and reveal their understanding of local marine conservation, wildlife and habitats. Data were collected between January and June 2014 with the online questionnaire being advertised through local networks and social media. I analysed feedback from 85 respondents who had visited the Yorkshire coast using those questions relevant to the values (i.e. cultural services) people associate with the Yorkshire coast and their knowledge and views on its species, ecosystem, and conservation. The full online questionnaire is shown in Appendix IV. The first section covered the various reasons why people visited the Yorkshire coast. These were to relax, snorkel/ swim, surf, kayak, sail, scuba dive, walk dogs, collect wild food e.g. seaweed, collect bait, enjoy a family day out, fish (recreational), bird watch, take photographs, and 'other'. This was followed by reasons why people do not visit the coast, to better understand what barriers might exist or what activities might increase the benefits of visiting. The next section covered people's knowledge and perception of marine species and of the North Sea ecosystem. Respondents were asked to tick from the following options regarding their knowledge: It is full of biodiversity including many interesting marine creatures, it is visited regularly by whales, dolphins and sharks, it is almost completely unprotected, It is an important economic resource for our local community, It is important for renewable energy, It is something I would like to know more about, and It is cold and dirty. This was followed by ticking which of the following taxa are found in the North Sea: porpoise, dolphins, skates and rays, whales, seaweed, limpets, coral, seals, anemones, crabs, lobsters, sea urchins, mackerel, sponges, kelp and sharks. Respondents were then asked a series of questions of how they felt about the ocean and how it benefitted their lives in terms of ecosystem service provision. Further questions assessed how respondents felt about the different pressures on the North Sea, how they felt about marine protected areas and marine conservation zones, and about their knowledge of existing and proposed MPAs in the Yorkshire. Full details on the questions and choices of answers are available in Appendix II.

5.2.4 Analysis

I first summarized the characteristics of respondents from both surveys (age, gender, frequency of visits to the Yorkshire coast and, in the case of the online questions, information on education, employment and whether participants had children). I use Chi square Goodness-Of-Fit tests to ascertain whether gender balance and age distribution was even across the group and between cliffs and seaside sites. I use the Likert package (Bryer and Speerschneider, 2014) in R to visualize all Likert-type responses. Responses were grouped according to the three target activities – rockpooling, birdwatching and wildlife tours – as well as between the two location categories (cliffs and seaside). I then ran Chi Square tests of independence to see if there were differences in preference of activities based on responses from the two sites.

5.3 RESULTS

5.3.1 Demographic characteristics of respondents

FACE-TO-FACE INTERVIEWS

Across all sites, 82 people were interviewed. Chi square Goodness of Fit on the total sample population show that the overall gender balance was even (χ^2 = 0.78, df=1, P = 0.377) but respondents were skewed towards the 60+ age group (χ^2 = 27.02, df=4, P < 0.0001) (table 5.1). Comparison of demographics between the two classes of site showed that the cliff site had a higher proportion of males. Age distribution was even at the seaside site, (χ^2 =4.5, df=4, P=0.342) but not at the cliff site, (χ^2=26.18, df=4, P <0.0001) with more respondents, particularly at the cliff sites, being

50+ (table 5.1).

The gender balance in the study sample population was representative of England population (X-squared = 3.2413, df = 1, p-value = 0.0718). The age demographics were skewed towards the older age groups, for the 50-59 and 60-69 age groups. This is because the study sample population was skewed towards the older age groups as lot of people in the older age group visit Bempton Cliffs.

Concurring with tourism statistics, there was a high rate of returning and regular visitors in this region. 51 % of respondents (n=41) visit the Yorkshire coast 1-3 times a year (table 5.2) and 39 % (n=31) had first come here 30-40 years ago (table 5.3). 39 % of the visitors (n=32) were from Yorkshire, 40 % (n=33) were from other parts of England, Scotland, or further afield (including Germany and one person from Mauritius). The remaining 21 % (n=17) did not say where they had come from. I further broke down the distance travelled by each visitor and grouped them into three categories – people who had travelled for less than 50 miles, ones who had travelled between 50-100 miles and ones who had travelled over 100 miles. Results showed that 21% (n=17) of visitors were local and had travelled from within Yorkshire. 30 % (n=25) had travelled between 50-100 miles and 27% (n=22) had travelled further than 100 miles, including 3 visitors who were from abroad. 22% (n=18) did not say where they were from.

Table 5.1 Demographic breakdown of the 82 interviewees by age group, gender (M or F), and location (seaside = Whitby, Scarborough and Robin Hood's Bay, Cliffs = Flamborough and Bempton Cliffs).

	Seaside		Cliffs		
Age	M	F	M	F	*Totals*
20-29	1	1	0	1	*3*
30-39	3	4	1	5	*13*
40-49	2	2	5	3	*12*
50-59	5	2	9	9	*25*
60+	3	5	16	5	*29*
Totals	14	14	31	23	**82**
	28		***54***		

Table 5.2 Demographic breakdown of the 82 interviewees by age and frequency of visits to the Yorkshire coast at the 5 locations - Whitby, Scarborough, Robin Hood's Bay, Flamborough and Bempton Cliffs. 3 individuals did not answer how frequently they came.

Age	*weekly*	*monthly*	*1-3 times a year*	*Less than once a year*	*1st time*	*Total*
20-29	1	0	2	0	0	3
30-39	2	0	6	5	0	13
40-49	0	1	5	4	1	11
50-59	3	1	13	4	4	25
60+	2	2	15	5	3	27
Totals	**8**	**4**	**41**	**18**	**8**	**7**

Table 5.3 Demographic breakdown of the 82 interviewees by age and when they first visited the Yorkshire coast at the 5 locations - Whitby, Scarborough, Robin Hood's Bay, Flamborough and Bempton Cliffs.

Age	*1st time here*	*5-10 years*	*10-20 years*	*20-30 years*	*30-40 years*	*50-60 years*
20-29	0	2	1	0	0	0
30-39	0	6	2	1	4	0
40-49	1	5	1	4	1	0
50-59	4	5	2	1	12	1
60+	3	6	1	3	14	2
Totals	**8**	**24**	**7**	**9**	**31**	**3**

ONLINE QUESTIONNAIRE

Results from the North Sea Survey carried out online generated 85 responses of which 60% (n=51) were females and 40% (n=34) were males (table 5.4). 75 of the respondents lived in Yorkshire, with 13 respondents in Scarborough (15%), 12 in York (14%) and 9 in Hull (11%) and the remaining 41 from other towns within Yorkshire. 10 respondents came locations outside Yorkshire. Out of the 85 respondents, 39 had children and 46 did not. When asked how often they visited the sea, 35% (n=30) said they visited a few times a year, 34% (n=29) said they visited weekly, 26% (n=22) said they visited monthly and 5% (n=4) said they have never visited the Yorkshire coast before. Occupation and level of education were also captured and broken down according to gender which characterize the type of stakeholder who took part in the survey. Results show that 67% (n=58) of respondents had post-graduate (n=22) or university degrees (n=36). 26% (n=22) worked in the charity and environment and conservation sector. 20% (n=17) worked in the public sector. The remaining 54% were made up of students (n=11), people working in finance, health or IT (n=5), teachers (n=8), retired (n=12) and apprenticeship/unemployed (n=12).

Table 5.4 Demographic breakdown by age and gender of the 85 interviewees who took part in the online questionnaire run by Yorkshire Wildlife Trust

Age	**Female**	**Male**
18-29	13	7
30-49	18	16
50-65	17	9
65+	3	2
Totals	51	34

Table 5.5 Demographic breakdown by age and how often respondents visited the sea from the 85 interviewees who took part in the online questionnaire run by Yorkshire Wildlife Trust

Age	18-29	30-49	50-64	65+
A few times a year	7	13	8	2
Monthly	4	11	6	1
Never	1	1	2	0
Weekly	8	9	10	2
Totals	20	34	26	5

5.3.2 What do people enjoy when they visit the Yorkshire coast?

FACE-TO-FACE INTERVIEWS

The most important coastal activities to respondents were visiting historical sites and coastal walks (figure 5.2). 63 % of the respondents (n = 52) considered coastal walks as very important and one of the main reasons for visiting the Yorkshire coast. Fossil hunting, water sports and angling were cited as the least important activities. Building sandcastles and sunbathing were considered very important as well and 28% (n=23) and 16% (n=13) considered these two activities is to be the main reason for visiting the coast. Patterns were similar at both the cliff and the seaside sites except for two activities. For birdwatching, 42% (n=23) said it was 'very important' and 'the main reason for visiting' at the cliffs site, whereas at the seaside site 24% (n=7) picked those two categories. For coastal walks, 41% (n=24) at the cliffs side said it was 'main reason for visiting' compared to 25% (n=7) at the seaside.

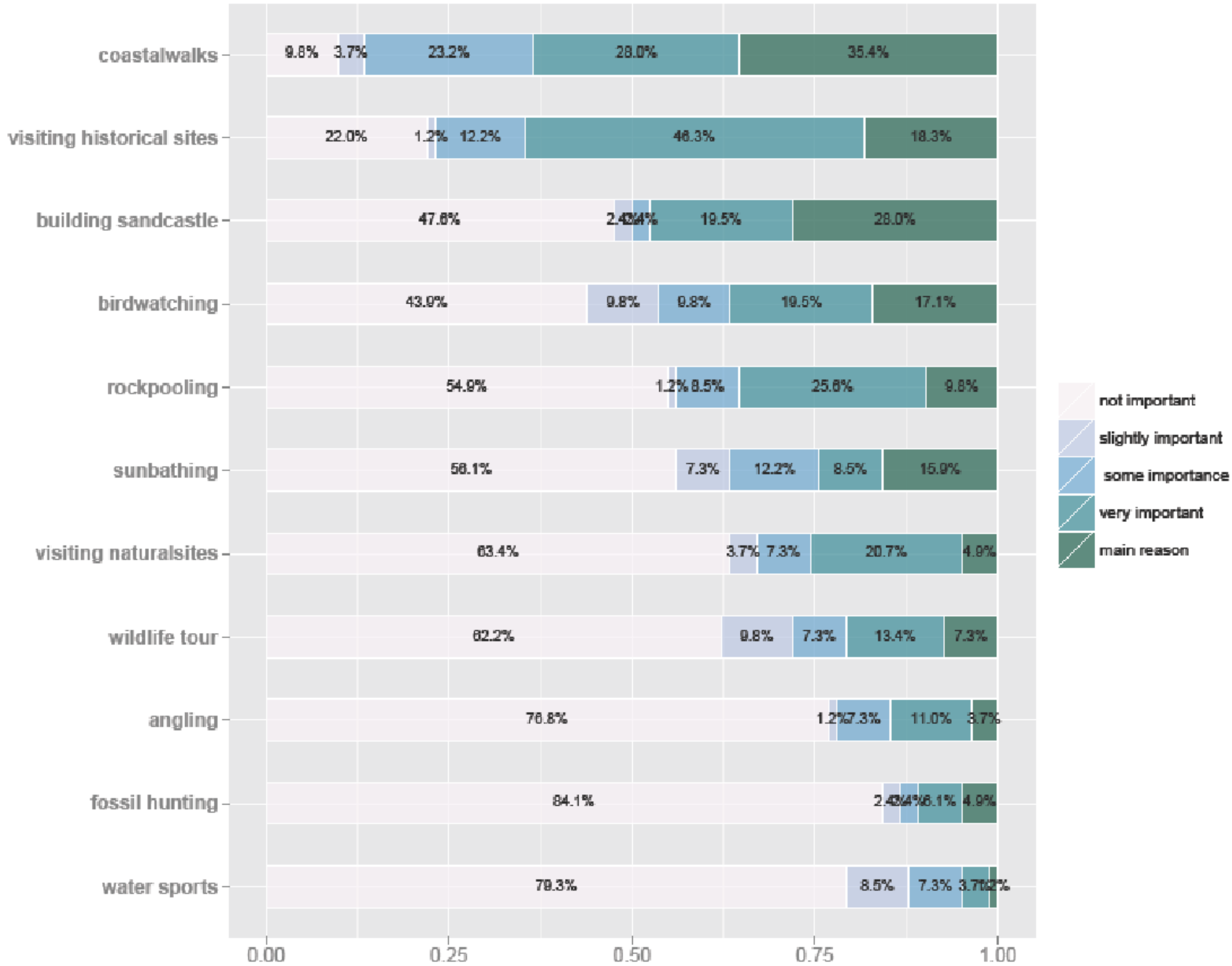

Figure 5.2 Ranking of importance of reasons for visiting the Yorkshire coast by 82 respondents to face-to-face interviews. Coastal walks and visiting historical sites ranked the most important and fossil hunting was least important for those people interviewed.

ONLINE QUESTIONNAIRE

Relaxing (89%, n=73), taking photos (66%, n=54), enjoy a family day out (57%, n=47) and birdwatching (55%, n=45) were the most popular reasons for visiting the sea (figure 5.3). Swimming (23%, n=19) and walking the dog (21%, n=17) were popular as well. Most of the other known reasons were mentioned by less than 10% of the people. 23 people cited 'other' and no one cited 'collecting bait' as a reason for visiting the coast.

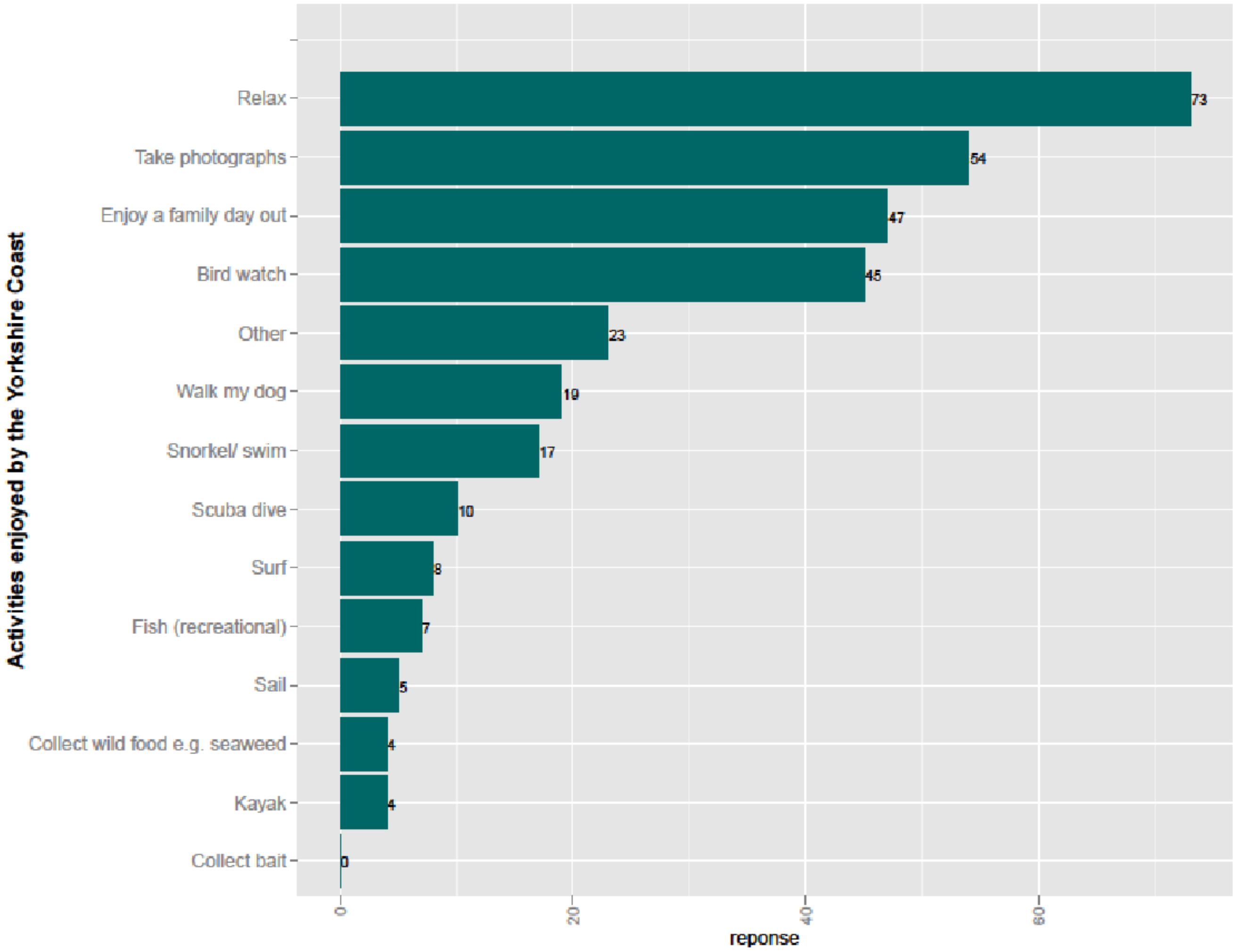

Figure 5.3 Activities enjoyed at the Yorkshire coast by 85 respondents who completed an online questionnaire as part of 'Relationship with the North Sea' research project run by Yorkshire Wildlife Trust.

5.3.3 What aspects of biodiversity do people enjoy along the Yorkshire coast?

I asked the 37 respondents who had stated that they enjoyed the three coastal activities associated with biodiversity – rockpooling, birdwatching and wildlife tours - a further set of questions to gauge what specifically they liked about these activities and whether it is related to abundance, diversity or rarity of species.33 % (n=27) respondents enjoyed rockpooling, 41 % (n=34) respondents enjoyed wildlife tours and 45 % (n=37) enjoyed birdwatching. Their answers on specific questions related to each activity are shown in figures 5.4 to 5.6. Respondents found it more important to see a high abundance of wildlife rather than any particular kind of species. Finding rare species was least important for both birdwatching and rockpooling. Seeing whales was much more important than seeing dolphins or seals during boat based wildlife tours.

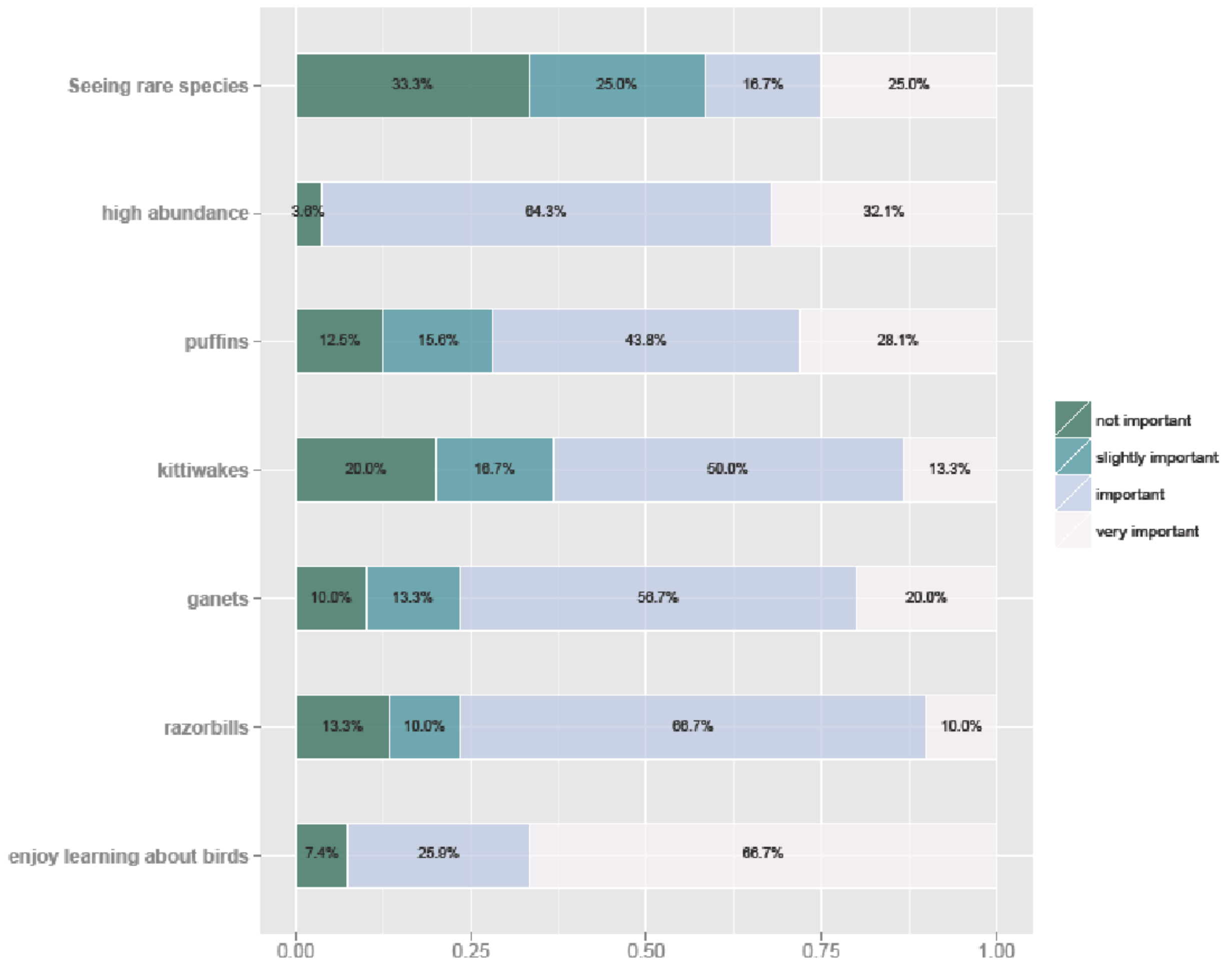

Figure 5.4 Ranking of reasons enjoyed when bird watching that are linked to different aspects of biodiversity - abundance, rarity, occurrence of charismatic species and learning about birdlife. There are 5 categories to choose from but no one had ticked 'some importance' so it is not included in the figure legend.

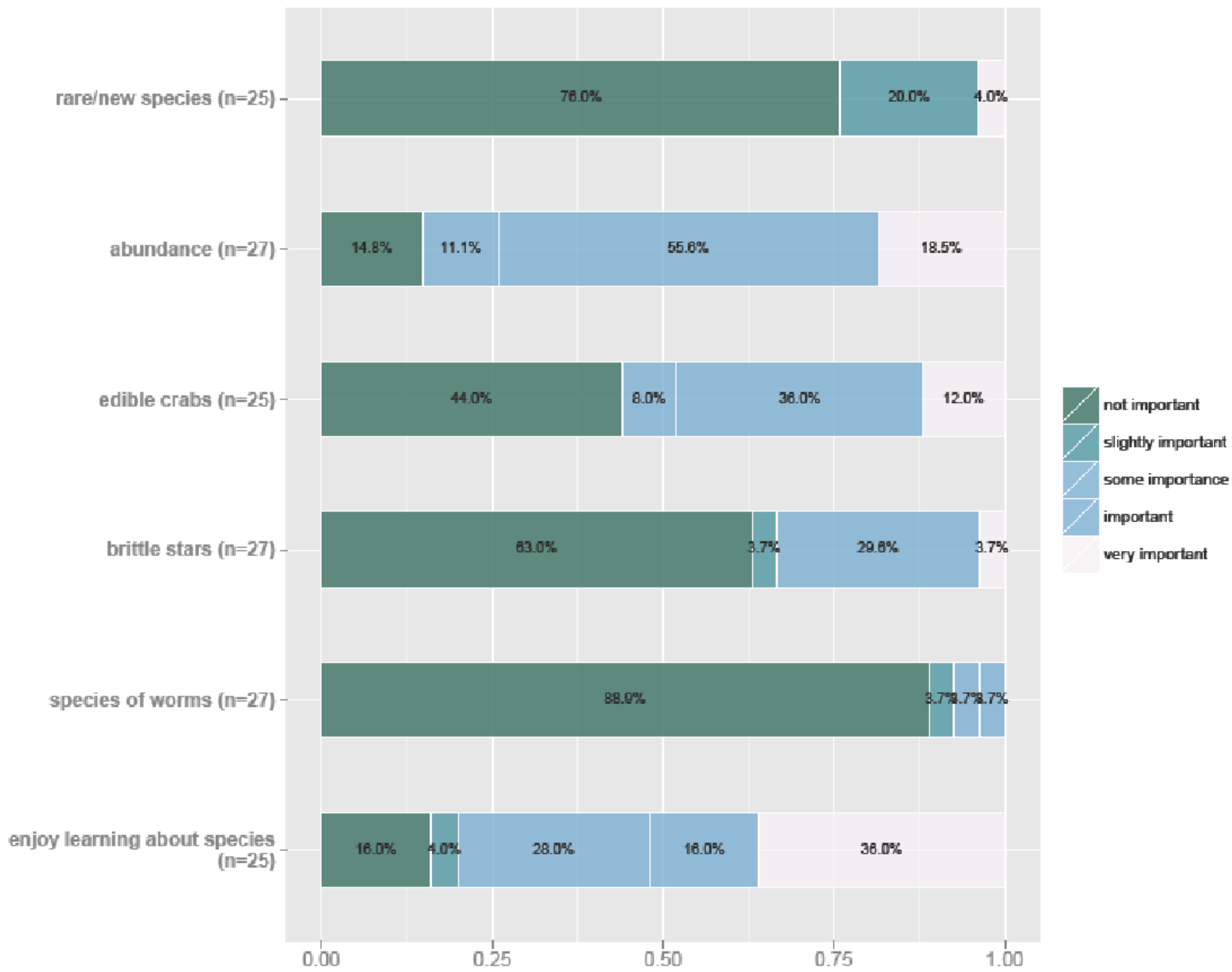

Figure 5.5 Ranking of reasons enjoyed during rockpooling and whether it is important to see specific species, rare species, abundance of marine life or just the opportunity to learn about species.

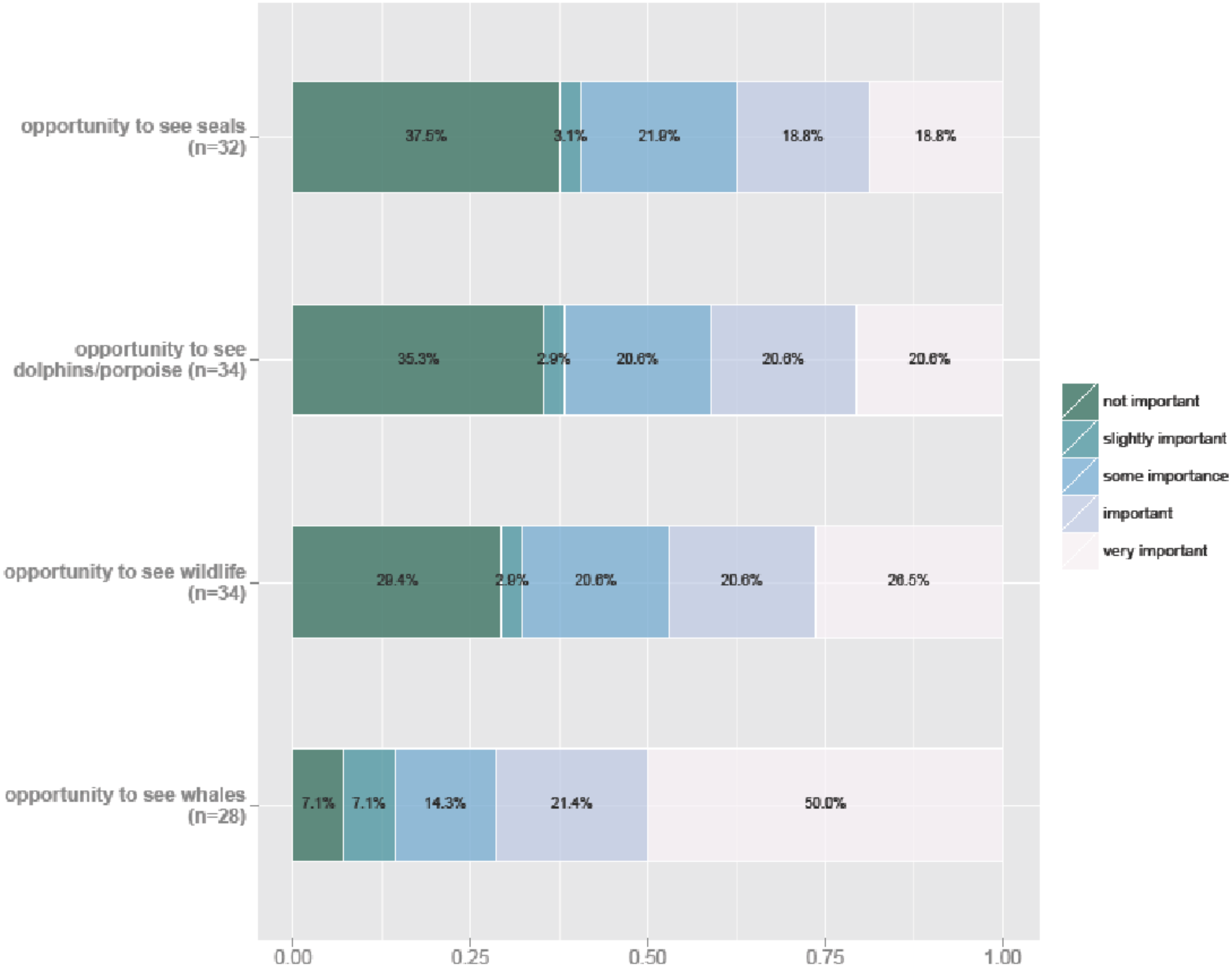

Figure 5.6 Ranking of reasons enjoyed during wildlife tours and whether it is important to see specific species or just the opportunity to see wildlife.

5.3.4 Knowledge and perception of North Sea species and ecosystem

FACE-TO-FACE INTERVIEWS

39-63 % of respondents (n=32-53) stated that they did not know whether any of the four species mentioned had changed in abundance (figure 5.7). 18 % (n=15) thought that the population of gulls had increased whereas 15 % (n=12) that there was a decrease. Only 19 % (n=16) thought lobsters and crabs had increased and 26 % (n=21) thought that seals had increased as well. There was no relationship between these perceptions and the length of time they had been visiting the coast.

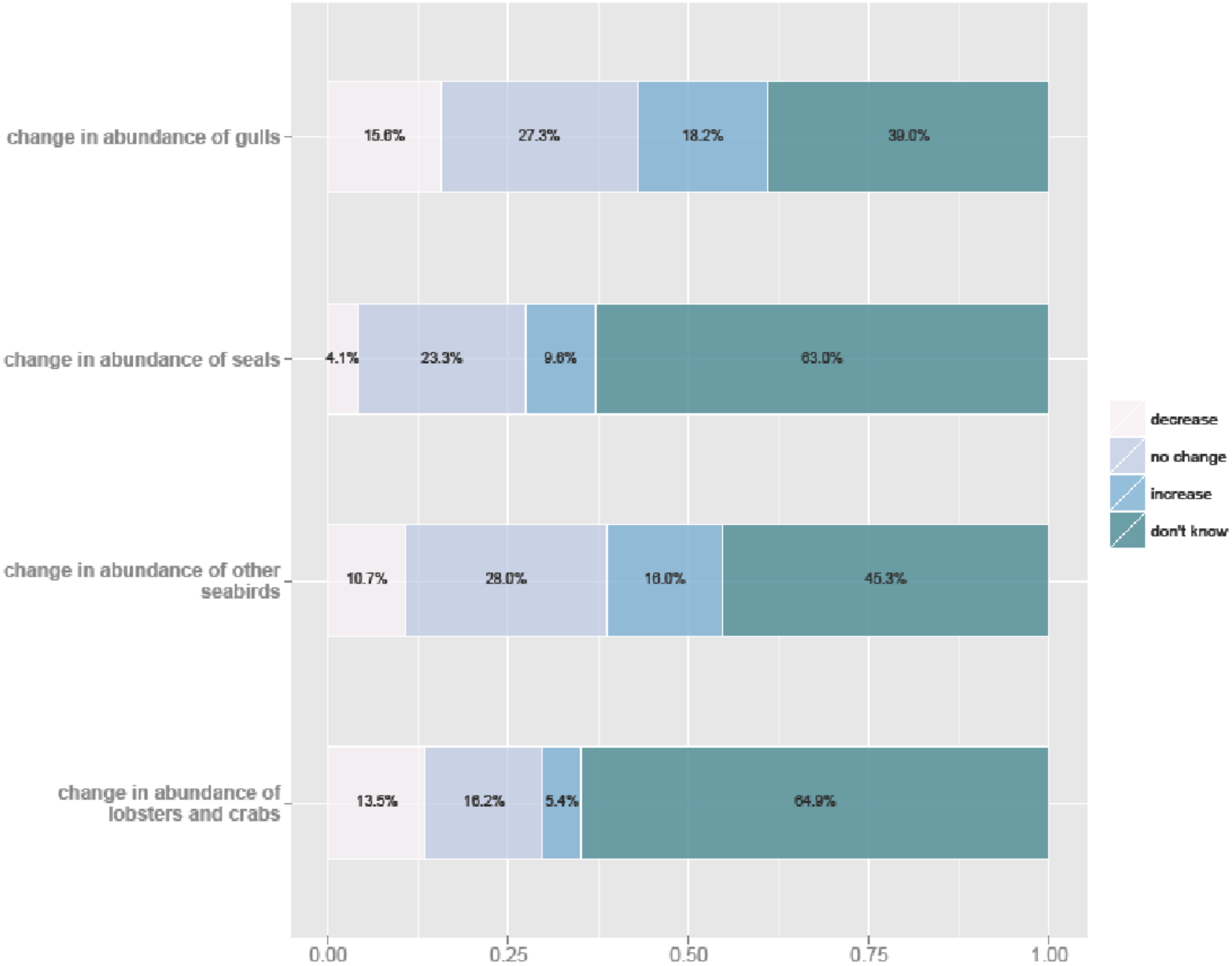

Figure 5.7 Perception on change in abundance of seals, gulls, other seabirds, and marine invertebrates – lobsters and crabs – in the time period 82 respondents who took part in face-to-face interviews had visited the Yorkshire coast.

ONLINE QUESTIONNAIRES

5.3.5 What biodiversity is present in our local seas?

Table 5.6 shows the number of respondents who knew that different taxa were present in the North Sea - note that all of the taxa are present in the local area (Walday and Kroglund 2011). Results show that whilst almost all respondents were aware that some groups, such as seaweed, crabs and seals were found in this region, there was less knowledge of other groups like sponges, sharks and corals.

Table 5.6 Knowledge on what species are present in the North Sea as perceived by the 85 respondents who filled out the online questionnaire

Species present in the North Sea	Number of responses for presence	Proportion of responses
Seaweed	84	0.99
Crabs	83	0.98
Seals	81	0.95
Limpets	79	0.93
Lobsters	77	0.91
Kelp	69	0.81
Anemones	68	0.8
Porpoise	67	0.79
Mackerel	67	0.79
Dolphins	64	0.75
Sea urchins	64	0.75
Whales	59	0.69
Skates and rays	56	0.66
Sponges	50	0.59
Sharks	47	0.55
Coral	40	0.47

Table 5.7 Perception of North Sea ecosystem and the ecosystem services it provides by 85 respondents who filled out the online questionnaire

Perception of North Sea Ecosystem	Number of Responses	Proportions of Responses
It is full of biodiversity including many interesting marine creatures	71	0.84
It is an important economic resource for our local community	68	0.80
It is almost completely unprotected	45	0.53
It is important for renewable energy	43	0.51
It is visited regularly by whales, dolphins and sharks	41	0.48
It is something I would like to know more about	36	0.42
It is something I know very little about	12	0.14
It is cold and dirty	5	0.06

Results on the question of how the ocean add quality to their lives (respondents could only click one of the three choices given) showed that 40% (n=34) mentioned it was important for relaxation and recreation (cultural services), 25% (n=21) mentioned it provides food (provisioning services) and 31% (n=26) mentioned it helps to regulate the climate (regulating services).

5.3.6 Limitations and improvement in ecosystem services provided by Yorkshire coast

Questions about improvement to CES experience showed that the respondents felt guided tours for activities such as birdwatching, rockpooling and coastal walks would improve the benefits and encourage more people to take part in them (figure 5.8). 50% (n=41) of individuals said that cleaner beaches and cheaper accommodation would not make a difference as the beaches were already clean and accommodation cheap enough relative to other seaside resorts. Just 17% of people (n=14) believed that more water sports would improve CES. The only other variable on infrastructure

related to improvement in CES, besides cheaper accommodation, was public transport. 39% (n= 33)
believed that it would improve services whereas 32% (n=27) said no and 29% (n=25) said don't know.

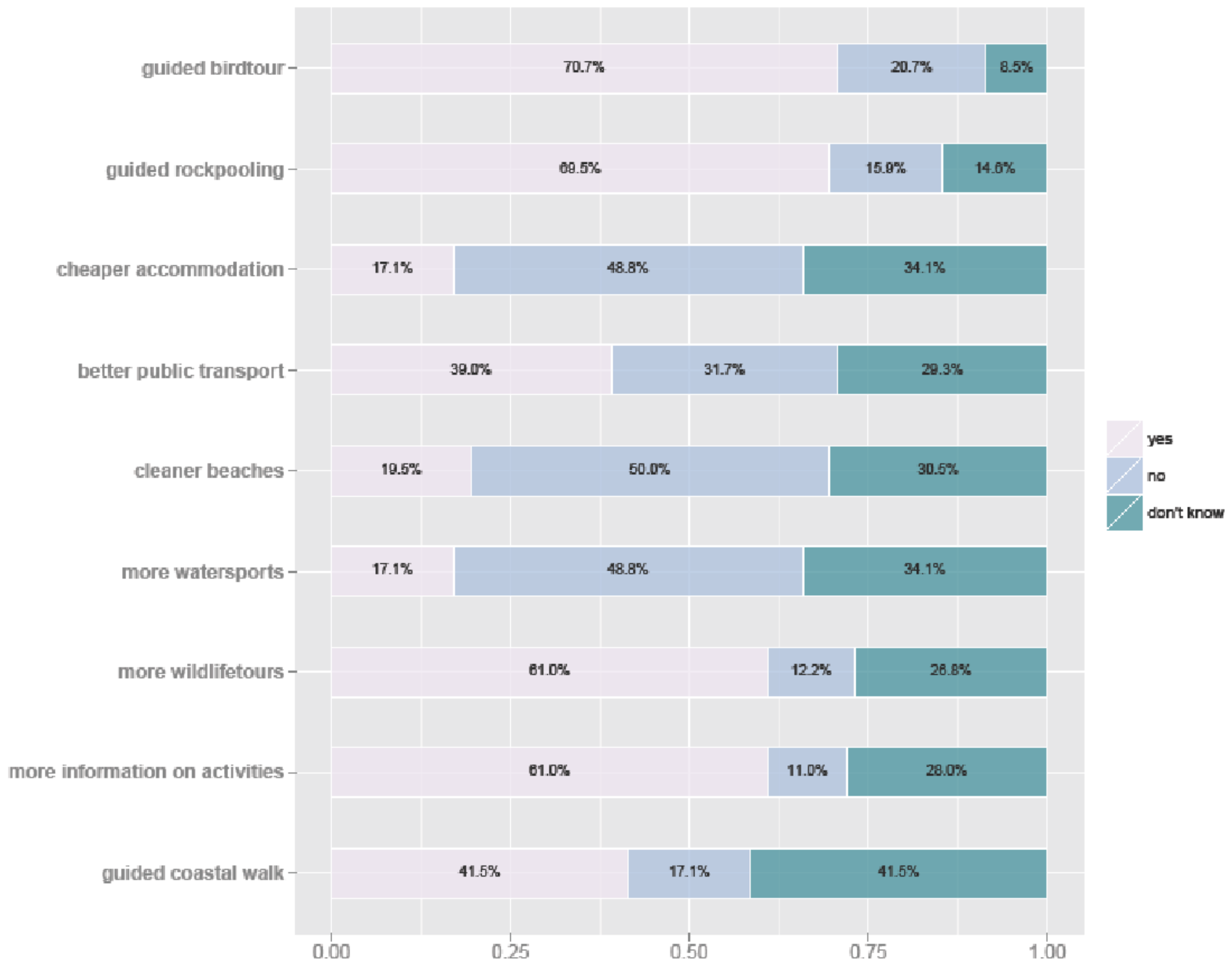

Figure 5.8 Opinion of 82 respondents during face-to-face interviews on what would improve their experience of the activities they enjoy by the Yorkshire coast

5.3.7 What would put you off visiting the sea?

57% (n=48) of respondents said nothing would put them off visiting the sea, followed by 16% (n=15) who said they do not have time, 15% (n=13) who said they are put off because it is too far, and 12% (n = 10) who said it was dirty and full of litter. Other reasons attracted few responses.

5.3.8 Knowledge and opinions on coastal conservation, pressures and future ecosystem services

Results from both face-to-face interviews and online questionnaire showed that there is high approval for MPAs. During the interviews respondents were asked about future ecosystem services – development of offshore windfarms and marine protected areas in the North Sea. 60% (n=49) approved of MPAs, 12 % (n=10) did not and 28 % (n=23) were not sure. When asked if offshore windfarms would harm marine species, 39% (n=32) felt it would be harmful to birds, 30% (n=25) felt it would be harmful to marine mammals and 24% (n=20) felt it would be harmful to invertebrates.

43% (n=35) of respondents were not sure whether birds, marine mammals, or invertebrates would

be harmed by offshore windfarms. 92 % (n=78) of the online questionnaire respondents felt that MPAs protected habitat and wildlife (table 5.8). At the same time, 66% (n=56) felt that MPAs would restrict human activity.

Table 5.8 Attitude on Marine Protected Area by the 85 respondents who filled out online questionnaire

Marine Protected Areas result in the following	Response
Restrict human activity to varying degrees	56
Safeguard important habitats and wildlife	78
Allow nature to recover and thrive	63

Online questionnaire results on marine protected areas and marine protected zones (questions 21 to 28, see Appendix III online questionnaire) showed that 62 % (n=53) thought that Yorkshire had MPAs, 8% (n=7) did not think there were any and 26% (n=22) were not sure. With regards to how important MPAs were to individuals, 56 % (n=48) thought they were very important, 34% (n=29) thought they were important, 5% (n=4) had no opinion and only 1% (n=1) thought they were not important. When asked about existing MPAs at Flamborough Head and the Humber, 52% (n=44) responded that they knew there were two MPAs already. 36% (n=31) thought there were no MPAs and 12% (n=10) were not sure. Results on level of importance for protection of local marine wildlife showed that 74% (n=63) respondents thought it was very important, 25% (n=21) thought it was important. 92% (n=78) respondents said they wanted to learn more about the sea, with just 8% (n=7) saying no. The majority of people (92%, n=78) believed that MPAs safeguard important habitat and wildlife.

85-88% (n=72-75) of the respondents believed that awareness of MPAs should be made available through schools at primary and secondary levels. Alongside organized activities such as coastal walks 87% (n=74), primary and secondary level education were cited as the most effective for spreading awareness (table 5.9). The lowest number of respondents 53% (n=45) and 48% (n=41) believed it should be done at higher education levels and through printed literature

5.3.9 Pressures on the North Sea ecosystem

From the online questionnaire, 95% (n=81) of the respondents thought our local seas were facing pressure from human activities. Table 5.10 shows that respondents perceive the biggest threats to the North Sea to be litter, pollution and overfishing. Renewable energy is perceived to cause no pressure by 28% (n=24) of the respondents.

Table 5.9 Number of people who filled the online questionnaire on methods that can be used to increase awareness on Marine Conservation Zones

How do you think awareness on MCZ can be increased?	Number of people
Through our primary education system	75
Through our secondary education system	72
Through our tertiary education system	45
Through organized activities such as coastal walks, snorkeling and rock pooling	74
Through information boards at local sites	66
Through better online information resources	57
Through printed literature e.g. books, newspapers, magazines	41
Through topical talks and lectures	55
Through short courses	52
Through joining groups and recreational clubs	57

Table 5.10 Activities that are putting pressure on North Sea ecosystem as perceived by the 85 respondents who took part in the online questionnaire

Pressure on North Sea Ecosystem	No of Responses	Proportion of Responses
Litter	81	0.95
Pollution	73	0.86
Overfishing	68	0.8
Climate change	62	0.73
Coastal development	59	0.69
Invasive species	55	0.65
Agricultural run-off	55	0.65
Population growth	47	0.55
Fossil fuels	46	0.54
Recreational Use	28	0.33
Renewable Energy	24	0.28

5.4 Discussion

Our results suggest that people value biodiversity more for its aesthetic role rather than recreational role in cultural ecosystem services along the Yorkshire coast. Biodiversity is valued as part of the larger seascape and people place importance on activities such as coastal walks and day spent relaxing by the sea far more than they do on activities specifically related to biodiversity (e.g. rockpooling, wildlife viewing).

Even though biodiversity encompasses the diversity of species and ecosystems, within the framework of ecosystem services, there is debate over whether biodiversity is an ecosystem service in itself, or whether it is a service providing unit (SPU) (Mace et al., 2012, Harrison et al., 2014). According to Mace et al. (2012) biodiversity has a role in different stages of the ecosystem service framework - as a regulator of ecosystem processes, as a final ecosystem service and as a good itself. The relationship between biodiversity and ecosystem services is complex and this complexity has been studied far more in provisioning, regulating and supportive and less in the role of biodiversity in cultural ecosystem services (Chan et al., 2012). Recommendations from previous studies on the relationship between biodiversity and CES call for more novel methods to capture the values associated with biodiversity and how it benefits CES. With this overarching question in mind, I carried out our study to capture how different stakeholders benefit from coastal CES and what aspects of biodiversity is associated with these benefits. Previous studies have shown that biodiversity is valued for the intrinsic value of species themselves, though this is usually applied to charismatic species, but very few shows how biodiversity fits into the wider benefits received from cultural ecosystem services.

Several studies have been conducted on the benefits of nature on health and wellbeing (Brown and Grant, 2005), notably the success of 'green gyms' and people's affinity for parks and other green spaces. In this study I saw that coastal walks rank high in importance in the activities that people enjoy along the coast, especially in the older age group 50-60. In addition, a high percentage of them believed that guided walks would improve benefits and enjoyment. In line with the findings of this study, I would suggest more research on 'blue gyms' as a means to quantify such CES benefits from coastal areas. Findings from this study also supported previous work done on links between blue spaces and wellbeing, on the health benefits people receive from the coastal environment (White et al., 2010). When asked to rank how the ocean adds quality to respondent's lives, 40% had said they enjoy the ocean for recreation and relaxing (CES) in comparison to 31 % who chose provisioning and 25 % who chose regulating services. From this study, I addressed two of the gaps in the literature – Firstly, what is the role of biodiversity in CES? Our findings suggest that biodiversity serves more of a role in aesthetic and intrinsic value rather than being important for recreational value. From our study, the benefits received from biodiversity as a final ecosystem service are quite low where activities linked to biodiversity along the Yorkshire coast are not perceived as important to majority of stakeholders. The individuals (n=37) who enjoyed activities strongly linked with biodiversity such as rockpooling, birdwatching and wildlife tours said that overall abundance was important, and individual species were important too. Likewise those on wildlife tours. It was only really rockpoolers who did not, and even they said that overall abundance was important. The majority of respondents were unaware of changes in species where 39-63% replied that they did not know if gulls, seals, cetaceans and lobsters and crabs had increased, decreased or had not changed. This has already been seen in other systems: people associate wellbeing with perceived biodiversity rather than actual biodiversity present in a particular ecosystem (Dalimer et al., 2012).

Secondly I addressed the question of how valuation of CES incorporating biodiversity can be done and integrated better into the ecosystem service framework. What I found in this study was that seascape character is more important to people than the value or importance of particular species or feature of the marine environment. This is in line with previous studies on landscape level aesthetics (Daniel et al., 2012) and studies on geodiversity and ecosystem services (Gordan and Barron, 2013). In this study, from the face-to-face interviews, I found that coastal and nature walks plus visiting historical sites were the activities that people enjoyed most. From the online questionnaire, relaxing and having a family day out were the most popular responses. These imply that people benefit from the wider ecosystem as a whole, rather than specific aspects of biodiversity. They enjoy the views and being by the sea and the cliffs, rather than seeing different species within that ecosystem. That said, certain groups of species (e.g. puffins, whales) were important to some groups of visitors to the coast.

The fact that species richness did not rank high on importance to respondent's enjoyment (See figures 5.4-5.6) of the coast does not imply that they do not care about whether these species are there or that there is no CES associated with biodiversity. In fact their responses to later questions on MPAs (table 5.8), their willingness to pay more for eating local fish and their views on increasing environmental awareness implies that they also place value to the goods and services provided by biodiversity, but it falls under 'aesthetic value' rather than 'recreational value' associated with cultural ecosystem services. Capturing these attitudes and views regarding marine protection and future services such as MPAs and windfarms can also help measure how people value cultural services, whether for intrinsic value of biodiversity or aesthetic value related to tourism.

One aspect of cultural ecosystem services is that of the intangible benefit associated with sense of identity and place linked to a given ecosystem. According to Tengberg et al. (2012), heritage values and cultural identity are part of benefits of CES and the fact that a high proportion of our respondents were returning visitors and had been visiting the Yorkshire coast for 30-40 years might imply that they identify heritage and sense of place with the Yorkshire coast. I make the argument that people's willingness to protect the Yorkshire coast, marine biodiversity and ecosystem is attached to this CES of shared identity and sense of place. Even though people might just want to enjoy a day by the sea irrespective of what biodiversity is present, they will want to conserve this biodiversity based on the benefits they received that are associated with sense of place.
Furthermore using such methods of capturing people's values of cultural heritage, I can start to gather data on historical values as well, how they have changed over time and possible capture

historical drivers of change in landscapes as well. According to Tengberg et al. (2012), such methods for valuation of cultural heritage and identity in landscapes should be integrated into assessments of ecosystem services.

Another subject that is important in the literature of ecosystem services is the issue of trade-offs between services (Costanza et al., 2011, Casalegno et al., 2013). This is also very topical subject when it comes to applying an ecosystem approach in marine spatial planning. This is seen in Lyme Bay where the recreational industry benefited from areas closed to trawling (Rees et al., 2010). On the other hand this was limiting for other local industry there. In our study we see such trade-offs amongst different stakeholders – in particular how fishermen feel towards wildlife such as birds and seals (see Chapter 4) compared with how tourists feel about these species (chapter 5.) Wildlife tour operators and tourists favour the presence of gulls and seals whereas fishermen perceive these species as nuisance as it conflicts with fisheries. This is even more pertinent when it comes to future CES such as development of offshore windfarms and marine protected areas. I observed the conflict amongst stakeholders regarding off shore windfarms where respondents in this study approve of them yet many felt that they might harm wildlife.

This chapter differs from the rest of this thesis because it does not utilize a historical approach to study changes in coastal ecosystem services. It focuses instead on a particular type of ecosystem services – cultural - which have been least studied and integrated into the wider ecosystem service framework. It focuses on the values people associate with coastal environments and in particular the role biodiversity plays in this valuation. But the focus of this study still fits in with the overall thesis focus as it addresses the trade-offs in services and how that can shift over timescales spanning 100 years. For example, in chapter 3 one of the case studies is on Bempton Cliffs and the change in demand for provisional services (egg collection) to cultural services (bird watching). This is picked up on in this chapter where participants discuss the cultural and recreational values associated with the same species. At the same time this value differs from how fishermen value biodiversity as discussed in chapter 4 where they perceive an increase in gull and seal populations that they consider to be harmful to their livelihoods. One of the focuses of this thesis is to address changes in societal demand for services and to show that even though the ecosystem might not change in certain aspects, changes in society can still cause a shifting baseline in the bundle of ecosystem services available at any given point in time. This is captured in this chapter which shows that people place value on the wider seascape and the biodiversity associated with it. The value of birdwatching at this local scale is high within the bundle of ES available whereas at a different point in time, the cultural value associated with bird species was not the same.

5.5 Limitations of the study and future recommendations

Inference from our study is limited by the characteristics of the stakeholders I engaged. I only interviewed a subset of the diverse range of stakeholders that make use of the North Sea ecosystem. This subset was representative of UK population in terms of gender balance, but not for all the age groups. In follow up studies on links between biodiversity and cultural ecosystem services, I would incorporate a wider range of stakeholders. This includes stakeholders such as divers and anglers who may derive more direct benefits from biodiversity.

We conducted face to face interviews using semi structured questionnaires as opposed to online questionnaires as we wanted to capture what values visitors to the Yorkshire Coast associated with biodiversity, while they were actually there and experiencing it. We wanted to reach specific target locations (visitors at Bempton Cliffs and Flamborough Head) and compare with visitors at popular seaside resort towns such as Whitby and Scarborough. There are a number of limitations with using a questionnaire approach, mainly to do with biases associated with the design of the questionnaire as well as with the responses. The researcher might be making assumptions when designing the questions in terms of what is important and might miss out capturing relevant information pertaining to the subject. On the other hand, there is subjectivity in how the respondent interprets the question and more so how truthfully they respond. There is an argument that a questionnaire is inadequate in capturing feelings, behaviour and emotions and there are also limitations in the analysis of such data and what one can infer from responses. However, the fact that large amounts of information can be collected from a relatively large sample group in a very short period of time was one of the main benefits of using a questionnaire. Other advantages for open-ended questioning include freedom and spontaneity of answers, as well as the opportunity to probe for testing hypotheses about ideas or awareness (Bird, 2009). This combined with the fact that we wanted to capture local values as mentioned earlier, is the reason I carried out the survey using this method of data collection.

Between the two sets of respondents, the online survey group is assumed to have some level of interest in the North Sea biodiversity and ecosystem as they willingly chose to partake in a survey. The demographic characteristics of this group, where a high percentage of respondents were from the charity, environmental, and academic sector and a high percentage had finished university or had a higher degree, implied that perhaps they would have a stronger affinity towards biodiversity conservation and that they would have a higher level of knowledge and awareness of coastal environmental issues. Studies have shown that several factors such as level of education, wealth, profession, and location effects attitude towards conservation issues and environmental protection (Törn et al., 2007). This could further be extended to people's knowledge, perceptions and the benefits they receive from marine biodiversity and coastal ecosystems. For example, the type of job you do can dictate how often you get to visit the coast, despite location, and how much you are willing to pay for marine protection and conservation management.

Within the face-to-face interview group of stakeholders, the cliffs group had a strong bias towards having an interest in biodiversity (even though it was specific for birds) but there is also the wider perception and knowledge of coastal environment and habitat of these birds. The seaside group on the other hand had the least bias as they were randomly selected at different beaches, regardless of the activity they were partaking in – sunbathing, swimming, building sandcastles or just walking along the pier. The age group 50+ represented 66 % of the number of people interviewed. This could be due to the fact that more than half the interviews were in Bempton Cliffs where mostly older people go for birdwatching. The other reason is possibly due to the fact that this age group were more willing to give interviews rather than parents with young children who were by the seaside. Either way, there is a strong bias created with uneven age distribution of respondents.

Findings from this study indicate that people may not know about or enjoy specific attributes of biodiversity (diversity, abundance, rarity) but they value biodiversity as part of the wider landscape. In line with the findings of Martin-Lopez et al. (2009) on rethinking the assessment of ecosystem services provided by biodiversity, I find biodiversity to be more of a service providing unit (SPU) than a final service. It provides cultural benefits in a more holistic way than as a separate entity. In the future, I recommend carrying out further research on a larger population sample and possibly designing the questionnaire using Choice Experiment to capture value of species versus visions of the seascape. For instance, in future studies, I would set up images with different seascape views, one with images of biodiversity e.g rockpools and different species of birds and another one of image of just the sea and being able to relax by the beach. This kind of approach has its roots in random utility theory and in experimental design and study by Hanley et al (1998) has given insight into how it can be used to assess the UK visitors demand for recreation. In such studies, pair-wise choices are offered to understand the marginal values for the attributes of different environmental assets.

CHAPTER 6 DISCUSSION AND RECOMMENDATIONS

6.1 Summary

The phenomenon of shifting baselines has been widely demonstrated in marine ecology, highlighting the importance of using marine historical ecology in ecosystem conservation and management (Schwerdtner et al., 2014). According to Kittinger et al. (2015) when it comes to marine conservation and ocean planning efforts, scientists and practitioners tend to focus on mitigating adverse effects caused by current and future human activities. They have tended to ignore historical data on past impacts and hence set targets too low for improvement in the health of the ecosystem. This is the core of what Pauly (1995) defines as shifting baselines syndrome –"when each generation of marine scientists accept as a baseline the stock-size and species composition that occurred at the beginning of their career, and uses this to evaluate subsequent changes, often assuming that inadequate data exist for earlier periods". Marine historical ecology aims to address this issue, and to document the shifting of baselines through time. It is used in restoration projects (Bullock et al., 2011), in academic research on better understanding of long term changes (Rosenberg, 2005), and in policy directives (EC, 2008). Yet gaps still exist in the literature on shifting baselines, concerning inclusion of humans in past records of the ecosystem, changes in historic ecosystem services, and in the study of adaptations in socio-ecological systems from long term ecosystem changes.

At the same time the concept of ecosystem services has helped to put biodiversity conservation in the forefront of environmental policies and frameworks such as the Marine Strategy Framework Directive (Directive 2008/56/EC) and Ecosystem Based Management (Granek et al., 2010) by linking the value of biodiversity with human well-being. The Economics of Ecosystem and Biodiversity (TEEB) (2010) outlines a three tiered process in linking biodiversity, ecosystem services and human wellbeing – by recognizing, demonstrating and capturing the value of biodiversity. Several studies have demonstrated the links between biodiversity and ecosystem function, which leads to provisional and regulating services (Naeem et al., 2009; Loreau et al., 2001; Duffy, 2009). But there are still gaps in the research such as the role that biodiversity plays in cultural ecosystem services (Harrison et al., 2014).

In this thesis I have applied a historical ecology approach to the issue of ecosystem service provision, documenting the extent to which the provision of services by coastal ecosystems may be affected by the shifting baseline syndrome. In doing so, I have attempted to identify how this historical context on ecosystem services might be incorporated in the management and conservation of marine ecosystems. Specifically I aimed to 1) identify shifting baselines in people's perception of changes in the ecosystem and provision of ecosystem services, 2) characterize drivers of change on marine ecosystem and service change through time to inform future management and environmental change scenarios in a system, 3) explore linkages between biodiversity and less studied ecosystem services e.g. cultural services so that it can be used in marine spatial planning, and 4) evaluate whether historical context adds value and informs the bundles of ecosystem services scenarios considered for future management. I utilized both social scientific methods and a modelling approach using path analysis to address these objectives.

In this final chapter, I discuss the findings and implications of each specific study and hypothesis in chapters 2-5. I then provide recommendations from the findings of this thesis and how they can be implemented in future research.

In this thesis, I used the Yorkshire coast of the North Sea as a case study as there are good records of biological, physical and social data related to ecosystem services here. Using such long term data sets, I was able to explore direct and indirect links between long term drivers of change, ecosystem properties, and ecosystem services (chapter 2). In addition I was able to characterize historic changes in ecosystem service provision using 3 case studies (chapter 3); to investigate the role of biodiversity in cultural ecosystem services (chapter 5); and to showcase how local ecological knowledge (LEK) can be used to understand long term changes and shifting baselines in a socio-ecological system (chapter 4). The overarching theme was to explore shifting baselines in ecosystem services in addition to changes in perception on the physical and biological components of an ecosystem.

6.2 Key findings synthesis

6.2.1 Use for long term data analysis

Historical ecology can provide important insight into past changes in an ecosystem, but clearly it benefits from the availability of long term data. The North Sea is one of the better studied marine ecosystems and has a good history of long term ecological surveys for certain species groups e.g. zooplankton monitored by the Continuous Plankton Recorder survey (www.sahfos.ac.uk), or UK government bottom trawl surveys of demersal fish (www.cefas.co.uk). But this is not the case for other species groups and even in the North Sea most surveys began only in the 1970s and were not standardized until the late 1980s. Hence it is really important to look at other ways of gathering such long term datasets. In my study on path modelling in chapter 2, I had to bring together different sources of effort data, digitize records of fishing effort in terms of number of hours in the North Sea by all sail, steam and motor trawls (beam and otter trawler >10m) from England & Wales for the period 1924-2010, and standardize effort into smack-units following Engelhard (2009). This is just one example of how one can go about putting together long term datasets and several studies have used different methods of extracting long term datasets (Thurstan et al., 2015, Mackenzie et al., 2011, Poulsen et al., 2007) which has yielded valuable information for current and future marine management.

Such composite long-term datasets enable testing of frameworks used to link up drivers of change, ecosystem and services, such as the adapted DIPSR framework presented in chapter 1, intended to highlight the study of socio-ecological systems. The data compiled in chapter 2 included components representing each element of such an adapted framework (table 2.1), to look at both direct and indirect ways that different pressures – climate change and anthropogenic drivers – can affect aspects of the ecosystem as well as services. Even though the results were limited due to gaps in data and issues of scale, they still demonstrate that imperfect long-term historical datasets can help to derive a better understanding of the links between drivers, ecosystem function and processes and ecosystem services. Using such historical datasets for regions like the North Sea that have good records of long term data of biological communities can aid in establishing baselines for restoration (Jackson and Hobbs, 2009) and can potentially identify indicators for achieving 'good environmental status' as outlined in the MSFD (EC, 2008). Analysing long term data can also help to disentangle the effects of drivers, which might have affected the ecosystem differently at different period in time (Marshall et al., 2015). This is one of the reasons why the study of marine historical ecology is gaining importance – the fact that in the era of climate change, there is the need to decipher which changes in the past are brought about by natural, and which ones by anthropogenic drivers. This is seen in study by Link et al (2009) which used multiple methods to identify the relative importance of fishing and environmental factors and how they differed across different types of ecosystems.

These unique long-term data sets provide an environmental baseline for predicting complex ecological responses to environmental change (Mckenzie et al., 2011). Documenting past changes using these datasets can be used to predict future changes in ecosystem services as seen in the Back-to-the-Future (BTF) initiative which is a science-based restoration ecology that uses past ecosystem states as potential policy goals for the future (Pitcher et al (2004). Finally, and most pertaining to this thesis, by using such long term data sets, we can add to the literature on shifting baselines which in the past has been shown for ecosystem (Cardinale et al., 2010, Lotze et al., 2010, McClenachan et al., 2012) and in this study we showed that it applies to services as well.

6.2.2 Role of biodiversity in cultural ecosystem services

I examined the role of biodiversity in cultural ecosystem service provision in chapter 5, where I used questionnaires – both online and face-to-face interviews – to ascertain how people valued the Yorkshire coast, what activities they enjoyed the most, and whether biodiversity is an important component of the benefits they received from the coastal environment. Results showed biodiversity serves more of a supporting role in the provision of cultural ecosystem services. People valued biodiversity as part of the wider seascape, but it also depended on the demographic characteristic of the site they visited. This has been demonstrated in other in other parts of England (Dalimer et al., 2012). In the wider policy context, this knowledge is useful for applying an Ecosystem Approach (EA) in management of coastal ecosystems. We know that there is strong emphasis in the EA on putting biodiversity and ecosystem services in social and economic context when making policy decisions (Haines-Young and Potschin, 2010). My results suggest that characteristics of different stakeholders and socio-economic demographics play a part on how people value biodiversity. This is seen in the study by Törn et al (2007) on how stakeholders felt about the development of tourism and the results showed that stakeholder's opinions were influenced by socioeconomic and demographic factors. At our study sites, there were differences between the cliffs and the seaside regarding how people valued different aspects of biodiversity – abundance, richness, and rarity. Furthermore the two activities that people valued the most in terms of CES from the coast were coastal walks and a relaxing day out by the beach. Seascape characteristics were of more importance than biodiversity. Based on my findings from this study, I would suggest that biodiversity be integrated into wider landscape characterization when carrying out marine spatial planning and implementing an ecosystem based management for the Yorkshire coast, as recommended by Ruiz-Frau et al. (2011). So rather than only estimating the value of specific activities related to biodiversity (e.g. birdwatching), we have to consider the value of biodiversity as part of the value of coastal footpaths. People placed high importance on coastal walks in our study but also appreciated biodiversity being part of the Yorkshire coastal seascape. This is similar to what is discussed in a study by Gray (2011) on the concept of geodiversity (the abiotic equivalent of biodiversity) and geosystem services, such as the environmental quality associated with local landscape character.

6.2.3 Capturing the knowledge and values of local stakeholders in the study of socio-ecological systems

Our interviews with different stakeholders (both in chapter 4 and 5) emphasized the need to utilize a more social approach in identifying future needs and ecosystem services that is desired by different stakeholders such as local people living in the area, tourists, local authorities, businesses etc. Doing so links people's preferences to the range of services that can be provided by the possible state of ecosystem under threats of climate change and other potential future scenario. Interdisciplinary research of this kind has been done in other parts of the world (Perry et al., 2011) and has yielded interesting results, such as the fact that both ecological and societal stresses combine to drive changes in marine social–ecological systems. The four case studies described in this study also show that social responses have short and longer time spans. The interviews I conducted in chapter four captured similar values and attitude of how different stakeholders adapt to socio-ecological changes. Such knowledge is important in understanding human-nature interactions and is a focal aspect in the study of socio-ecological systems (Rounsevel et al, 2010). This is seen in other studies utilizing such social scientific methods (Törn et al., 2013, Martın-Lopez et al., 2012, Le Fur et al., 2011) and has proven to be useful for gathering wide ranging knowledge of the coastal ecosystem.

6.2.4 Understanding substitutability and tradeoffs between ecosystem services across temporal scales

One of the challenges of the integration of ecosystem services in management and decision making is the issue of tradeoffs (De Groot et al., 2009, Nelson et al., 2009). In chapter 4 I examined shifting baselines in fishermen's perspective on long term changes in ecosystems and the results highlighted both how a socio-ecological system can change over time (from fishermen to shellfishermen) as well as trade-offs in services (fishermen to wildlife tour operators) due to both ecological and societal changes. In chapter 3 I used a more qualitative approach and presented three case studies that highlighted different ways that ES can change over long periods of time. I looked at lost services, change in services due to societal changes as well as changes in services due to ecosystem change. These case studies highlight that there are domains in ecosystem services with lots of substitutability of biodiversity within a domain (Bennet et al., 2009) and the fact that changes in an ecosystem service (e.g. from whitefish to shellfish) can be driven by changes in societal needs rather by than changes in the ecosystem itself. It also addresses how major shifts in societal perspectives can change the way biodiversity is valued, such as how the value of seabirds has changed from provisional (egg collection) to recreational (birdwatching). In this chapter I showed how linking historical data to services can reveal how ecosystems might change in composition without a noticeable effect on provision of services, due to changed social norms. Such linkage between ecosystem services and historical landscape is highlighted in study by Burgi et al. (2015) which shows that looking at changes in historic ecosystem reveals knowledge on the evolution and changes within ecosystem services and at possible tradeoffs as well.

6.4 Recommendations for future research

6.4.1 Scaling up collection of survey data from different stakeholders

In this thesis, I have carried out two small scale studies at a very local scale. The first one aimed to understand fishermen's perspectives on changes in socio-ecological systems, how they perceive these changes and have adapted to it. The second study considered how stakeholders value biodiversity and what benefits they get from cultural ecosystem services provided by coastal ecosystems. There is potential to gather a substantial amount of data if the scale of the study is increased to encompass a larger area as well as a larger and more diverse representative of stakeholders. Such a scaling-up could also help in understanding how ecosystem services are packaged into bundles, as well as trade-offs in provision for future ecosystem states. Carrying out such studies at this level of spatial resolution is useful for local planning and management, but for it to feed into wider policy frameworks there needs to be regional and national collaborations. The same methodology needs to be applied across sites and data collated to provide the evidence for different stakeholders perception of changes and preference for future ecosystem services. For instance, a study was done by Kenter et al (2013) which investigated the recreational use and non-use values of UK divers and sea anglers for 25 Scottish potential Marine Protected Areas (pMPAs), 119 English recommended Marine Conservation Zones (rMCZs) and 7 existing Welsh marine Special Areas of Conservation (SACs). The study used a combination of monetary and non-monetary valuation methods and an interactive mapping application to assess site visit numbers. Even though this study found that more research and engagement is needed with sea anglers and divers to make sure that value of nature to these groups is taken into consideration for marine planning (Kenter et al, 2013), studies at such scale provides better evidence of different stakeholders perception and views.

6.4.2 Continued monitoring of species and ecosystems

Documenting long term changes in a marine ecosystem, and understanding the drivers of change within an ecosystem and the provision of services, requires the use of long term datasets (Pinnegar and Englehard, 2007, Kittinger et al., 2015). One of the limitations of our model in chapter 2 was not being able to add more variables due to the lack of such long term data. The North Sea is one of the best studied marine ecosystems and this region has been the focus of numerous long-term and/or spatially extensive ecological surveys. However, as noted above, even in such a data rich region, the data collection has been long term only for certain groups of species, and even then it has been patchy. The study in chapter 2 also addressed the need for collaboration and integration for better fishing effort data from all the countries neighbouring the North Sea, as I was able to use only fishing effort from British vessels.

At the same time, other studies utilizing long term data have shown insight into past abundance and richness (Cardinale et al., 2011, Zu Ermgassen et al., 2012), and collaborations such as HMAP have improved understanding of ecosystem dynamics and the impact of human activities across several regions of the world (Kittinger et al., 2015). I would recommend prioritizing this in research and continuing to collect long term data on not only species and ecosystems, but link it up with past human activities as highlighted in Postlethwaite et al (2014) on major scientific discoveries made using long-term measurements of the ocean. I have shown in this study in chapter two and chapter three that we can use different sources of long term data to better understand past ecosystem states and how anecdotal data on social changes can also help to piece together the bigger picture on past socio-ecological systems. The case studies used in chapter 3 has given insight into how globalization (demand for shellfish from other countries) and socio-political changes (introduction of seabird protection bill) can also bring about changes in ecosystem services and it just shows that using long term historical data is useful for better understanding past socio-ecological changes. This adds to the knowledge base of marine social–ecological responses to environmental change and impacts of globalization. For instance, Perry et al. (2010) highlighted four such case studies which capture how fishermen cope, both in the short term and long term, when faced with changes such as globalization. This study showed that fishing communities cope with short-term change through intensification and diversification of fishing, migration and 'riding out the storm'. Over the longer term, they look at economic diversification, retraining and adapting to changes in policy and fisheries governance (Perry et al., 2010).

6.4.3 Better integration of social and natural sciences in the study of socio-ecological systems

It has been shown in previous research that methods such as local fisher knowledge (LFK) yield quantitative results that are comparable to scientific surveys (Coll et al., 2014, Silvano & Begossi, 2012). From my study, I can also recommend it being useful for collecting data on socio-ecological changes that have occurred as well over long periods of time. These include adaptation strategies, trade-offs between services, and shifting baselines in ecosystem service provision. I recommend better integration of social scientific methods in natural sciences for studying socio- ecological systems and specifically, the utilization of data collections methods such as LEK as they can broaden the scope of data collected. This is specifically relevant in regions that have poor data available on species and ecosystems in general. Study by Folke (2004) show that the use of LEK in marine and non-marine ecosystems contribute to understanding the effects of human-use impacts on long-term ecological composition, structure, and function. My findings are in agreement with other studies using LEK which have shown that fishermen's knowledge can be comparable to scientific survey data (Mcdonald et al., 2014). However, a review of collaborative engagement of LEK in marine ecosystems by Thornton and Scheer (2012) illustrates that there are still limitations in embracing a collaborative approach where LEK is used in natural sciences and communities are involved in different stages of research. Based on the findings from my study on using social sciences methods for data collection, I would recommend better collaborations between social and natural scientists to develop methodology that integrates more local knowledge in data collection and analysis.

6.5 Conclusion

There is a strong need for social and natural scientists to work together and this is increasingly being recognized across the globe such as in the principles of marine ecosystem based management (Long et al., 2015), and in policy drivers such as UK National Ecosystem Assessment (UK NEA, 2011)This is one of the main issues I wanted to address in my thesis and I did that by combining path modelling with long term datasets, collecting anecdotal stories and data collection through interviews with stakeholders. This thesis has demonstrated that historical marine ecology, employing a combination of social and natural sciences, can yield a better understanding of changes in socio-ecological systems. Doing so provides new insight into shifting baselines in ecosystem services, highlights long term adaptations in socio-ecological systems on a local scale and from this thesis, I have shown that fishermen have good recollection of catch but this only extends as far back as their personal experience. Recommendations are provided on how these findings can aid in marine conservation and policy, particularly in marine spatial planning in the Yorkshire region. The findings from interviews with local stakeholders can also contribute to the knowledge base on people's attitudes towards and valuation of the Yorkshire coast. It can be used to inform management of future marine ecosystem services in this region. Furthermore the methodology can be improved upon, standardized and spread across other coastal areas to capture past human-nature interactions and as a result, have a better understanding of tradeoffs and changing valuation of marine ecosystem services.

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APPENDIX I SUPPLEMENTARY DATA FOR DEFINING 'FISHING' AND 'CLIMATE' REGIMES IN CHAPTER 2

Fishing effort has changed considerably over the course of the 20th Century. In particular, there has been a general decline since the 1970s, largely as a result of increased regulation (e.g. via the EU Common Fisheries Policy). To identify when the increase in effort following the dip during the Second World War switched to the more recent decrease, we modelled $\log_{10}$(trawling effort) from 1946—2010 as a second-order polynomial function of year. The resulting model displays an excellent fit ($R^2 = 0.96$; fig S1A), with an inflexion point towards the end of 1971. This matches well results from a GAM of $\log_{10}$(trawling effort) over the whole time series modelled as a smoothed function of year, which has a local maximum in 1974 followed by a steady decline thereafter (85% deviance explained; fig S1A).

To assess differences in climate regime, we modelled the trend in SST using a GAM of SST as a smoothed function of year over the entire time series. The model has a reasonable fit (34% deviance explained; fig S1B) and indicates that SST was relatively stable from the 1920s to the 1970s, but has increased steadily in subsequent years. The fitted model has a local minimum in 1973. Furthermore, if we model this time series as a linear model with a single breakpoint, the optimal breakpoint position (lowest AIC, highest R^2) selected from all years between 1934 and 2000 occurs between 1971 and 1972 ($R^2 = 0.32$; fig S1B). Thus, SST shifts from relatively stable to steady increase at approximately the same time that fishing effort switches from stable and high to a steady decline.

Given this consistency in results between trawling effort and SST, we model our system as two regimes: a 'fishing' regime (1924—1971) characterised by high fishing effort followed by a 'climate' regime (1972—2010) in which increasing SST is more prevalent.

As a further check on the relevance of these two regimes, we modelled landings of each fish species as a function of trawling effort, regime, and their interaction. In each case (fig S2A-C), there was a significant interaction between regime and trawling effort, indicating that the relationship between fishing effort and fish landings is different in the two regimes. In equivalent analyses of the relationship between SST and landings for the three species, the SST x regime interaction was never significant, however in models excluding the interaction regime was always highly significant, again showing that the relationship between SST and landings differs between fishing and climate regimes (fig S2D-F). In particular, for a given trawling effort or SST, landings are typically lower in the climate regime than in the earlier fishing regime.

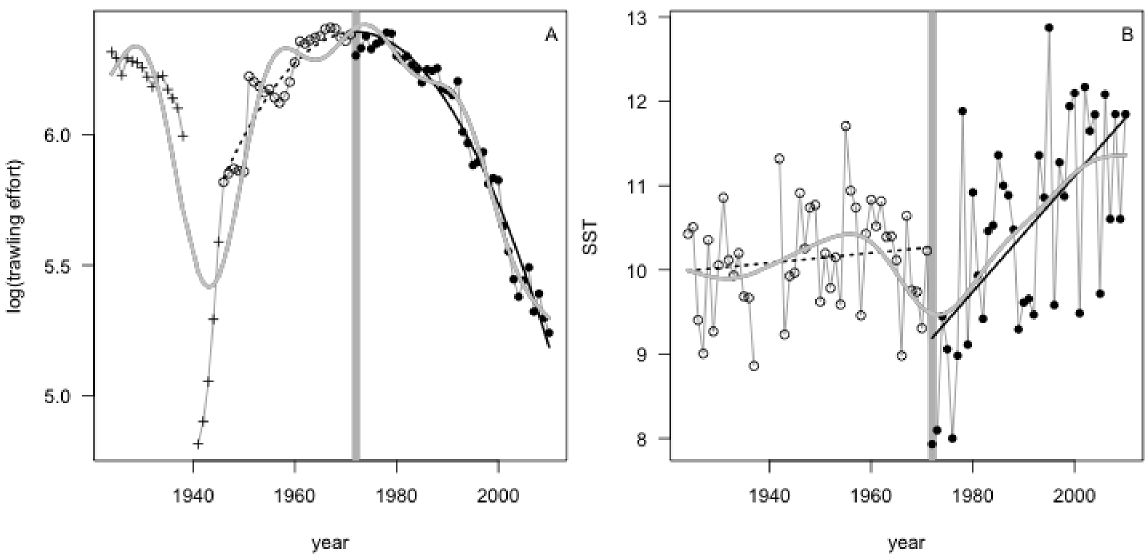

Figure S1. Time series of (A) trawling effort (log_{10}-transformed) and (B) SST. The proposed division between Fishing Regime (open symbols) and Climate Regime (filled symbols) in 1972 is shown as a vertical grey line. In (A) this is based on a quadratic function fitted to post-war trawl data, shown here as a dashed line pre-1972 and solid line post-1972. Earlier years not included in this model are shown as crosses. The light grey line shows the fit of a GAM to the entire time series, with a local maximum in 1974. In (B) we modelled the SST time series as a simple linear break point model; the optimum break point was at 1972, and the resulting fits are shown as dashed (pre-1972) and solid (post-1972) lines. As in (A), a GAM fitted to the entire time series is also shown as a light grey line, with a local minimum in 1973.

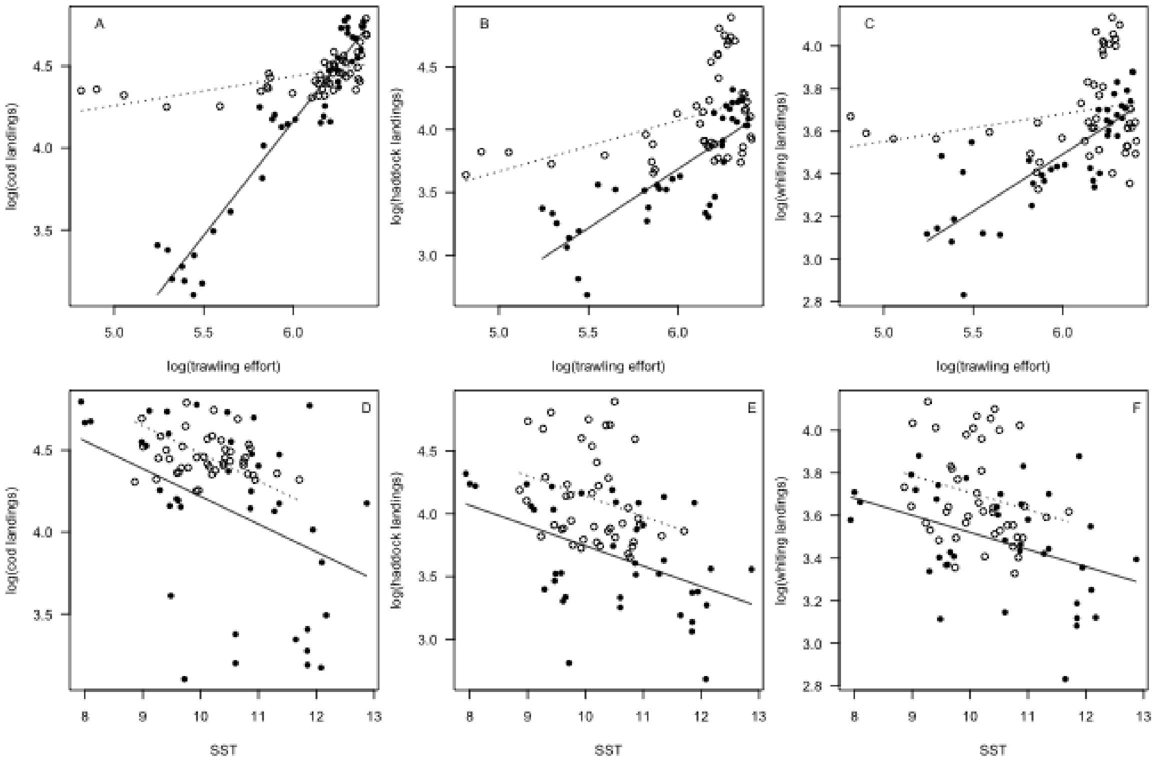

Figure S2. Relationships between landings of the three commercial species in our study and trawling effort (A-C) or SST (D-F), showing that the relationship differs between the Fishing Regime (1924-1971, open symbols and dashed lines) and Climate Regime (1972-2010, filled symbols and solid lines). The interaction between trawling effort and regime is highly significant for all three species (A-C; $P < 0.005$ in each case). There is no significant interaction between SST and regime for any species. However, in each case the decline in landings with SST is significant (D-F, $P < 0.005$), and importantly so is the main effect of regime ($P < 0.005$), showing that landings were higher in the Fishing Regime than in the Climate Regime, regardless of SST.

APPENDIX II QUESTIONNAIRE FOR CHAPTER 4 - GATHERING LOCAL ENVIRONMENTAL KNOWLEDGE

Knowledge and Perception on Changes in North Sea Fisheries

Name/ID:………………………… Age Range: 20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 ☐

Contact Information:..………………………………………………………………………

Profession:……………………………………………………………………………………

Location:………………………………………………………………………………………

Researcher:…………………………………………..Date:…………………………………………

When completing the question on fishing area in this section, reference should be made to the numbered boxes on the chart provided (On Separate Sheet)

Section A: Background Information

This section aims to understand a little of your background and history as a skipper. It also aims to understand your general and current fishing patterns, including the types of gear you use, and some information about your crew.

Brief background.

1. What year did you start fishing? ……………………………………………………….

2. Do members of your family fish for a living? (tick as many as appropriate)

[ ] YES, my sibling(s) [ ] YES, my parent(s)

[ ] YES, my grandparent(s) [ ] YES, my great grandparent(s)

[ ] YES, my child (ren) [ ] NO

Boat Type

What kind of boat do you skipper? (Tick the ones most appropriate box)

[ ] <10m [ ] >10m

[ ] Inshore [ ] Offshore

Gear types used

What is the main type of fishing gear you currently use on the boat you skipper? (Tick the one most appropriate box)

[ ] Beam trawl – Stonemat gear

[ ] Beam trawl – Open gear

[ ] Otter trawl

[ ] Twin otter trawl

[ ] Gill nets

[ ] Seine nets

[ ] Pots

[ ] Other, specify:

General fishing patterns

This question is about what fish do you target throughout the year.

For each month, please list the main species you target.

Please make sure you have all the months of the year covered. If a new target species is targeted half way through the month, please make a note of it. If you take time off during the year please indicate when that is.

Month	**Target species**
January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	

December	

Section B: Knowledge on changes in the main commercial fish and other species

This sections aims to understand your knowledge/ observation of changes in abundance, size and areas fished for 8 commercial fish and shellfish.

If not applicable to you, tick Not Applicable

1. **COD [ ] Not Applicable**

COD										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

How has the abundance of Cod over your time fishing?

[ ] Much Less [ ] Less [ ] More [ ] Much More [ ] No Change

……………………………………………………………………………………………………

Has the typical size of cod changed over the course of your time fishing?

Size Range was:

[ ] Bigger [ ] Smaller [ ] No Change

2. **HADDOCK [ ] Not Applicable**

HADDOCK										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

How has the abundance of Haddock changed over your time fishing?

[ ] Much Less [ ] Less [ ] More [ ] Much More [ ] No Change

……………………………………………………………………………………………………

Has the typical size of Haddock changed over the course of your time fishing?

Size Range was:

[ ] Bigger [ ] Smaller [ ] No Change

……

WHITING [ ] Not Applicable

WHITING……… ……………………… ……………………… ……………………… ……………………… ………HITING										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

How has the abundance of Whiting changed over your time fishing?

[ ] Much Less [ ] Less [ ] More [ ] Much More [ ] No Change

……

Has the typical size of Whiting changed over the course of your time fishing?

Size Range was:

[ ] Bigger [ ] Smaller [ ] No Change

……

3. LOBSTERS [ ] Not Applicable

How has the abundance of Lobsters changed over your time fishing?

[ ] Much Less [ ] Less [ ] More [ ] Much More [ ] No Change

……

Has the typical size of Lobsters changed over the course of your time fishing?

Size Range was:

[ ] Bigger [ ] Smaller [ ] No Change

……………………………………………………………………………………………………

4. CRABS [ ] Not Applicable

How has the abundance of Crabs changed over your time fishing?

[ ] Much Less [ ] Less [ ] More [ ] Much More [ ] No Change

……………………………………………………………………………………………………

Has the typical size of Crabs changed over the course of your time fishing?

Size Range was:

[ ] Bigger [ ] Smaller [ ] No Change

……………………………………………………………………………………………………

5. SOLE [ ] Not Applicable

SOLE										
Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

How has the abundance of Sole changed over your time fishing?

[ ] Much Less [ ] Less [ ] More [ ] Much More [ ] No Change

……………………………………………………………………………………………………

Has the typical size of Sole changed over the course of your time fishing?

Size Range was:

[ ] Bigger [ ] Smaller [ ] No Change

……………………………………………………………………………………………………

6. PLAICE [ ] Not Applicable

PLAICE										
Area of fishing (refer to map)	1		2		3		4		5	

	6a		6b		7		8		9	

How has the abundance of Plaice changed over your time fishing?

[ ] Much Less [ ] Less [ ] More [ ] Much More [ ] No Change

………

Has the typical size of Plaice changed over the course of your time fishing?

Size Range was:

[ ] Bigger [ ] Smaller [ ] No Change

7. OTHER SPECIES [ ] Not Applicable

Area of fishing (refer to map)	1		2		3		4		5	
	6a		6b		7		8		9	

How has the abundance of ……………. changed over your time fishing?

[ ] Much Less [ ] Less [ ] More [ ] Much More [ ] No Change

Has the typical size of …………………. changed over the course of your time fishing?

Size Range was:

[ ] Bigger [ ] Smaller [ ] No Change

Section C: Changes in other Species

Have you observed changes in abundance or size of the following species?

Gulls More ( ) Less ( ) I do not know ( )

Other sea birds	More ( )	Less ( )	I do not know ( )
Seals	More ( )	Less ( )	I do not know ( )
Other whales/ dolphins	More ( )	Less ( )	I do not know ( )
Sea Star	More ( )	Less ( )	I do not know ( )

Any other species……………………………………………………………………………………..

If Yes to any other species, how have they changed?

……

Section D: Knowledge and Opinions on sustainability of North Sea Fisheries

1. How would you describe the current condition of the fishery stocks of the North Sea?

Under fished ( ) Sustainably Fished ( ) Unsustainably Fished ( ) Depleted ( )

Additional Comments:

……

……

2. Are there any places in the North Sea that were once productive fishing grounds but are now depleted?

   If the answer was yes, list those places that were formerly productive. (Please locate the places in the attached map)

……

……

3. Do you know of any species that were once important in commercial or sport fisheries but are no longer or very rarely caught?

   Yes ( ) No ( ) I do not know ( )

If your answer was yes, list each species and the main cause you think was responsible for their disappearance.

……

……

4. Do you know of species that are now caught that did not used to be part of commercial fisheries?

Yes ( ) No ( ) I do not know ( )

If your answer was yes, list each species and the main cause you think is causing their numbers to increase

……………………………………………………………………………………………………….

……………………………………………………………………………………………………….

Optional Information on opinion of management (Data for future ES)

Management Opinions: What do you think should/needs to be done to manage North Sea fishery? **In terms of changes in quotas, policies, MPAs etc.**	

APPENDIX III QUESTIONNAIRE FOR CHAPTER 5 - ROLE OF BIODIVERSITY IN CULTURAL ECOSYSTEM SERVICES

Name/ID

Age Range: 20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 ☐ 60+ ☐

Where have you travelled from?

When did you first visit the Yorkshire Coast?

- Less than 5 years ☐ 5-10 years ☐
- 10-20 years 20-30 years ☐
- 30 years or longer

How frequently do you visit the Yorkshire Coast?

- Weekly ☐ Monthly ☐
- Once a month Once a year ☐
- Less

Have you been to the following places along the Yorkshire coast?

- Flamborough Head ☐
- Bridlington ☐
- Whitby ☐
- Scarborough ☐
- Filey ☐
- Robin Hoods Bay ☐
- Other places ☐

If ticked more than one, which one(s) have you visited most frequently?

……….

What do you like to do by the seaside along the Yorkshire Coast? Tick the following on a scale of 1 to 5 (Unimportant – Most important) of how important each is to you:

1 = Unimportant
2= Slightly important
3 = Important
4 = Very important
5 = Main reason for visiting seaside

• Rock pooling	1	2	3	4	5
• Sun bathing	1	2	3	4	5

• Building sand castles	1	2	3	4	5
• Bird Watching	1	2	3	4	5
• Wildlife Tours	1	2	3	4	5
• Water sports	1	2	3	4	5
• Angling	1	2	3	4	5
• Coastal Walks	1	2	3	4	5
• Visiting historic sites	1	2	3	4	5
• Natural history (general)	1	2	3	4	5
• Fossil hunting	1	2	3	4	5

Other Reasons for visiting:

- Cheap Accommodation ☐ Near my Home ☐
- Pier Activities(rides, shops, games) ☐ Others ☐

IF ticked Rockpooling –

Why do you like this activity? Tick one category of important this is to you

I enjoy that fact that I might find rare or new species that I haven't seen before

Not important to me 1 2 3 4 5 Very important to me

I enjoy finding an abundance of different species of crabs, anemones, sea stars

Not important to me 1 2 3 4 5 Very important to me

I enjoy finding Edible Crabs

Not important to me 1 2 3 4 5 Very important to me

- **I enjoy finding Brittle Stars**

Not important to me 1 2 3 4 5 Very important to me

- **I enjoy finding different species of worms**

Not important to me 1 2 3 4 5 Very important to me

- **I enjoy learning about local invertebrates**

Not important to me 1 2 3 4 5 Very important to me

Any other reasons? ………..

If ticked 'yes' to Bird Watching

Why do you like this activity? Tick one of the options

I enjoy seeing vulnerable or rare species

Not important to me 1 2 3 4 5 Very important to me

I enjoy seeing high abundance of all kinds of sea birds

Not important to me 1 2 3 4 5 Very important to me

I enjoy specifically being able to see Puffins in this area

Not important to me 1 2 3 4 5 Very important to me

I enjoy seeing Kittiwakes

Not important to me 1 2 3 4 5 Very important to me

I enjoy Gannets

Not important to me 1 2 3 4 5 Very important to me

I enjoy seeing Razorbills

Not important to me 1 2 3 4 5 Very important to me

I like learning about diversity of sea birds

Not important to me 1 2 3 4 5 Very important to me

I don't know about any particular sea birds but I enjoy seeing them

Not important to me 1 2 3 4 5 Very important to me

If ticked Yes to Wildlife Tours:

What do you like about this activity?

I will have opportunity to see seals

Not important to me 1 2 3 4 5 Very important to me

I will have opportunity to see dolphins and porpoises

Not important to me 1 2 3 4 5 Very important to me

I will have opportunity to see some wildlife

Not important to me 1 2 3 4 5 Very important to me

I will have opportunity to see whales

Not important to me 1 2 3 4 5 Very important to me

Perception of changes in species:

Do you think there have been changes in the abundance of Gulls in the span of time that you have visited this coast?

Increased	Decreased	No Change	Don't know

Do you think there have been changes in the abundance of Seals in the span of time that you have visited this coast?

Increased	Decreased	No Change	Don't know

Do you think there have been changes in the abundance of other sea birds in the span of time that you have visited this coast? Give Names

Increased	Decreased	No Change	Don't know

Do you think there have been changes in the abundance of lobsters and crabs in the span of time that you have visited this coast?

Increased	Decreased	No Change	Don't know

Would the following improve your seaside holiday along the Yorkshire Coast?

Guided bird watching tours	Yes	No	Makes no difference
Guided rock pooling activities	Yes	No	Makes no difference
Cheaper Accommodation Options	Yes	No	Makes no difference
Better public transport to destinations	Yes	No	Makes no difference
Cleaner Beaches	Yes	No	Makes no difference
More water sports	Yes	No	Makes no difference
More Wildlife Tours	Yes	No	Makes no difference
More information on all above activities	Yes	No	Makes no difference
Guided coastal walks	Yes	No	Makes no difference

Any others

General questions:

Are a member of the RSPB? **Yes** **No**

Are you a member of any other nature conservation organization or club? **Yes** **No**

Do you think the North Sea is overfished? **Yes** **No** **Not Sure**

Would you approve of Marine Protected Areas in the region? **Yes** **No** **Not Sure**

Do you think off shore Windfarms would be harmful to the birdlife in this area? **Yes** **No** **Not Sure**

Do you think off shore Windfarms would be harmful to marine mammals in this area? **Yes** **No** **Not Sure**

Do you think off shore Windfarms would be harmful to invertebrates in this area? **Yes** **No** **Not Sure**

Thank you for your participation!

APPENDIX IV ONLINE QUESTIONNAIRE FOR NORTH SEA SURVEY ADMINISTERED BY YORKSHIRE WILDLIFE TRUST

This survey is designed **to look at our attitudes towards, and interactions with, the marine environment.** Your participation in this survey is critical to help inform our future decisions and activities. http://www.ywt.org.uk/north-sea-survey-2014

Do you currently live in Yorkshire?: *

- Yes
- No

Please enter the nearest town or city to where you live: *

Please enter your postcode: *

Please use capital letters and put in a space between the first and last group of characters e.g. YO24 1GN

What is your gender?: *

- Male
- Female

Which age category do you fit into?: * - Select -

Do you have children?: *

- **Yes**
- **No**

If yes, how many are under 18?:

What is your occupation?: * Student

What is your highest level of education?: * - Select -

Please tick the relevant options with regards to the following statement: "I visit the sea/seaside in Yorkshire to...": *

- Work
- Relax
- Snorkel/ swim
- Surf
- Kayak

- [ ] Sail
- [ ] Scuba dive
- [ ] Walk my dog
- [ ] Collect wild food e.g. seaweed
- [ ] Collect bait
- [ ] Enjoy a family day out
- [ ] Fish (recreational)
- [ ] Bird watch
- [ ] Take photographs
- [ ] Other

How often do you visit the sea/seaside in Yorkshire?: *

- ○ Weekly
- ○ Monthly
- ○ A few times a year
- ○ Never

What would put you off visiting the seaside? Please tick the relevant options: *

- [ ] I don't know where is good to visit
- [ ] There are no facilities e.g. toilets
- [ ] Nothing, I enjoy going to the seaside and go regularly
- [ ] It's too far away
- [ ] I prefer to visit the seaside on holidays
- [ ] Weather - I don't want to get wet
- [ ] It's full of litter/pollution
- [ ] It's boring
- [ ] Unsure of public access rights
- [ ] I don't have time

Please tick the relevant options with regards to the following statements about our local sea, the North Sea: *

- [ ] It is something I know very little about
- [ ] It is full of biodiversity including many interesting marine creatures
- [ ] It is visited regularly by whales, dolphins and sharks
- [ ] It is almost completely unprotected
- [ ]

It is an important economic resource for our local community

- [ ] It is important for renewable energy
- [ ] It is something I would like to know more about
- [ ] It is cold and dirty

Which of the following do you think can be found in our local seas?: *

- [ ] Porpoise
- [ ] Dolphins
- [ ] Skates and rays
- [ ] Whales
- [ ] Seaweed
- [ ] Limpets
- [ ] Coral Seals
- [ ] Anemones
- [ ] Crabs
- [ ] Lobsters
- [ ] Sea urchins
- [ ] Mackerel
- [ ] Sponges
- [ ] Kelp
- [ ] Sharks
- [ ]

Do you feel that the ocean and its resources are important to your quality of life?: * [- Select -]

If yes, how do you think it contributes to your quality of life?: [- None -]

Do you eat seafood?: * [- Select -]

If yes, what do you eat?:

- [ ] Cod
- [ ] Haddock
- [ ] Mackerel
- [ ] Plaice
- [ ] Salmon
- [ ] Sea bass

- [ ] Crab
- [ ] Lobster
- [ ] Mussels
- [ ] Whelks
- [ ] Other

Do you buy your seafood locally?: - None -

Do you know if it has been locally caught?: - None -

Where do you think Europe's largest shellfish port is?: * - Select -

Which of the following would increase your willingness to pay slightly more for seafood?:*

- [ ] Caught locally
- [ ] Low environmental impact
- [ ] Full traceability
- [ ] Preserving fishing heritage
- [ ] Higher quality
- [ ] None of the above

Do you feel our local seas are facing pressure from human impacts?: * - Select -

Which of the following do you consider as damaging to our seas?: *

- [ ] Agricultural run-off
- [ ] Climate change
- [ ] Coastal development
- [ ] Fossil fuels
- [ ] Invasive species
- [ ] Litter
- [ ] Over fishing
- [ ] Pollution
- [ ] Population growth
- [ ] Recreational use
- [ ] Renewable energy

Do you understand what is meant by the term Marine Protected Areas (MPAs)?: * - Select -

Do you think Marine Protected Areas are places that: *

- [ ] Allow nature to recover and thrive
- [ ] Restrict human activity to varying degrees
- [ ] Safeguard important habitats and wildlife

Mark all that apply.

Do you think Yorkshire has Marine Protected Areas?: * [- Select -]

Do you think Marine Protected Areas have been proposed in Yorkshire?: * [- Select -]

How important are Marine Protected Areas to you?: [- None -]

Did you know there are two existing MPAs within Yorkshire called European Marine Sites?: * [- Select -]
The two sites are Flamborough Head and the Humber.

Did you know there is a proposal to designate a further six MPAs called Marine Conservation Zones?: * [- Select -]

How important is it to you to see your local marine wildlife protected?: * [- Select -]

Do you support the designation of these proposed Marine Conservation Zones?: * [- Select -]

Which of the following do you think is most important to protect?: * [- Select -]

Would you like to learn more about our seas?: * [- Select -]

How do you think people should learn more?: *

- [ ] Through our primary education system
- [ ] Through our secondary education system
- [ ] Through our tertiary education system
- [ ] Through organised activities such as coastal walks, snorkelling and rock pooling
- [ ] Through information boards at local sites
- [ ] Through better online information resources
- [ ] Through printed literature e.g. books, newspapers, magazines etc
- [ ] Through topical talks and lectures
- [ ] Through short courses
- [ ] Through joining groups and recreational clubs
- [ ] Other

If you would like to find out more please leave your email address: