The ecological and economic analysis of beach management strategies in Scotland

Caroline Griffin

Biological and Environmental Sciences

School of Natural Sciences

University of Stirling

A thesis submitted for the degree of Doctor of Philosophy

December 2016

General abstract

Coastlines are particularly susceptible to the necessary trade-offs which occur between different ecosystem services. Should the areas be managed for biodiversity or for people? Where sandy beaches are found there is usually a management decision to be made between managing for recreation or for biodiversity. Many popular tourist beaches (particularly those with a Beach Award) are often groomed with mechanical equipment to remove any stranded seaweed and associated litter which can get entangled in the wrack. This is likely to be having a negative impact on coastal biodiversity, with wide ranging implications for the entire habitat, including the intertidal zone, sand dunes and shorebirds. Beached wrack should be allowed to naturally decompose providing a habitat for numerous species of macro-invertebrates. These macro-invertebrate communities not only include many endemic species found exclusively along the strandline but they also provide a very rich source of food for shorebirds. The re-mineralised nutrients resulting from the decomposed macrophytes should then become available to provide a rich source of nutrients to dune, strandline and marine ecosystems populations of the strandline. In previous studies grooming has been shown to have a negative impact on the invertebrates of the strandline and this study reveals that tidal range has an effect on the impacts of grooming with a higher tidal range having a more negative impact on the invertebrates. A study to observe the impacts of grooming on both adult plant and seed bank communities of the sand dunes found that grooming is having a negative impact on these populations.

Grooming is predominantly driven by beach managers who aspire to gain Beach Awards in order to attract tourists to their beaches. Using non-market valuation in the form of a stated preference choice experiment and a travel cost model, it was observed that Beach Awards are not valued by beach goers but are instead influenced to visit a particular beach by good bathing water quality, high levels of biodiversity and low levels of litter. It was also shown that stranded seaweed on the beach does not deter visitors.

Future management suggestions include attempting to reduce the confusion arising from the presence of multiple beach awards by either removing them altogether or by making their criteria more clear and direct with consistency in their design and designation. Bathing water quality should be completely removed from the Beach Award system and real-time information in the form of electronic signage and a publicly available App should replace it.

Acknowledgements

I would like to thank my supervisors Andre Gilburn, Nils Bunnefeld and Nick Hanley for their amazing help, support and encouragement throughout this PhD. It has been a long journey with many steep learning curves and I wouldn't have managed it without any of you.

From the Economics Department I need to thank Danny Campbell for putting up with me and my endless questions and to Katherine Simpson who has not only been a brilliant help and mentor but also has become a great friend.

From the Biology and Environmental Science department I have to thank many people for their help over the course of this PhD. Tim Paine for great stats advice, Nigel Willby for sorting me out, Alan Law for being an excellent person to talk about stats with and for making me laugh, both Adam Hayward and Lilly Herridge for invaluable advice and feedback and finally to Cerian Tatchley for being my economics/ecology fusion buddy and being there for me throughout.

The work I carried out in Sweden was made possible thanks to Maren Wellenreuther of Lund University kindly providing funding. Thank you for giving me with this wonderful opportunity. A big thank you also to Hannah Rosenquist for all your help out on the beach and showing us the many joys of Sweden. Particularly the pastries. My work in Sweden would not have been possible without Nicola Day my friend and colleague who carried out much of the field work.

Special thanks goes to the staff from Estates and campus services based up at the Greenhouses for giving help and advice and especially to Eileen Iggo for watering my plants. Thanks also to Mario Vallejo-Marin for allowing me to use one of his polytunnnels.

I have spent a lot of time out on cold, rainy (sometimes sunny) Scottish beaches during the course of this PhD and I would like to thank Gillian Flint, Alan Law, Fiona Thompson, Cerian Tatchley and Ealasaid Hidson for all the time you gave up to get wet, cold, sunburnt or verbally abused.

My friends, office mates in 3B156 and other PhD pals have been such a brilliant support network throughout my PhD. I really think that I have made some fabulous (hopefully) lifelong friends during my time here at Stirling. Huge thanks to Lilly Herridge, Gillian Flint, Rebecca Barclay, Lucinda Kirkpatrick, Zarah Pattison, Adam Varley, Cerian Tatchley and Rachael Cooper-Bohanon. You have all made this journey so much easier and so much fun. A special thank you goes out to Matthew Gollock and Sarah Ledger for believing in me. Always.

To all my family, a big heartfelt thank you. To both my Mum and Dad (Liz and Tony) and my in-laws (Olwen and Harry) thanks for being so supportive and positive throughout.

To my Husband Ian for enduring a number of Scottish beach holidays which were actually just field trips and for all the dinners made and child entertaining hours and for your long term support and encouragement and for making me laugh throughout it all. Mainly though for making me realise that if you could do it then I definitely could!

And finally, thank you to my wonderful children Kate and Euan. You have helped me in so many ways; help out on the beach and teaching me about the power of yet, but most of all by being the perfect excuse to enjoy time out and have fun and hugs. I hope that in some small way, seeing me finish this PhD will show you that you can achieve your goals even if at times they seem impossible.

Contents

List of Figures

List of Tables

Chapter 1: General introduction

1.1 *Biodiversity loss: the role of natural and anthropogenic activities*

Biodiversity can be defined as all hereditarily based variation at all levels of organisation, from the genes within a single population or species, to the species composing all or part of a community and finally to the community themselves that compose the living parts of the multifarious ecosystems of the world (Wilson, 1997). Explained more simply it is the sum total of all biotic variation from the level of genes to the level of ecosystems (Purvis, 2000). The number of species currently estimated to be on the planet is 8.7 million (Mora, 2011) and it is thought that 86% of land species and 91% of marine species are yet to be discovered. Maintaining biodiversity is important as it provides us with valuable resources (i.e. fuel and food) and delivers vital ecosystem services (i.e. climate regulation, nutrient recycling and pollination) without which we could not survive.

Anthropogenic impacts are arguably the single biggest threat to global biodiversity. Human activities are disturbing the Earth's ecosystems, eliminating genes, species and biological traits at an alarming rate (Cardinale *et al.* 2012). Regardless of continued efforts from conservationists, biodiversity has continued to decline over the past 40 years. Indicators of the state of biodiversity including species' population trends, habitat range and condition and community composition have revealed significant declines whilst indicators of pressure on biodiversity (resource consumption, invasive alien species, nitrogen pollution, overexploitation and climate change impacts) have all shown increases (Butchart *et al*. 2010).

The coastal environment is under threat from multiple natural and anthropogenic pressures. Sandy beach environments occupy a narrow zone between the land and sea and are therefore exposed to pressures from both sides. The seaward side is under pressure from global climate change and the threat of sea level rise results in increased levels of beach and sand dune erosion, which in turn increases the risk of localised flooding. The landward side is under ever increasing pressure from population growth, demographic shifts and economic development which inevitably will lead to coastal development (both residential and tourist), increased recreational pursuits and more intense agricultural activity (Schlacher *et al.* 2008). Beach management strategies are often focused upon erosion prevention, flood protection and attracting tourists to try and bring money into the local area. This can often conflict with managing beaches to maintain or improve levels of biodiversity and managers tend to believe they have to choose one type of management over the other. The ideal scenario would be to apply a combined approach which would both manage the problems associated with beaches and provide recreational services whilst simultaneously helping to promote levels of biodiversity. These kind of "human-wildlife conflicts" have been identified as an important issue which require careful management strategies that can enable the integration of both the social and wildlife aspects (Redpath *et al.* 2013).

This thesis looks at how beaches can be managed more effectively for both the environment and for beach users. Mechanical beach grooming is just one type of anthropogenic pressure affecting the coastal environment. The reasons behind beach managers' decisions to groom their beaches and what impact this is having on biodiversity are examined and possible solutions are identified.

1.2 *The role of Beach Awards*

Many popular tourist beaches in the UK and Europe work to try and attain Blue Flag Status. This is a worldwide initiative aimed at raising environmental awareness and increasing good environmental practice amongst tourists, local communities and beach marina operators. Blue Flag beaches must adhere to 26 specific criteria including bathing water quality, environmental education and information and environmental management. The initiative was introduced in 1987and is recognised in 41 countries around the world. It is administered in Scotland by Keep Scotland Beautiful on behalf of the Foundation for Environmental Education.

The Seaside Award was introduced in 1992 by the Tidy Britain Group, an independent but partly government funded organisation (Nelson *et al.* 2000). This award scheme runs only in Scotland, Wales and Northern Ireland and allows for the very different character of Scottish beaches as it is divided into both resort and rural categories. The main difference is that resort beaches are encouraged to offer facilities such as toilets and cafés etc. The rural award means that many beaches which would not qualify for Blue Flag status are eligible for an award.

In 2012 seven beaches in Scotland achieved Blue Flag status. The majority of these beaches are located in Fife (Aberdour Silver Sands, Burntisland, Elie Harbour, Elie Ruby Bay and Pettycur) with one being in Dundee (Broughty Ferry) and one down in Berwickshire (Coldingham). A further 31 beaches were awarded Seaside Award Status (See Figure 1).

Figure 1: Award beaches in 2012 in Scotland. Blue symbols denote Blue Flag beaches and yellow symbols denote Seaside Award beaches.

Both the Blue Flag and the Seaside Award winners are under pressure to keep their beaches clean. This often means that beach managers take the decision to clear stranded seaweed (or wrack) from the beach using mechanical equipment. However, in the guidelines (criterion 15) it is clearly stated that seaweed or other vegetation/natural detritus should only be removed if it becomes a hazard, and that if it is removed consideration should be given to environmentally friendly forms of disposal (e.g. composting or for use as a fertilizer). Many of the councils in Scotland currently clear the tourist award beaches on a regular basis, weekly or even sometimes daily (Scottish local councils representatives 2011-personal communication). This is obviously not recommended by the guidelines and is likely to be having a detrimental effect on the beach ecosystem, including the invertebrate populations, birds and sand dune formation and stability (Gilburn, 2012; Dugan, 2010).

The pressure on beach managers may however be misinterpreted, however, as recent work looking at the value of beach awards to the public shows much confusion and lack of understanding with respect to beach award schemes (Nelson *et al.* 2000). The study produced results suggesting that the public give priority to scenery and landscape quality, followed by beach safety, water quality and then absence of sewage related debris and litter. Most beach managers imply that a Blue Flag or Seaside Award greatly increases tourism revenue, however Nelsons study suggests that the value of beach awards to the public is questionable

The economic aspects of beach management need to be taken into consideration when assessing the value of beach awards. A report for Fife Council carried out by SQW (an independent provider of research and analysis in economic and social development) in 2001 estimated that in 2000, 250,000 visits were made to 30 beaches in Fife, which resulted in £2.33M being spent. This information is supported by Keep Scotland Beautiful in an unpublished in-house report (Helen Darvill 2011, Keep Scotland Beautiful Economic Facts. Personal communication). The report suggests that beaches are a major pull for tourists visiting Fife and that beach awards are an important reason for their attraction to the area. Fife council spent £110K on their 14 Blue Flag and Seaside Award beaches in 2000. This means that approximately £8K was spent per beach. According to SQW £20 is returned to the local economy for every £1 that is spent and at award beaches this spend per visit is increased. SQW state that in 2004 the average per person spend per visit increased from £2.80 at a non-award beach to £3 at a Seaside Award beach, to £7.80 at a Blue Flag beach (Roberts, 2005). However, it could be argued that the beaches which tend to apply for and win Blue Flags are beaches which have good and extensive facilities already available. This therefore means more places to spend money such as shops, cafés and water sports centres, and so people would arguably spend more money there regardless of whether they have a Blue Flag or not.

McKenna, (2011) suggests that it is not surprising that in Britain beach awards have little sway over the choices beach visitors make. Due to the lack of warm sunny days, many trips to the beach are spontaneous day trips which are not planned in advance. The main reasons for visiting a beach are likely to be proximity and personal attraction to the area rather than the fact that the beach has an award (McKenna, 2011). As previously stated, Scotland as a whole has very few Blue Flag beaches and the few that it does have are mainly located in Fife. Of the further 31 Seaside Awards the majority of these fall into the 'rural' rather than the 'resort' category. McKenna suggests that these figures reflect the feelings of beach managers about the significance of such resort-type awards in a country where there are very few resort-type beaches and that arguably the best of Scotland's beaches are the more remote rural type beaches anyway. Seaside Awards, although less strict with their guidelines, are still an incentive for councils to groom their beaches mechanically. Aberdeenshire council is a prime example of this. They have a large number of Seaside Awards beaches stretching along their coastline and their beach management strategy up until 2012 involved driving a tractor with grooming equipment attached (plate 1: section 1.4) around the entire coastline and then dropping the grooming equipment when they reach an award beach. So even though these awards appear to be of little attraction to the visitors and the beaches are thought of as rural, the council were still incentivised to ‘clean’ the beaches mechanically.

A study carried out in Scotland by TNS Travel and Tourism, (2004) found that in Scotland, out of 807 respondents, 75% ranked a clean beach and 54% ranked clean water as the dominant criteria in their beach selection. The possession of an award was selected by only 9% of respondents. A further study by Tudor and Williams, (2005) found that clean litter-free sand and clean water were the factors consistently ranked as the highest priority when choosing a beach and that refreshment facilities, distance to travel and beach awards scored much lower down in the ranking. The same study found that awareness levels of beach award schemes were very poor. Approximately 58% of respondents were aware of award schemes with 27% able to name the Blue Flag scheme. Forty percent of beach users were unaware of awards schemes and very few had heard of awards other than the Blue Flag scheme. The researchers found that the majority of beach users weren’t even sure if the beach they were on actually had an award. Other studies have had similar results (Nelson *et al*. 2002). This study points to the fact that for the majority of beach users, the main priority is not whether the beach has an award, but whether the beach is clean. The definition of “clean” however is not discussed further in these studies and so it would be interesting to find out how beach grooming fits in to the public’s perception of “clean” beaches.

The Green Coast Award is a new award designed by the Green Sea Partnership which runs only in Ireland and Wales. It has been established to acknowledge, promote and protect the environment of rural beaches. The award is for beaches which have excellent water quality, but which are also prized for their natural unspoilt environment (McKenna *et al*. 2011). This means that the exceptional appeal of the beach may not naturally sit well with the high levels of infrastructure and intensive management, which are normally associated with traditional seaside resort beaches. This award seems to be a step in the right direction for beach management and is possibly the system that beach managers in Scotland should aspire to. However, it is argued by Nelson *et al*. (2002) that yet another beach award flag will do little but further confuse consumers.

McKenna, (2011) found that beach managers in Ireland and the UK were uncertain about the value of beach awards. They were unsure of how successful awards are in attracting tourists and simply saw them as useful management tools and a good way to compete for much-needed resources. Similarly Nelson *et al*. (2002) found that regardless of whether the Green Coast Award attracts visitors, the management measures introduced by the GCA had increased environmental quality on all the beaches used in their study. McKenna, (2011) suggests that award schemes should switch their focus from the current emphasis on their own criteria to carry out basic research into the preferences and priorities of the revenue generating component, i.e. the beach users. Another proposition is to try and simplify the variety of beach awards on offer as currently the public seem to be confused by them.

1.3 *Problems of marine and coastal litter*

Marine and coastal litter is currently a huge problem globally. A report by the Marine Conservation Society (2015) found that in the UK there are nearly 2,500 items of rubbish for every kilometre on a beach and that plastic litter on beaches has increased 140% since 1994. Not only does this look unsightly and deters tourists, it is hazardous to human health and is a danger to wildlife which may get entangled in it or ingest it. The Marine Conservation Society (MCS) and Surfers Against Sewage (SAS) do a very impressive job of removing some of this litter with the help of local volunteers. However, the sheer scale of the problem means that volunteers cannot keep on top of the constant tide of rubbish washing ashore on the beaches and so beach managers have to try to control litter levels. The quickest way of getting their beaches litter free is to mechanically groom them (see section 1.4).

There is an obvious need for beaches to be cleaned of litter but it is imperative that beach managers are able to distinguish between natural beach litter and cultural litter. They should take the former into consideration when managing the latter (Nordstrom, 2000). The removal of litter usually results in the removal of anything else associated with it, which often means stranded seaweed or wrack and often some of the sand. It is important to understand the impacts of removing this seaweed and the implications this has for the entire coastal ecosystem.

1.4 *Mechanical beach grooming*

Mechanical beach clearing or “grooming” as it is more commonly known occurs all over the world, specifically on beaches that are associated with tourists. The practice of clearing stranded wrack from Scotland’s beaches has become increasingly common in recent years. Popular tourist beaches (particularly those with beach awards) are often groomed with mechanical equipment (Plate 1) to remove any stranded macro-algae and associated marine litter which can get entangled in the wrack. Beach grooming is likely to be having a negative impact on coastal biodiversity, with wide-ranging implications for the entire habitat, including the intertidal zone, shorebirds and sand dunes. (Llewellyn and Shackley, 1996; Gilburn, 2012; Dugan, 2010). This thesis aims to measure the impacts grooming has on the ecology of the beach habitat including both the strandline and dune habitats and this opening chapter explains why stranded wrack is so important for these habitats.

The grooming of beaches has been shown to be driven by beach awards and the belief by beach managers that gaining a beach award will attract more tourists to the local area, therefore increasing local revenue (Gilburn, 2012). The beach award guidelines however, urge beach managers to avoid mechanical grooming if alternative litter removal methods are available.

Plate 1. Mechanical Grooming equipment on Long Niddry beach, East Lothian

The Blue Flag guidelines (FEE, 2012) actively discourage seaweed removal and states that algae and other vegetation should be left to decay on the beach unless it constitutes a nuisance. The guidelines also state that sites should be managed in order to prevent long-term irreversible damage to the natural environment and be sensitive to biodiversity.

Suspension of beach cleaning operations or substitution of mechanical for manual cleaning have been suggested as environmentally viable options that allow vegetation to decompose and native plant communities and dunes to become established. Several possible compromises that have been suggested include restricting cleaning operations to summer months or to lower portions of the beach profile. The uppermost wrack line could be left intact, with its seeds and nutrients (Nordstrom, 2000). Alternative solutions will be explored over the course of this thesis, with suggestions of other options for beach managers and any mitigating techniques are discussed.

1.5 *The Importance of stranded wrack in the coastal environment*

The strandline is important to the beach ecosystem for 4 major reasons:

a. It provides food and shelter for a large number of invertebrates.
b. These invertebrates provide food for birds and mammals.
c. The wrack acts as a precursor, stabiliser and fertiliser of sand dunes.
d. It plays a significant role in biogeochemical processes by providing nutrient re-mineralisation and recycling.

a. Invertebrates

The strandline (the line of washed up seaweed and other debris at the high tide line) provides food and shelter for a great abundance and diversity of invertebrates which, in turn, go on to provide food for birds and mammals from both marine and terrestrial ecosystems. Invertebrates use stranded macrophyhte input as both refuge and food supply. Due to the strandline's ephemeral nature, it provides a unique habitat which is both diverse and dynamic. Its inhabitants must adopt spatial and temporal strategies in order to exploit this important resource (Colombini, 2000). The habitat is neither exclusively marine nor terrestrial and is colonised by invertebrates from both ecosystems (Gheskiere, 2006). The spatial and temporal variability in the supply of macrophytes leads to a responding variability in population abundance and zonation of macroinfaunal detritus feeders inhabiting the upper shore (Jaramillo, 2006). Stenton-Dozey and Griffiths (1983) found not only abundance and biomass of the macroinfauna were concentrated around the strandline of algal wrack deposits, but also species richness was higher. Dugan *et al.* (2003) have provided evidence that inputs of algal wrack deposits play a significant role in macroinfaunal community structure by increasing species richness and population abundance.

Trends in composition of fauna will vary between beaches and between different localities and also within the same beach both seasonally and daily with the changing tidal cycle. The age of the wrack is also of importance, with certain species preferring older wrack and others only being found in freshly washed-up wrack. A study carried out in Malta by Deidun *et al.* (2009) found that the macrofaunal assemblages associated with older wrack beds which had been allowed to accumulate on non-groomed beaches were distinct from the younger wrack beds on groomed beaches. The older wrack beds had higher individual abundance values for isopods, coleopteran larvae and the polychaete *Ophelia bicornis*, and some taxa such as staphylinid beetles and dipteran larvae were only found on the aged wrack.

Patch size has an effect on species abundance and richness. Small patches have fewer species and individuals than medium and large patches (Olabarria *et al.* 2007). The types of seaweed present within the stranded wrack may also be a determining factor for the abundance and diversity of invertebrate fauna found within it. It is therefore difficult to report on the abundance and richness of different types of invertebrates in wrack beds as such variability exists. However there are general trends which have been reported in the literature.

Inglis, (1988) carried out a study in New Zealand analysing the colonisation of stranded wrack and he found that the wrack was colonised in two phases. First, the macrofauna including Talitrid amphipods, adult Diptera and Coleoptera colonised the kelp with highest numbers recorded by day three. After this the macrofauna numbers declined and the meiofauna, consisiting of nematodes, enchytraeids and Dipteran larvae and mites become increasingly abundant. Jederzejczak, (2002) found similar results during a study looking at successional changes and colonisation of wrack. Macrofauna including Talitrid amphipods, adult Diptera and Coleoptera colonised the wrack within a day, maximum numbers being recorded after 3 days. Subsequently, macrofauna numbers declined and meiofauna, consisting of nematodes, oligochaetes, turbellarians and Dipteran larvae became increasingly abundant.

Colombini, (2000) carried out a study of the temporal and spatial use of stranded wrack by macrofauna and found that predatory taxa such as Staphylinoidea and Talitrid amphipods were most abundant whereas Diptera larvae and Tenebrionidae (Darkling beetle) were scarce. Successional changes throughout a semi-lunar period were shown, with molluscs invading wrack during the first days of deposition and histerids (Hister beetles) during the last.

b. Birds and Mammals

Birds

Birds in the UK have seasonal appearances on the beach. Birds are either resident, stop on passage or overwinter. Many birds can be dependent on the shoreline for feeding and many use the strandline as a source of food, (e.g. oystercatchers (*Haematopus ostralegus*), skylarks (*Alauda arvensis*), eider ducks *Somateria mollissima* and ringed plover (*Charadrius hiaticulas*)). There are reports of Ringed Plover breeding on beaches and Starlings actually nesting within the wrack beds (L. Humphreys, British Trust for Ornithology Personnel communication, June 2012). The removal of wrack by mechanical grooming has obvious implications for birds which use it as a food source, although of more concern is the effect on birds which use the beach and wrack for breeding and nesting. Very little literature is available on associations between birds and stranded wrack, particularly in the UK. Dugan, (2003) carried out studies in California and found positive correlations between the mean abundance of two species of plover and both the standing crop of macrophyte wrack and the abundance of wrack associated macrofauna and taxa. Tarr and Tarr, (1987) found higher densities of shorebirds occurred in areas with higher densities of stranded kelp on the west coast of South Africa. Bradley and Bradley, (1993) showed increased numbers of wintering shorebirds following the recovery of kelp beds in southern California.

A knock-on effect for many birds is the damage caused to sand dunes by beach grooming. Some birds, such as Ringed Plover, use the dunes to nest in and therefore if the dunes disappear then so too do their breeding habitats. Shore nesting birds which use the dunes as habitat include terns *Sternidae* and shelduck *Tadorna tadorna*. In the summer skylarks *Alauda arvensis*, meadow pipits *Anthus pratensis*, linnets *Carduelis cannabina* and stonechats *Saxicola torquata* are abundant. Birds of prey (including short- eared owl *Asio flammeus* and merlin *Falco columbarius*) hunt the dunes and slacks whilst passage birds- including fieldfares *Turdis pilaris* and redwings *Turdis illiacus*- winter among sea buckthorn *Hippophae rhamnoides* where they feed on berries. On fixed dunes and dune heaths and grasslands, species such as skylark and meadow pipit *Anthus pratensis* are typical, (Lack, 2010).

Mammals

Small mammals that use the shoreline include several species of vole (bank *Myodes glareolus* and common *Microtus arvalis*) mice *Mus* spp. and rabbits *Oryctolagus cuniculus* who's grazing is important in maintaining the varied vegetation structure and consequently the diverse range of habitats for plants and other animals. Small mammals and shore nesting birds attract predators such as foxes *Vulpes vulpes*, weasels *Mustela nevalis* and stoats *Mustela ermine*. Roe deer *Capreolus capreolus* have also been seen, as have brown hares *Lepus europaeus* (Llewellynn & Shackley 1996).

c. Sand dunes and dune plants

Coastal sand dunes develop where there is an adequate supply of sand (sediment within the size range 0.2 to 2.0mm) in the intertidal zone and where onshore winds are prevalent. The strandline can act as a precursor, stabiliser and fertiliser of sand dunes. The drift macrophytes enhance organic content and thus allow pioneer plants such as sea sandwort *Honkenya peploides,* sea rocket

Cakile maritime and saltwort, *Salsola kali,* to establish. The plants are then able to trap sand, which enables the formation of embryo dunes (Chapman, 1976).

Sand dune vegetation forms in zones which develop in relation to the time elapsed since the sand was deposited, the degree of stability and the local hydrological conditions. To begin with embryo dunes develop on the seaward side of the dune with formation starting in the strandline. Pioneer plants establish here, fertilised by the strandline seaweed and organic detritus. Embryo dunes lead into semi-fixed dunes which have a surface which is still largely bare sand but the cover of plant species gradually increases. As the pioneer plants die and decay, they go on to provide good, fertile growing conditions and the soil starts to become less alkaline as pioneer plants grow and trap rainwater. As more plants colonise the dunes, the dunes change colour from yellow to grey. Fixed dune grassland is formed as some soil development begins. Calcareous fixed dunes support a diverse range of plant species. On dunes which have been acidified by leaching, acid dune grassland or dune heaths develop. Dune slack vegetation occurs in wet depressions between dune ridges. Fixed dunes and dune heath are particularly threatened habitats and are regarded as priorities under the EC Habitats Directive (Doody, 1997).

Seeds of dune plants are usually distributed by the tides and they therefore have a unique association with the strandline. When the seeds have been dispersed and germination has taken place, the seedlings are guaranteed a convenient supply of nutrients in the form of decaying organic matter from the seaweed and carrion that is present in the strandline. The drift macrophyte not only provides a variety of nutrients, including nitrates, but it also helps with water retention of the roots of the plants.

If dune plants are found which appear not to be associated with the stranded wrack, it is generally the case that by digging around the plants they can be seen to be rooted in macrophyte wrack that has been buried by the sand (Salisbury, 1952). Seeds which are dispersed onto the upper beach face an onslaught of environmental pressures. Wind, erosion, burial, overheating, desiccation sea spray, nutrient availability, flooding by seawater and human activity are all hazards facing the seedlings. Establishing plants are therefore highly dependent upon stranded macroalgae for shelter, anchorage and nutrition. (Crawford, 2008; Maun, 1993). Very little research has been conducted to assess the impacts of mechanical beach clearing on sand dunes in the UK and it is therefore important that further work is carried out in this field.

Sand dunes are constantly under stress from the double pressures of erosion and accretion. Combined with this are the complications of climate change and effects of coastal developments and mechanical beach grooming (Dugan *et al.* 2010) Beach grooming may eliminate the minor obstacles which would initially catch and trap the sand, or destroy the embryo dunes at an early stage in their formation (Llewellyn & Shackley, 1996). Mechanical grooming eliminates developing dunes, habitat for nesting birds, seed sources for pioneer dune colonizers and food for fauna, and artificially small, stabilised fore dunes reduce the variability in microenvironments necessary for biodiversity (Nordstrom *et al*. 2000) The dunes also play an important role in coastal defence and this is a progressively important issue as rising sea levels become an ever-increasing concern.

Dune plants

Sand dunes in Scotland have strandlines which are colonised mainly by nitrophilous annual species and the perennial species marram grass *Ammophila arenaria*, lyme grass *Leymus arenarius and* sand couch *Elytrigia juncea*. Examples of annuals that can be found include sea rocket *Cakile maritime*, sea sandwort *Honckenya peploides* and oraches *Atriplex sp.*

Strandlines do not usually have a great variety of species present and this is due to the harshness of the environment, namely high and quite variable seasonal levels of salinity, a dynamic and mobile habitat, erosion and accretion and a limited supply of nutrients (Lee & Ignaciuk, 1985). Within sand dunes the supply of nutrients is low apart from in the area directly associated with the strandline. This is thought to restrict the growth of strandline plants and may also prevent or reduce seed production. It is thought that the addition of any type of fertiliser which results in a growth response will cause a change in species composition. Faster-growing species are encouraged at the expense of slow-growing ones. We would therefore expect different and possibly reduced species diversity where the strandline has been removed. It is important for strandline adapted annual species to time their germination so that it corresponds to decomposition of drift macrophytes. Late May is when bio-available nitrogen reaches its highest levels and this has been shown to correlate with annuals reaching their highest growth rate (Lee & Ignaciuk, 1985). Perennial species may also exploit any drift algae that is stranded during the autumn and which therefore decays slowly over the winter and acts like a slow-release fertiliser (Lee *et al.* 1983). Lee *et al*. (1982) reported that the growth of saltwort *Salsola kali* is dependent on the position of establishment within the strandline. Plants which are located directly on the strandline establish better and exhibit the greatest increase in biomass compared to those further away. The limiting factors are thought to be nitrogen and phosphorus concentrations in the substrate.

The strandline plants are not restricted to the narrow strandline area and often are found growing in the foredunes and further back into the dune system. However, plants on the foredune are quite often seen to be stunted, chloritic and set little seed (Keddy, 1982). It is thought that these plants are only able to grow there because of the landward dispersal of seed from the strandline plants (Keddy, 1982). Plants growing in sand dunes can have a salt stimulation of growth at certain salinities. In some dune plants, such as *S. kali* this stimulation is nitrogen-dependent. Plants which have a better supply of nitrogen will show a greater stimulation of growth than plants which are deficient in nitrogen (Pakeman & Lee, 1991). The plants are not dependent upon salt being present at certain levels but it may be a useful property which could allow strandline plants to maximise growth rates (Lee & Ignaciuk, 1985). Pakeman & Lee, (1991) carried out experiments adding fertilizer to plots on the strandline and foredunes where *Salsola kali* and *Cakiole maritima* were growing. His results showed that addition of nitrogen produced plants with greatly increased biomass and suggested the performance of these plants was dependent upon their ability to access the mineralized reserves of nitrogen from stranded macroalgal wrack.

Similar results were found by Pemedasa and Lovell, (1974) who carried out both field and glasshouse experiments on a number of dune annual plants and found that under both conditions, addition of a complete nutrient solution to dune sand improved the growth of all species considerably. Nitrogen and phosphorus in the substrate were found to be the limiting factors. The importance of potassium has also been noted by Willis, (1965) during his experiments on *Ammophila arenaria*, He found that the plants needed substantial levels of nitrogen, phosphorus and potassium for good growth. Potassium is known to stimulate phosphate uptake and therefore absorption of phosphate is limited by the presence or absence of potassium (Mattson, 1949).

The importance of stranded macrophytes for the dune system is not only down to the nutrients that it supplies but also to the ability for the strandline to trap sand and debris along the beach, including the seeds and fruits of dune plant species. Keddy, (1982) found in an experiment with eelgrass, that comparison of quadrats with and without patches of dead eelgrass revealed that quadrats with eelgrass present yielded the overwhelming majority of fruits.

d. Nutrient Flow

The seaweeds within the strandline provide food and refuge for a huge diversity of organisms through its nutrient cycling and decomposition, including bacteria, yeasts and fungi in the microflora, nematodes, invertebrate larvae and mites in the meiofauna and numerous species of macrofaunal invertebrates of marine and terrestrial origin (Zemke-White *et al.* 2005).

In highly dynamic ecosystems such as sandy beach environments, part of the carbon produced by primary producers may not be utilised locally, but is transferred to an entirely different ecosystem where it is exploited within the food webs there. (Colombini, 2008). Exposed sandy beaches are characteristically lacking in primary producers and are therefore reliant upon allocthonous material as a food source for the beach’s supralittoral fauna which is generally concentrated in the high eulittoral (Griffiths *et al.* 1983; Inglis,1989).

Macrophyte drift or wrack is a major source of carbon and organic material for the intertidal zone of exposed sandy beaches in many parts of the world (Dugan, 2010) The majority of beaches receive some drift material but in certain places such as sandy beaches which are next to rocky shores, the input can be extremely high (Brown & McLachlan 1990). Results of a study on Californian beaches by Dugan (2010) provide evidence that in regions with high marine macrophyte production the community structure of sandy beach macrofauna is closely linked with the input and fate of macrophyte wrack. Changes in the availability and input of either phytoplankton or macrophyte wrack could shift infaunal community structure and alter energy flow to consumers and prey availability to higher trophic levels (Dugan *et al.* 2003).

Most of the seaweed that is washed up on the beach begins to form detritus which is immediately accessible food for many animals and its nutritional value may also be improved as microbes begin to colonise (Mann, 1986). The strandline becomes colonised by bacteria, which leads to the production of dissolved organic matter (DOM) and particulate organic matter (POM). It is possible that both DOM and POM provide an important continuous non-seasonal source of food for coastal fauna, which is especially important when fresh food is less plentiful (Mann, 1986). Removal of the wrack is therefore likely to affect the overall balance of the ecosystem.

Griffiths and Stenton-Dozey, (1981) suggest that between 60% and 80% of beach-cast kelp is consumed, primarily by amphipods and dipteran larvae, within 14 days of deposition. They propose that the remainder dries out and may remain stable for considerable periods before eventually decomposing or being eaten by infaunal species. It is also suggested that the organic matter produced from decomposing wrack beds is utilised by filter and detritus feeding organisms in the intertidal zone as backwash enters this zone of the beach. Koop *et al.* (1982a) provide evidence for the role of bacteria in the biodegradation of wrack beds. They calculated that 23-27% of carbon in kelp is converted to bacterial carbon. The remaining 73-77% is instead mineralised by the sand beach microbes within 8 days. Koop *et al*. (1982b) however, suggested that although as much as 95% of the nitrogen cast up onto the strandline may ultimately be returned to the sea this meets only a small proportion of the nitrogen requirements of the primary producers in the adjacent nearshore system. Ince *et al.* (2006) found that the presence of marine derived wrack on beaches in south-western Australia influence the macro-invertebrate abundance and community structure and is likely to contribute substantially to the terrestrial populations and food web structure of the beach macrofauna. The wrack not only provides food for terrestrial animals, but when washed back out to sea goes on to deliver food for filter feeders, gastropods and fish.

Kirkman and Kendrick, (1997) suggest that in Australia, surf-zone feeding fish and abalone fisheries are to some extent supported by the breakdown of sub-tidal and beach-cast wrack. The floating component of the drift algae may also play a significant role in the dispersal of beach invertebrates and could also be important in the dispersal of juvenile fish (Zemke-White *et al.* 2005). Mellbrand, (2011) studied the food web dynamics of shore ecosystems and found a larger inland reach of the marine nutrients than could be accounted for by deposited macrophytes on shores alone, and that dipterans and spiders were potential vectors for the inflow. This suggests that macrophyte inputs are important for near-shore terrestrial ecosystems high above the water's edge as well as for the intertidal, littoral zones and sand dunes.

The wrack once washed up on the shore, is colonised by different species at different times and at different states of decomposition (Griffiths & Stenton-Dozey (1981); Colombini *et al.* (2000)). Many macrofaunal species undergo tidal, wave or beach slope migrations allowing them to feed on freshly stranded wrack. Predators then move in to feed on the detritivores (Brown & McLachlan, 1990). Adin and Riera (2003) looked at food source utilization among stranded macroalgae by Talitrid amphipods using stable isotopes. They found that *Talitrus saltator* was a key consumer of the stranded macroalgae and also that *T. saltator* had a preference for *Fucus serratus* as a food source within the available pool of a number of different species of stranded algae.

The rate at which herbivores consume stranded macrophyte species is unknown and estimates vary widely. Griffiths *et al.* (1983) estimate that more than 70% of wrack is consumed by herbivores, Koop and Lucas, (1983) suggest 4-9% and Inglis, (1989) reports it as negligible at <1%. Lastra, (2008) suggests the rates of consumption of drift macrophytes by different herbivores may be dependent upon the macrophyhte species and associated physicochemical and morphological characteristics. The relationship is clearly a complex one, with biomass, composition and palatability of macrophytes being factors, along with abundance, composition and structure of the consumer populations (Orr *et al*. 2005). Spatial and temporal variability in wrack composition and therefore composition, abundance and demographic rates of consumers are also factors which will affect these processes (Dugan *et al.* 2003; Stenton-Dozey & Griffiths, 1981; Lastra *et al.* 2008).

In beach sand, nitrification is the principal activity and organic nitrogen is mineralised to nitrate. The increased organic load raises equilibrium levels and so it is therefore only at greatly increased levels that a beach cannot cope and ammonia and anoxia take hold (McLachlan, 1983). McLachlan, (1983) found that the nutrient pool of the surf zone can be replaced in a just a few days or weeks by the mineralising actions of the benthos. Interstitial fauna were found to be of higher importance than the macrofauna in this procedure with 63% of nutrient regeneration being accounted for by interstitial fauna.

Seaweed can act as nitrogen sinks within the beach ecosystem. Seaweeds have the ability to assimilate and store large quantities of nutrients when ambient supplies are greater than what is needed for growth (Hanisak, 1993). This clearly illustrates what an important source of nitrogen decaying seaweed is both for the coastal waters and the beach environment. The level at which a beach accumulates nitrogen is thought to be dependent on the category of beach, whether it is eroding, equilibrium or prograding. Eroding beaches are clearly not likely to be nitrogen sinks. Equilibrium beaches are in a state of constant flux with groundwater and wave flushing being balanced out by organic input in the form of drift macrophytes. Prograding beaches however are seen to be in general nitrogen sinks unless groundwater through-flow is high enough to remove nutrients from the system faster than they accumulate. McLachlan claims to have excavated partially decomposed algae in sand dunes on a prograding beach from 40 years earlier, (McLachlan, 1986).

1.6 *Ecosystem Services: Linking ecology and economics*

Ecosystem services can be defined as the benefits people obtain from ecosystems (Millennium Ecosystem Assessment, 2005). These benefits can be both direct, in terms of the sole provision of welfare faring goods (e.g. animals for those who enjoy watching wildlife) or indirect, where ecosystem services combine with human and manufactured capital in the production of goods (e.g. in the case of farming and food production) (Bateman *et al*. 2013). Although many of these services are taken for granted, they provide a variety of critical services which would be extremely costly to replace if they were to fail. People are often unaware of these services because unlike the ecosystem goods (clean water and food etc.) the services underpinning these goods (water purification and pollination) have no obvious market value. There are therefore no direct price mechanisms to indicate the degradation of these services until they fail (Salzman *et al*. 2001). In order to value these ecosystem services, there needs to be adequate assessment of the links between the structure and function of natural systems, the benefits (i.e. goods and services) derived by humanity, and their subsequent values (Heal *et al.* 2005). It is clear that collaboration across disciplines is essential to achieve this aim. Practical decision making for policy should not be undertaken without adequate knowledge regarding the natural environmental processes.

This thesis aims to marry the two disciplines of ecology and economics in order to provide useful management advice for beach managers. In order to understand the best management options for beaches it is necessary to not only be informed as to how beaches are currently being managed and how this impacts on the ecosystem services but also to be aware of how these services are valued by the beach users. The conceptual diagram in Figure 2 shows how the ecological and economic analysis are worked into the ecosystem service cascade and the feedback mechanisms in place.

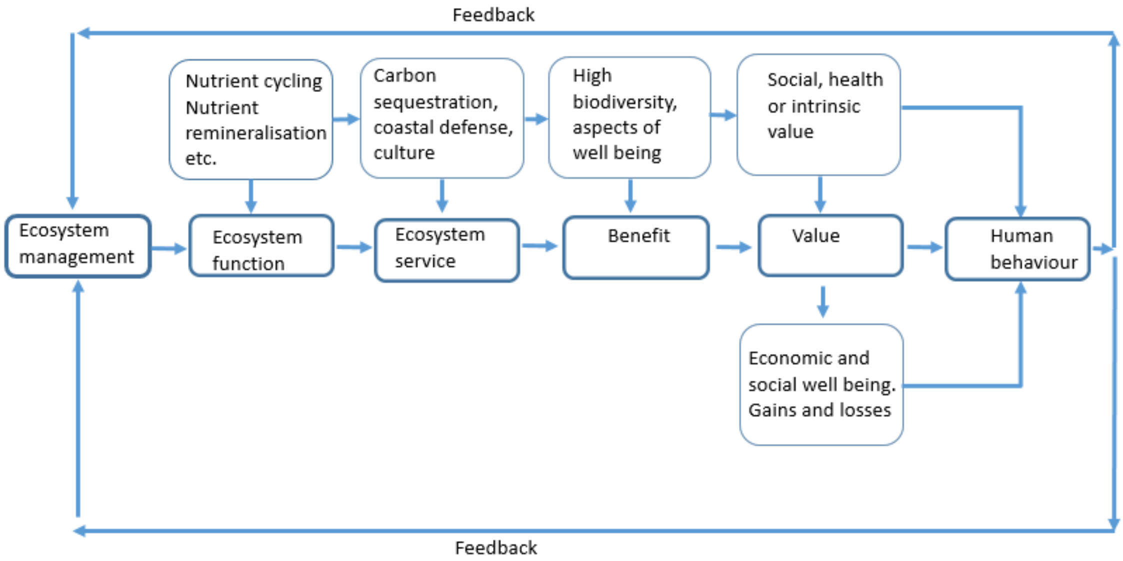

Figure 2: Conceptual diagram showing the integration of ecology and economics for tackling environmental issues.

1.6.1 Ecosystem services provided by beaches

Coastal ecosystems have unique geographical characteristics which produce multiple functions that are of more significance than those provided by any other ecosystems (Barbier *et al.* 2011). The ecosystem services provided by beaches and sand dunes are listed below:

- Protection from erosion, storm and wave damage and coastal flooding: dunes often replace the need for artificial sea defences;
- Climate regulation: carbon sequestration due to rapid soil development;

- Water quality: water purification;
- Wild species diversity: high diversity of rare/unique plants, animals, birds and insects;
- Cultural services: sites of cultural significance/heritage;
- Recreation and tourism;
- Physical/mental health: exercise, wilderness, local meaningful space; and
- Education/ecological knowledge: resource for teaching, public information, scientific study.

It is important when making policy decisions about beach management to remember that the beach provides an array of benefits for both people and the natural environment. The economic values of coastal resources includes both market and non-use values. Often these non-market values are not taken into consideration because they are not easily valued in monetary terms (Guo, 2013). Although it could be argued that putting a market value on natural resources is not possible because ecosystems and biodiversity have multiple incommensurable values (Spash *et al*. 2012), it does present a direct way to show the importance and scarcity of natural resources. By understanding the maximum amount people would pay to gain or lose ecosystem services, we can make decisions more accessible and effective through comparing the overall net gain to society yielded by each use (Kumar *et al.* 2008). One way of measuring the value of ecosystem services and other non-market goods is to use the economic methods referred to as non-market valuation.

1.7 *Non-market valuation*

In order to understand the value that is placed by an individual on a good or service, we need to understand the utility they derive from it. Utility in economic terms can be described very simply as the benefit gained by an individual in choosing one thing over another. They are "better off" or "happier" with one decision over another. This concept is a difficult one to quantify and has a greater scope then can be dealt with here. For our purposes it is sensible to think of utility in terms of welfare and that an increase in utility can be thought of as an increase in an individual's social welfare (Perman *et al.* 2011). Choice experiments are methods which can be used to understand an individual's utility gained from non-market goods.

A number of techniques have been devised over the past three decades for non-market valuation. Monetary valuation techniques assign economic values to changes in ecosystem benefits in monetary terms (Feather *et al.* 1995). These techniques ask how much people are willing to pay for services, e.g. how much are people willing to pay for recreation on a beach or for restoration of a wetland? The more they are willing to pay, the more utility they are seen to obtain from it. This question can be presented in a number of different ways depending on how preferences are elicited, but the two main methods are the revealed and the stated preference techniques. The revealed preference technique infers an individual's preference by actually observing peoples' behaviour or choices towards the goods or services (Pearce *et al.* 2006). Methods available include the travel cost method and hedonic price method. In certain situations information on actual behaviour is not available and in these circumstances economists use stated preference methods, where a hypothetical market is constructed where goods and services can be traded. Examples of these techniques are contingent valuation and choice experiments. This thesis uses the travel cost method and the stated preference choice experiment technique to try and understand how much people are willing to pay for different beach attributes and therefore establish peoples' preferences for the management of their beaches.

1.8 *Outline of the Chapters*

This thesis uses a combination of ecological and economic techniques to try and provide useful management advice for beach managers. Chapter 2 introduces the concept of mechanical beach clearing (grooming) and looks at how impacts of beach grooming are affected by other environmental factors found in the coastal environment. Previous studies have indicated that beach grooming is having a negative impact on coastal biodiversity and chapter 2 takes this idea further by identifying how we can predict the impacts of grooming in ecologically contrasting environments (Scotland and Sweden) and therefore aim to manage them more effectively.

Chapter 3 focuses on the dune habitats of beaches and how biodiversity within the sand dunes are impacted by mechanical grooming. Both the adult plant populations and the seed banks of dune systems on the east coast of Scotland are studied to determine whether grooming is having an effect on these habitats.

Chapter 4 explores the links between ecology and economics by using a revealed preference method (travel cost method) to observe the actual behaviour and choices of people and their utility gained from a number of different beach attributes. This study aims to understand why people choose to visit a certain beach and what values they place upon different aspects of beaches on the east coast of Scotland.

Chapter 5 augments the results from chapter 4 by using a stated preference choice experiment to understand not only the direct use values but also the passive use values that people gain from different beach attributes. By understanding both the direct and the indirect preferences for these different attributes, a better understanding of how beaches should be managed to benefit both the environment and society is achieved.

Chapter 6 concludes by considering the ecological and economic findings of these four data chapters and discusses the management and policy implications derived from the outcomes.

Chapter 2: Increased impacts of beach grooming on biodiversity along a coastline with high tidal range

This chapter has been submitted as a research paper to Estuarine and coastal shelf science and is currently under review. The following authors were contributors to this paper.

Griffin, C.[1]*, Day, N.[2], Rosenquist, H[3], Wellenreuther, M[3,4], Bunnefeld, N[1] & Gilburn, A.S.[1]

[1] School of Biological and Environmental Sciences, University of Stirling, Stirling, Scotland FK9 4LA, UK

[2] Ecus Ltd, Suite 5/12, Scion House, Stirling University Innovation Park, Stirling. FK9 4NF

[3] Department of Biology, Molecular Ecology and Evolution Group, Lund University, 223 62 Lund, Sweden

4 Plant and Food Research Limited, Nelson 7010, New Zealand

Abstract

Sandy beach strandlines play a vital role in the beach ecosystem; they provide food and shelter for a large number of invertebrates which themselves provide food for birds and mammals, they act as a precursor, stabiliser and fertiliser of sand dunes and they play a key role in nutrient re-mineralisation and recycling. Sandy beach management often involves the use of mechanical grooming to remove litter and beached wrack even though evidence shows that mechanical beach grooming generally reduces strandline biodiversity. To date there are no studies examining how interactions between grooming and environmental variables, such as tidal range, affect macroinvertebrate biodiversity. Tidal range is likely to impact recovery rates of strandline ecosystems after grooming, as it will alter the spatial and temporal patterns of seaweed deposition. We investigated macroinvertebrate biodiversity at groomed and ungroomed beaches on two coastlines at similar latitudes in Northern Europe but with pronounced differences in tidal ranges (60 sites on the east coast of Scotland and 60 sites on the south-west coast of Sweden). We used presence-absence of eight key macroinvertebrate taxa as an indicator of biodiversity and collected additional data on algae depth, exposure and salinity. Macroinvertebrate biodiversity was positively correlated with algae depth. Taxon diversity and algae depth were affected by interactions between tidal range, beach grooming and season (winter or summer). Swedish sites had a tidal range of 5-20cm which is considerably lower than Scotland's sites, which range between 4-5m. We found sites with a higher tidal range recovered more slowly following grooming. In Sweden, the wrack bed often straddled the waterline and much of the material was left submerged after grooming. The lower level of biodiversity found on Scottish

beaches outside the grooming season could be because it takes longer for seaweed deposits to be replenished through storm events whereas a ready supply of wrack can still be available in areas with lower tidal range. These results suggest that beach management to maintain coastal biodiversity should consider the tidal range at mechanically groomed beaches.

2.1 *Introduction*

Cumulative pressures on the world's coastlines are putting beaches at risk from an increasing variety of anthropogenic and natural impacts. Anthropogenic pressures include residential, recreational, agricultural and commercial use of land and water (Nordstrom, 2000; Davenport & Davenport 2006), and these are only expected to worsen as the number of people living near the coast increases (Brown & McLachlan, 2002; Schlacher *et al*., 2007; 2008; Defeo *et al.* 2009). Ecological processes such as beach erosion and accretion, freshwater transport, sediment transport and flooding, coupled with these increasing anthropogenic pressures can substantially reduce the ecosystem services provided by beaches (Schlacher *et al*. 2007).

It is becoming apparent that the need to act on the various natural and anthropogenic pressures on beaches is an urgent undertaking (Brown & McLachlan, 2002; Defeo *et al.* 2009). An increase in sea level rise has been reported globally over the last century (Meehl *et al*. 2007). This rise is inevitably going to lead to increased beach erosion and landward retreat of shorelines, which in turn will lead to extensive habitat loss, particularly on beaches where human development halts natural inland migration of the shoreline (Feagin *et al*. 2005). The protection of beaches and sand dunes is becoming even more critical as a defence against rising sea levels. Mechanical beach grooming is one of a number of anthropogenic impacts which are adding to the natural pressures beaches are facing (Calvao *et al.* 2013). Beach grooming occurs on a global scale although only few studies have been carried out on the impacts that removal of wrack has on the beach environment. Studies in California (Dugan, 2010; Hubbard *et al*. 2014) highlight the impacts that grooming has on the sand dune vegetation and invertebrates in those regions but little has been done elsewhere in the world.

The beach environment is especially vulnerable to the trade-offs which necessarily exist between the need to manage for both biodiversity and for people. Beaches are large tourist attractions and can bring in much needed revenue for local economies. One way that beach managers may think they can both attract tourists and maintain biodiversity is by obtaining a beach award such as the European Blue Flag. This is a worldwide initiative aimed at raising environmental awareness and increasing good environmental practice amongst tourists, local communities and beach marina operators (FEE, 2016). Another award is the Seaside Award scheme which runs only in Scotland, Wales and Northern Ireland. This scheme allows for the very different character of Scottish beaches as it is divided into both resort and rural categories. Managers of beaches with an award often take the decision to clear the stranded wrack from the beach using mechanical equipment. Many of the councils in Scotland and Sweden clear the tourist award beaches on a regular basis, weekly or even sometimes daily. One of the habitats affected by beach grooming is the strandline community. The strandline is an essential aspect of the beach ecosystem and an important habitat for birds and dune plants and facilitates nutrient remineralisation (Maun, 1998). Beach managers trying to obtain or hold on to Blue Flag status are far more likely to mechanically groom their beaches (Gilburn, 2012).

Mechanical grooming and beach award status are associated with low strandline biodiversity in Scotland (Gilburn, 2012). This study found 46% fewer taxa on groomed beaches compared with ungroomed beaches. A study carried out in

California by Dugan, (2010) found that wrack cover was more than nine times lower and plant abundance and richness were fifteen and three times lower, respectively, on groomed beaches. Mechanical grooming on beaches in south Wales was seen to have a serious deleterious effect on overall strandline-related species diversity and population abundance (Llewellyn & Shackley, 1996). Previous studies of the impacts of grooming (Dugan, 2010; Gilburn, 2012 and Llewellyn & Shackley, 1996) have concentrated only on the effects of grooming in one location. Differing ecological variables associated with different geographical locations may have synergistic or antagonistic effects together with grooming, which may lead to ecological “surprises” (Lindenmayer *et al*. 2010). These additional variables have largely been ignored in the literature until now, and this study aims to investigate their importance.

The objective of this work was to determine the impacts on biodiversity associated with grooming and other environmental variables, along two environmentally contrasting coastlines in Scotland and Sweden. These two countries differ markedly in their beach ecology, and this work concentrates specifically on the impacts associated with tidal range. By observing the impacts of grooming and other environmental variables we can begin to understand the changes that beach grooming will bring to different beaches on a global scale, and how other environmental factors may interact and affect the beach environment. The key aim of this study was to determine how tidal range may interact with and amplify the negative impacts of beach grooming. To do this we compared the presence or absence of eight key invertebrate taxa on groomed and ungroomed beaches in Sweden and Scotland. All of the taxa chosen are reliant upon the presence of stranded macrophytes (or seaweed) on the beach to complete their life cycle. Along with the presence or absence of the eight taxa, measurements of environmental variables including tidal range, salinity, algal wrack depth, exposure, aspect, slope and substrate were also taken during both the summer and the winter.

2.2 *Materials and Methods.*

2.2.1 Survey sites

Survey sites were located in both Scotland and Sweden (see Figure 2 a & b). The Baltic Sea has been described as a giant estuary (Jansson, 1978) and there is a marked salinity gradient along the Swedish coast with salinities varying from 0 to 30 psu (Baden & Bostrom, 2001). Salinity ranges in Scotland are much more consistent and vary only where freshwater input from rivers and run-off occurs. The tidal regime in Sweden is also different with a much lower tidal range than in Scotland. The Skagerrak has tides between 10-40cm and the Kattegat ranges from 5-20cm, whereas the Baltic Sea itself is too small to have its own tides (Leppäranta & Myrberg 2009). The Baltic Sea also has too narrow an opening to the North Sea to be influenced by the North Atlantic tides and so the tidal effect is only a few centimetres. The Scottish coastline has a tidal range between about 4-5m.

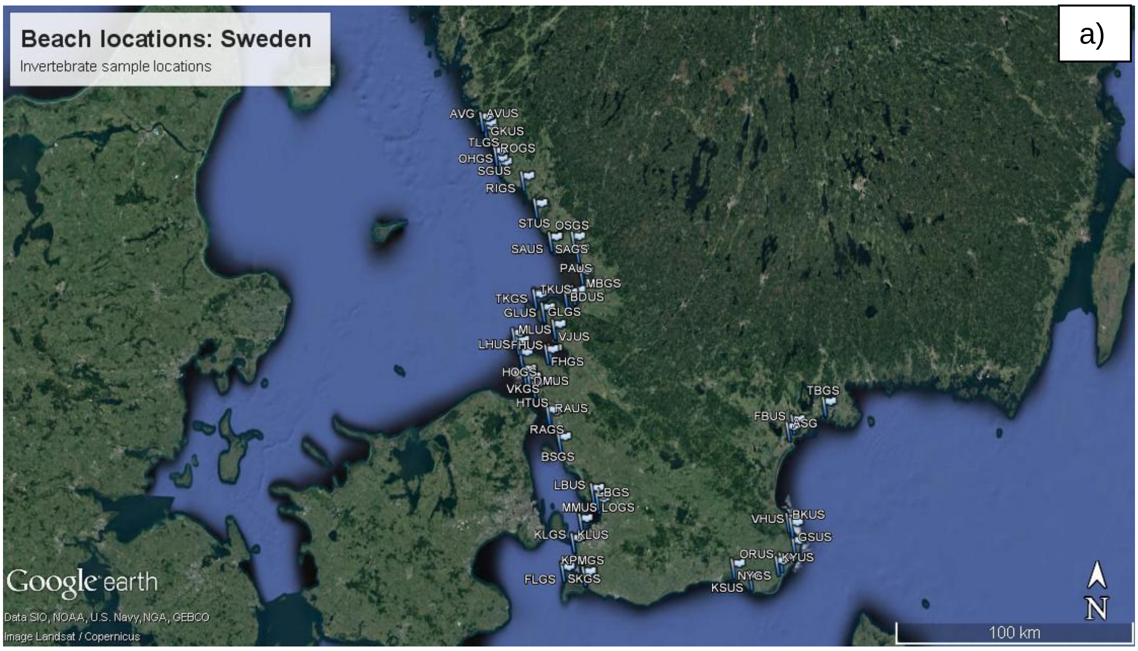

Figure 3: Maps showing Swedish a) and Scottish b) beach sampling locations for wrack invertebrates

In total 120 sites were visited during this study; 60 sites were visited in Scotland and 60 in Sweden. The sites were visited during both the summer grooming season (May-September) and also during the winter non-grooming season (October-April). This allowed any seasonal differences to be observed. Some of the study sites were sections of the same beach as often only a part of the beach is groomed and the rest is left as it is. Where groomed and ungroomed sections of the same beach were not found then the next closest beach was used. The Swedish sites were located between Kåseberga (55.399386N and 12.978539E) and Apelviken (57.083448N and 12.256786E) along the south and west coasts. Of the 60 sites in Sweden, 30 were groomed and 30 were ungroomed and 3 had obtained a Blue Flag in that year (2014). These award beaches were Båstad, Lomma and Råå. The Scottish sites were all on the east coast between Inverboyndie (57.669834N and -2.546297E) and Barns Ness (55.987167N and -2.451667E) and consisted of both sites with beach awards and ones without. The awards were a mixture of Blue Flag and Seaside Award (both resort and rural). In total 31 beaches had obtained a Seaside Award in the year of the experiment (2012) and six had gained a Blue Flag Award. The Blue Flag holders were Broughty Ferry, Aberdour Silver Sands, Burntisland, Elie Harbour Beach, Elie Ruby Bay, and Pettycur.

Each site was sampled over a period of 10 minutes using the same method as Gilburn, (2012). The sampling technique involved searching for each of the eight macroinvertebrate taxa within and underneath beached wrack for a period of ten minutes. This period did not include time spent moving between patches of wrack at a site. Where possible wrack deposits at various positions up the beach, and therefore of different age, were sampled. A fixed searching duration was used to eliminate a sampling bias which favoured ungroomed beaches. All identification was carried out *in situ*. The depth of the wrack bed was measured using a wooden metre ruler in the deepest part of the wrack bed. The method for sampling involved searching for the eight study taxa in, on or under the wrack which had been stranded on the beach. Patches of wrack at all zones on the beach (from the high water springs down to the swash zone) were searched which resulted in wrack beds of different ages and stages of desiccation being covered.

2.2.2 Study organisms

Taxon richness was used as a biodiversity indicator of the fauna inhabiting the stranded seaweed as this has been shown to be an efficient surrogate for species richness (Gilburn, 2012, Williams & Gaston 1994, Balmford *et al*. 1996). The eight taxa chosen in the surveys were used as they are all commonly found on beaches throughout the UK and Sweden and are a diverse selection of organisms with different niches within the strandline environment. Six of the taxa were assessed at the family level, while one, mesostigmata mites, was assessed at the level of order (due to the difficulty of separating the families in situ), and one taxa was assessed to the level of sub-class (due to the difficulty of separating the orders in situ). The eight taxonomic groups used were: 1) Diptera - coelopidae (*Coelopa frigida* and *Coelopa pilipes*); 2) Diptera - sepsidae (*Orygma luctuosum*); 3) Diptera - anthomyiidae (*Fucellia maritima*); 4) Diptera - sphaeroceridae (*Thoracochaeta zosterae*); 5) Coleopteran - staphylinidae – (*Cafius xantholoma* and *Aleochara algarum*); 6) Amphipoda - talitridae (of three genera *Talitrus*, *Talorchestia* and *Orchestia*); 7) Mesostigmata (*Parasitus kempersi* and *Thinoseuis fucicola*); and 8) Oligochaeta - oligochaete worms.

2.2.3 Data analysis

Statistical analyses were undertaken using R version 2.14 (R Core Team 2012). The ‘lme4’ (Bates *et al.* 2014) and ‘MuMIn’ package (Barton, 2013) were used for statistical analysis, whilst ‘ggplot2’ (Wickham, 2009) and the ‘effects’ package (Fox, 2003) were used for graphics. We performed a series of Generalised Linear Mixed-Effects Models (GLMMs; Zuur, 2009) with binomial distribution and logit link. Using GLMMs we were able to determine the influence of environmental factors on taxon diversity. We ran models using taxon richness as the response variable with 'site' included in all models as a random (grouping) factor to quantify both within- and between-site variance. The following predictor variables were included in the starting model: log tidal range, salinity, exposure, country, grooming season, grooming status and log algae depth. Tidal range was log-transformed and fitted as a linear covariate; salinity was fitted as a linear covariate; country was fitted as a fixed factor with two levels (Scotland and Sweden); grooming season was fitted as a fixed factor with two levels (winter and summer); grooming status was fitted as a fixed factor with two levels (groomed and ungroomed) and algae depth was log-transformed and and fitted as a linear covariate. Models were compared and the best model selected using an information theoretic approach (Akaike Information Criteria, AIC, Burnham & Anderson 2002). Akaike weights give the probability that a model is the best model, given the data and the set of candidate models (Burnham & Anderson 2002). A further linear model was performed with algae depth as the response variable and grooming season and grooming status as predictor variables.

2.3 ***Results***

2.3.1 Taxon diversity

Results from the GLMM show that algae depth, tidal range and grooming season were significantly associated with taxon diversity (Table 1). Algae depth was positively associated with taxon diversity regardless of whether beaches were groomed or ungroomed (Figure 3). Groomed beaches have significantly lower taxon diversity compared to ungroomed beaches, both in winter and summer (Figure 5).

Table 1: Model parameter estimates for the GLMM with binomial distribution and log link. (The intercept in this case is showing the coefficient for ungroomed beaches in winter).

Fixed Effects:	**Estimate**	**Std. Error**	**z value**	**P**
Intercept	-3.433	0.758	-4.531	<0.001***
Groomed	-0.313	0.516	-0.606	0.544
Summer	1.808	0.0515	3.509	<0.001***
Tidal range	-0.745	0.136	-5.486	<0.001***
Algae depth	1.578	0.177	8.897	<0.001***
Groomed: Summer	-0.794	0.333	-2.382	0.017*
Summer: Tidal range	-0.344	0.085	-4.029	<0.001***
Tidal range: Algae depth	0.327	0.044	7.489	<0.001***
Summer: Algae depth	-0.364	0.167	-2.175	0.029*
Groomed: Algae depth	-0.153	0.161	-0.951	0.342
AIC	1750.1			
BIC	1799.0			
Log Likelihood	-866.1			
Number of observations	1696			

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05

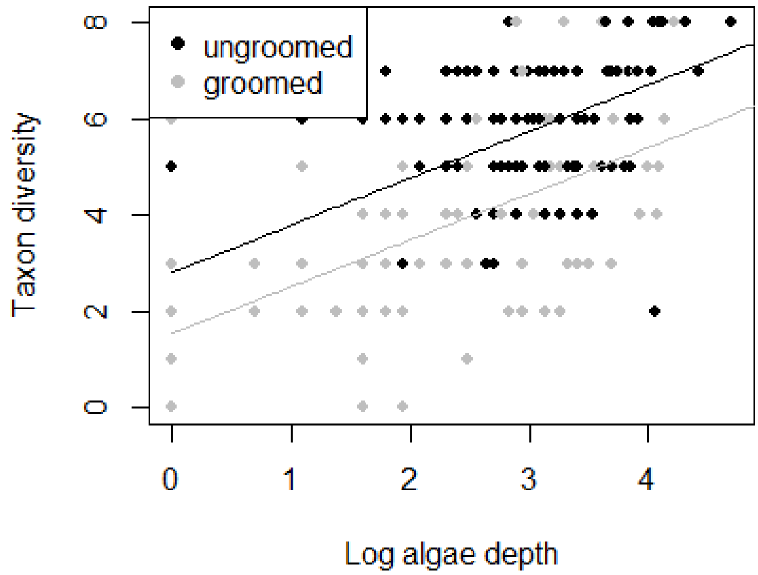

Figure 4: Association between taxon diversity and algae depth on groomed and ungroomed beaches. Points show raw data for each beach; lines show predictions from the generalized linear mixed-effects model.

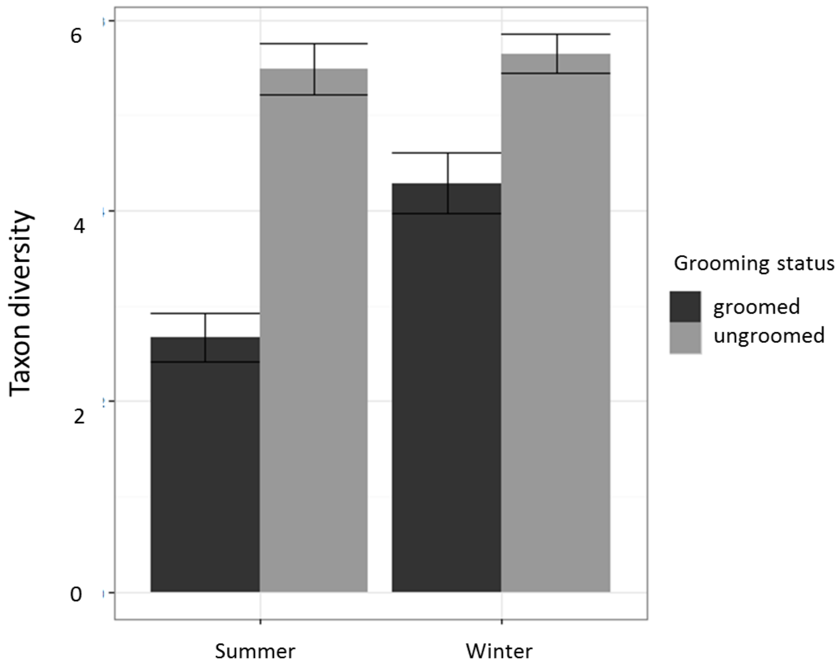

Figure 5: Effect of both grooming season and grooming status on mean taxon diversity. Predictions from the generalized linear mixed-effects model. Error bars represent standard error.

2.3.2 Interactions

Interactions between tidal range, grooming season and grooming status affected taxon diversity. Figure 6 shows that beaches differ in taxon diversity depending on season and tidal range. The grooming of beaches exaggerates these differences. On both groomed and ungroomed beaches there is greater taxon diversity with greater tidal range in winter. The beaches which have been groomed during the summer have less taxon diversity on the whole but still show the same trend of increasing diversity with increasing tidal range. In summer the trend is reversed and the beaches with a greater tidal range have less taxon diversity. This is exacerbated on groomed beaches and diversity is significantly lower on groomed beaches, especially in Scotland where the tidal range is greater compared to Sweden.

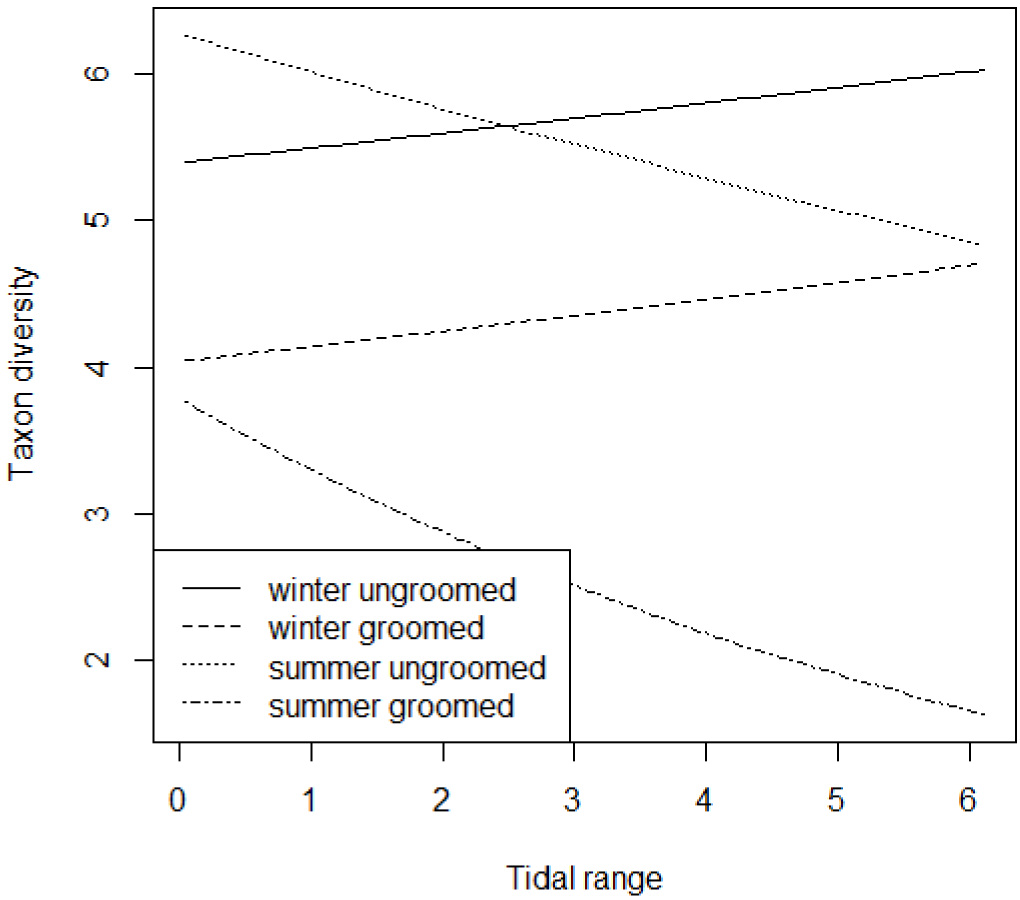

Figure 6: Interaction plot showing the effect on taxon diversity of interactions between tidal range, grooming status (groomed or ungroomed) and grooming season (summer or winter). Predictions from the generalized linear mixed-effects model.

2.3.3 Algae depth

Algae depth is positively associated with taxon diversity and is seen to vary depending on whether beaches are groomed or not and from summer to winter. Table 2 shows the parameter estimates from a linear model which was performed to determine the impact of grooming status and grooming season on algal depth. The coefficients show that groomed beaches in summer have the lowest levels of stranded algae.

Table 2: Model parameter estimates for a linear model estimating algae depths during summer and winter on groomed and ungroomed beaches. The intercept is showing the coefficient for ungroomed beaches in winter.

Coefficients:	**Estimate**	**Std. Error**	**z value**	**P**
Intercept	3.16	0.12	26.17	<0.001***
Groomed	-0.24	0.17	-1.40	0.160
Summer	-0.68	0.17	-4.02	<0.001***
Groomed: Summer	-1.17	0.24	-4.78	<0.001***

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05

2.3.4 Location

Algae depth is considerably higher in both Scotland and Sweden during the winter months when grooming does not occur, in comparison to the summer grooming season (Figure 7). Greater algae depths are found in Sweden (in comparison to Scotland) during the winter months, but in the summer months Scotland has the greater depths.

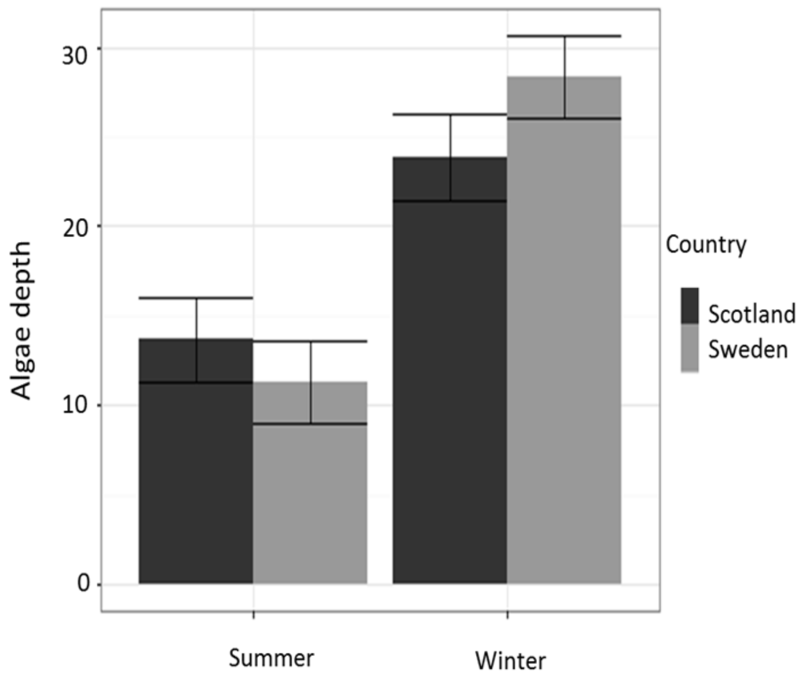

Figure 7: Differences in algae depth in Scotland and Sweden during winter and summer. Predictions from the generalized linear mixed-effects model.

2.3.5 Season

Grooming season affects algae depth, with both groomed and ungroomed beaches having greater algae depths in winter (Figure 8). As algae depth is closely associated with taxon diversity, we examined whether grooming has an impact on levels of algae depth in winter. Beaches which are groomed during the summer months have significantly less algae than in winter. There is less of a difference in depths during the winter months although groomed beaches still have less deep algal deposits.

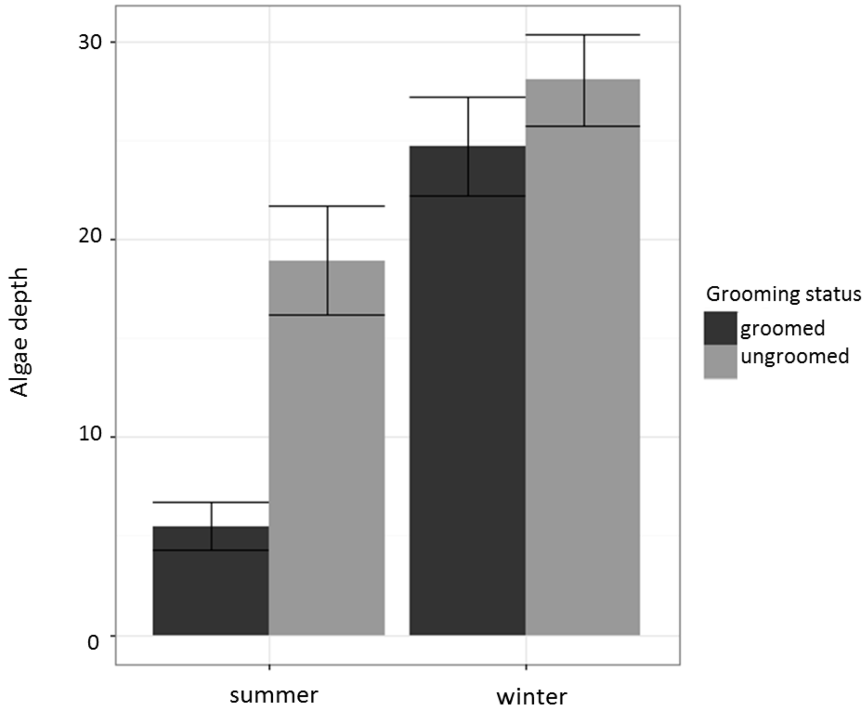

Figure 8: Plot showing the effect of grooming season and grooming status on algae depth.

2.4 *Discussion*

Sandy beach strandlines play an essential role in beach ecosystems on an international scale; they provide specialised habitats which support a large number of invertebrates which themselves provide food for birds and mammals, they help to build, stabilise and fertilise sand dunes and they play a vital role in biogeochemical processing. There is currently a lack of understanding about exactly how grooming affects biodiversity and no studies have looked at how environmental variables such as tidal range may affect the impacts of grooming. This study clearly indicates that different environmental conditions may lead to different impacts of beach grooming.

2.4.1 Taxon diversity and algae depth

Our study shows that mechanical beach grooming on beaches in both Scotland and Sweden is having a marked effect on macroinvertebrates found in the strandline. This study was carried out on a large scale in Scotland and Sweden and showed a decrease in strandline biodiversity. Specifically, the depth of deposited algae has a major impact on the number of taxa found on each beach. This is corroborated by work from California showning that species richness, abundance and biomass of wrack associated macrofauna, plus some wrack-feeding bird species are significantly correlated with levels of stranded wrack (Dugan *et al*. 2003).

In line with our findings that algae depth is positively associated with taxon diversity, patch size has previously been shown to have an effect on species abundance and richness, with small patches having fewer species and individuals than medium and large patches (Olabarria *et al*. 2007, Wellenreuther & Connell 2002). This may mean that on groomed beaches where large areas of wrack are removed, there is less biodiversity and therefore fewer available prey items for birds and mammals. Ince *et al.* (2007) recorded higher macroinvertebrate abundance levels from beaches with high wrack inputs than from those with smaller inputs. Here we show how tidal range plays a role in determining the depth of groomed beaches during the winter months with areas with higher tidal range recovering more slowly. Wrack colonisation is known to occur in succession with talitrid amphipods, diptera and coleoptera settling first followed by oligochaetes, mites and meiofauna (Deidun *et al.* 2009). Grooming is more likely to impact these later colonisers.

2.4.2 Interactions

An interaction between grooming season, grooming status and tidal range was seen to affect taxon diversity. These three variables play an important role in determining the levels of algae that are found on the beach which in turn is seen to influence the levels of biodiversity present on the beach.

Unexpectedly, beaches with a larger tidal range are more impacted by grooming. This is evident both during the summer months when grooming is occuring and in winter when grooming has ceased. It was noticed that in Sweden, where tidal range are comparatively lower, algal material commonly got retained along the water's edge where grooming does not occur. The low tidal range means that wrack is unlikely to be deposited high on the beach other than during storm events, whereas in Scotland high tides deposit wrack well above the next low tide mark making its removal by grooming much easier. The relative difficulty in removing all wrack material in Sweden may partially mitigate the impacts of grooming by the presence of a ready supply of wrack in the water to replace the removed material. By contrast in Scotland and in other areas with high tidal range, such as in many parts of the USA and Australia, a storm event is likely to be needed to replenish the lost wrack resulting in prolonged periods of its absence heightening the impacts of its removal. Increased tidal range results in a wider spread distribution of the wrack on the beach and therefore shallower depths. As depth of wrack is key for macroinvertebrate biodiversity, this combined with the increased ease of grooming as the wrack is further away from the water line at low tide means that beaches with higher tidal range are doubly impacted in terms of reduced algal depth.

2.4.3 Seasonal effects

Algae depths are significantly different on groomed and ungroomed beaches during the summer months, with much higher levels found on ungroomed beaches. In winter the differences are not significant and similar amounts are found on both groomed and ungroomed. However, there is a marked effect of grooming on taxon diversity during the winter months with significantly less taxa being found on beaches which have been groomed during the summer. This indicates that the grooming of beaches may be disturbing the life cycles of certain taxa and preventing their recovery over the winter months. One example of that are Talitridae (sandhoppers), whose life cycle can be disturbed by beach grooming due to their annual univoltine (i.e. one brood of offspring per year) reproductive cycle. This means that only one generation reaches maturity each year and their breeding season directly coincides with the grooming season on beaches i.e. May–August (William, 1978). Therefore, the removal of the strandline by grooming equipment can destroy an entire generation, which will then be unable to recover during the winter months. These animals cannot recolonise easily as they are unable to fly and are prone to dessication without the damp covering of seaweed provided by the stranded wrack (Llewellyn & Shackley 1996).

2.4.4 Management implications

Gilburn, (2012) found that award beaches were much more likely to be groomed, with 69% of award beaches surveyed being groomed compared to only 6% of non-award beaches. The awarding bodies advise against cleaning beaches with mechanical equipment and suggest that stranded macroalgae should only be removed once it has reached a nuisance level. This is clearly not happening on many of the beaches in Scotland and Sweden, with a large number of beaches adopting cleaning regimes on a daily or weekly basis regardless of the amount of seaweed present. The results from this study lead to a number of management recommendations which should be put forward to beach managers. As we know that tidal range has a major impact on recovery rates on groomed beaches, it is possible for managers in different areas to use this information and tailor their policies to try and minimise the impacts of grooming. In Sweden, for example, the impacts of grooming are being partially mitigated by the presence of wrack along the water line. It could be recommended here that beach managers ensure that this supply of wrack is left along the waterline and the lowest part of the beach to allow a more rapid recovery of the macro-invertebrate community after the end of the grooming season and to reduce its impact during the grooming season. In areas with higher tidal range the impacts of grooming could be partially mitigated if there was still a supply of wrack near or at the water's edge at that level of grooming intensity. If beach managers avoided grooming at low tide and therefore left some wrack on the lower parts of the beach, this might provide sufficient wrack to partially mitigate some of the major negative impacts of grooming. The frequency of grooming in areas of higher tidal range should also be reduced to occasional ad hoc events, once nuisance levels of stranded seaweed have been reached and also to leave some wrack on the beach during these clearing events. In certain locations and on occasions when storms have been severe, there may be a need for beaches to have a one-off grooming session to reduce the size of any exceptionally large banks of algae that have built up. This should be on a restricted basis and only when deemed necessary. Rather than being removed the seaweed could be transported to a more suitable area of the beach where it is less likely to be considered a nuisance by the public and where it can naturally decompose to recycle nutrients into both dune and marine environments.

In areas with high tidal range, it is advised that wherever possible an alternative to mechanical grooming should be found. In certain locations in both Scotland and Sweden, the local community takes control of how certain aspects of their beach are managed. This means that they decide how and when their beaches are cleaned. Local volunteers clean the beaches by hand on a regular basis without the need for mechanical equipment. These types of beaches are usually quite rural in nature and often do not receive as many tourists as some of the resort beaches. These rural beaches tend not get as much litter entangled into the seaweed, although obviously still do receive litter washed ashore of a marine origin. It is important that action is taken to prevent litter from getting into the sea in the first place, but this is an issue that beach managers simply can do little about other than to provide educational material at their beaches. Larger resort beaches could employ beach cleaners to remove litter from the beach by hand during the key summer months and this would probably come at a fraction of the cost of using tractors and grooming equipment. In addition to these physical grooming strategies, beach managers should aim to provide educational material at their beaches which inform local people and tourists of the importance of stranded wrack to the beach environment. Reminders that visitors need to take their litter home with them should also be provided.

2.5 *Conclusions*

This study is the first to observe interactions between beach grooming and other environmental variables, in this case tidal range. It has already been established that beach grooming reduces strandline biodiversity, but the results from this study clearly indicate that different environmental conditions may lead to different impacts of beach grooming. An interaction between grooming status, grooming season and tidal range affect the amount of algae on the beach and therefore the levels of biodiversity. Larger tidal ranges are more impacted by grooming and beach managers should use this information to plan their beach management strategies according to the type of beach they manage, although the clear message everywhere is the less mechanical grooming the better. The results from this study also suggest that other environmental variables not included in this study may have an impact on the effects of grooming and these may also require future investigation.

Chapter 3: Does removal of macrophyte wrack by mechanical grooming have an ecological impact on the seedbank composition and adult vegetation of sand dunes?

Abstract

Coastal strand and dune systems are internationally important ecosystems which support a wide abundance and diversity of plant life. Recent estimates suggest that loss of this habitat is predicted to continue in the future due to the impacts of sea-level rise and coastal erosion resulting from climate change. No studies have been carried out on the impacts of mechanical beach grooming on the dune plants and coastal seedbanks of Scotland until now. We investigated the impacts of the mechanical removal of stranded wrack on the dune vegetation and seedbank communities of groomed and ungroomed beaches on the east coast of Scotland.

Results show a difference in both the adult plant and seedbank species composition and richness on groomed and ungroomed beaches. The greater the depth of the seaweed found on the beaches, the greater the species richness and abundance of plants found on the dunes and seedbanks. Sand dune vegetation is a critical aspect of erosion prevention and any threats to the plants growing on the dunes need to be thoroughly investigated. Concerns about climate change, the current political climate, and the uncertainty regarding European environmental legislation lead to suggestions that a precautionary approach to beach management is essential. Further study into the impacts of grooming on the entire coastal ecosystem and how this may interact with differing environmental conditions is therefore advisable.

3.1 *Background*

Coastal strand and dune ecosystems are an internationally important habitat which provide support for a number of unique ecological communities and functions (Dugan, 2010). There are more than 70,000 ha of sand dunes in the UK, 50,000 of which are found in Scotland (Provoost *et al.* 2011). It is estimated that the UK has lost approximately 30% of its dune habitat since 1900 and it is predicted that further losses will occur due to climate change leading to sea-level rise and coastal erosion (Delabaere, 1998). Cumulative pressures on the world's coastlines are putting beaches at risk from an increasing variety of anthropogenic and natural impacts. Anthropogenic pressures, including residential, recreational, agricultural and commercial use of land and water, may be intensified due to global climate change (Maun, 2009). Other man-made pressures in coastal areas are becoming more problematic with growing development and urbanisation in increasingly industrialised nations. Natural impacts are mainly related to storms and weather events which lead to increased and sometimes chronic beach erosion (Phillips & Jones, 2006). Mechanical beach grooming is just one of a number of anthropogenic impacts which are adding to the numerous pressures facing our beaches. This chapter aims to assess the impacts of mechanical grooming on both the vegetation and seedbank composition of the sand dunes by comparing groomed and ungroomed beaches on the east coast of Scotland.

3.2 *The ecology of sand dunes*

The successional development of sand dunes is a dynamic process which sees a transition from bare sand to full vegetation and soil development (Dugan, 2010).

Strandline communities contain seedbanks which are made up of both seeds from the plants growing in the dunes and from seeds which have been washed ashore. The germination of these seeds is dependent on a variety of factors and disturbances (such as wave action and tides), but is known to be reliant upon inputs of detached macro-algae (Ignaciuk & Lee 1980). Once these plants establish they form the starting point of dune development. The stranded wrack both traps sand as the sand grains collect behind it and provides nutrients for any plants which grow there. Small embryo dunes are formed which can start to become vegetated with pioneer plant species such as marram grass (*Ammophila arenaria*), lyme grass (*Leymus arenarius*) and various oraches (*Atriplex spp.)*. The plants develop and trap more sand, binding it together with their roots. As these plants die and decompose they create fertile conditions which are less alkaline. This enables less resilient plants to establish and as stresses such as wind, sand movement and salt become less of a challenging environment, soil development begins along with the establishment of more diverse communities of vegetation (Provoost *et al*. 2011). As the dunes develop, a system of dune ridges begin to form which become more stable with distance from the sea (Figure 9).

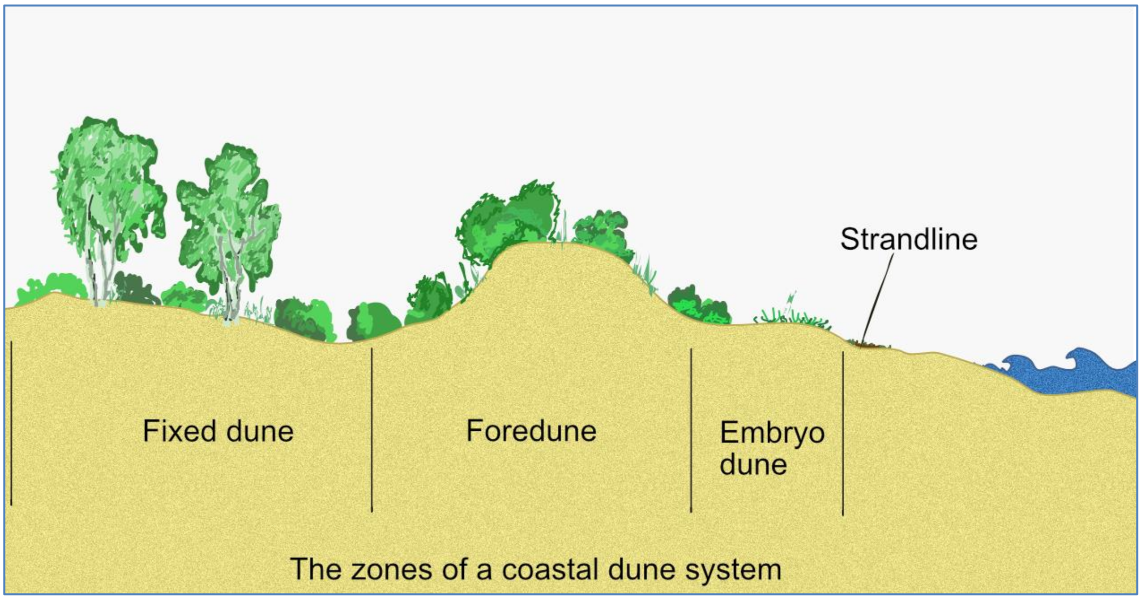

Figure 9: The geomorphological zones of sand dunes.

3.3 *Dune vegetation*

The vegetation of sand dunes evolves over time from pioneer species to climax vegetation. At each stage of the process there is a change in the plant community which results in a different microclimate and the soil type, leading to the establishment of a different composition of species. As the succession develops one community of plants replaces the previous one. Finally, the vegetation reaches a state of equilibrium with the environment known as a climax community. The plants which grow in the dune environment have to adapt to an environment which is nutrient-poor, lacking in water, saline and very dynamic. Sand dune systems can take hundreds of years to develop from the embryo dunes into the fixed grey dunes and are fragile and vulnerable environments (Provoost *et al*. 2011).

Embryo or pioneer dunes: These plants are highly specialised to enable them to withstand the harsh conditions. They exhibit features such as waxy and hairy layers on their leaves and stems, and the ability to grow close to the ground to reduce their exposure to strong winds and bombardment by sand particles. They tend to have strong root systems and can spread rapidly even with low levels of nutrients (Plate 2e). Examples include sea rocket (C*akile maritima*- Plate 2a.); saltwort (*Salsola spp*.); frosted orache (*Atriplex laciniata*-Plate 2b.); sea couch (*Elytrigia atherica*); Lyme grass (*Elymus arenarius*-Plate 2c.); and sand wort (*Honckenya peploides*-Plate 2d.) (Pakeman & Lee 1991).

Foredune or Yellow dunes: The plant species found here are more complex due to the increased levels of nutrients. The plants in the yellow dunes have a stabilizing effect on the developing dunes and include species such as Marram grass (*Ammophila arenaria*) and sand sedge (*Carex arenaria*). These plants help to bind the surface as they provide more cover and have large horizontal root systems. Plants which are often found on waste ground such as dandelions, hawkbits, hawkweeds and ragworts will often rapidly colonise any bare patches on the dunes. These plants usually have windblown forms of seed dispersal and are able to grow quickly, produce flower and set seed (McLachlan & Brown, 2006).

Fixed or Grey dunes: The fixed dunes have higher levels of species diversity and are occupied by more complex and developed vegetation. There are more perennials present, less marram and a more or less continuous level of plant cover. The plants here are much more protected from the harsh conditions found closer to the beach, are more sheltered from strong winds and have much lower salinity levels to contend with. As the soil becomes less sandy and develops into a more nutrient-rich environment, marram grass will die out and lichens are seen to colonise the dunes giving them their characteristic grey colour (Houston, 2008). Plants found in grey dunes include sea buckthorn (*Hippophae rhamnoides*- Plate 2e.), chickweeds (*Cerastium* spp.) and early hair grass (*Aira praecox)* (Chapman, 1976).

Plate 2a. Sea rocket (C*akile maritima*)

Plate 2b. Frosted orache (*Atriplex laciniata*)

Plate 2c. Lyme grass (Elymus arenarius)

Plate 2d. Sandwort (Honckenya peploides)

Plate 2e. Strandline, embryo & yellow dune

Plate 2f. Sea buckthorn (*Hippophae rhamnoides*)

3.4 *Dune seedbanks*

The seedbank of any dune habitat contains unknown numbers and types of seed which can potentially add to the plant community. Some of these seeds may lay dormant in the soil for many years. This can be extremely important for any community experiencing disturbance of any kind. Some species can persist in the seedbank for hundreds of years before proper conditions for germination and emergence return them to the adult community (Baker, 1989). The seedbank is the plants survival strategy for when conditions are adverse and buffers plant populations against environmental variability (Thompson, 2000). In strandline and sand dune environments the persistence and durability of the seeds in the seedbank are a key mechanism for the survival of this plant community. The ability of seeds to withstand prolonged immersion in sea-water and an ability to float are a huge advantage. On some temperate beaches which show marked sand accretion, the sea probably provides the major seed source of annual species (Lee and Ignaciuk 1985).

In the UK, strandlines are rarely colonized by more than six plant species (Lee & Ignaciuk 1985). This is explained by the harshness of the environment, characterised by factors including high salinity, burial of seedlings by sand, accretion, erosion and lack of nutrients. Supply of nutrients is known to be very low in strandline environments except in the immediate locality of drift seaweed and other organic matter which has been washed ashore. This is known to both restrict growth of the plant and may even prevent seed production (Lee, 1988). In this harsh environment the soil seedbank becomes even more important. Perenniality also significantly reduces the effect of environmental uncertainty. Therefore it is perhaps more likely that the majority of seeds found in the seedbanks of beaches are actually those of annual plants with far fewer being from biennials and even fewer from perennials.

Germination of seedlings, especially from annuals, is timed to coincide with a reduction in levels of salinity in the sand and an increase in temperature in the spring. It also occurs at the same time as the rapid decomposition of wrack bed seaweed (Lee & Ignaciuk 1985). Large amounts of algae are cast onto the beach over the winter months and early spring during storm events and available nitrogen reaches a peak in late May which coincides with the highest growth rates of annual plants (Lee & Ignaciuk 1985). According to Lee & Ignaciuk (1985), some seeds can germinate as late as early July if the wind brings the seed near to the surface, but these are rarely seen to set seed and usually show poor growth. This is thought to be because the seeds have missed the major period of decomposition. This may also be the fate of any seedlings brought to the surface by raking during beach grooming in the summer. The seeds would in effect begin to germinate and then have poor growth rates due to the lack of decomposing wrack. The plants which grow in the strandline are precursors of sand dunes and without these primary colonisers the secondary dunes, yellow dunes, and grey dunes would be unable to become established. The strandline soil seedbank is therefore potentially vital to the dune habitat. These communities of plants and the seedbanks they depend on may be negatively impacted by the mechanical grooming of the beaches to remove litter and seaweed. It is thought that removal of seaweed from the beach can slow down or prevent the dunes from forming and may lead to erosion of dunes already formed. This study aims to understand the impact that mechanical beach grooming and strandline removal have on both the seedbank present in the strandline and the adult vegetation found growing on the dunes.

3.5 ***Sampling methods***

3.5.1 Adult vegetation survey

Vegetation surveys were carried out on 16 beaches (8 groomed, 8 ungroomed) on the east coast of Scotland (Figure 10) during the summer of 2012 between May and September. A belt transect method was used (Figure 11).

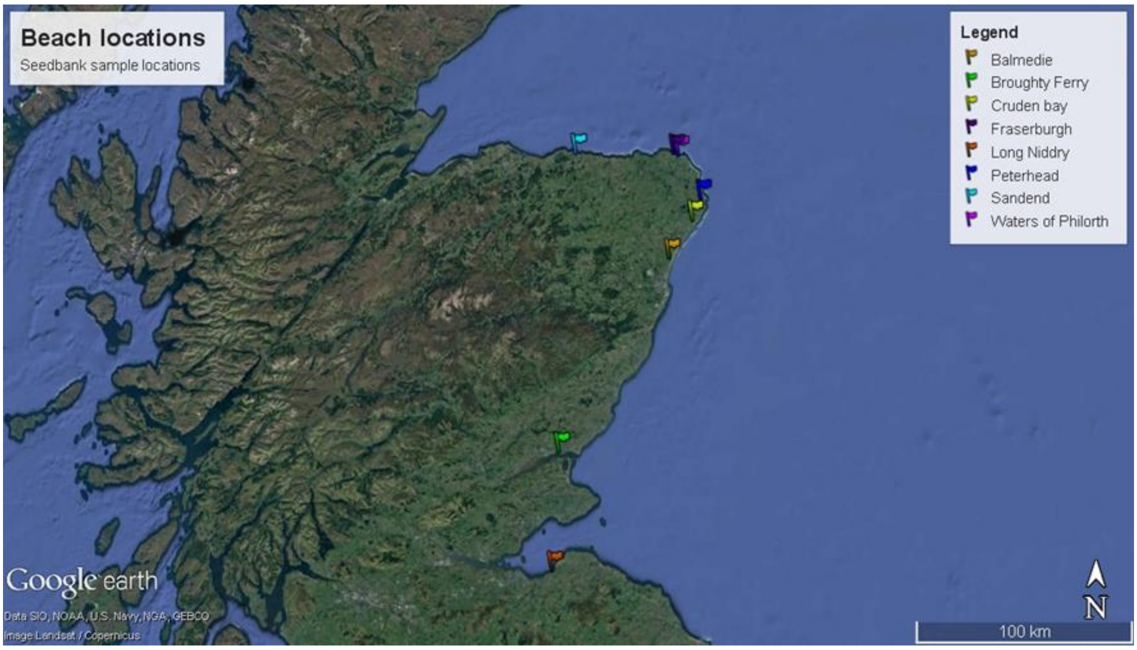

Figure 10: Location of beaches for plant transect samples

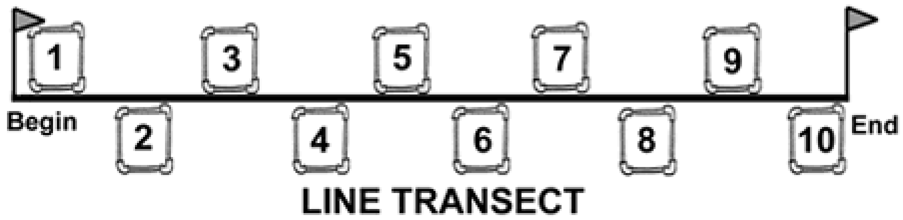

Figure 11: An example of a belt transect. Each square symbolises a 0.5m by 0.5m quadrat.

This method is similar to the line transect method but gives information on abundance as well as presence or absence of species. Three transects were taken along the beach where the samples had been collected. Coastal dune vegetation was sampled inside 0.5m x 0.5m squares. The percentage cover of every plant was visually estimated in each plot as the vertical projection of the aerial part of the plants onto a horizontal surface. The canopies of the plants inside the quadrat will often overlap each other, so the total percentage cover of plants in a single quadrat will frequently add up to more than 100%. Quadrats were sampled all the way down the transect line at each 1m point by the same person to ensure estimation of cover was consistent. The plots were positioned along 3 transects which had been selected at random along each beach. Each transect was 10m in length and was designed to cover vegetation of the embryo dunes in the drift lines and further back into the more stable vegetation of the semi-fixed and fixed dunes. Slope, aspect and exposure type were also recorded for each beach along with whether it was groomed or ungroomed. Beaches were groomed between May and September. The beaches sampled contained sections which were both groomed and ungroomed, therefore samples were taken from different sections of the same beach. The average percent cover was calculated for each species measured for all of the quadrats by adding the percent cover in each plot and then dividing by the total number of plots.

3.5.2 Seedbank survey

Samples were taken from 12 beaches around the east coast of Scotland (Figure 12). Six of these beaches had been groomed mechanically and six had been either left un-cleared or had only been cleared by hand. The samples were taken from different sections of the same beach so that other environmental conditions were kept as constant as possible.

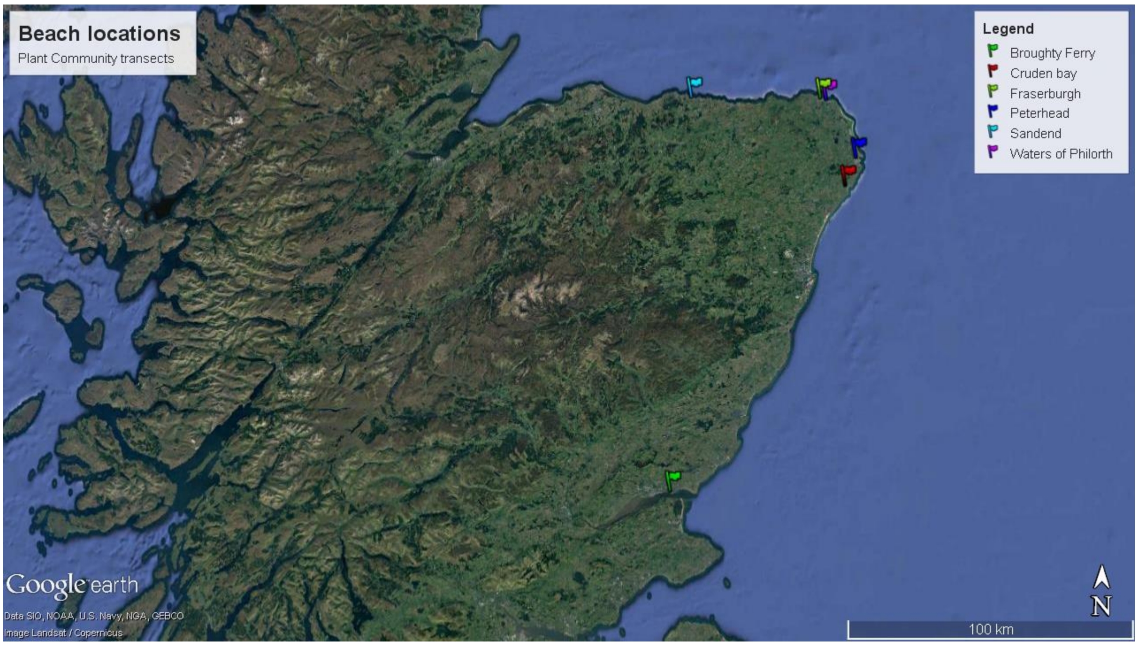

Figure 12: Location of beaches seedbank samples

Samples were collected using a cylindrical core to a depth of 10cm and with a diameter of 6.5cm. At each site 6 cores were taken at 10 stations, which were 10m apart on the beach for a total of 60 samples per beach. Samples were collected in late winter/early spring on the 14th March 2012 to ensure that they had been exposed to a natural cold stratification period. Previous studies show that soils exposed to a cold spell produce more seedlings than samples collected before the winter (Ter Heerdt, 1996).

Once back at the greenhouse the 6 samples from each of the 10 stations along the beach were pooled as these were replicates. The sand was spread out in 25cm x 20cm plastic trays which contained a 3cm deep layer of potting compost (Verve multi-purpose compost). This potting compost increased the sample volume and helped to slow the rate of desiccation of the thinly spread samples. The samples were then placed in a polytunnel at the University of Stirling.

The samples were watered daily with tap water using the polytunnel sprinkler system. As the seedlings were from a temperate environment, it was not necessary to adjust the temperature they were kept at. The trays were examined for newly emerged seedlings at 3 day intervals. Upon identification the seedlings were removed from the trays. If the seedlings could not be identified immediately they were transferred to plant pots where they were allowed to grow on until identification was possible. Species lists for both adult plants and seedbanks can be found in Appendix A.

3.5.3 Data Analysis

Statistical analyses were undertaken using R version 2.14 (R Core Team, 2012). The lme4 (Bates *et al*. 2014) and MuMIn package (Barton, 2013) were used for statistical analysis. We performed a series of Generalised Linear Mixed-Effects Models (GLMMs; Zuur 2009) with a Poisson error distribution. Using GLMMs we were able to determine the influence that grooming and other environmental factors had on species richness of plants growing on the sand dunes and species richness within the seedbank.

For both adult plants and seedbanks we ran models using species richness as the response variable with ‘site’ included in all models as a random (grouping) factor to quantify both within- and between-site variance. The following predictor variables were included in the starting model: exposure, wrack depth (cm), tidal range and aspect. Exposure was fitted as a fixed factor with for levels (1 = most exposed, 4 = least exposed); wrack depth was fitted as a linear covariate; tidal range was fitted as a linear covariate; aspect was fitted as a linear covariate. Models were compared and the best model selected using an information theoretic approach (Akaike Information Criteria, AIC, Burnham & Anderson 2002). Akaike weights give the probability that a model is the best model, given the data and the set of candidate models (Burnham & Anderson 2002).

Non-metric multidimensional scaling (NMDS) was used to compare how the constituent species, or the composition of the species, changes between communities. Here, we compared the species composition of groomed and ungroomed beaches. NMDS represents the pairwise dissimilarity between beaches in a low-dimensional space: it collapses information from multiple dimensions into just a few so that they can be easily visualized and interpreted. It is a rank-based approach which substitutes the original distance data with ranks. This use of ranks removes any problems associated with absolute distance and is a very flexible approach which can be used on a number of different data types (Clarke, 1993). Interpretation of the NMDS is relatively simple, in that objects that are ordinated closer to one another are more likely to be similar than those further apart. The scale of the axes are arbitrary. The NMDS analyses we carried out compare the community composition of groomed and ungroomed beaches. Each beach is compared with every other beach; the closer beaches are more similar to each other than ones further away.

3.6 *Results*

3.6.1 Comparison of adult plant and seedbank community composition of groomed and ungroomed beaches using a Generalized Linear Mixed Effects Model (GLMM).

Results from the GLMM for adult plant species diversity show that grooming is associated with wrack depth and exposure and that these three factors affect plant community composition of sand dunes. The best model (model 3 from Table 3) shows that grooming, wrack depth and exposure all influence the number of species found on sand dunes. The model parameter estimates from model 3 can be seen in Table 4. Wrack depth (cm) has a positive impact on the number of plant species found. In model 5 when the term for wrack depth is removed, grooming is no longer significant. This suggests that it is the reduction in wrack depth by grooming which has the most impact on plant community composition.

Table 3: Adult plants: Model parameter estimates for Generalized Linear Mixed Models (GLMMs) with Poisson error distribution. (The intercept in this case is showing the coefficient for ungroomed beaches). The models were compared by removing each term from the full model and the best model selected based on the AIC scores and *p* values (in this case model 3).

Model	Intercept	Grooming	Tidal range	Aspect	Exposure	Wrack depth	Site	AIC
1	4.45	0.64**	-1.32	0.00	1.25*	0.15***	0.24	128.2
2	4.31	0.62**	-1.27	-	1.25*	0.15***	0.24	126.3
3	0.20	0.65**	-	-	0.45*	0.16***	0.34	126.6
4	1.35***	0.63**	-	-	-	0.15***	0.53	128.2
5	0.64**	-5.27	-	-	2.91	-	0.35	145.4

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05

In Figure 13 it can be seen that as wrack depth increases, number of species increases. Species numbers appear to be higher on the groomed beaches but this may be due to the fact that the higher wrack depths only occurred on the ungroomed beaches and so the predictions for the groomed beaches above a wrack level of 5cm were not possible. This figure also illustrates that the exposure level of the beach affects the number of species present on the sand dunes with less exposed beaches having the most species. (Exposure levels range from 1 to 4 with 1 being the most exposed and 4 the least. No level 3 sites were present in this analysis). Site was used in the model as a random factor and was seen to be highly significant.

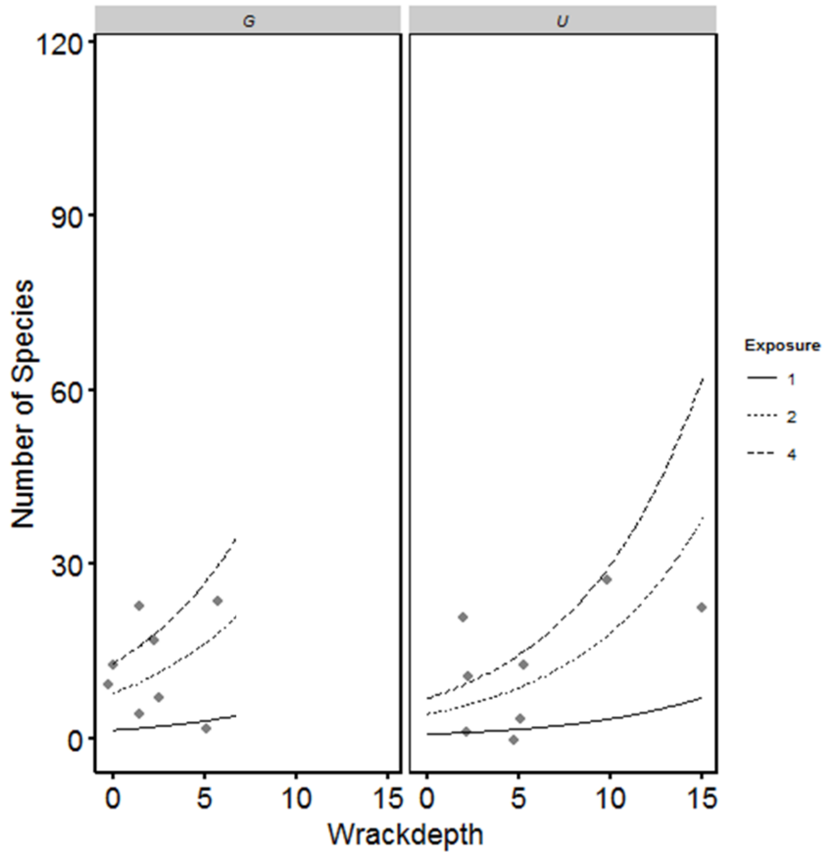

Figure 13: The association between wrack depth (cm) and adult plant species diversity, on Groomed (G) and ungroomed (U) beaches, and at different levels of exposure (1, 2

and 4). Exposure levels: 1=most exposed, 4= least exposed. Points are raw data and lines show predictions from model (3) in Table 3.

Table 4: Adult plant species diversity: Model parameter estimates for the best model (model 3) chosen from the Generalized Linear Mixed Model (GLMM) with Poisson error distribution.

Fixed Effects	**Estimate**	**Std. Error**	***Z* value**	***p***
Intercept	0.20	0.70	0.29	0.77
Grooming	0.65	0.21	3.10	0.002
Exposure	0.47	0.23	2.03	0.04
Wrack depth	0.16	0.04	4.26	<0.001
Random Effects	**Estimate**	**Std. Deviation**		
Site	0.34	0.58		

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05

Results from the GLMM for the seedbank species diversity show that wrack depth is the only factor which influences the number of species found in the seedbank. The best model selected using the AIC scores (Model 4 from Table 5) shows that tidal range, aspect, exposure and grooming are not significantly affecting the community composition of the seedbank. The parameter estimates from model 4 are shown in Table 6. Figure 14 shows that as wrack depth increases, number of species increases. Again, although groomed beaches appear to have greater species richness, this is probably because the ungroomed beaches were the only beaches which had larger wrack depths on them and therefore the predictions from the groomed at these wrack depths were not possible.

Table 5: Seedbank species diversity: Model parameter estimates from Generalized Linear Mixed-effects Models (GLMMs) with Poisson error distribution. (The intercept in this case is showing the coefficient for ungroomed beaches). The models were

compared by removing each term from the full model and the best model selected based on the AIC scores and p values (in this case model 4).

Model	Intercept	Grooming	Tidal range	Aspect	Exposure	Wrack depth	Site	AIC
1	8.28	-0.78	-2.40	0.002	1.48	0.14**	0.10	68.2
2	2.14	-0.68	-0.20	-	-0.03	0.14**	0.11	66.7
3	1.57	-0.68	-0.18	-	-	0.14**	0.11	64.7
4	1.14***	-0.74	-	-	-	0.15***	0.12	63.2
5	1.31***	0.15	-	-	-	-	0.42	68.5

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05

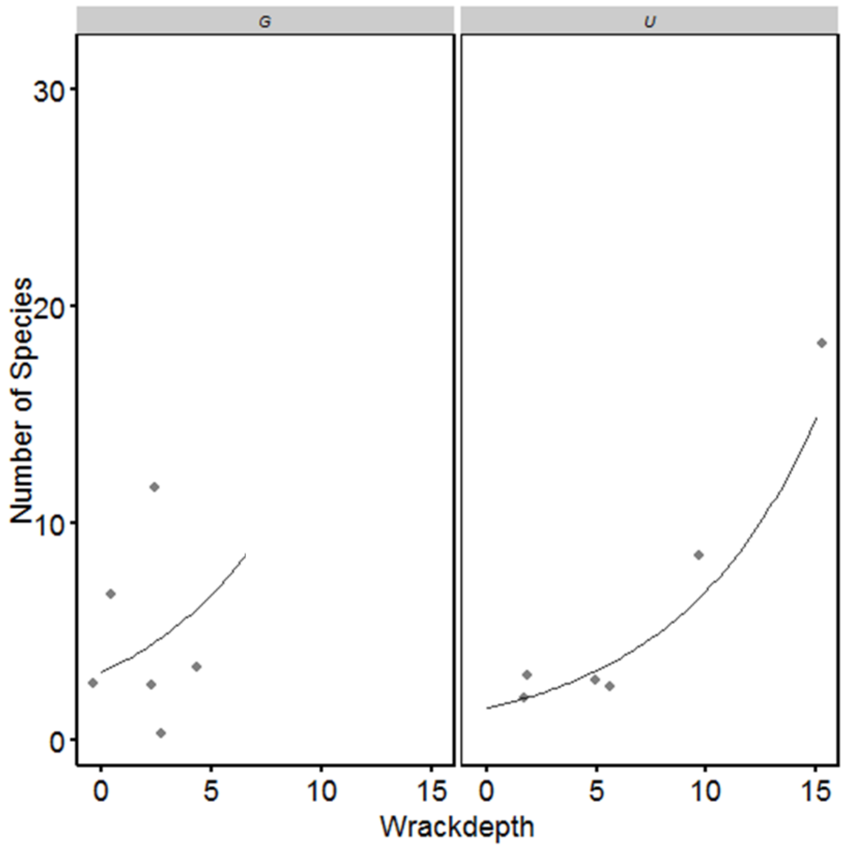

Figure 14: The effect on seedbank species diversity of wrack depth and grooming (groomed (G) or ungroomed (U)). Points are raw data and lines show predictions from model 4 in Table 2.

Table 6: Seedbank: Model parameter estimates for the final model chosen from the GLMM (model 4, Table 2) with Poisson error distribution.

Fixed Effects	Estimate	Std. Error	*Z* value	*P*
Intercept	1.14	0.27	4.31	<0.001

Grooming	-0.74	0.46	-1.60	0.10
Wrack depth	0.15	0.05	3.37	<0.001
Random Effects	**Estimate**	**Std. Deviation**		
Site	0.12	0.35		

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05

3.6.2 Comparison of adult plant and seedbank community composition of groomed and ungroomed beaches using Non-metric multidimensional scaling (NMDS)

Results from the NMDS show that adult plant species richness on groomed and ungroomed beaches has a large amount of overlap. The hull plot in Figure 15 indicates that both the groomed and ungroomed sections of Long Niddry and the ungroomed beach at Cruden Bay are the beaches which are most different from the others

The NMDS for seedbank samples (Figure 16) shows a large overlap of groomed and ungroomed beaches. The groomed beaches at Waters of Philorth and Fraserburgh appear to be the beaches most dissimilar to the others.

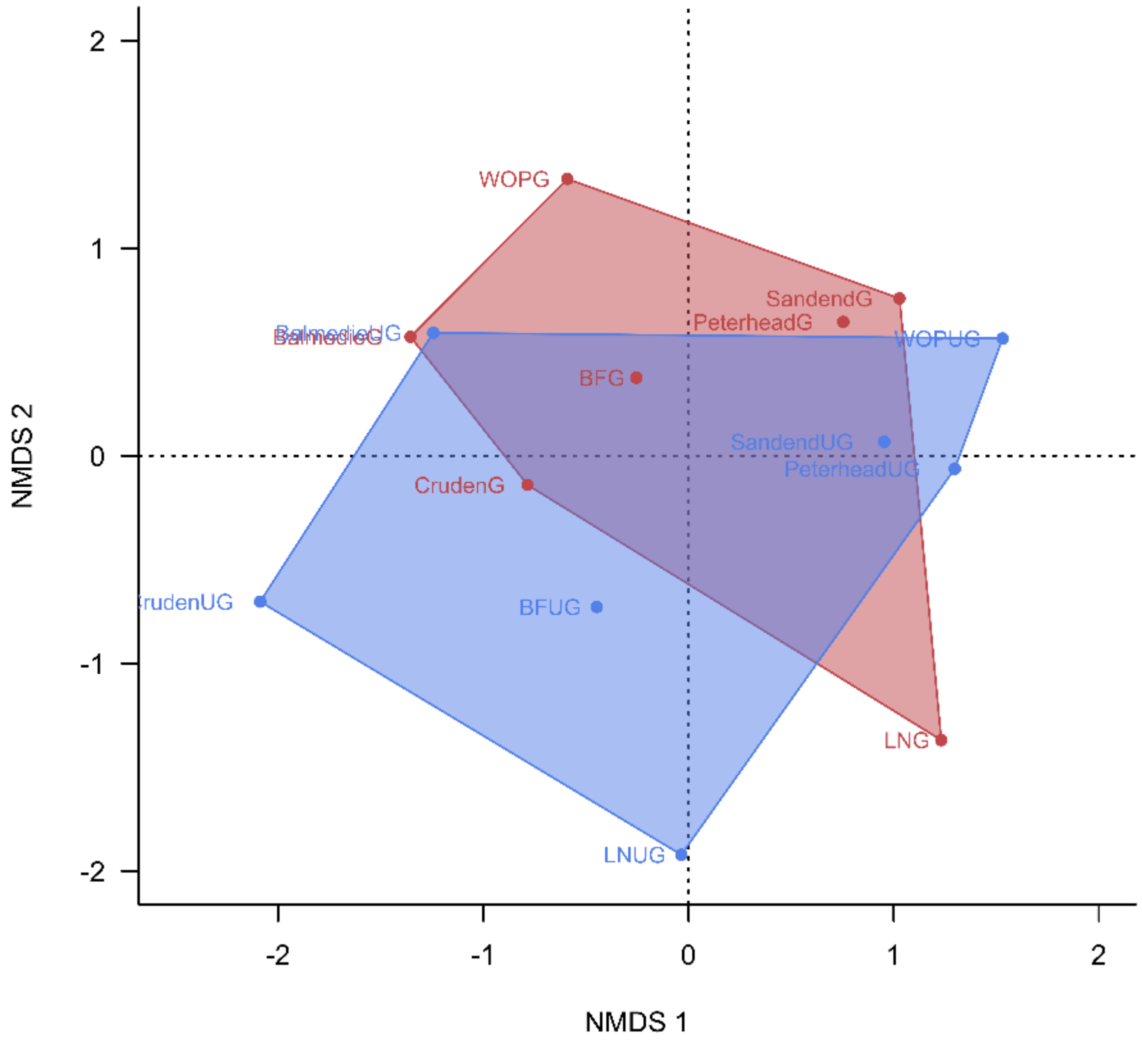

Figure 15: Non-metric multidimensional scaling ordination (NMDS) plot for mean adult plant species composition on groomed (red hull) and ungroomed beaches (blue hull). All stress values <0.2. Red and blue coloured hulls represent 95% confidence intervals around groomed and ungroomed centroids. Red dots represent groomed beaches and blue dots represent ungroomed beaches.
(G = groomed, UG = ungroomed, LN = Long Niddry, WOP = Waters of Philorth, BF = Broughty Ferry)

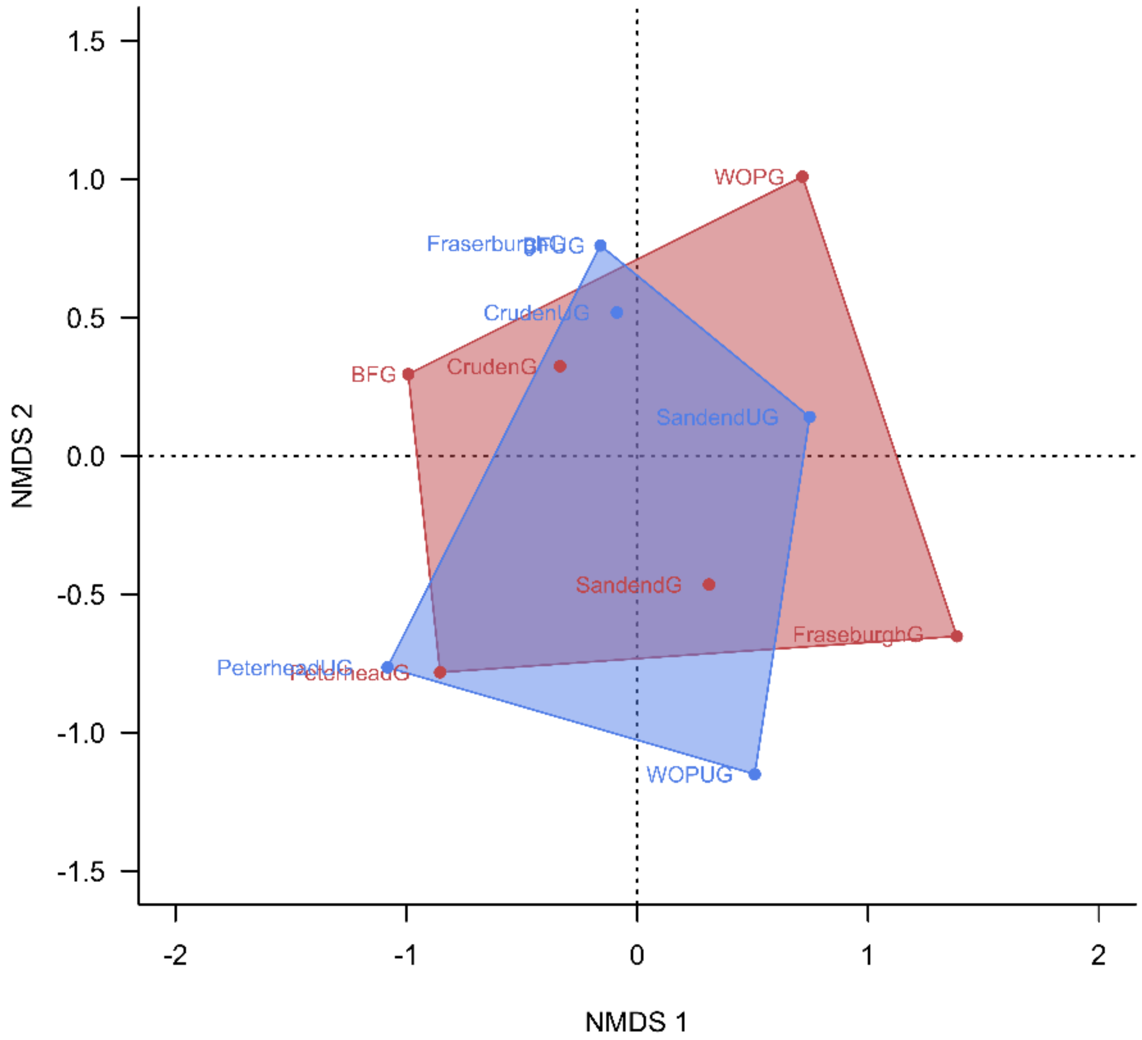

Figure 16: Non-metric multidimensional scaling ordination (NMDS) plot for mean seed bank species composition on groomed (red hull) and ungroomed beaches (blue hull). All stress values <0.2. Red and blue coloured hulls represent 95% confidence intervals around groomed and ungroomed centroids. Red dots represent groomed beaches and blue dots represent ungroomed beaches.
(G = groomed, UG = ungroomed, WOP = Waters of philorth, BF = Broughty Ferry)

3.7 *Discussion.*

The importance of stranded wrack for the development and stabilisation of sand dunes has been well-documented in the past (Crawford, 2008; Chapman 1976). The seaweed which remains stranded on the beach after high tide is a vital part of the coastal ecosystem. It provides a ready supply of nutrients and helps to build and stabilise the dunes. Removal of the wrack by mechanical beach grooming has been associated with significant alterations in the cover, distribution and abundance of coastal vegetation on beaches in California (Dugan, 2010). Differences in recruitment to the local seedbank were also seen between groomed and ungroomed beaches. The aim of this study was to assess the impacts of mechanical grooming on both the vegetation and the seedbank composition of sand dunes in Scotland by comparing groomed and ungroomed sandy beaches on the east coast. Results show a difference in both the adult plant and seedbank species composition and richness on groomed and ungroomed beaches. The greater the depth of the seaweed found on the beaches, the greater the species richness and abundance of plants found on the dunes.

Adult plants: Grooming, wrack depth and exposure were all seen to influence the number and diversity of adult plants found on sand dunes. The greater the wrack depth, the greater the species richness and abundance of the adult plant community. The exposure level of the site was also seen to influence the plant community composition, with the least exposed beaches found to have the highest plant abundance and species diversity. This is to be expected, as beaches which are more sheltered provide a less harsh environment for these dunes to develop and for any plants growing there to survive. (Crawford, 2008).

Tidal range and aspect were not seen to significantly affect the community composition. The tidal range in Scotland does not differ greatly between locations and so it was not expected that these small differences would have an effect. The aspect of the beach is the compass direction that it faces and it can have a strong influence on temperature: for example, a south-facing beach will be warmer than a north-facing beach. It appears that exposure is more important for dune plants than aspect on the sites in this study. The results from the NMDS suggest that the difference between groomed and ungroomed beaches is not a huge one, but that there are some differences in species composition and this may impact other aspects of the beach ecosystem. Some of the plants which are missing from the groomed beaches may be rare or unusual species which provide an important niche for an invertebrate or other species. Likewise there may be opportunist species which can thrive on the groomed sand dune environments and alter the species composition by outcompeting other less robust species.

Seedbanks: Results from the seedbank show that wrack depth is the only factor which positively affects the number of species found in the seedbank. Tidal range, aspect, exposure and grooming are not seen to significantly affect the community composition. As the wrack depth increases, so too do the number of species. This implies that removal of the wrack is having a negative impact on the seedbank. Exposure, tidal range and grooming are not seen to significantly affect the germination of seedlings in our experiment, although if the seeds were left to germinate out on the beach and not in a greenhouse environment, they could be influenced by these other environmental factors. Similarly to the adult plants, the NMDS plots show that, although there is not a huge difference in species composition and although there is some overlap of species, there are some differences in species composition and this could have impact on other aspects of the beach ecosystem. The seedlings which develop and grow on the groomed sites may be opportunistic and may influence aspects of competition, outcompeting rarer, less robust species.

3.7.1 Limitations of this study.

There are numerous limitations and difficulties associated with this study which are problematic to improve upon but which should be mentioned here for clarity. Any future work should attempt to take these into consideration.

Proximity of study beaches: In order to accurately compare groomed and ungroomed beaches, it was necessary to use a beach which had both groomed and ungroomed sections. If a groomed section of one beach was compared to an ungroomed beach close by, there would have been so many other variables that it would have been difficult to accurately compare impacts of grooming. This resulted in groomed and ungroomed transects being located right next to each other. Without further investigation of how nutrients are transported within the sand it is impossible to say that nutrients from the ungroomed section are not getting through to the groomed section and acting as a fertiliser to the plants that grow there.

Greenhouse conditions: The seeds that were collected during the seedbank sampling may not have all germinated because of the conditions in the greenhouse, or more may have germinated than would have done on the beach. Although every attempt was made to replicate as closely as possible the conditions suitable for germination, a seed tray in a hot, still greenhouse is not an exact replication of conditions on an exposed, windy beach. This could result in an underestimation or overestimation of the number of viable seeds present in the seedbank. An alternative approach to this experiment is the seedling emergence method, which sieves the sand using a fine enough mesh size to catch the seeds. The seeds are then collected and the concentrated sample is spread over trays of compost. Although time-consuming, this method is reported to have germination rates between 81 and 100% of the viable seeds present (Ter Heerdt, 1996). For our study, this method was too labour-intensive and time-consuming, but is worth considering for any further work in addition to an experiment located in a beach environment.

Limited sampling locations: It was very difficult to find beaches that had sections which were both groomed and ungroomed, hence the low number of sites sampled. However, it would have been even more difficult to find groomed beaches with a suitable ungroomed beach directly adjacent to it, which displayed the same physical characteristics. The sample numbers were very low for this study, and it is suggested that any further work could incorporate more sample sites and possibly venture to other countries where grooming also occurs.

3.8 *Conclusions*

These findings are in line with results from Dugan (2010) and also comparable with findings from Chapter 1 of this thesis. The results suggest that grooming could be having a negative impact on other aspects of coastal ecosystems and further work into this area is encouraged. The lack of understanding about how grooming affects all aspects of the beach environment, coupled with the numerous additional environmental factors which inevitably arise when working in a coastal environment, make it exceptionally difficult to scientifically recognise the impacts that mechanical grooming has on beaches.

There are relatively few examples of scientific literature which observe impacts of mechanical beach grooming on the coastal environment. Grooming has been shown to have an impact on the biodiversity of invertebrates in the strandline (Gilburn, 2012; Llewellyn and Shackley, 1996) and Dugan (2010) has observed how grooming impacts dune vegetation on Californian beaches. Due to the findings of this and previous studies, it would be prudent to carry out further work to establish any other impacts that grooming may be having on the coastal environment. With increasing pressure from climate change and therefore sea-level rise, beaches all over the world are at greater risk from erosion (Feagin, 2007). Sand dune vegetation is an essential way to halt and prevent erosion and any threats to the plants growing on the dunes should be fully understood. Concerns about climate change, coupled with the current political climate and the uncertainty regarding European environmental legislation suggests that a precautionary approach to beach management is important. Further study into the impacts of grooming on the entire coastal ecosystem and how this may interact with differing environmental conditions is therefore advisable.

Chapter 4: A Choice Experiment to assess the significance of Beach Awards in Scotland.

Abstract

Managers of popular tourist beaches in Scotland often try to attain a Beach Award in order to attract more tourists to their beaches. Assurances of good bathing water quality, facilities such as shops, café's and toilets, and the promise of clean litter free sand are used as a marketing tactic to try and attract tourists so that they spend some money in the local area. However, it is uncertain whether beach users are actually attracted to a certain beach by these awards, or even if they fully understand what the awards represent. A stated preference choice experiment was carried out to investigate the significance of Beach Awards to beach users and to determine the willingness to pay for different beach attributes. Results indicated that people are not willing to pay for Beach Awards and are most willing to pay for high levels of biodiversity and high levels of Bathing Water Quality. Respondents were willing to pay more for litter only to be removed from the beach rather than litter and seaweed, which suggests that seaweed is not seen as a negative beach attribute and that beach managers need not mechanically groom their beach. It is suggested that Bathing Water Quality should not be included in the criteria of Beach Awards, and that the introduction of real time information via electronic signage and an App would be much more beneficial to beach visitors. Educational posters and infographics should also be made available at beaches to explain the importance of leaving stranded seaweed where it is, instead of grooming the beach with mechanical equipment.

4.1 *Introduction*

Many popular tourist beaches in Scotland, and indeed the rest of Europe, often try to attain a beach award in order to try and attract more tourists to their beaches. Local council beach managers believe that Beach Awards are a major pull for tourists and that a beach award will help to generate income for the local economy (McKenna *et al*. 2011, Nelson *et al*. 2000). The promise of high levels of water quality, facilities such as cafés, toilets and shops and the promise of clean sand which is free from litter are used as a marketing tool to try and entice tourists to spend money in the local area. However, there is increasing evidence in the literature that that beachgoers are attracted to clean water, litter-free sand, wildlife, or location, rather than the facilities on offer (Tudor & Williams, 2003; McKenna *et al*.; 2011 Nelson *et al.* 2000).

Beach Awards often have very strict criteria which must be adhered to in order to achieve the award status. Two types of award are found in Scotland, the European Blue Flag and the Seaside Award. The European Blue Flag is a worldwide initiative aimed at "raising environmental awareness and increasing good environmental practice amongst tourists, local communities and beach marina operators" (FEE, 2016). Blue Flag beaches must adhere to 26 specific criteria including Bathing Water Quality, Environmental education and information and Environmental Management. It was introduced in 1987 and is acknowledged in 41 countries around the world. It is administered in Scotland by Keep Scotland Beautiful on behalf of the Foundation for Environmental Education.

The second type of award found in Scotland is the Seaside Award. The Seaside Award was introduced in 1992 by the Tidy Britain Group, an independent but partly government funded organisation (Nelson *et al*. 2000). This award scheme runs only in Scotland, Wales and Northern Ireland and allows for the high degree of variation found around the Scottish coastline, being divided into both resort and rural categories. The main difference between resort and rural beaches is that resort beaches are encouraged to offer facilities such as toilets and cafés, shops and playgrounds.

In 2012 seven beaches in Scotland achieved Blue Flag status, the majority of these beaches are located in Fife. A further 56 beaches were awarded Seaside Award Status. Both the Blue Flag and the Seaside Award winners are under pressure to keep their beaches clean. This means that beach managers often take the decision to clear the stranded wrack from the beach using mechanical equipment even though this type of beach cleaning is advised against in the award guidelines. After phoning or emailing local councils, it was determined that many of the councils in Scotland currently clear the tourist award beaches on a regular basis, weekly or even sometimes daily. This is not recommended by the Blue Flag guidelines (FEE, 2016) and is likely to be having a detrimental effect on the beach ecosystem; the invertebrate populations, birds and sand dunes (Llewellyn *et al*.1996; Gilburn, 2012).

As a consequence of these detrimental effects, beach mangers are now interested in the public perception of Beach Awards and beach cleaning and their awareness of these issues. One such way of gauging public awareness is choice experiments. Choice experiments are an economic tool which can be used to try to value an environmental good or attach a value to unpriced services provided by the natural environment by finding out people's willingness to pay for those services (Hanley *et al*.1998). Choice experiments can be used to aid policy-making and improve regulation by enabling the economic value of the protection of ecosystem services to be determined. Previous studies using choice experiments have looked at potential improvements to coastal water quality which may result from implementation of changes to the European Union's Bathing Water Directive in 2015 (Hynes *et al*. 2013) and lake ecosystem management priorities in the United States and Canada (Smyth *et al.* 2009). This study used a choice experiment to investigate the significance of Beach Awards to beach goers and to determine willingness to pay for beach attributes. This choice experiment tries to answer the following specific questions:

1. Do people value Beach Awards?
2. How do people feel about litter & seaweed at the beach?
3. Do people value biodiversity?
4. Is bathing water quality important?

4.1.1 ***Theoretical framework***

The economic valuation carried out in both chapters 4 and 5 have a number of crucial assumptions from economic theory which form the basis for deriving theoretical and empirical nonmarket values.

a) Rationality

Rationality is the foundation of economic theory and implies that people will act in ways that best suit their particular set of circumstances, including the choices they face. In order to make a choice you have to have a set of preferences over the options you are presented with. This “utility theory” implies consumers are able to rank preferences and offers an empirical, logical structure to microeconomics (Sen, 1973). These Axioms of preferences are outlined below:

i) Completeness. Whether one is indifferent to, or prefers one set of options over another, they must always be able to make that choice. In other words an individual can always rank a set of possibilities as either better, worse, equal or at least as good/bad as another.

ii)Transitivity. Individuals are able to order their preferences in a logical way, i.e. if you prefer A to B and B to C you must therefore prefer A to C.

iii)Continuity. This refers to the fact that there are no “jumps” in people’s preferences and that if an individual prefers point A along a preference curve to point B, points very close to point A will also be preferred to B.

b) Substitutability property

Economists and ecologists both use the term “value” but in two different ways when discussing environmental services and ecosystems. Ecologists are usually referring to the fact that in nature many things have an intrinsic value i.e. its value is not derived from its utility, but is independent of any use or function it may have in relation to something or someone else (Callicott, 1989). Economists instead talk about instrumental value, meaning a thing which is valued as a means to some other end or purpose and are referring to something which would have an equivalent in money or commodities (Fisher, 1981). In the economists view, the value of something lies in its contribution to some other goal (Constanza and Folke, 1997).

The concept of intrinsic value as applied to the environment is an acceptable way of valuing the environment, it does not provide a way of dealing with problems of environmental management, whereas the instrumental concept provides an effective tool for managers of environmental systems. The basic principles of welfare economics are that the purpose of economic activity is to increase the well-being of the individuals who make up society and that each individual is the best judge of how well off he or she is in a given situation. (Freeman et al, 2014). The standard economic theory for measuring changes in individual's well-being is based on the assumption that people have well-defined preferences among alternative bundles of goods, where bundles consist of various quantities of both market and non-market goods. If the quantity of one element in an individual's bundle is reduced, it is possible to increase the quantity of some other element so as to leave the individual no worse off because of the change. This is referred to as substitutability and is at the centre of the economist's concept of value because it establishes trade-off ratios between pairs of good that matter to people. The trade-offs that people make when they substitute more of one good for less of another reveals information about the values people place on those goods. Even when monetary values are not available for these goods the trade-off ratios can be interpreted as expressions of economic values (Viscusi et al, 1991). Value measure based on substitutability can be expressed in terms of either willingness to pay (WTP), or willingness to accept (WTA) and these measures can be defined in terms of any good that the individual is willing to substitute for the good being valued.

4.2 *Methodology; Discrete Choice Experiments*

Discrete choice experiments (DCE) as described by Louviere *et al*. (2000) and Hensher *et al*. (2005) are part of a wider collection of valuation techniques, known as stated preference methods. This group also includes Contingent Valuation (CV) which was originally proposed by Ciriacy-Wantrup, (1947). The choice experiment works by defining a good (in this case Beach Awards) in terms of its characteristics or attributes, which can take a number of different and often hypothetical levels. Choice experiments have been in use since the 1970s (Green & Srinivasen, 1978, 1990) but have become increasingly popular in the field of environmental economics in the last ten years, previously being used mainly in market research (Carson *et al*., 1994).

The choice experiment can be carried out in person, via post or increasingly commonly via the internet. Respondents are given a series of hypothetical choices in the form of a choice card (see Figure 17). Each alternative choice offers a different combination of the attributes on offer and the respondent has to make a decision about which combination of those choices (attributes) they would prefer.

The attributes which are significantly influencing respondent's choices are indicated and the trade-offs and willingness to pay for these different attributes can be calculated. Analysis of the data is based on the random utility model (McFadden, 1974). The respondents' willingness to pay for attributes and the trade-off rates between different attributes can be determined from the choices respondents make on the choice cards.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award?	Award	Award	No Award
B. The extra cost on your council tax for this beach would be £	£40	£25	No extra cost
C. Litter management practice	Remove both litter and seaweed	Remove only litter	Remove neither litter nor seaweed
D. Level of water quality	Very little risk	5% risk	10% risk
E. Diversity of birds on the beach and health of the dunes 	High numbers of many different species of birds and healthy dune systems. **High biodiversity**	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**
Please pick the ONE option you prefer	☑	☐	☐

Figure 17: Example choice card used in the pilot study and full survey.

According to the random utility model, the indirect utility function for each respondent *i* (*Ui*) consists of two additive and independent parts: a deterministic part (*V*) which is determined by the attributes of the alternatives in the choice experiment and characteristics of the respondent, and a stochastic part (*e*) which represents unobservable influences on individual choice:

Equation (1)

$$U_{ij} = V_{ij}(X_{ij}) + e_{ij} = \beta_{ij} X_{ij} + e_{ij}$$

Where β_{ij} is the utility weight associated with attribute X_{ij}. Individuals are assumed to compare all of the alternatives *j* in each of the choice cards and choose the alternative which yields the highest utility. The probability that any particular respondent prefers option "g" in the choice set to any other option "h", can be expressed as the probability that the utility associated with option "g" exceeds that associated with all other options:

Equation (2)

$$P[(U_{ig} > U_{ih})\forall g \neq h] = P[(V_{ig} - V_{ih}) > (e_{ih} - e_{ig})]$$

If the random term is assumed to be independent and identically distributed (IID) extreme value type I across individuals, alternatives and choice cards, the multinomial logit (MNL) model can be used to estimate the parameters of *V* (McFadden 1974). In the MNL model, these β parameters are not individual-specific, since a single β value is estimated for each attribute. This represents the average preference, or marginal utility, for any attribute across the sample of choice data unfounded by a scale parameter.

Because preferences are not homogenous, we need to account for unobserved taste heterogeneity across individuals (Hynes *et al.* 2008). The latent class (LC) model extends the MNL model by relaxing the assumption that observations are independent, and allowing the β parameters to vary across individuals (Hynes *et al.* 2013). The LC model assumes the existence of latent heterogeneous groups within the sampled population, membership of which is determined by observed characteristics of respondents. Within each group or latent class, a single β value is estimated for each attribute. Joint estimation of group membership parameters and utility parameters allows one to relax the assumption that observations are independent (Boxall & Adamowicz 2003) and thus allows for error correlation.

Willingness to pay for a particular attribute can be obtained by dividing the β parameter for an attribute by the β parameter for the price attribute which then gives us the marginal utility associated with an attribute in the form of a price. This price shows us peoples' preferences and how much they are willing to pay to obtain or avoid a particular attribute. This can also be used as a relative and an absolute indicator of value as they can show at what rate people are willing to trade off a less desirable attribute for more of an alternative desirable attribute (Boxall & Adamowicz 2002). Another technique for accounting for preference heterogeneity is the Random Parameter Logit model (RPL). This has not been used in this study due to a previous study (Hynes *et al*. 2008) that showed that the LC approach offers a better solution to the problem of understanding heterogeneity of preferences and is suggested as providing more useful information for natural resource managers.

According to the conditional logit model, eliminating a beach site would cause visitors to redistribute themselves across the remaining beach sites in a way which leaves the relative probability of visiting those sites unchanged. This is known as the Independence of Irrelevant Alternatives (IIA) assumption. Some people think that this is possibly an unreasonable assumption and a test for IIA was developed by Hausman and McFadden in 1984. Simulation studies by Fry and Harris (1996, 1998) and Cheng and Long (2006) have shown the Hausman-McFadden test to perform poorly and declared that this test for the IIA assumption is unsatisfactory and irrelevant for applied work. It has therefore not been included in this study.

4.3 *Survey design*

The main aim of this choice experiment was to discover the valuation of features found at tourist beaches on the East coast of Scotland. The group of respondents selected were people living at or near to the coast and therefore those most likely to have a vested interest in how their local beaches are managed. The respondents for the choice experiment were randomly selected from the Electoral Register and contacted via mail. In total 2000 households were contacted from 11 different counties on the east coast of Scotland. Addresses were known, but prior to the survey no information on gender, age, income or occupational status were known. A postal survey was chosen due to both financial and time constraints. A postal survey would enable a geographically wide range of people to be reached and would be both faster and more cost effective than face to face surveys either in a workshop format or simply asking visitors on the beach. The postal survey also allowed for non- users of beaches to be included. These people may also have valid responses to the survey as they may have passive-use values which would otherwise be missed. This was also why the travel cost method was not used for this particular study.

The choice attributes were selected because they had been shown to be of most interest to visitors in previous studies (Hynes *et al*. 2013) and also in focus groups carried out within the University of Stirling. Focus group trials were carried out on 20 people prior to the final choice card design. This helped us to understand how informed people were of the various attributes involved and therefore how much detail was needed in the questionnaires. A range of socioeconomic questions were also included in the pilot survey to gauge which were influential on the choices made. The pilot survey was posted out to 50 people at random addresses taken from the electoral register. A 20% response rate was achieved and provided valuable information on how suitable the questionnaire was for respondents. Following these two trials the final attributes chosen were: Beach Awards, price, litter management, health risk and wildlife and the environment. A D-efficient design with 2 blocks and a total of six choice cards was chosen. The respondents were asked to choose their hypothetical “favourite beach” from the different beaches on offer on the choice cards. The full surveys are included in Appendix B and C and the design syntax can be found in Appendix E.

4.3.1 Health Risk (Water Quality)

The water quality of bathing waters is arguably an important criterion for any beach which wishes to attract tourists. Visitors to the beach need to know that they can safely enter the sea without fear of serious illness or the inconvenience and upset of minor gastrointestinal infections. There are a number of ways that a potential visitor to a beach can find out about the water quality of their chosen beach. The Good Beach Guide is a publication and website produced by the Marine Conservation Society (MCS) which lists beaches which have achieved their MCS recommended grade. Samples are taken from the water during the bathing season (June –September in Scotland) once a week and are tested for bacteria (total and faecal coliforms) which indicates the presence of pollution from sewage. The beach must then meet the legal minimum ‘mandatory’ standard which must be achieved by 95% of the samples taken (Marine Conservation Society, 2013).

If a beach has a Beach Award then it is guaranteed that the beach has attained a certain level of water quality. Blue Flag beaches must meet the legal ‘excellent’ standard as stipulated under the European Bathing Water Directive (2006/7/EC). The beach must also fully comply with the water quality sampling and frequency requirements. If a beach has a Seaside Award (either resort or rural) then the beach must have attained at least the mandatory standard as outlined in the Bathing Water Directive (2006/7/EC). The results of the current season’s water quality monitoring and the standards of the previous three years must be posted. These two awards have different criteria to meet due to their very different nature but the water quality standards are the same for both.

This study had to take into account the fact that bathing water quality and Beach Awards are linked. In order to get an award a beach has to have achieved a certain level of bathing water quality. Results from previous studies have found that there is a lack of awareness and some levels of confusion from members of the public about what criteria are included in the awards (Nelson *et al*. 2000, Buckley, 2002). To account for this we kept the two attributes of Health Risk and Beach Awards separate and did not mention any link between them in the survey questionnaire. By doing this we were relying on respondent’s previous knowledge about these two attributes to make their decisions, thereby reflecting how they would make those choices in real life.

An additional problem for the study is that of bathing water quality being reported from the previous year’s samples. Samples are collected every 30 days from each beach during the bathing season (May to September) and the award is presented depending on the previous year's results. Therefore the bathing water quality is not being reported in real time. Again this was not brought to the respondent's attention and we relied upon their knowledge (or lack thereof) about this information. Water quality was explained to respondents as how much of a risk it would be to swim/paddle or take part in water sports in the sea with three given levels of water quality. The respondents were asked to choose which of these they would be willing to accept in combination with the other attributes on offer. The three levels of health risk were as follows**:**

10% Risk - Sufficient Water Quality. This is the highest level of risk a beach is permitted in order to still achieve status as a designated European bathing water. There is a 10% risk of stomach upsets or ear infections.

5% Risk – Good Water Quality achieved with a somewhat reduced risk of stomach upsets and ear infections generally although still a risk in particular to vulnerable groups such as children.

Very Little Risk - Excellent Water Quality achieved with a larger reduction in the risk of stomach upsets and ear infections.

4.3.2 Beach Awards

As discussed above, in Scotland two different levels of award can be given to beaches. Beach Managers can apply for these awards if their beaches meet the specified criteria. It is a desirable feature for a beach to have an award as beach managers believe that they attract larger numbers of tourists. In the Choice

Experiment we do not specify which award the beach hypothetically has in order to keep it simple for the respondents. There are just two options:

The beach has an award

The beach has no award

4.3.3 Litter Management

Litter management and its removal can be a huge problem for beach managers and is specified as a requirement for both types of award. The Blue Flag criteria states that “the beach and surrounding areas must be clean and maintained at all times. Litter should not be allowed to accumulate causing these areas to become unsightly or hazardous”. The criteria does advise that beach cleaning can be either mechanical or manual depending on the beach but that mechanical cleaning should be done only occasionally. Many of the beaches studied in this PhD have seen mechanical beach clearing carried out as a normal management tool on a regular or very regular basis either currently or in the recent past.

The respondents are informed about the different types of litter management available, i.e. mechanical grooming and hand picking then three options are given:

Litter is removed

Litter and seaweed are removed

Nothing is removed

4.3.4 Wildlife and the environment (Biodiversity)

Mechanical grooming has been shown to reduce levels of biodiversity found on Scottish sandy beaches (Gilburn, 2012). Biodiversity however is a fairly difficult concept for members of the public to grasp. Biodiversity was explained here as "the number of different plants and animals found in the environment". We then used the numbers of different bird populations and health of the sand dunes as a way to measure levels of biodiversity. We asked the respondents to consider 3 different levels:

a) There has been major disruption to the natural environment, loss of bird populations and sand dune erosion. Low levels of biodiversity

b) Disruption to the environment is reduced but bird and dune plant numbers are still likely to be affected to some extent. Moderate levels of biodiversity

b) Healthy bird populations and dune systems. High levels of biodiversity

4.3.5 Cost

The final choice needed in the Choice Experiment is the cost attribute. This is required in order to estimate measures of economic benefit from changes in the non-monetary attributes above. The cost of managing beaches is mainly met by the public through their council taxes and therefore it was felt that this would be a suitable method of estimating respondent's willingness to pay for the 5 attributes. This method has also been used successfully in a number of other studies (Garrod & Willis 1998; Luisetti *et al*. 2011; Wardman & Bristow 2004). Although potentially some of the respondents may not pay council tax, it was important to find a payment vehicle that was easy to understand. Most people would understand the concept of paying extra money on top of their council tax, even if at present they don't pay any themselves. It was decided not to use per visit travel cost which has been successfully used in other choice experiments because many of the respondents may not actually need to visit a particular beach to gain the benefit and environmental services that the beach has to offer. Simply knowing that it is being managed in a certain way may be enough. We asked how much extra people would be prepared to pay per year on their council tax towards beach management, if they could be certain that any increase would indeed go to better beach management. The options were:

No extra cost. Beach management is either non-existent or at such a level that it does not lead to an increase in council tax.

An increase of **£5** per year is added on to the council tax

An increase of **£10** per year is added on to the council tax

An increase of **£25** per year is added on to the council tax

An increase of **£40** per year is added on to the council tax

Choice questionnaires were sent out in June 2014. 2000 in all were posted to randomly selected addresses from the electoral role within council areas on the east coast of Scotland (Figure 18). A cash incentive was included of the chance to be entered into a draw to win a £100 Amazon voucher. This was hoped to increase the response rate. 161 useable responses were received, once they had been checked for protest votes and any partially or incorrectly completed scripts had been removed. Along with the choice cards, respondents were also asked a series of questions about their income, education, occupation and other household characteristics to try and evaluate whether socioeconomic variables affects the choices they make.

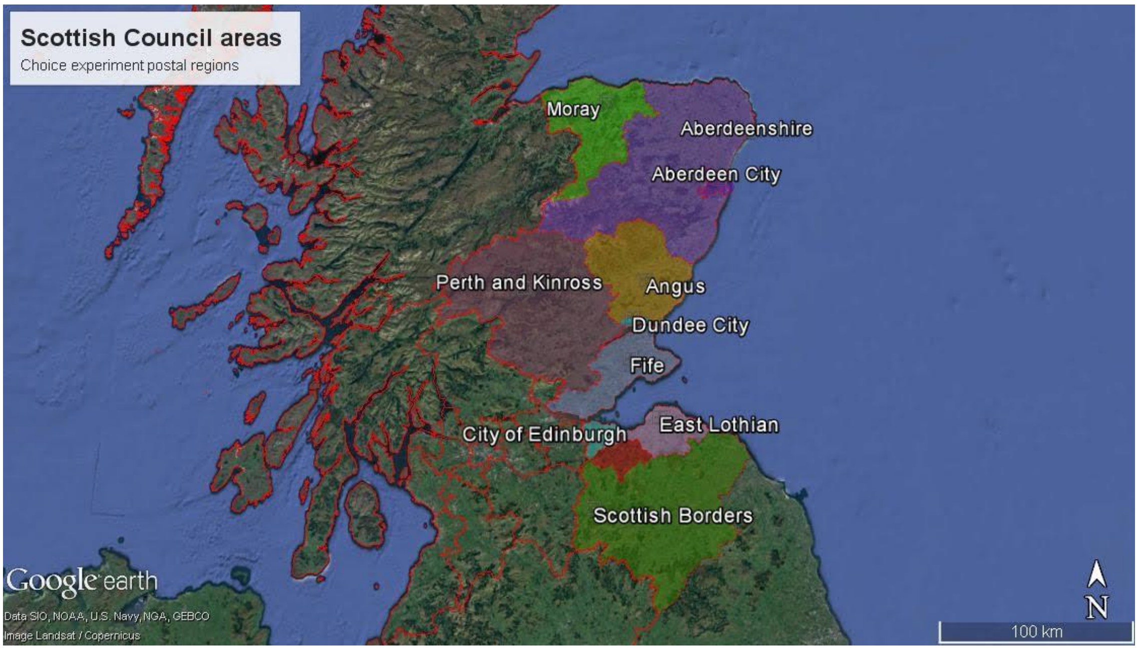

Figure 18: Council regions used in the postal survey

4.4 *Results*

4.4.1 Sample characteristics

The total number of respondents was 180 out of a total of 2000 questionnaires posted out. Once incorrectly filled out questionnaires (and those returned as the addressee moved, was deceased or for another unknown reason) were removed, 161 useable questionnaires remained. This is a relatively low number as the expected response rate seen in other choice experiments (Wattage *et al*. 2011, Jobstvogt *et al*. 2014) is between 10% and 20%. A follow-up reminder letter is one way of helping to improve the response rate of postal choice experiments but due to financial constraints this was not possible for this study. Table 7 presents some summary statistics for the sample. The socio-demographic data revealed that the sample was not representative of the Scottish population as a whole (Scottish Executive, 2004). The largest age group in our sample was the group age 50+ which made up 73% of our respondents. In the wider population this age group makes up only 14%. There may be some sampling bias here which can be attributed to the fact that coastal populations were sampled and often these areas tend to have larger numbers of pensioners and retired people who have moved out of towns and cities to retire by the seaside (Atterton, 2006). The next largest age group consisted of those aged between 30-49 and made up 22% of the population. The younger age groups (under 18 and 18-29) were underrepresented in this study with just 0% and 1.3% respectively. These type of postal questionnaires often are biased towards older respondents as these are people who have a lot of time available and are therefore more likely to fill out and respond to the questionnaire. Of those questioned, 27% were members of a conservation body such as (RSPB, WWF or national Trust). This figure is very high compared to an estimation of environmental group membership in the UK population in 1999 of 1.5% (Dalton, 2005) and suggests that there may be a selection bias. People may be more likely to fill out a survey about conservation and environmental issues if they are already interested in the subject. The question was asked to try and determine whether people who have an interest in wildlife and conservation may be more inclined to answer positively to the biodiversity choices.

Table 7: Sample summary statistics

Variable	**Category**	**Percentage of respondents**
Sex	Male	46
	Female	53
Age	Under 18	0

	18-29	1.3
	30-49	22
	50+	73
Education	School	17
	College	34
	University	49
Income	Under £15,000	18
	£15,000-£30,000	30
	£30,000-£50,000	25
	£50,000-£75,000	16
	Over £75,000	10
How many Children live in your household?	0	75
	1	10
	2	9
	3	4
	4	1
Do you own a dog?	Yes	29
	No	71
How many adults live in your household	1	26
	2	60
	3	13
	4	1

Results from a simple Multinomial Logit (MNL) Model can be seen in Table 8. All attributes apart from Price were Dummy coded. Table 8 shows that all environmental variables are positively valued by respondents, are statistically significant and show positive scale effects. This means that “high biodiversity” gives a higher increase in utility than “moderate biodiversity”, and a “10% health risk” gives a lower level of utility than a “5% health risk”. Litter Management 1, which is the removal of only litter from the beach, is more highly valued than both litter and seaweed being removed from the beach or neither being removed. Beach Award is not significantly different from zero, indicating that respondents’ utility does not increase when awards are present at a beach. The Pseudo R^2 value for the estimated model is 0.19 which is a fairly low value. Values between 0.2 and 0.4 are generally considered to be a decent fit (Hensher *et al*. 2005) but Can and Alp (2012) argue that there are many cases in the literature having values as low as the 0.07. It is therefore acknowledged that our value is within an acceptable range. The willingness to pay (WTP) estimates show that respondents were more willing to pay for high levels of biodiversity and low levels of litter. The award coefficient had a very low WTP value.

Table 8: Attribute coefficients and Willingness To Pay (WTP) estimates for the Multinomial Logit (MNL) model.

Variable	Coefficient	WTP
Award	0.040 (0.607)	1.74
Price	-0.023 (0.005)*	
Litter management 1 (only litter)	1.191 (0.103)*	50.96
Litter Management 3 (remove litter & seaweed)	1.081(0.149)*	46.27
Health risk 10%	-0.598 (0.095)*	-25.56
Health risk 5%	-0.226 (0.979)*	-9.66
Biodiversity moderate	1.011 (0.152)*	43.23

Biodiversity High	1.449 (0.111)*	61.97
Log Likelihood Function	-855.784	
Pseudo R^2	0.1873	

Notes: Figures in parenthesis indicate the values of the standard errors

*Indicates significant at 1%

Table 9 show results from a latent class model, with two latent classes being identified. Latent class modelling provides the ability to both understand and incorporate preference heterogeneity in choice experiment analysis (Boxall & Adamowicz, 2002). The model splits the data into two or more latent heterogonous groups or classes depending on observed characteristics of respondents. A single β value is estimated for each attribute. The model was estimated using 2, 3 and 4 classes and a 2-class model was seen to fit the data best (see Table 9). This was based on several criteria including the BIC and AIC statistics. The LC model allocated 69% to class one and 31% to class two. Respondents in class 1 show a stronger preference for high levels of biodiversity whereas respondents in class 2 have preferences for litter management and bathing water quality. In class 2, price is negative and not significant, indicating that class 1 have stronger price sensitivity. Respondents in class 1 have a stronger preference for high levels of biodiversity and interestingly individuals in class 1 also have a higher probability of having attended University. These people therefore may have a greater understanding of biodiversity and why it is important.

Respondents in class 2 show a stronger preference for litter management and bathing water quality. These individuals have a higher probability of being members of a conservation group such as the RSPB or the WWF. Again, these people may be more aware of beach management issues, either because they spend more time outside observing wildlife or walking etc. or they may read about these issues in newsletters and conservation magazines which the groups provide as part of their membership. Income was surprisingly found to not be significant even when price was constrained in the model. This may mean that income is correlated with education level. This could be studied in greater detail during any further studies of this data.

Table 9: Latent class (LC) model (2 classes).

	Class 1	WTP	Class 2	WTP
Variable				
Award	0.0356 (0.114)	0.85	0.345 (0.123)*	8.22
Price	-0.042 (-0.007)**		-0.001 (0.006)	
Litter management 1	1.126 (0.143)**	26.81	2.074 (0.222)**	9.34
Litter Management 3	0.545 (0.209)*	12.98	2.426 (0.280)**	53.40
Health risk 10%	-0.510 (0.130)**	-12.14	-0.669 (0.158)**	-15.92
Health risk 5%	-0.073 (0.164)	-41.38	-0.256 (0.160)	-6.10
Biodiversity moderate	1.288 (0.245)**	9.07	0.850 (0.202)**	20.24
Biodiversity High	1.813 (0.174)**	43.17	0.823 (0.154)**	19.60
Average class probabilities	0.69		0.31	
Conservation Group	-0.975 (0.481)*			
University educated	0.871 (0.374)*			
Constant	0.700			
McFadden Pseudo R-squared	0.245			
Log Likelihood Function	-796.494			
Pseudo R^2	0.244			

AIC	1.701
BIC	1.803

Notes: Figures in parenthesis indicate the values of the standard errors

**Indicates significant at 1%
*Indicates significant at 5%

4.4.2 Survey follow-up questions

The survey follow-up questions revealed that the majority (72%) of respondents found Beach Awards to be unimportant when making their choices. 81% of respondents agreed that biodiversity was an important factor in their choices. Litter management was also seen to be important in respondents' decisions with 84% finding this significant when making their choices. 77% found health risk to be important for their choices. Only 50% found cost to be an important aspect to consider when making their choices. This indicates that 50% of respondents paid no attention to cost. This suggests that some people ignored the cost aspect of the choice cards which led to attribute non-attendance. This means that the assumption of unlimited substitutability between the attributes does not hold true in this case. The respondents are expected to make trade-offs between the five different attributes and should choose their most preferred alternative from the choice set (Scarpa *et al.* 2009). This attribute non-attendance poses a problem when analysing the choices as they then cannot be represented by a conventional utility function. In order to account for this we constrained the price parameter in the latent class model.

4.5 ***Discussion***

The aim of this study was to investigate the significance of Beach Awards to beach goers and used the choice experiment method to estimate respondents' willingness to pay for different beach attributes. The multinomial logit model has demonstrated a coefficient for Beach Awards which was not significantly different from zero which indicates that people are not willing to pay for Beach Awards and that they are not seen as a reason to visit a particular beach. Respondents are most willing to pay for high levels of biodiversity to be present at the beaches they visit. Respondents are willing to pay for litter only to be removed from the beach rather than litter and seaweed or neither. This is an interesting result and implies that beach grooming is something that people do not want on their beaches and would instead prefer an alternative type of litter management such as litter picking by hand. This may also be a cheaper option for managers as the cost of using mechanical clearing equipment is extremely high. Some managers use people on community service to clear the beach (Dundee council) which would also help to reduce the cost. This result also suggests that people may be aware that seaweed is part of the biodiversity of the beach. People's attitudes towards bathing water quality is considered in this study using the proxy of health risk. As would be expected the greatest health risk had a negative coefficient which reveals that people are willing to pay for good bathing water quality. They would gain utility from knowing that they can enter the water without the risk of becoming ill.

A latent class model found that a 2-class model fitted the data best. These 2 classes were found to be influenced by a number of different socio-economic variables, namely education and conservation group membership. Class 1 indicated a stronger preference for biodiversity and people were more likely to be in this class if they had attended university. This suggests that people with a higher level of education are more aware of what biodiversity is and also why it is important to maintain high levels of biodiversity at the beach. People in Class 2 were more interested in litter management and bathing water quality. These people were more likely to be a member of a conservation group, such as the RSPB or Scottish Wildlife Trust. Again, this result indicates that people who show an interest in conservation are aware of the negative impacts of litter and poor bathing water quality on beaches.

These results reinforce previous work carried out by McKenna, (2011) and Tudor & Williams (2005), who indicated that Beach Awards are not the main attribute a beach goer finds attractive about a beach and that it is purely incidental that the beaches with Beach Awards attract the most number of tourists. It has been suggested that other attributes, such as location, scenery, landscape quality, beach safety, water quality and possibly absence of sewage related debris and litter are what actually attract tourists to a beach and that the relevance of Beach Awards is questionable (Nelson, 2000). Bathing water quality is associated with Beach Awards as each beach has to achieve a certain level of water quality in order to obtain an award. These levels are not useful to bathers however, as they are obtained from the previous year's water quality data and therefore have very little significant information for the swimmer/paddler/surfer. An example of a much more useful way of providing this information to beach users is the Safer Seas Service which is supplied by the Surfers Against Sewage organisation. This is a national real-time water quality app which provides real-time information about bathing water quality. The service alerts water users when sewer overflows discharge untreated human sewage into the seas or when water quality is reduced by diffuse pollution. Unfortunately this service is only available at the moment in England and Wales but there are some electronic information signs provided by SEPA available at 23 bathing waters in Scotland. These provide daily predictions of water quality at the beach so beach goers can make a decision on whether they want to visit the beach or not. The results from this study would indicate that Beach Awards should not have bathing water quality as a criteria and that if Beach Awards are necessary they should be more concerned with litter prevention and the provision of certain facilities such as toilets and disabled access.

A further suggestion from the results of this study is that more education is needed about beach management. Posters and infographics could be made available at the beach explaining the importance of leaving stranded seaweed where it is, instead of grooming the beach with mechanical equipment. Some information about the importance of seaweed to the birds, invertebrates and dune plants could help people to understand why a less intensive approach to litter management is more appropriate to try and conserve the fragile beach environment.

There were a number of drawbacks to this study which could be improved upon in any future work in this area. Firstly the response rate was relatively low and fairly biased towards older respondents. This is to be expected when using a postal vote but may also result from the complexity of the questionnaire. Some people may have had difficulty understanding the questionnaire and this could be investigated further with more thorough focus group sessions and an increased numbers of pilot questionnaires sent out. A postal vote may not have been the best option and future studies could use the alternative methods of face to face interview, telephone interview or an internet-based approach. Unfortunately due to time and cost constraints postal questionnaires were seen as the best option for this study. This study only covered a somewhat limited area on the east coast of Scotland. It would perhaps have been more useful to cover the whole of Scotland, including inland residents or possibly extend the study to cover the whole of the UK. Unusually this study did not provide a 'status quo' or 'do nothing' option. These are usually included because one of the alternatives should always be in the respondents' feasible choice set so that the results can be interpreted in standard welfare economic terms (Hanley et al., 2001). This study does not have the option to include a status quo option as the beaches in question are all hypothetical and so the respondent has no knowledge of the current conditions of the beach. This is not of concern for the very reason that the beaches are hypothetical and therefore one of the alternatives will always be in the respondents' feasible choice set.

4.6 **Conclusions**

The most important finding from this study has been that people are not willing to pay for beach awards. This has implications for the beach award organisations and suggests that an alternative way of 'awarding' beaches or informing the public of the quality of their beaches should be found. The fact that people were more willing to pay for high levels of biodiversity and excellent bathing water quality suggests that the management of these beaches should aim for a more environmentally focussed approach to beach management. Importantly, people preferred to have only litter removed from their beaches rather than litter and seaweed and this is a clear message from the public that beach grooming is not an unwanted form of litter control. This research has provided valuable new information to the literature in this field and hopefully some useful guidance to beach managers on how they can manage their beaches in order to benefit both the beach visitors and the beach environment.

Chapter 5: Do the public value beach awards? A travel cost model of recreational demand for beaches in Scotland

Abstract

Coastal areas are the favoured holiday destination for European holiday makers and the coastal tourism sector generates a total of €183 billion in gross value added and employs over 3.2 million people. To try and attract more holidaymakers to their beaches, managers often try and gain a Beach Award. Beach managers believe that Beach Awards are a significant factor in beach users' decision making and that an award may help to generate income for the local economy. A number of previous studies have suggested that it is not the Beach Award which attracts the tourists but other attributes which are associated with the award such as clean water, litter free sand, wildlife and location. It is thought that Beach Awards may be little more than a management tool when competing for resources rather than a way to increase visitor numbers. In order to gain a Beach Award, many managers choose to groom their beaches with mechanical equipment to remove litter and seaweed from their beaches. Mechanical beach grooming and beach award status have been shown to be associated with low strandline biodiversity in Scotland. A Travel Cost model was carried out to try and understand how and why beach users are influenced in their decision to visit a particular beach. Coefficients for beach awards were not significant, suggesting that beach awards were seen to be unimportant both to local visitors and to holiday makers. The importance of bathing water quality was not seen to be significant and made no difference to number of trips taken by either holiday makers or local visitors. The absence of litter from the beach did make visitors more likely to make a trip to a certain beach. It is suggested that this study be carried out on a wider scale, incorporating the whole of the UK or

even Europe in order to try and get an idea on a larger scale of people's attitudes to beach awards and beach management in general.

5.1 *Introduction*

Coastal areas are the preferred destination for many holidaymakers throughout Europe and the coastal and maritime tourism sector generates a total of €183 billion in gross value added and employs over 3.2 million people (Queffelec, 2009). In Scotland domestic visits to seaside locations generate an average of 1.5 million trips, 6.5 million nights and £323 million per year (Visit Scotland, 2016). In order to attract more tourists to their beaches, managers in many parts of Europe often try to gain a beach award. Local council beach managers reason that beach awards are a significant factor in beach users' decision making, and that a beach award may help to generate income for the local economy (Nelson *et al*. 2000). Winners of beach awards must achieve certain standards in a variety of specified criteria such as water quality, litter, safety and general beach management practice. These awards can then be used as a marketing tool to try and attract tourists to the local area. However, previous studies imply that it is not the beach award itself that attracts the tourist but that the attributes associated with the award, such as clean water, litter free sand, wildlife and location which are the main attractions and that beach awards may be little more than a management template and a useful tool when competing for resources, rather than a way to increase visitor numbers (Tudor & Williams 2003; McKenna *et al.* 2011; Nelson *et al.* 2000).

Mechanical beach grooming and beach award status have been shown to be associated with low strandline biodiversity in Scotland (Gilburn, 2012).

Mechanical grooming involves removing litter and anything associated with it (such as seaweed and invertebrates) from the beach using a tractor and raking equipment. Gilburn found that beaches which had an award were found to be much more likely to be groomed (69%) compared to those that had no award (6%) and subsequently had a reduction in beach biodiversity. In Scotland, as of 2014, 63 beaches in Scotland had a beach award (61 held a Seaside Award and 2 held Blue Flag awards). Based on the work of Gilburn, (2012) there is a likelihood that Scottish beaches with a Seaside or Blue Flag award will have had a reduction in biodiversity due to the grooming practices used by beach managers to maintain the quality of the beach desirable for the beach award. Consequently, a concern for beach managers is now whether beach grooming should continue and if this stops, is there a potential impact on tourism due to the reduced likelihood in earning a beach award? This research aims to address one aspect of this beach management problem by investigating to what extent locals and tourists visiting beaches in Scotland are influenced by a beach having an award or not, specifically how much more likely are people to visit a specific beach if it has an award.

One possible method of exploring beach use in Scotland and whether a beach having an award influences visit rates is the travel cost method (TCM). The TCM is a revealed preference method for valuing non-market environmental goods, such as outdoor recreational activities including visits to the beach (Ward & Beal, 2000). It aims to convert the benefits people experience from recreation into monetary terms by using consumption behaviour in related markets. Although no entry fee is charged in the UK to visit environmental resources such as forests, national parks and beaches, the cost of travelling to one of these resources can be used as a proxy for a non-existent market price. The cost of travel to the beach is the implicit price that beach visitors pay in order to use that recreational facility. The relationship between the travel cost to the beach and the number of visits per year can then be used to produce a demand curve (Zhang *et al*. 2015). A beach visitor chooses to visit a certain beach because of specific attributes that beach has in comparison to others in the local area. These beaches differ not only in attributes (such as location, facilities and bathing water quality) but also in the cost to visit each beach. By modelling this demand for different beaches we can estimate the willingness to pay for differences in these sites (Haab & McConnell, 2002). The prospective beach visitors are assumed to react to different travel costs in the same way they would react to changes in an admission fee. Because visitors live at differing distances from each beach and therefore face different 'prices' for using the beach, so they can be observed to 'purchase' differing numbers of trips in any given time period as a partial function of the costs of visiting (Perman *et al.* 1996). Travel cost models can be set up to predict which site a person will choose to visit amongst a set of alternatives and/or how many trips they will take in total to all sites or one particular site over some time period. Environmental quality (e.g. bathing water quality) can be used to co-determine choice of site, as long as this varies across sites. Both perceived and objective levels of environmental quality can be used to explain demand.

The Travel Cost Model is an application of weak complementarity. This assumption states that if the site is too expensive and no trips are made, then changes in the condition or availability of sites do not affect utility. There may be occasions when individuals do care about the condition or availability of sites even if it is too expensive for them to visit as they may have non-use or passive values. Unfortunately the Travel Cost model cannot measure these values.

Several other studies have used the TCM to try and understand how and why beach users are influenced in their decision to visit a particular beach. Bell and Leeworthy, (1990) studied the recreational demand by tourists for Florida beach visits by looking at consumer surplus. They found that annual consumer demand by individual tourists for Florida beach days is positively related to travel cost per trip and inversely related to on-site cost per day. Zhang *et al*. (2015) looked at the recreational value of Australia's gold coast beaches and the efficiency of the value transfer method. They estimated the value of a single visit beach visit to the Gold coast to be $19.47 per person. Other studies have specifically looked at variations in environmental quality to explain the number of trips that people make. Englin and Mendelsohn (1990) studied the recreational value of different quality levels of forest management and Smith and Desvousges, (1985) looked at the water quality benefits using the generalized travel cost method.

This paper estimates the value of recreational visits to beaches in Scotland and considers what influences peoples' choices when visiting the beach. An onsite visitor survey was developed and undertaken at eight beaches across Scotland during summer 2014. A TCM was developed to estimate the consumer surplus for recreational beach visits. Variables considered include travel cost, travel time, activity choice, water quality, whether the beach has an award and socio-demographic characteristics.

5.2 ***Method***

5.2.1 Travel cost method (TCM)

The TCM was first established by Hotelling, (1947) and has since then been advanced and developed with a number of different variants of the model. The Zonal Travel Cost Method (ZTCM) was developed by Clawson and Knetsch, (1966) and takes into account the cost of travelling to the site from a particular area or zone. The Individual Travel Cost Method (ITCM) improves on this method by also taking into consideration the fact that each visitor has different socio-economic characteristics. The third TCM method is the Random Utility Model (RUM). This method allows for much more flexibility but also needs much more information. It is most useful when estimating quality changes and when many substitute sites are used. The TCM is simple, low cost and relatively non-controversial as it is based on people's actual behaviour. The TCM uses information on distance and time spent travelling along with information about income and other socio-economic characteristics. Time is included in these calculations because any time which is spent travelling has an opportunity cost. That time could have been used for doing other alternative activities such as working, hobbies, sport, being with friends, cleaning or relaxing. The value of a person's time is measured using their income or a proportion of their income.

There are limitations to this method which most importantly include the fact that because it looks at actual revealed preference behaviour, it is ignoring any non-use values. For example, people may gain increased utility from simply knowing that a beach is being effectively managed to maintain high levels of biodiversity.

Other issues with the TCM are that it assumes each trip is single purpose, whereas visitors may visit a beach because it happens to be next to a castle they want to visit or some other local place of interest. The TCM also has trouble in accounting for the fact that some people enjoying travelling and that, for them, the longer journey may be a preferred one (Chavas *et al.* 1989). Another limitation is the issue of ignoring non-visitors to the site or truncation. This occurs because the survey excludes the possibility of gathering information from non-visitors. Demand is truncated at one as the people being interviewed must have made at least this one single trip to the beach (Hynes *et al*. 2015). Another limitation that occurs is that of endogenous stratification. On-site sampling will tend to over-sample people who visit the site more often (Hanley & Barbier, 2009). Both truncation and endogenous stratification have been accounted for in the final model. For our purposes the TCM is a good choice, particularly as a similar and related stated preference study has been carried out to account for any passive-use values. The TCM is an ideal method to use when estimating the value of recreational activities (such as visiting a beach) as these activities are not traded in markets and so therefore have no market prices. The cost of travelling to the beach can therefore be used as a proxy for a market price which does not exist.

Count data models are appropriate for the analysis of travel cost data as these deal with non-negative integer valued dependent variables, such as the number of trips and also take into account the positively skewed distribution i.e. the number of trips is expected to decrease as price increases (Haab & McConnell, 2002). This study aims to determine what factors influence people’s choices when choosing which beach to visit. The model we used therefore shows number of trips to the beach dependent upon various attributes of the beach. The first model applied is the Poisson model where y is the number of trips to the beaches made in a year:

$$\Pr\,(y \mid \mu) = \frac{e^{-\mu}\lambda^{\mu}}{y!}\ , y = 0, 1, 2,$$

where µ is the Poisson parameter and expected number of trips, is modelled as a function of the explanatory variables thought to influence y .

However, the Poisson model may not fit all recreational data sets due to problems of over-dispersion resulting in under-estimated standard errors (Long & Freese, 2014). An alternative model which addresses this failure is the negative binomial model:

$$\Pr(y \mid x) = \Gamma\frac{y + \propto^{-1}}{y!\,\Gamma(\propto^{-1})}\left(\frac{\propto^{-1}}{\propto^{-1} + \mu}\right)^{\alpha-1}\left(\frac{\mu}{\propto^{-1} + \mu}\right)^{y}$$

where Γ(.) is the gamma function and the parameter ∝ determines the degree of dispersion in the predictions. Statistical tests can show whether the Poission or Negative Binomial model is a better fit for a specific data set.

The number of beach visits per annum to an individual site is used as the dependent variable in this analysis. The expected value of the dependent variable in a Negative Binomial Regression can be written as Long and Freese (2006)

$$E(y|\mathbf{x}) = \exp(\beta \cdot \mathbf{x})$$

$$= \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_i\, x_i).$$

Respondents who reported visiting the beach more than once per day (over 365 times) were adjusted to visiting the beach 365 times to avoid further over-dispersion in the data. The independent variables included are the importance of bathing water quality to visitors, levels of litter normally found at the beach, possession of a beach award, local or holiday visitor and a number of socio-economic variables including age, gender and income were chosen because they are likely to affect beach visits and had also been used in the stated choice experiment so would provide consistency between the two studies. The importance of bathing water quality to respondents was used as opposed to measured (objective) water quality or perceived water quality because if bathing water quality is not an issue that people are concerned about, then the water quality (perceived or actual) would not be a significant factor in the decision making process. Variables that were not included in the final model included importance of biodiversity and membership of an environmental group (e.g. RSPB, WWF etc.). These variables had little variation and therefore were not useful in the model. The variable for levels of seaweed present was also removed as visitors would not have known the levels of seaweed until they arrived at the beach and therefore could not have based their decision making on this. The final model below gives us a demand function:

$$V_{ij} = f(C_{ij}, W_{ij}, L_{ij}, B_{ij}, H_{ij}, G_{ij}A_{ij}, I_{ij})$$

where V_{ij} is the number of visits made per year by individual *i* to site *j*, C_{ij} is the visit cost faced by individual *i* to visit site j (this includes both the cost of travel and the opportunity cost of time), W_{ij} is individual i's concern for bathing water quality, L_i is individual *i*'s impression of litter levels at site *j*, B_{ij} is individual i's knowledge about Beach Awards at site *j*, H_{ij} is whether individual *i* has travelled to site *j* from home or is on holiday, $G_{ij,}$ is individual *i*'s gender, A_{ij} is individual *i*'s age and I_{ij} is individual *i'*s income.

Time can be measured in a number of ways. The cost associated with travel time however, is one of the most widely debated issues in travel cost analysis: travel to recreational sites is undertaken in leisure time and time is scarce (Hanley & Barbier, 2009). A commonly used assumption is calculating travel time costs using one-third of the standard wage rate as identified by Cesario, (1976). This method has been used by Whitehead, (1992) in his valuation of willingness to pay for a sea turtle protection programme. More recently, Fezzi, Bateman and Ferrini, (2014) argue that three-quarters of the wage rate provide a reasonable approximation for the value of travel time. In this instance we have used both the time in hours and the opportunity cost of travel time by using one third of the standard wage rate. People will not be giving up an hour of work to drive to the beach and so using a fraction of the wage rate as the price of leisure time (Smith & Desvouges, 1986) takes this into account.

Travel cost variables were analysed as continuous variables and all other variables were analysed as categorical variables. The analysis was carried out using STATA version 14.0.

5.2.2 Survey design

The population of interest was identified as beach visitors on the east coast of Scotland. The survey was initially designed using small focus groups within the university followed by a pilot survey at two of the chosen beaches (Broughty Ferry and Yellowcraigs). This helped to ensure people understood the questions and enabled any necessary extra questions, which may have been overlooked, to be identified. The survey contained a mixture of open questions about recreational activities followed by questions which used a Likert scale to obtain information about peoples' opinions on different beach attributes. Travel cost was estimated using respondent's chosen method of transport combined with the distance they had travelled both ways. The final part of the survey consisted of a number of socio-economic questions. The onsite surveys were completed at eight east coast beaches, (Figure 19) by the first author and three other trained interviewers and were carried out between May and September of 2014. Surveys were also attempted later in the year to achieve a greater variety of beach users but due to the weather conditions and fairly low population sizes in the local area this was not successful. The interviews took approximately 10 minutes to complete by the interviewer. The surveys were carried out systematically by moving from one side of the beach to the other. By doing this everyone on the beach was surveyed unless they were not willing to do so. Once one lap of the beach had been completed the interviewers then walked back in the opposite direction in order to observe any newcomers to the beach who were missed initially. 293 usable responses were collected across the nine beaches. Several beaches were visited as it was important to get a mixture of both groomed and ungroomed beaches, and those with and without an award.

Figure 19: Location of survey beaches for Travel Cost Model.

5.2.3 Overview of survey questions.

(Questions 11-16 were presented on a Likert scale). For full survey please see Appendix D.

1. Why have you chosen to visit this particular beach?
2. What activities do you do at the beach usually?
3. How did you travel here?
4. How many people (including yourself) have you come here with today?
5. How long did it take you to get here?
6. Did you travel from home today or are you on holiday?
7. If you are on holiday how far is this beach from your accommodation?
8. How far is it in miles from your home?
9. In the last 12 months how often have you visited this particular beach?
10. Is your trip today exclusively to visit the beach or are you planning on other activities in this area?
11. How important is bathing water quality to you in deciding on which

beach to visit?

12. How would you rate the levels of man-made litter on this beach normally (e.g. crisp packets, drinks bottles, fishing gear etc.)?
13. How acceptable do you find the levels of man-made litter on this beach? (Please tick one level)
14. How would you rate the levels of seaweed which have been washed up on the beach? (Circle one)
15. How acceptable do you find the levels of seaweed?
16. How important is the natural environment, wildlife and biodiversity to you?
17. Do you know if this beach has an award?

5.3 ***Results***

5.3.1 Sample characteristics

Self-reported socio-demographic characteristics show that the majority of the sampled population were female and aged between 30 and 49. This may be due to the surveys being undertaken on weekdays during the school holidays when more mothers were responsible for childcare, (Table 10). A study carried out by Visit Scotland, (2016) also found that coastal tourism was most widely utilised by the 35-44 year old demographic group. The model average household gross income group (£30,000 - £50,000) was higher than the Scottish average income (£23,000). 35% of respondents were on holiday with the remaining sample visiting the beaches as a day trip. 18% of respondents were visiting the beaches from elsewhere in Scotland; 14% from the rest of the UK and 1% of visitors were international. Of those who said they were on holiday 34% were visiting St Andrews; 16% Elie Ruby Bay and 14% North Berwick.

Table 10: Characteristics of sampled population

	Sample size	Percentage of sample size
Survey location		
Broughty Ferry	41	14%
Elie Ruby Bay	26	9%
Gullane	35	12%
North Berwick	37	13%
Portobello	46	16%
St Andrews	59	17%
Tentsmuir	35	12%
Yellow Craigs	23	8%
Visitor type		
Local	190	65%
Scotland (elsewhere)	53	18%
Rest of UK	39	13%
Europe	4	1%
Rest of the world	3	1%
Unknown	2	1%
Holiday or day trip		
Holiday	102	35%
Day trip	190	65%
Gender		
Female	211	72%
Male	81	28%
Age		
18 – 29	24	8%
30 – 49	184	63%

50 +	84	29%
Education		
School	46	16%
College	86	29%
University	160	55%
Income category		
Less than £15,000	27	11%
£15,000 - £30,000	52	22%
£30,000 - £50,000	74	31%
£50,000 - £75,000	53	22%
£75,000 +	35	15%
Environmental Group Member		
No	216	74%
Yes	76	26%

5.3.2 Beach visitation and preferred activities

The questionnaire asked respondents to give reasons for visiting the beach. The most popular reason measured in percent for visiting the beach on the day of the survey was the beach being close to home (40%) followed by holiday (23%) and the location of the beach (22%). The least popular reason for visiting the beach was because it has a beach award (0%). It would appear that in this study nobody visited a beach solely because it had an award. Beach attributes such as bathing water quality (4.4%) and no litter (4.1%) proved to be less popular than activities such as surfing (7.2%) and Frisbee (7.2%) which was contrary to expectation

(

Figure 20 and Table 11).

Looking at the individual beaches, the most popular reason for Broughty Ferry, Portobello and North Berwick was the beach being close to home. Portobello was also the most popular beach for surfing (20%). The most popular beaches for people on holiday were St. Andrews and North Berwick. These two beaches also have a large number of other tourist attractions and sight-seeing opportunities and also provide lots of accommodation nearby. People who found litter and bathing water quality to be important when visiting a beach were most likely to go to Yellowcraigs. Gullane was a popular choice for walkers (14%) and dog walkers (11%) and this is probably because it is a long stretch of fairly remote beach. Visitors to Yellowcraigs found facilities to be important for their choice of beach (43%) and this may be due to the provision of new toilets and a playpark which would be likely to attract families with small children. Apart from this one exception, beach facilities and beach awards had very little impact on the reason people chose to visit the beach that day. Beach awards scored 0% for attracting beach visitors and it would appear that nearly all people were unaware their chosen beach had an award or were indifferent to it.

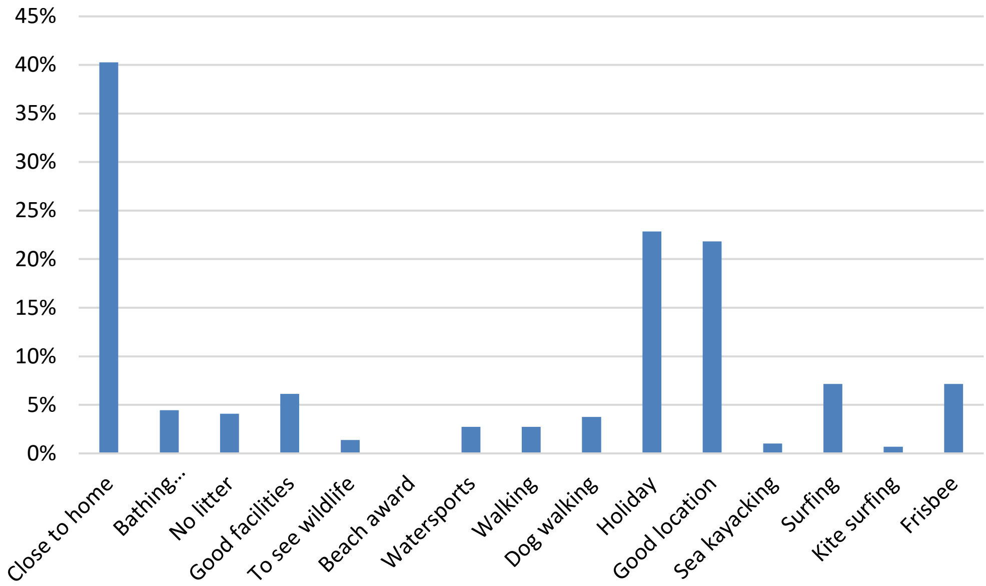

Figure 20: Main reasons for visiting the beach on the survey day (all beaches).

Table 11: Main reasons for visiting the beach on the survey day (by beaches)

	Broughty Ferry	Elie Ruby Bay	Gullane	North Berwick	Portobello	St Andrews	Tentsmuir	Yellow Craigs
Close to home	80.49%	19.23%	28.57%	45.95%	60.87%	14.29%	28.57%	34.78%
Bathing water quality	4.88%	7.69%	11.43%	2.70%	0.00%	2.00%	2.86%	8.70%
No litter	2.44%	0.00%	11.43%	2.70%	2.17%	2.04%	0.00%	17.39%
Good facilities	7.32%	0.00%	5.71%	5.41%	2.17%	0.00%	0.00%	43.48%
To see wildlife	0.00%	0.00%	5.71%	2.70%	0.00%	0.00%	2.86%	0.00%
Beach award	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Water sports	0.00%	7.69%	5.71%	2.70%	4.35%	0.00%	0.00%	4.35%
Walking	0.00%	0.00%	14.29%	2.70%	2.17%	2.04%	0.00%	0.00%
Dog walking	0.00%	0.00%	11.43%	0.00%	2.17%	0.00%	5.71%	17.39%
Holiday	2.44%	26.92%	25.71%	43.24%	8.70%	53.06.%	2.86%	13.04%
Good location	9.76%	11.54%	42.86%	2.70%	6.52%	32.65%	28.57%	52.17%
Sea kayaking	0.00%	0.00%	0.00%	0.00%	0.00%	4.08%	0.00%	4.35%
Surfing	2.44%	7.69%	0.00%	8.11%	19.57%	4.08%	8.57%	0.00%
Kite surfing	4.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Frisbee	0.00%	26.92%	8.57%	0.00%	4.35%	0.00%	25.71%	0.00%

The most popular beach activities are shown in Figure 21 for all beaches and Table 12 by beach. The most popular beach activities usually undertaken by visitors were paddling (75%) and playing with children (68%). This result was expected as the survey was undertaken during the summer holidays. Other popular activities were swimming (50%) and relaxing (48%). Gullane was the most popular beach choice for kite flying (11.43%) and wildlife watching (11.43%) which may be because of its exposed and fairly remote situation. Kite flying was also popular in St. Andrews (12%) and Yellowcraigs (13.04%) probably due to the exposed nature of these beaches. Tentsmuir was the most popular location for dog walking (28.57%). This beach is situated in a National Nature Reserve right next to a forested area and is therefore an ideal location for this activity. Elie Ruby Bay was the preferred beach for visitors wanting to swim (84.62%) possibly because it is a small, shallow, sheltered bay with a life guard in attendance.

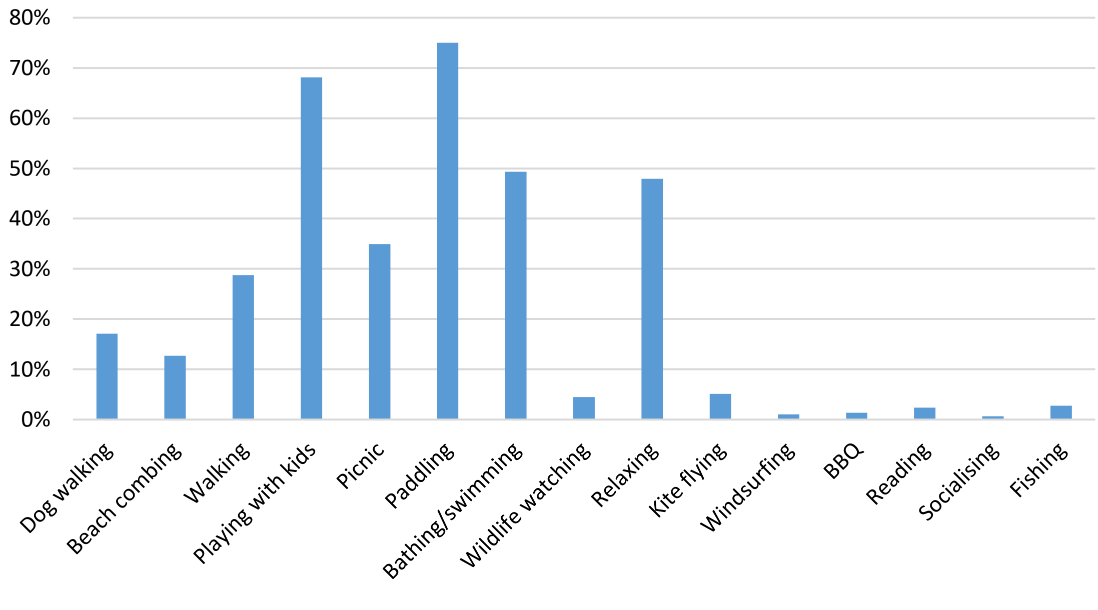

Figure 21: Main activities undertaken at the beach usually (all beaches).

Table 12: Main activities undertaken at the beach usually (by beach).

	Broughty Ferry	Elie Ruby Bay	Gullane	North Berwick	Portobello	St Andrews	Tentsmuir	Yellow Craigs
Dog walking	17.07%	3.85%	14.29%	10.81%	23.91%	14.29%	28.57%	21.74%
Beach combing	0.00%	15.38%	17.14%	16.22%	21.74%	16.33%	0.00%	13.04%
Walking	9.76%	11.54%	34.29%	43.24%	13.04%	46.94%	45.71%	17.39%
Playing with kids	80.49%	65.38%	71.43%	67.57%	56.52%	65.31%	62.86%	82.61%
Picnic	0.00%	30.77%	57.14%	13.51%	19.57%	69.39%	14.29%	91.30%
Paddling	85.37%	92.31%	74.29%	72.97%	65.22%	69.39%	68.57%	82.61%
Bathing	51.22%	84.62%	42.86%	43.24%	50.00%	42.86%	45.71%	43.48%
Wildlife	2.44%	3.85%	11.43%	5.41%	0.00%	6.12%	5.71%	0.00%
Relaxing	87.80%	76.92%	37.14%	45.95%	21.74%	46.94%	17.14%	65.22%
Kite flying	2.44%	0.00%	11.43%	0.00%	0.00%	12.24%	2.86%	13.04%
Windsurfing	0.00%	0.00%	8.57%	0.00%	0.00%	0.00%	0.00%	0.00%
BBQ	0.00%	3.85%	0.00%	2.70%	2.17%	2.04%	0.00%	0.00%
Reading	2.44%	0.00%	5.71%	8.11%	0.00%	0.00%	2.86%	0.00%
Socialising	0.00%	0.00%	2.86%	0.00%	0.00%	2.04%	0.00%	0.00%
Fishing	0.00%	0.00%	2.86%	0.00%	2.17%	12.24%	0.00%	0.00%
Golf	0.00%	0.00%	2.86%	2.70%	2.17%	4.08%	2.86%	0.00%

The majority of visitors visited the beach once per year or between two and four times per year, (Table 13). There was a significant difference in the number of visits between the different beaches (χ^2 (49) = 81.90, $p < 0.01$). Portobello appears to be the most popular beach for repeat visits with over 40% of the sample visiting at least fortnightly or more frequently. This is to be expected as 79% of visitors are local residents. St. Andrews is the beach most visited as a one- off, once a year trip (54%). This may be because more visitors are on holiday and are visiting St. Andrews for other reasons, such as the golf course or the University and just happen to visit the beach while they are there.

Table 13: Frequencies of beach visits throughout the year

	All beaches	Broughty Ferry	Elie Ruby Bay	Gullane	North Berwick	Portobello	St Andrews	Tentsmuir	Yellow Craigs
Once a year	38%	22%	50%	49%	30%	20%	54%	46%	48%
2 - 4 times per year	27%	27%	42%	23%	27%	24%	27%	29%	30%
5 - 11 times per year	12%	22%	8%	9%	16%	7%	8%	17%	17%
at least once per month	7%	17%	0%	6%	14%	11%	6%	3%	0%
at least fortnightly	2%	2%	0%	0%	3%	7%	2%	0%	0%
once or twice per week	7%	7%	0%	11%	6%	17%	2%	6%	4%
at least three times per week	2%	7%	0%	3%	6%	7%	2%	0%	0%
at least daily	1%	0%	0%	0%	0%	9%	0%	0%	0%

5.3.3 Beach quality and beach awards

For the majority of respondents (88%) water quality was either “quite important” or “very important” when deciding which beach to visit (Table 14). This may mean that if water quality is an important factor to them in deciding which beach to visit, it may have been a reason for choosing that particular beach to visit, i.e. they felt that it was a safe place to paddle or bathe. Only at Tentsmuir did respondents appear to be less concerned about water quality with 23% stating it “was not important at all”. Across all beaches only 10% of respondents stated the litter was either “of considerable or large amount” and this response was broadly similar across all beaches except Tentsmuir where 65% of respondents stated litter was either “large or considerable”. Furthermore, at Tentsmuir, 60% stated the levels of litter were unacceptable, significantly higher than the other beaches sampled (χ^2 (21) = 142.22, $p < 0.01$). This would appear to be down to an unusually large amount of rubbish washing ashore that day because a large street litter bin had somehow been dumped on the beach and its contents (including some dirty nappies) had been left strewn across an otherwise very clean beach. This anomaly is problematic as it appears to have been a one-off unusual event which, none the less, affected people’s opinions of that particular beach on that particular day. Across all beaches 85% of respondents rate the levels of seaweed as either a “small amount” or “none”. Gullane appeared to have the least amount of seaweed with 74% of respondents stating it had none. In contrast 35% of respondents at Elie Ruby Bay and 32% of respondents at St Andrews stated these beaches had “a considerable amount”. Despite this, across all beaches at least 63% of respondents felt this level of seaweed was acceptable (Elie Ruby Bay) rising to 98% for Portobello.

Table 14: Beach quality responses by beach

	All beaches	**Broughty Ferry**	**Elie Ruby Bay**	**Gullane**	**North Berwick**	**Portobello**	**St Andrews**	**Tentsmuir**	**Yellow Craigs**
How important is bathing water quality when deciding which beach to visit?									
Not important at all	8%	10%	0%	3%	11%	11%	6%	23%	0%
Not very important	3%	0%	0%	3%	0%	9%	0%	0%	4%
Not sure	1%	0%	4%	0%	0%	2%	0%	3%	9%
Quite important	32%	22%	42%	31%	32%	46%	31%	20%	35%
Very important	57%	68%	54%	63%	57%	33%	63%	54%	52%
How would you rate the levels of litter on this beach normally?									
None	37%	51%	46%	63%	41%	24%	35%	0%	48%
Small amount	53%	44%	50%	37%	60%	70%	64%	34%	52%

Considerable amount	9%	5%	4%	0%	0%	7%	0%	54%	0%
Large amount	1%	0%	0%	0%	0%	0%	0%	11%	0%
How acceptable do you find the levels of man-made litter on this beach?									
Unacceptable	12%	7%	4%	3%	11%	7%	2%	60%	0%
Quite bad	3%	0%	0%	3%	3%	2%	8%	0%	4%
Not sure	0%	2%	0%	0%	0%	0%	0%	0%	0%
Not too bad	18%	2%	15%	9%	19%	30%	16%	29%	26%
Acceptable	67%	88%	81%	86%	68%	61%	73%	11%	70%
How would you rate the levels of seaweed washed up on this beach?									
None	23%	37%	0%	74%	0%	37%	2%	9%	17%
Small amount	62%	59%	62%	26%	95%	37%	66%	86%	78%
Considerable amount	15%	5%	35%	0%	6%	26%	32%	3%	4%
Large amount	1%	0%	4%	0%	0%	0%	0%	3%	0%
How acceptable do you find the levels of seaweed on this beach?									
Unacceptable	3%	5%	15%	0%	5%	0%	2%	0%	0%
Quite bad	2%	0%	0%	0%	0%	0%	12%	0%	0%
Not sure	0%	0%	0%	0%	0%	0%	0%	0%	4%
Not too bad	9%	2%	23%	3%	16%	2%	18%	3%	4%
Acceptable	86%	93%	62%	97%	78%	98%	68%	97%	91%

Respondents were also asked their knowledge of beach awards (Figure 22 and Table 15). 35% of respondents stated the beach had some level of award and over 50% said they did not know if the beach had an award. All beaches except Tentsmuir had the Seaside Award and in addition Broughty Ferry and Elie Ruby Bay had the Blue Flag Award. Of those respondents who stated they knew whether the beach had an award or not only four respondents knew the beach had a Seaside Award. 25 respondents stated the beach had the Blue Flag award but in 10 cases this was incorrect.

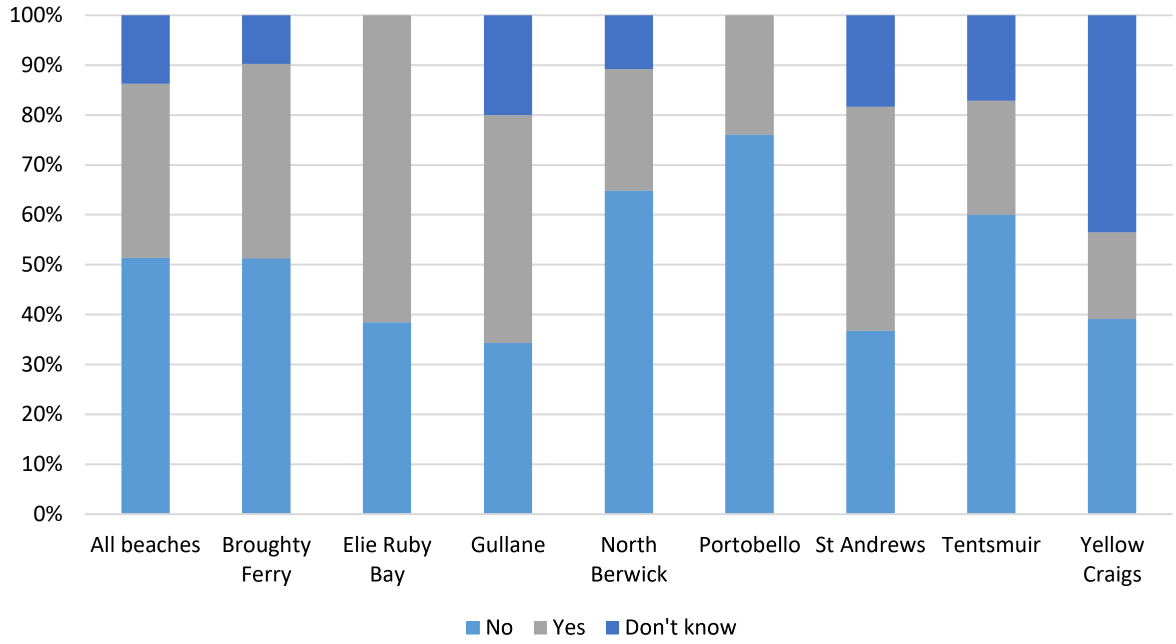

Figure 22: Chart showing percentage of respondents who knew whether the beach had an award or not.

Table 15: Respondents who said the beach had an award and stated which one.

Which award?	Broughty Ferry	Elie Ruby Bay	Gullane	North Berwick	Portobello	St Andrews	Tentsmuir	Yellow Craigs
Seaside Award	1	-	3	-	-	1	-	-
Blue Flag	9	6		3	4	3	-	-
Bathing award	-	-	1	-	-	-	-	-
Beautiful beach	-	1	-	-	-	-	-	-
Clean beach	-	-	-	-	3	-	-	-
No award	5	9	12	6	4	17	4	4
Unsure	1	-	-	-	-	1	4	-

5.3.4 Travel costs

The travel cost method treats trips to a site (or beach) as the quantity demanded, and the cost of the trip as the price of access to the site. These assumptions result in a demand function as seen below:

$$r_i = f(p_i z_i)$$

Where r_i is the number of trips taken by individual *i* to a given beach during a given time period, p_i is the cost of access to the site (which usually consists of the cost of travel and opportunity cost of travel time), and z_i is a vector of individual characteristics that are believed to influence the number of trips an individual takes.

Table 16 presents various travel costs used in the analysis. BTC is the cost of travelling to the beach. For cars this is calculated using 45p per mile with an additional 5p per mile for each passenger based on HMRC (2015) data. Bike costs were calculated at 20p per mile. For those who caught the bus, travel cost was based on the average return fare in Scotland (£4.57). Return rail fares were calculated on an individual basis using the nearest station to their home and the nearest station to the beach visited. The standard return ticket cost was used from National Rail Enquiries (adjusted to 2014 values). For those who walked to the beach, a travel cost of zero was used.

Travel time and distance from home to site was calculated using the average driving time taken from AA routeplanner. This can then be used to calculate the value of travel time using travel time multiplied by an associated time cost and the number of visitors per group. Due to the complex issues surrounding travel time and which method to use, both the standard one-third and newer three-quarter value of travel time are included in the analysis

A further issue when calculating the value of travel time is determining which wage rate to use (Wieland & Horowitz 2007). Two methods to calculate wage rate were used in this analysis: average wage rate and household income. The UK average wage rate of £15.11 per hour (ONS, 2015) was used for the basic value of travel time calculations. Household value of travel time was calculated using the mid-point of the annual household income category from the survey divided by the number of adults in the household. An average of 1650 annual hours was used to calculate income per hour. This follows the method of Zhang *et al*. (2015

A summary of travel costs and calculations for all respondents and for holiday and home respondents are listed in Table 16 and 17 respectively. Table 16 shows a large difference between the BTC and the methods which use the travel time calculated with a percentage of either wage rate or household income. Previous studies have used a variety of methods to estimate time cost and the ideal method is still very much under debate. This study uses the time that respondents took to travel to the beach multiplied by a third of the average UK wage rate as suggested by Cesario, (1976). It can be seen in Table 16 that there was no significant difference between wage rate and household income, and because some of the respondents were unwilling to provide us with household income information, we decided to use household wage rate to value travel time for the travel cost modelling. We compared this to a BTC model and also a BTC which included travel time in hours.

Table 16: Summary of travel costs and calculations for all respondents

Variable	Obs	Mean	Std. Dev.	Min	Max
Basic Travel Cost (BTC)	291	13.68	19.57	0.00	202.80
Travel Cost + travel time (hours)	292	13.83	19.68	0.00	203.13
Travel cost + travel time (0.33 UK wage rate)	291	23.65	32.12	0.17	365.60
Travel cost + travel time (0.75 UK wage rate)	291	36.31	50.61	0.38	619.20
Travel cost + travel time (0.33 household income)	240	21.69	31.18	0.08	326.00
Travel cost + travel time (0.75 household income)	240	32.04	47.88	0.17	529.64

Table 17: Summary of travel costs by holiday and home respondents

Holiday Respondents	Obs	Mean	Std.Dev.	Min	Max
Basic Travel Cost (BTC)	101	12.53	14.87	0.00	84.00
Travel Cost + travel time (hours)	102	12.79	15.18	0.02	86.00
Travel cost + travel time (0.33 UK wage rate)	101	20.76	24.76	0.42	143.88
Travel cost + travel time (0.75 UK wage rate)	101	31.21	37.92	0.94	219.96
Travel cost + travel time (0.33 household income)	85	19.58	23.70	0.52	132.00
Travel cost + travel time (0.75 household income)	85	29.14	35.94	1.18	193.09

Home respondents	Obs	Mean	Std.Dev.	Min	Max
Basic Travel Cost (BTC)	190	14.30	21.67	0.00	202.80
Travel Cost + travel time (hours)	190	14.83	21.85	0.02	203.13
Travel cost + travel time (0.33 UK wage rate)	190	25.19	35.39	0.17	365.60
Travel cost + travel time (0.75 UK wage rate)	190	39.02	56.11	0.38	619.20
Travel cost + travel time (0.33 household income)	155	22.85	34.62	0.08	326.00
Travel cost + travel time (0.75 household income)	155	33.62	53.36	0.17	529.64

Note: For respondents on holiday, the travel time and costs were calculated from their holiday residence rather than their actual home.

5.3.5 Travel cost estimation

Pooled count data models were used to estimate factors associated with number of visits per year in this estimation as there was no available data on number of trips by each person to each of the beaches in our sample and because visitors were not asked about why they chose one beach over another. These count data models were first used to estimate both local and visitors demand for beach visits over a twelve-month period. In the model chosen, *the number of trips taken = f (travel costs per trip), age, gender, income, main reason for visiting, importance of bathing water quality, normal rate of litter on the beach, Beach award ownership or not.* The explanatory variables were chosen because they had been shown to be of most interest to visitors in previous studies (Hynes *et al*. 2013b) and also in focus groups carried out within the University of Stirling. Beach awards are the attribute of most significance to this study and it was important to get an understanding of whether people are more attracted to beaches which have them. It was essential to know how people felt about litter on the beach as this is the main reason that seaweed is removed from beaches using grooming equipment. Because litter gets caught up in the seaweed, beach managers feel it is easier and more cost effective to remove all the seaweed too. Bathing water quality is central to the beach award schemes and they are often won or lost on this issue. It was vital to know if people considered bathing water quality to be important and if it would affect their decision to go to the beach or not. Variables not included in the final model included the importance of biodiversity. Nearly all respondents felt that biodiversity was important to them and therefore this variable had no variation and was of no use in explaining the outcome of the model. The same was true of membership of an environmental group and the figures did not reflect the true population. Levels of seaweed on the beach were not used as this could not effect a decision to visit the beach or not as prior knowledge was not available. The same explanatory variables were used in all specifications.

The basic travel cost plus one third of the household wage rate was used. A basic travel cost model and one with both travel cost and travel time were also reported as comparisons. Variables included in the model are shown below:

- *Travel cost (a): Basic travel cost plus 0.33 of the UK wage rate.*
- *Travel cost (b): Basic travel cost*
- *Travel cost (c): Basic travel cost plus travel time in hours*
- *Socio-demographics (age, income, gender, environmental group membership, education)*

- *Main reason for visiting (i.e. Good facilities, wildlife, surfing, bathing water etc.)*
- *Importance of bathing water quality*
- *Normal rate of litter on the beach*
- *Whether they knew it had a beach award or not*

The parameter estimates for the on-site recreational travel cost model are presented in Table 18. In line with the work of Hynes *et al.* (2015), two alternative specifications of the demand model were estimated using the Poisson and negative binomial model. The test for over-dispersion showed that the negative binomial model was preferable to the Poisson model ($\chi^2 = 5548.25$) and the over-dispersion parameter is positive and significant, indicating the data is over-dispersed. Thus negative binomial regression is used for the remainder of the analysis.

The results of the Poisson and Negative Binomial models are shown in Table 18. Estimate coefficients for travel and cost are significant and negative for both the Poisson and negative binomial models. They are also of a similar magnitude. Presence or absence of a Beach Award is only significantly associated with number of beach visits in the Poisson model. The parameter estimate on the importance of bathing water quality in the Poisson model suggest that visitors are likely to take fewer trips to the beach if they are concerned about bathing water quality. However, the estimates are not significant for the negative binomial model, except for those people for who consider bathing water quality not to be important. These people would be more likely to take more trips to the beach. Both models show a negative estimate coefficient for the beach having a large amount of litter although this is only significant for the Poisson model. The positive significant coefficient for a small amount of litter indicates that people will make more trips to beaches which have less litter.

Table 18: Comparison of Poisson and Negative Binomial for the on-site recreational travel cost model.

	Poisson		Negative Binomial	
	coefficient	**SE**	**Coefficient**	**SE**
Visits per annum				
Basic Travel Cost	-0.10***	0	-0.02***	0
What is the main reason for visiting the beach today?				
Home	0	(.)	0	(.)
Bathing water	-1.11***	-0.24	-1.26*	-0.57
No litter	-2.85***	-0.71	-2.38*	-1.13
Good facilities	-1.40***	-0.18	-1.41*	-0.64
Wildlife	-0.43	-0.45	-1.79	-0.97
Water sports	-0.08	-0.08	2.04**	-0.74
Walking	0.03	-0.52	-1.41	-0.92
Dog walking	0.33***	-0.08	0.44	-0.6
Holiday	-0.95***	-0.12	-1.29***	-0.34
Good location	-0.79***	-0.08	-1.15***	-0.27
Sea kayaking	2.57***	-0.11	2.07*	-0.91
Surfing	-1.31***	-0.11	-1.02**	-0.39
Kitesurfing	-2.25*	-1	-3.10*	-1.53
Frisbee	-1.49***	-0.16	-1.67***	-0.47
How important is bathing water quality when deciding which beach to visit?				
Not important at all	0	(.)	0	(.)
Not very important	1.47***	-0.12	1.59**	-0.61
Not sure	-1.62***	-0.37	-1.26	-0.83
Quite important	0.71***	-0.11	0.64	-0.47
Very important	0.49***	-0.11	0.7	-0.45
How would you rate the level of litter on this beach usually				
None	0	(.)	0	(.)
Small amount	0.66***	-0.04	0.64***	-0.19
Considerable amount	0.82***	-0.07	0.27	-0.35
Large amount	-2.25**	-0.72	-1.89	-1.36
Does this beach have an award?				
No	0	(.)	0	(.)
Yes	0.21***	-0.03	0.31	-0.19
Don't know	-0.19*	-0.09	-0.86*	-0.34
Are you visiting from home or on holiday?				
Holiday	0	(.)	0	(.)
Home	1.77***	-0.1	1.32***	-0.28
Gender				
Female	0	(.)	0	(.)
Male	0.54***	-0.03	0.51*	-0.2

Age				
Between 18 and 29	0	(.)	0	(.)
Between 30 and 49	0.28***	-0.08	0.78*	-0.39
Aged 50 and over	0.27**	-0.09	0.64	-0.41
Income				
Less than £15,000	0	(.)	0	(.)
£15,000 - £30,000	0.42***	-0.06	-0.01	-0.35
£30,000 - £50,000	0.34***	-0.06	0.26	-0.35
£50,000 - £75,000	-0.52***	-0.07	0.02	-0.35
Over £75,000	0.18**	-0.07	0.04	-0.39
Constant	0.80***	-0.18	0.22	-0.67
Pseudo R^2	0.6		0.14	
Degrees of freedom	31		31	
Number of observations	240		240	
Alpha (overdispersion parameter)			0.17	

The negative binomial basic travel cost variable (BTC) (a) in Table 18 was then compared to a model of basic travel cost plus one third UK wage rate (BTC+0.33) (b) and to a basic travel cost with travel time in hours (BTC+TTH) (c).

Table 19 shows results from a model with all three variables. The results of the BTC and the BTC+TTH are very similar and show no great differences in any of the coefficients which is fairly unexpected. It would be more expected that the BTC+TTH would have a lower travel cost coefficient and that once travel time is also considered along with distance the number of beach visits per annum would be lower. The output from BTC+0.33 differs from the other two variables and has much higher consumer surplus and willingness to pay for beach visits (Table 20).

Table 19: Negative binomial regression results (correlation coefficient) comparing Basic Travel Cost, Basic Travel Cost plus ⅓ UK wage rate and basic Travel Cost plus Travel Time in hours.

	Basic travel cost (a)	Basic travel cost + ⅓ UK wage rate (b)	Basic travel cost + travel time (hours) (c)

	coefficient	SE	coefficient	SE	coefficient	SE
Visits per annum						
Basic Travel Cost	-0.017***	0	-0.014***	0	-0.017***	0
What is the main reason for visiting the beach						
Home	0	(.)	0	(.)	0	(.)
Bathing water	-1.26*	-0.57	-1.19*	-0.56	-1.22*	-0.55
No litter	-2.38*	-1.13	-2.49*	-1.06	-2.55*	-1.07
Good facilities	-1.41*	-0.64	-1.01*	-0.63	-1.05*	-0.63
Wildlife	-1.79	-0.97	-0.25	-1.24	-2.66*	-1.30
Watersports	2.04**	-0.74	1.99**	-0.72	2.17**	-0.74
Walking	-1.41	-0.92	-1.4	-0.9	-1.26	-0.93
Dog walking	0.44	-0.6	0.29	-0.6	-0.31	-0.60
Holiday	-1.29***	-0.34	-1.00***	-0.33	-1.04***	-0.34
Good location	-1.15***	-0.27	-1.11***	-0.27	-1.12***	-0.27
Sea kayacking	2.07*	-0.91	2.40*	-0.94	2.49**	-0.95
Surfing	-1.02**	-0.39	-0.85*	-0.37	-0.89**	-0.37
Kitesurfing	-3.10*	-1.53	-2.84*	-1.48	-2.92*	-1.49
Frisbee	-1.67***	-0.47	-1.40***	-0.46	-1.43**	-0.46
How important is bathing water quality when deciding which beach to visit?						
Not important at all	0	(.)	0	(.)	0	(.)
Not very important	1.59**	-0.61	1.39*	-0.59	1.40*	-0.60
Not sure	-1.26	-0.83	-0.99	-0.81	-0.92	-0.82
Quite important	0.64	-0.47	0.63	-0.44	0.65	-0.45
Very important	0.7	-0.45	0.79	-0.43	0.79	-0.44
How would you rate the level of litter on this beach usually						
None	0	(.)	0	(.)	0	(.)
Small amount	0.64***	-0.19	0.4.3**	-0.18	0.42**	-0.19
Considerable amount	0.27	-0.35	0.35	-0.35	0.10	-0.35
Large amount	-1.89	-1.36	-1.51	-1.36	-1.50	-1.39
Does this beach have an award?						
No	0	(.)	0	(.)	0	(.)
Yes	0.31	-0.19	0.25	-0.19	0.24	-0.19
Don't know	-0.86*	-0.34	-1.04**	-0.34	-1.06*	-0.35
Are you visiting from home or on holiday?						
Holiday	0	(.)	0	(.)	0	(.)
Home	1.32***	-0.28	1.28***	-0.29	1.25***	-0.29
Gender						
Female	0	(.)	0	(.)	0	(.)
Male	0.51*	-0.2	0.23*	-0.2	0.25	-0.21
Age						
Between 18 and 29	0	(.)	0	(.)	0	(.)
Between 30 and 49	0.78*	-0.39	0.7	-0.38	0.76*	-0.38
Aged 50 and over	0.64	-0.41	0.52	-0.39	0.59	-0.4
Income						
Less than £15,000	0	(.)	0	(.)	0	(.)
£15,000 - £30,000	-0.01	-0.35	-0.14	-0.33	-0.17	-0.34

£30,000 - £50,000	0.26	-0.35	0.29	-0.33	0.21	-0.34
£50,000 - £75,000	0.02	-0.35	-0.19	-0.33	-0.24	-0.34
Over £75,000	0.04	-0.39	0.06	-0.37	0.01	-0.41
Constant	0.20*	-0.09	-1.12	1.4	-0.17	1.46
Consumer surplus	58.28		71.13		57.41	
Pseudo R2	0.14		0.14		0.15	
Degrees of freedom	31		31		31	
Number of observations	240		240		240	

* p<0.05, ** p<0.01, *** p<0.001

Consumer surplus (CS) of a trip to the beach can be defined as the difference between the total amount that consumers are willing and able to pay for their trip and the total amount that they actually do pay. In this case the cost is the opportunity cost of the time taken and the travel cost. The CS for the basic travel cost model is £58.28. This is calculated by dividing 1 by the coefficient from the regression (0.017). The 95% confidence intervals are also calculated (see Table 20). This cost would include not only the cost of travel to the site but also the opportunity cost of the time it takes which they could be spending doing other things. The CS for the BTC+0.33 variable was markedly higher than the other two variables at £71.13. The BTC+TTH CS is, unexpectedly, slightly lower than the BTC variable at £57.41 and £58.28 respectively. Once the BTC has been corrected for endogenous stratification and truncation the CS is lower at £43.48. By combining CS per visitor with average travel cost of the visitors, we get the average willingness to pay (WTP) for a trip to the beach (Table 20). The visitors who are on holiday are willing to pay £59.35 compared to home visitors who have a WTP of £30.74. This is a fairly large difference and reflects both the distance, time and opportunity cost associated with taking a holiday. Home visitors to the beach are not on “holiday” as such and therefore may not be so keen to spend as much money as people who are on holiday and may have budgeted for the extra expenditure in their holiday plans. The home visitors may be making an opportunistic trip to the beach due to good weather. People would probably be less likely to spend money on these kind of ad hoc visits. In all of the models the consumer surplus makes up a very high proportion of total WTP. This implies that a significant proportion of the value of a recreational beach trip in Scotland is retained by the visitors in the form of consumer surplus. This is useful information for beach managers as the marketing of tourism depends on the consumer surplus experienced by the tourist. If consumer surplus is high then the tourist is more likely to visit again and also to recommend that others visit too. (Latimer, 1981)

Out of the three travel cost variables the average travel cost, WTP and CS of the BTC+0.33 model are all considerably higher than the other two models and therefore caution should be applied when using this model for CS and WTP. As the BTC and BTC+TTH results are so similar the final choice of model was the BTC. Therefore the BTC corrected for endogenous stratification and truncation would be the best choice for estimating the value of recreational trips.

Table 20: Benefit estimates for negative binomial models of Basic Travel Cost (BTC), Basic Travel Cost + ⅓ UK wage rate (BTC+0.33) and BTC + Travel time in hours (BTC+TTH)

	Average travel cost	Consumer surplus (CS) per trip	95% Confidence Intervals for CS	Maximum Willingness to pay per trip
BTC	13.68	58.28	41.67-111.11	71.96
BTC +ES+T	13.68	43.48	43.68-113.10	57.16
BTC + 0.33	23.65	71.13	50.32-121.33	94.78
BTC + TTH	13.68	57.41	39.29-106.50	71.09
BTC Home	14.30	30.74	30.76-88.78	45.04
BTC Holiday	12.53	46.82	32.27-85.33	59.35

5.4 *Discussion*

This study uses a travel cost model to understand which beach attributes attract visitors (both locals and holiday makers) to visit a certain beach. The attribute of most interest to us is the beach award; specifically do visitors choose to go to a beach because it has a beach award? Questionnaire data was collected from beaches on the east coast of Scotland during the summer months and a negative binomial count data model was fitted to the data. Coefficients for beach awards were not significant, suggesting that beach awards were seen to be unimportant both to local visitors and to holiday makers. This result is comparable to findings from a stated preference choice experiment carried out at the same time by the author to estimate respondent's willingness to pay for different beach attributes. That study used a multinomial logit model which demonstrated a coefficient for beach awards which was not significantly different from zero. These conclusions have also been found elsewhere in the literature (Tudor & Williams, 2005; McKenna, 2001; Nelson *et al.* 2000).

When asking respondents whether they knew if the beach had an award or not, 35% said that they knew the beach had an award and of these only four respondents knew the beach had a Seaside Award. 25 respondents specified that the beach had a blue flag but in 10 cases were wrong. 50% of respondents stated that they did not know if the beach had an award. These figures suggest that although beach visitors do have some knowledge of beach awards, it is uncertain how much of this is influencing the decision process for beach trips. It would appear that there is some confusion for beach visitors about beach awards and it seems that they are not fully informed about which awards beaches have and what awards are presented for. A similar study carried out in Wales by Nelson and Botteril (2002) showed low levels of awareness and knowledge of beach awards from respondents and confusion over their true meanings, with 58% claiming knowledge of the awards but only 21% actually aware that the beach had an award. This supports our findings that beach awards are not an attribute that beach goers use when making decisions about beach trips.

Unlike in the parallel stated preference study, the importance of bathing water quality was not seen to be significant and made no difference to number of trips taken by either holiday makers or local visitors. Possibly as the questionnaires were all carried out on fairly popular beaches during the summer months, there may be an assumption that the bathing water quality must be of a high standard or they would either close the beach or be warnings in place. This strengthens the argument put forward by Rees, (1997), that beach awards and bathing water quality should not be combined. This study indicates that beach visitors are not attracted to a beach because it has a beach award or due to the promise of excellent bathing water quality. However, bathing water quality is an important issue and information on levels of bathing water quality should be available to the public. Beach awards are not an appropriate way of signalling quality and these two matters should not be intertwined. Alternative methods of providing water quality data is available via real time electronic information signs which are already available at 23 bathing beaches in Scotland. For visitors who do enter the water and for whom this information is important, this method is much more unequivocal, unlike beach awards which use bathing water quality data from the previous season and therefore is practically meaningless.

The results of the negative binomial model imply that if beach visitors have a perception of a certain beach usually having only a small amount of litter, they are more likely to make a trip to that beach than if it normally has significant amounts of litter. This is an expected result and beach litter is becoming a major problem, both in the UK and on a global scale. Although many beaches in the UK have local campaigns to regularly target beach litter and initiatives in place to encourage people to take their litter home when they visit the beach, it is important that action is taken to prevent litter from getting into the sea in the first place. This is clearly a large undertaking and an issue that beach managers can have little impact on.

There were a number of limitations to this study and recommendations are given for any future work. The sample size of 293 was relatively small, but given time and budget constraints it was difficult to ensure a large and representative sample of the Scottish population. The surveys had to be completed during the summer school holidays in order to get the largest number of respondents in the smallest number of trips. This meant that we had a lot more female respondents, mainly mothers of young children visiting the beach while the children were off school. Respondents were also more educated (55% university educated as opposed to the national average of 27%; (ONS, 2015), and also had higher incomes than the UK average. Although time and distance can be measured relatively precisely, other data is comparatively difficult to measure. Income and wage rate are clearly difficult to measure accurately and with limited time and budget this is not easily overcome.

There are several issues with the household value method. This technique assumes that the group are all adults earning the household wage and does not take into account differences in the composition of the group visiting the beach. Another concern with this method is the fact that not all respondents answered the question about household income. Zhang et al. (2015) have suggested using annual personal travel expenditure instead of household income as they believe people would be more willing to provide information on their travel expenditure than their household income. They found a positive significant correlation between household income and annual personal travel expenditure. However, whether this would be a reliable substitute is debatable. It would be very difficult for people to estimate how much they spend on all travel in a year and this would arguably vary hugely from year to year.

For any future studies an improved modelling approach would be to use the Random Utility Model (RUM) for this study, as this determines which beach visitors would choose from a set of different alternative beaches. Unfortunately, this could not be done with the data collected here as alternative site choices were not offered within the scope of this questionnaire. The RUM would give greater flexibility to the study and would enable us to calculate how consumer surplus changes if site quality at one or more of the beaches changes.

5.5 *Conclusions*

Results from the negative binomial model show that beach visitors are not influenced by beach awards or bathing water quality and that litter is the only attribute from this study which would effect a person's decision about making a trip to the beach. None of the socio-economic variables were significant but this is not surprising as there was a lack of variation in the sample. It would be interesting to do this study on a wider basis, possibly looking at beaches throughout the whole of the UK or even Europe to try and get an idea on a larger scale of people's attitudes to beach awards and beach management in general. This would enable a possible change in policy for how beaches are managed which would probably better reflect what people actually want from their beaches and not just rely upon beach awards which arguably have a more commercial purpose. The research presented in this chapter has provided valuable information on people's preferences when deciding which beach to visit. This is invaluable to beach managers and policy makers when considering how to manage their beaches and understanding what people want from their coastlines and how to manage the beach for the benefit of both people and wildlife.

Chapter 6: General Discussion

6.1 *Introduction*

Coastlines are particularly susceptible to the trade-offs which unavoidably occur between the need to manage for both biodiversity and for people. Beaches are honey pot sites which can bring in important revenue for local economies. Unfortunately, these human needs are often in conflict with the needs of the natural environment. Research which aims to understand the relationships among multiple ecosystem services and the mechanisms behind these relationships will improve our ability to sustainably manage ecosystems to provide multiple ecosystem services (Bennett *et al*. 2009). Results and recommendations from this thesis will help local beach managers to improve their management techniques to benefit both beach users and biodiversity.

6.2 *Impacts of mechanical grooming on the macroinvertebrate diversity*

The first half of this thesis discusses the impacts of mechanical beach grooming, a problem which affects beaches on a global scale. Chapters 2 and 3 demonstrate that negative impacts of grooming are clearly seen to affect macroinvertebrates on the beach, plants on the sand dunes and seeds in the seed bank. Depth of algae was positively correlated with biodiversity of the macroinvertebrates in the strandline, the adult plants growing on the sand dunes and the seeds within the dune seed banks.

In the first ever assessment of the impacts of beach grooming in two ecologically contrasting countries (Chapter 2) it was observed that mechanical grooming is having a marked effect on macroinvertebrates found in the strandline, but that differing tidal ranges have differing impacts. Sites with a higher tidal range recovered more slowly following a period of grooming. An interaction between tidal range, beach grooming and season were seen to affect the depth of the algae which in turn affected the macroinvertebrate diversity. Beaches in Scotland which had relatively high tidal ranges (4-5m) were surprisingly found to be more impacted by grooming than beaches in Sweden which had very low tidal ranges (5-20cm). The reason behind the different impacts in the two countries is thought to be because on Swedish beaches there is always algal material found to be at the water's edge which does not get cast up higher on to the beach due to the low tidal movement. This wrack therefore does not get removed by the grooming equipment. By contrast in Scotland, at each high tide, any algal material at the water's edge is cast up high on to the beach where it can easily be removed by the mechanical equipment. The beach then requires a reasonably large storm event in order to replenish the stocks of algal wrack leading to extended periods of time where no wrack is present, increasing the impacts of its removal.

The impacts of grooming were seen during both the summer months when grooming was taking place and in the winter when grooming had stopped. Even during the winter months there was a marked effect of grooming on macroinvertebrate diversity on beaches that had been groomed during the summer months. This is likely to be because grooming is disturbing the life cycles of some of the invertebrates present and interrupting their breeding season, leading to disruption of entire generations. This is particularly difficult for those animals which cannot fly such as sandhoppers (*Talitridae*) which may then struggle to recolonise (William, 1978).

6.2.1 Management implications

The removal of stranded wrack by grooming equipment has been shown to negatively impact the fauna in a number of previous studies (Gilburn, 2012; Dugan, 2010; Llewellyn & Shackley, 1996). Gilburn, (2012) also found that groomed beaches were much more likely to have a beach award (69%) compared to ungroomed beaches (6%). This statistic is somewhat shocking and despite the awarding bodies strongly suggesting that managers clean their beaches using gentler, more invertebrate friendly methods, it is clear that grooming is still taking place on a large scale. Armed with the knowledge that tidal range has a major impact on recovery rates, it is possible that managers can use this information to tailor their policies and attempt to minimise the impacts of grooming. If beach managers avoid grooming the wrack which is found close to the water's edge, and avoid grooming at low tide they are enabling the beach to replenish some of the cleared wrack and therefore possibly mitigating the impacts of grooming. It is also advised that in areas with a high tidal range, grooming is carried out only on an occasional basis when the levels of wrack start to reach a nuisance level for beach goers (although obviously this may be subjective).

6.2.2 Impacts of mechanical grooming on dune vegetation

Stranded wrack is the precursor and stabiliser of the dunes and also acts as an important source of nutrients for dune plants and seed banks (Chapman, 1976). It has been previously shown by Dugan, (2010) that removal of this stranded wrack significantly changes the abundance and distribution of coastal vegetation on Californian beaches. Impacts of grooming on vegetation has not been looked at on Scottish beaches until now. Results from this study show that there is a significant difference in both the adult plant and the seed bank species composition and richness on groomed and ungroomed beaches. These findings are comparable to those in chapter 2 as it is the depth of the seaweed present on the beach which affects the plant communities of the dunes. The greater the depth of the wrack, the greater the species richness and abundance of plants found on the dunes. Tidal range was not seen to have an impact on the plant communities like it did with the macroinvertebrates, but if this study was carried out in Sweden or a country with a similarly contrasting tidal range, there is the possibility that tidal range may be seen to influence the plant and seed communities. Exposure was seen to influence the plant community composition with less exposed beaches having greater adult plant diversity, but it did not influence the community composition of the seed bank.

6.2.3 Recommendations for further work

Although there were several limitations to this study which would be extremely difficult to improve upon if this study were replicated, the results indicate that grooming is negatively impacting sand dune vegetation. With the ever-increasing levels of erosion occurring to due climate change (Bird, 1985) it would be sensible to further investigate the impacts of grooming on the sand dunes and other aspects of the coastal ecosystem. Coastlines provide a large number of vital ecosystem services which interact with each other in complex and dynamic ways which are not yet fully understood (Bennett *et al*. 2009). Ecosystem Services such as flood protection are becoming ever more important in a world where there are increasing levels of uncertainty. Global politics are in a state of instability and we cannot guarantee that current environmental legislation will be in place in the future. It is clear that any improved scientific knowledge which can help to predict impacts to coastal ecosystem services are essential.

6.3 *Valuing ecosystem services*

Chapters 2 and 3 in this thesis have outlined the impacts that beach grooming has on the macroinvertebrates, plants and seeds of the coastal environment. These impacts are affecting a number of ecosystem services which the beach provides, including coastal defence, waste breakdown and detoxification, and nutrient recycling. These services sit alongside the types of ecosystem services that are more anthropogenic in nature such as leisure and recreation, cultural and spiritual wellbeing and aesthetic and inspirational services. The majority of environmental services lack markets which means that non-market valuation methods are relied upon when producing value estimates for policy and project implementation (Hanley & Barbier 2009). In the case of this study it has been observed that beach grooming is having a negative effect on biodiversity and grooming is mostly driven by the Beach Awards system. The aim of chapters 4 and 5 were to try and understand which coastal ecosystem services people value most highly and try to develop value estimates for local policy makers and beach managers to better manage their beaches.

Techniques available to elicit public preferences for available Environmental services in monetary terms include production function, revealed and stated preference. Two of these techniques (revealed and stated preference) have been used in this thesis and are designed to complement each other. Chapter 4 used a stated preference choice experiment to ask people via a postal questionnaire what their preferences were for different beach attributes. This resulted in an understanding of both use and non-use (or passive-use) values. Chapter 5 used a revealed preference technique known as the travel cost method to gain information about people's preferences by using their cost of travel to the beach.

This two tier approach results in information regarding actual beach users to be obtained, in addition to information from passive users who may be only interested in the existence value of beaches. They may never visit one but their utility is increased by knowing that they are being managed in a way that is satisfactory to them.

6.3.1 The value of beach attributes

Results from Chapter 4 find that people are not willing to pay for Beach Awards which indicates that they do not value them. Previous studies have reported a lack of understanding regarding Beach Awards and what they represent (Nelson *et al*. 2000) and this study reinforces that idea. It would appear that beach users do not consider a beach award a reason to visit one particular beach over another. The attributes of a beach which people were willing to pay for were biodiversity, good bathing water quality and litter free beaches. Interestingly, people were more willing to pay for litter only to be removed from their beaches in preference to the removal of both litter and seaweed. This suggests that contrary to beach managers' perceptions, beach users are not concerned about levels of seaweed and managers would attract the same number of tourists if they left the seaweed in place.

Results from Chapter 5 correspondingly found that Beach Awards were seen to be unimportant both to local visitors and to holiday makers. Anecdotal evidence from the beach surveys would suggest that not only are people not encouraged to visit a beach because it has an award, but also that they have little or no understanding of what a beach award represents. Similar results were found from a study in Wales by Nelson and Botteril, (2002). Unlike the stated preference experiment in chapter 4, the Travel Cost Model did not observe an influence of bathing water quality on number of trips taken to the beach. This may be because people assume that if the bathing water quality is poor, the beach would be closed or swimming in the sea would be forbidden. These results also suggest that people are not even aware that Beach Awards are tied in to bathing water quality information. This puts forward the need for bathing water quality to be dealt with as a separate issue and not to be associated with Beach Awards. Bathing water quality information that Beach Awards offer is not up to date information and actually relates to data from the previous year. This points to a need for a revamp of awards and what we use them for.

6.3.2 Difficulties in measuring the value of multiple ecosystem services

There is a need in environmental management to uncover some of the multiple and non-linear relationships which exist between ecosystem services. Often management which attempts to maximize the production of one ecosystem service often results in substantial declines in the provision of other ecosystem services (Bennett *et al.* 2009). Interactions between ecosystem services can result in management interventions affecting one service with only trivial effects on others or they can have significant effects on multiple services. For example, grooming a beach has a (supposed) positive effect on recreation but a negative effect on biodiversity, coastal defence, waste breakdown and detoxification, and nutrient recycling. Environmental services are complex and multi-dimensional and is difficult to know how management decisions will affect them (Turner *et al.* 2003). Non-market valuation is by no means a perfect solution to measuring people’s values and attitudes, but coupled with ecological knowledge it can be a powerful and informative tool. The fundamental aim is not to put a “price tag” on the environment or its component parts, but to express the effect of marginal change in ecosystem services in terms of a rate of trade off against other things people value (Randall, 2002; Hanley & Shogren, 2002; Turner 2003). Environmental economic valuation obviously has its limits but coupled with ecological research, a fusion of the two disciplines can produce useful information which can aid the decision making process of managers and policy makers.

6.4 *Synthesis of Ecological and Economic findings*

This thesis has combined the two disciplines of ecology and economics to try and understand the current beach management strategies in Scotland, what their impacts and consequences are for biodiversity, and observe public opinion on the existing and any alternative approaches. Although the consensus is that both ecological and social factors are essential dimensions of conservation research and practice, taking on a multiple disciplinary project has many unavoidable challenges. Much of the literature from multiple disciplinary collaborations focuses on the problems, barriers and obstacles of such associations and possible ways to overcome these issues. (Pooley *et al*. 2013). The limited impact of conservation science has been widely cited (Mascia *et al.* 2003) and it has been suggested that this lack of impact can be linked to a lack of attention to social factors. By marrying together the two disciplines of ecology and economics, researchers are essentially analysing both conceptions of natural resources for human use and considering the duty of care to the non-human world (Fischer *et al.* 2007). Both the social and ecological aspects are valuable in conservation research and if undertaken with well-defined goals, this “chimera” of multiple disciplinarily projects can lead to more successful, high impact conservation research (Pooley *et al*. 2013).

6.4.1 *Ecological versus environmental economics*

Environmental and ecological economics are related to each other but there are differences. The main difference between the two is the concept of "value". Environmental economists usually focus on human preferences (demand-side), while ecological economists usually focus on science and the environmental consequences of economic decisions (supply-side). Environmental economists are concerned with the efficient allocation of natural resources, ecological economists calculate the cost-benefit of preserving or protecting natural resources (van den Bergh, 2000). Ecological and environmental economics can lead to very different implications for policymakers. Policymakers are not likely to be interested in theoretical debates but more so in the models, forecasts and metrics that support specific policy decisions by comparing one policy to another. There have been suggestions that it would be more useful to encourage more co-operation between natural and social scientists to influence each other's way of thinking and develop joint theories and models in line with Wilson's concept of "consilience" (Wilson, 1998). The findings of this thesis suggest that this convergence of scientific knowledge is a useful way of carrying out scientific research. The ecological findings provided by chapters 2 and 3 naturally led on to a need for a more social science approach, in order to understand why beach managers chose to groom their beaches and then to understand if beach users preferred this method of beach management. This natural progression from ecology to economics suggests that there is other research both in coastal ecology and other disciplines which would benefit from a more integrated approach.

6.5 *Future management suggestions; the need for beach award reinvention*

Currently a number of different Beach Awards are available to beach managers both nationally and internationally. Amongst these the most commonly known in the UK and Ireland are the Blue Flag, the Seaside Awards and the Green Coast Award. On an international level the numbers of Beach Awards and the different attributes they cover varies hugely. This has resulted in confusion regarding the need for and use of Beach Awards and may be responsible for a type of beach award apathy amongst beach users. It is clear from the findings in this thesis that a new approach to the awards system and how beaches are managed is advisable. A simple solution to the problem would be to remove the use of Beach Awards and replace them with real time bathing water quality information, as is currently being used on some beaches in Scotland by SEPA. In addition, educational information about biodiversity and the types of wildlife that can be seen at each beach should be provided, with information about how beaches are being managed to benefit for both recreational users and for wildlife. If grooming normally occurs at a beach but has been stopped or reduced then information should be provided which explains why this is important for biodiversity on the beach. If people are informed and educated about why a beach is being managed in a certain way they are probably more likely to accept and support it.

It is, however, unlikely that Beach Awards will disappear in the near future, and they will undoubtedly continue to be used as an indicator of “good” beaches. It would therefore be beneficial to beach users and managers if the criteria and standards were clearer and more direct. The Blue Flag brands itself as an eco-label and as such discourages the grooming of beaches with mechanical equipment. This guideline is obviously not being adhered to and raises the question of which of the other criteria and guidelines are being disregarded. Many beaches in Scotland are not eligible for a Blue Flag award as they are so rural in nature and do not lend themselves well to many of the criteria (i.e. lifeguards, drinking water availability and toilets). They therefore have to apply for a Seaside Award instead. The presence of these different labels for beaches leads to confusion, and as has been seen in this study, a lack of understanding and awareness of the Beach Award system. It is apparent that consistency is needed in the design and designation of Beach Awards.

A further recommendation would be to completely remove bathing water quality standards from the Beach Award system. The information provided only guarantees that the water quality adhered to the EEC Bathing Water Directive criteria the previous year and is therefore not useful in preventing gastrointestinal infections on a real-time basis. The development of a real-time App which updates the public on a daily basis would be a convenient way to convey this information. Alongside electronic display boards at the beach, this would ensure that beach users could accurately assess the risk to their health that entering the sea would bring.

6.6 *The Global problem of beach grooming*

The problem of marine litter is a global one and all around the world beach managers are faced with the same problems and management decisions. Although research has been carried out in California by Dugan, (2010) which observed loss of coastal strand habitat associated with grooming, there has been little work done elsewhere in the world. In many Mediterranean holiday destinations it is considered the norm to have well-groomed, pristine beaches with no litter and no seaweed present. This management technique seems to have gone unquestioned and has led to a culture where tourists now expect these immaculate, and unnatural beaches (McKenna, 2011). Results from this thesis suggest that this cultural norm should be upturned and a process for change be instigated. Educating and informing both the beach managers and the public is an important step in trying to change attitudes and opinions, and this needs to be done on a global scale.

6.7 *The role of seaweed and litter as a source of faecal indicator organisms*

This thesis has focussed on the importance of leaving stranded seaweed on the beach in order to maintain and enhance levels of biodiversity in the coastal environment. A study by Quilliam *et al.* (2014) discusses the role that beach cast seaweed has in harbouring faecal indicator organisms (FIO's). FIO's have been found to be present on certain species of freshwater macroalgae in Eutrophic regions of the Great Lakes in the US (Ishii *et al.* 2006). Quilliam *et al.* (2014) found that senescing seaweed (i.e. beach cast wrack) can facilitate the survival and persistence of FIO's such as Escherichia coli, and that plastic litter was found to support the heterotrophic bacteria Vibrio spp. These FIO's could potentially be reducing the bathing water quality at popular tourist beaches. This raises an interesting issue regarding the benefits to biodiversity of leaving the seaweed on the beach, compared to the negative health aspects for people and bathing water quality. Kinzelman *et al.* (2008) state that the increased invertebrate biodiversity that stranded wrack brings to the beach also attracts birds which continually add more faecal matter to the sand, also increasing levels of FIO's to the bathing waters. Although this issue is one which needs to be taken seriously and possibly investigating further, there are other environmental pathways for contamination of bathing waters, such as the inputs from pasture grazed by livestock following a storm or point source inputs such as sewage discharges. All of these potential sources of FIO's could negatively impact on the quality of bathing waters and are the reason why a real-time App providing up to date information about health risks to bathers is an ideal solution to the problems of bathing water quality. This would enable seaweed to be left to decay on the beach providing all the benefits to plants, invertebrates, birds and the ecosystem as a whole, without putting beach users at risk of becoming ill unnecessarily. The role of improved catchment management in reducing contamination of bathing waters is also emphasised.

6.8 ***Management of litter***

Many of the problems discussed in this thesis stem from the huge increase in marine and coastal litter which has arisen over the last 20 years. For every kilometre of beach surveyed in 2015 the Marine Conservation Society recorded 3,298 items or 58,770,360 pieces of marine litter along the UK's mainland coast of 17,820km (MCS, 2013). Local Authorities in the UK spend approximately £18 million each year removing beach litter, which represents a 37% increase in cost over the past 10 years (Mouat *et al.* 2010). This is a problem which evidently cannot be solved solely by beach managers cleaning their beaches or providing more rubbish bins. Marine litter is an environmental problem on a global scale impacting human health, the economy and wildlife (SAS 2014). The majority of items that end up as marine litter are single-use disposable items such as plastic packaging and sewage related items. Long term solutions lie in the design of these items ability to recycle products. This type of circular economy would reduce the amount of and the litter being produced and therefore reduce the amount of litter ending up in the sea and on the beach. With less litter on the beach, managers would have no need to use mechanical grooming equipment which would result in an increased utility for beach users and beach managers and a healthy, biodiverse coastal environment.

References

Adamowicz, W., Swait, J., Boxall, P., Louviere, J. and Williams, M. (2003) Perceptions versus objective measures of environmental quality in combined revealed and stated preference models of environmental valuation. *The New Economics of Outdoor Recreation.* pp. 165.

Adin, R. and Riera, P. (2003) Preferential food source utilization among stranded macroalgae by Talitrus saltator (Amphipod, Talitridae): a stable isotopes study in the northern coast of Brittany (France). *Estuarine, Coastal and Shelf Science,* 56 (1), pp. 91-98.

Atterton, J. (2006) Ageing and coastal communities. *Report for the Coastal Action Zone Partnership Newcastle-upon-Tyne, Centre for Rural Economy. Newcastle University*.

Baden, S. and Boström, C. (2001) The leaf canopy of seagrass beds: faunal community structure and function in a salinity gradient along the Swedish coast. *Ecological Comparisons of Sedimentary Shores.* Springer, pp. 213-236.

Baker, H.G. (1989) Some aspects of the natural history of seed banks. *Ecology of Soil Seed Banks,* pp. 9-21.

Balmford, A., Green, M. and Murray, M. (1996) Using higher-taxon richness as a surrogate for species richness: I. Regional tests. *Proceedings of the Royal Society of London B: Biological Sciences,* 263 (1375), pp. 1267-1274.

Barbier, E.B., Hacker, S.D., Kennedy, C., Koch, E.W., Stier, A.C. and Silliman, B.R. (2011) The value of estuarine and coastal ecosystem services. *Ecological Monographs,* 81 (2), pp. 169-193.

Barton, K. (2013) *MuMIn: Multi-Model Inference.R Package Version 1.9.5.*

Bateman, I.J., Harwood, A.R., Abson, D.J., Andrews, B., Crowe, A., Dugdale, S., Fezzi, C., Foden, J., Hadley, D. and Haines-Young, R. (2014) Economic analysis for the UK national ecosystem assessment: synthesis and scenario valuation of changes in ecosystem services. *Environmental and Resource Economics,* 57 (2), pp. 273-297.

Bates, D., Maechler, M., Bolker, B. and Walker, S. (2014) lme4: Linear mixed-effects models using Eigen and S4. *R Package Version,* 1 (7).

Bell, F.W. and Leeworthy, V.R. (1990) Recreational demand by tourists for saltwater beach days. *Journal of Environmental Economics and Management,* 18 (3), pp. 189-205.

Bennett, E.M., Peterson, G.D. and Gordon, L.J. (2009) Understanding relationships among multiple ecosystem services. *Ecology Letters,* 12 (12), pp. 1394-1404.

Bird, E.C.E. (1985) *Coastline Changes, John Wiley, New York, 1985.* New York: John Wiley.

Boxall, P.C. and Adamowicz, W.L. (2002) Understanding heterogeneous preferences in random utility models: a latent class approach. *Environmental and Resource Economics,* 23 (4), pp. 421-446.

Bradley, R.A. and Bradley, D.W. (1993) Wintering Shorebirds Increase after Kelp (Macrocystis) Recovery. *The Condor,* 95 (2), pp. 372-376.

Brown, A. and McLachlan, A. (2002) Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. *Environmental Conservation,* 29 (01), pp. 62-77.

Buckley, R. (2002) Tourism ecolabels. *Annals of Tourism Research,* 29 (1), pp. 183-208.

Burnham, K.P. and Anderson, D.R. (2004) Multimodel inference understanding AIC and BIC in model selection. *Sociological Methods & Research,* 33 (2), pp. 261-304.

Butchart, S.H., Scharlemann, J.P., Evans, M.I., Quader, S., Arico, S., Arinaitwe, J., Balman, M., Bennun, L.A., Bertzky, B. and Besancon, C. (2012) Protecting important sites for biodiversity contributes to meeting global conservation targets. *PLoS One,* 7 (3), pp. e32529.

Callicott, J.B. (1989) In Defense of the Land Ethic. State University of New York Press, Albany, NY

Calvão, T., Pessoa, M.F. and Lidon, F.C. (2013) Impact of human activities on coastal vegetation-a review. *Emirates Journal of Food and Agriculture,* 25 (12), pp. 926.

Can, Ö. and Alp, E. (2012) Valuation of environmental improvements in a specially protected marine area: A choice experiment approach in Göcek Bay, Turkey. *Science of the Total Environment,* 439, pp. 291-298.

Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., Narwani, A., Mace, G.M., Tilman, D. and Wardle, D.A. (2012) Biodiversity loss and its impact on humanity. *Nature,* 486 (7401), pp. 59-67.

Carson, R.T., Louviere, J.J., Anderson, D.A., Arabie, P., Bunch, D.S., Hensher, D.A., Johnson, R.M., Kuhfeld, W.F., Steinberg, D. and Swait, J. (1994) Experimental analysis of choice. *Marketing Letters,* 5 (4), pp. 351-367.

Cesario, F.J. (1976) Value of time in recreation benefit studies. *Land Economics,* 52 (1), pp. 32-41.

Cesario, F.J. and Knetsch, J.L. (1976) A recreation site demand and benefit estimation model. *Regional Studies,* 10 (1), pp. 97-104.

Chapman, V.J. (1976) *Coastal Vegetation. .* Oxford: Pergamon Press.

Chapman, V.J. (2013) *Coastal vegetation.* Elsevier.

Chavas, J., Stoll, J. and Sellar, C. (1989) On the commodity value of travel time in recreational activities. *Applied Economics,* 21 (6), pp. 711-722.

Cheng, S., Long, J.S. (2006) Testing for IIA in the Mulitnomial Logit Model. *Sociological Methods & Research*, 35, pp 583-600

Ciriacy-Wantrup, S.V. (1947) Capital returns from soil-conservation practices. *Journal of Farm Economics,* 29 (4 Part II), pp. 1181-1196.

Clarke, K. and Warwick, R. (1994) An approach to statistical analysis and interpretation. *Change in Marine Communities,* 2.

Coastal Tourism in Scotland. Insights Department Topic Paper. Visit Scotland. (2016)

Colombini, I., Aloia, A., Fallaci, M., Pezzoli, G. and Chelazzi, M. (2000) Temporal and spatial use of stranded wrack by the macrofauna of a tropical sandy beach. *Marine Biology,* pp. 136-531.

Costanza, R., Folke, C., 1997. Valuing ecosystem services with efficiency, fairness and sustainability as goals. In: Daily, G. (Ed.), *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington, DC, pp. 49–70

Crawford, R.M.M. (2008) *Plants at the Margin: ecological limits and climate change.* Cambridge: Cambridge University Press.

Dalton, R.J. (2005) The greening of the globe? Cross-national levels of environmental group membership. *Environmental Politics,* 14 (4), pp. 441-459.

Davenport, J. and Davenport, J.L. (2006) The impact of tourism and personal leisure transport on coastal environments: A review. *Estuarine, Coastal and Shelf Science,* 67 (1–2), pp. 280-292.

Davidson, M.D. (2013) On the relation between ecosystem services, intrinsic value, existence value and economic valuation. *Ecological Economics,* 95, pp 171-177

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., Lastra, M. and Scapini, F. (2009) Threats to sandy beach ecosystems: A review. *Estuarine, Coastal and Shelf Science,* 81 (1), pp. 1-12.

Deidun, A., Saliba, S. and Schembri, P.J. (2009) Considerations on the Ecological Role of Wrack Accumulations on Sandy Beaches in the Maltese Islands and Recommendations for Their Conservation Management. *Journal of Coastal Research,* (, Special Issue No. 56. Proceedings of the 10th International Coastal Symposium ICS 2009, Vol. I), pp. 410-414.

Delbaere, B. (1998) *Facts & figures on Europe's biodiversity: state and trends 1998-1999.* European Centre for Nature Conservation.

Doody, P. (1997) Coastal dunes of Europe–recreational impacts and nature conservation. *Coastal Dunes Recreation and Planning.Leiden, the Netherlands,* pp. 50-59.

Dugan, J.E. and Hubbard, D.M. (2010) Loss of coastal strand habitat in southern California: The role of beach grooming. *Estuaries and Coasts.* 3 (1), pp. 67-77.

Dugan, J.E., Hubbard, D.M., McCrary, M.D. and Pierson, M.O. (2003) The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. *Estuarine, Coastal and Shelf Science,* 58, Supplement (0), pp. 25-40.

Englin, J. and Mendelsohn, R. (1991) A hedonic travel cost analysis for valuation of multiple components of site quality: the recreation value of forest management. *Journal of Environmental Economics and Management,* 21 (3), pp. 275-290.

Executive, S. (2004) Scottish economic statistics. *A Scottish Executive National Statistics Publication, ISBN: 0-7559-4311-2.*

Expenses and benefits: business travel mileage for employees' own vehicles Available:https://www.gov.uk/expenses-and-benefits-business-travel-mileage/rules-for-tax [Accessed: 15 Jul. 2015].

Feagin, R.A., Sherman, D.J. and Grant, W.E. (2005) Coastal erosion, global sea-level rise, and the loss of sand dune plant habitats. *Frontiers in Ecology and the Environment,* 3 (7), pp. 359-364.

Feather, P., Hellerstein, D. and Hansen, L. (1999) Economic valuation of environmental benefits and the targeting of conservation programs: the case of the CRP. *Economic Research Service AER,* 778.

FEE, 2016. Blue Flag Beach Criteria and Explanatory Notes. Foundation for Environmental Education. from: www.blueflag.org. [Accessed: December 2012].

Fezzi, C., Bateman, I.J. and Ferrini, S. (2014) Using revealed preferences to estimate the Value of Travel Time to recreation sites. *Journal of Environmental Economics and Management,* 67 (1), pp. 58-70.

Fischer, J., Manning, A.D., Steffen, W., Rose, D.B., Daniell, K., Felton, A., Garnett, S., Gilna, B., Heinsohn, R. and Lindenmayer, D.B. (2007) Mind the sustainability gap. *Trends in Ecology & Evolution,* 22 (12), pp. 621-624.

Fisher, A.C. (1981) Resource and Environmental Economics. Cambridge University Press.

Fox, J. (2003) Effect displays in R for generalised linear models. *Journal of Statistical Software,* 8 (15), pp. 1-27.

Freeman III, A.M., Herriges, J.A. and Kling, C.L. (2003) The Measurement of Environmental and Resource Values: Theory and Methods. Third edition. RFF Press.

Garrod, G. and Willis, K. (1998) Estimating lost amenity due to landfill waste disposal. *Resources, Conservation and Recycling,* 22 (1), pp. 83-95.

Gheskiere, T., Magda, V., Greet, P. and Steven, D. (2006) Are strandline meiofaunal assemblages affected by a once-only mechanical beach cleaning? Experimental findings. *Marine Environmental Research,* 61 (3), pp. 245-264.

Gilburn, A.S. (2012) Mechanical grooming and beach award status are associated with low strandline biodiversity in Scotland. *Estuarine, Coastal and Shelf Science,* 107, pp. 81-88.

Good Beach Guide. Marine Conservation Society. Available: http://www.goodbeachguide.co.uk/ [Accessed: October 2016].

Green, P.E. and Srinivasan, V. (1990) Conjoint analysis in marketing: new developments with implications for research and practice. *The Journal of Marketing,* pp. 3-19.

Green, P.E. and Srinivasan, V. (1978) Conjoint analysis in consumer research: issues and outlook. *Journal of Consumer Research,* 5 (2), pp. 103-123.

Griffiths, C.L., Stenton-Dozey, J.M.E. and Koop, K. (1983) Kelp wrack and energy flow through a sandy beach. . In: A. McLachlan and T. Erasmus, eds. *Sandy beaches as ecosystems.* The Hague: W. Junk, pp. 547-556.

Griffiths, C.L. and Stenton-Dozey, J. (1981) The fauna and rate of degradation of stranded kelp. *Estuarine, Coastal and Shelf Science,* 12 (6), pp. 645-653.

Guo, J. (2013) Valuation of the ecosystem services provided by coastal ecosystems in Shandong, China: developing a non-market valuation system.

Haab, T.C. and McConnell, K.E. (2002) *Valuing environmental and natural resources: the econometrics of non-market valuation.* Edward Elgar Publishing.

Hanisak, M. (1993) Nitrogen release from decomposing seaweeds: species and temperature effects. *Journal of Applied Phycology,* 5 (2), pp. 175-181.

Hanley, N., Barbier, E.B. and Barbier, E. (2009) *Pricing nature: cost-benefit analysis and environmental policy.* Edward Elgar Publishing.

Hanley N., S. Mourato, and R. E. Wright. (2001) Choice modelling approaches: a superior alternative for environmental valuation? Journal of Economic Surveys, 15:435-462.

Hanley, N. and Shogren, J.F. (2002) *Awkward choices: economics and nature conservation.* Blackwell Publishing, Oxford.

Hanley, N., Wright, R.E. and Adamowicz, V. (1998) Using choice experiments to value the environment. *Environmental and Resource Economics,* 11 (3-4), pp. 413-428.

Hausman, J.A. and McFadden D. (1984) Specification Tests for the Multinomial Logit Model. *Econometrica*, 52, pp 1219-1240

Heal, G.M., Barbier, E.B., Boyle, K.J., Covich, A.P., Gloss, S.P., Hershner, C.H., Hoehn, J.P., Pringle, C.M., Polasky, S. and Segerson, K. (2005) *Valuing ecosystem services.*

Hensher, D.A., Rose, J.M. and Greene, W.H. (2005) *Applied choice analysis: a primer.* Cambridge University Press.

HMRC (2015) Available: https://www.gov.uk/expenses-and-benefits-business-travel-mileage/rules-for-tax [Accessed September 2015]

Horowitz, J.K. and McConnell, K.E. (2002) A review of WTA/WTP studies. *Journal of Environmental Economics and Management,* 44 (3), pp. 426-447.

Hotelling, H. (1947) The economics of public recreation. *The Prewitt Report.*

Hotelling, H. (1947) Letter to the national park service. *An Economic Study of the Monetary Evaluation of Recreation in the National Parks (US Department of the Interior, National Park Service and Recreational Planning Division, 1949).*

Houston, J. (2008) Management of Natura 2000 habitats. 2130* Fixed coastal dunes with herbaceous vegetation (“grey dunes”). *European Commission.*

Hubbard, D., Dugan, J., Schooler, N. and Viola, S. (2014) Local extirpations and regional declines of endemic upper beach invertebrates in southern California. *Estuarine, Coastal and Shelf Science,* 150, pp. 67-75.

Hynes, S. and Greene, W. (2013a) A panel travel cost model accounting for endogenous stratification and truncation: A latent class approach. *Land Economics,* 89 (1), pp. 177-192.

Hynes, S., Hanley, N. and Scarpa, R. (2008) Effects on welfare measures of alternative means of accounting for preference heterogeneity in recreational demand models. *American Journal of Agricultural Economics,* 90 (4), pp. 1011-1027.

Hynes, S., O'Reilly, P. and Corless, R. (2015) An on-site versus a household survey approach to modelling the demand for recreational angling: Do welfare estimates differ? *Ecosystem Services,* 16, pp. 136-145.

Hynes, S., Tinch, D. and Hanley, N. (2013b) Valuing improvements to coastal waters using choice experiments: An application to revisions of the EU Bathing Waters Directive. *Marine Policy,* 40, pp. 137-144.

Ignaciuk, R. and Lee, J. (1980) The germination of four annual strand-line species. *New Phytologist,* 84 (4), pp. 581-591.

Ince, R., Hyndes, G.A., Lavery, P.S. and Vanderklift, M.A. (2007) Marine macrophytes directly enhance abundances of sandy beach fauna through provision of food and habitat. *Estuarine, Coastal and Shelf Science,* 74 (1-2), pp. 77-86.

Inglis, G. (1989) The colonisation and degradation of stranded Macrocystis pyrifera (L.) C. Ag. by the macrofauna of a New Zealand sandy beach. *Journal of Experimental Marine Biology and Ecology,* 125 (3), pp. 203-217.

Ishii, S., Yan, T., Shively, D.A., Byappanahalli, M.N., Whitman, R.L. and Sadowsky, M.J. (2006) Cladophora (Chlorophyta) spp. harbor human bacterial pathogens in nearshore water of Lake Michigan. *Applied and Environmental Microbiology,* 72 (7), pp. 4545-4553.

Jansson, B. (1978) The Baltic—A systems analysis of a semi-enclosed sea. *Advances in oceanography.* Springer, pp. 131-183.

Jaramillo, E., De La Huz, R., Duarte, C. and Contreras, H. (2006) Algal wrack deposits and macroinfaunal arthropods on sandy beaches of the Chilean coast. *Revista Chilena De Historia Natural,* 79 (3), pp. 337-351.

Jêdrzejczak, M.F. (2002) Stranded Zostera marina L. vs wrack fauna community interactions on a Baltic sandy beach (Hel, Poland): a short-term pilot study. Part II. Driftline effects of succession changes and colonisation of beach fauna. *Oceanologia,* 44 (3).

Jedrzejczak, M. (2002) Spatio-temporal decay ‘hot spots' of stranded wrack in a Baltic sandy coastal system. Part I. Comparative study of the pattern: 1 type of wrack vs 3 beach sites. *Oceanologia,* 44 (4).

Jobstvogt, N., Hanley, N., Hynes, S., Kenter, J. and Witte, U. (2014) Twenty thousand sterling under the sea: estimating the value of protecting deep-sea biodiversity. *Ecological Economics,* 97, pp. 10-19.

Keddy, P.A. (1982) Population ecology on an environmental gradient: Cakile edentula on a sand dune. *Oecologia,* 52 (3), pp. 348-355.

Kinzelman, J.L., Whitman, R.L., Byappanahalli, M., Jackson, E. and Bagley, R.C. (2003) Evaluation of beach grooming techniques on Escherichia coli density in foreshore sand at North Beach, Racine, WI. *Lake and Reservoir Management,* 19 (4), pp. 349-354.

Kirkman, H. and Kendrick, G. (1997) Ecological significance and commercial harvesting of drifting and beach-cast macro-algae and seagrasses in Australia: a review. *Journal of Applied Phycology,* 9 (4), pp. 311-326.

Knetsch, J.L. and Clawson, M. (1966) Economics of Outdoor Recreation.

Koop. (1982) Biodegradation and Carbon Flow Based on Kelp (Ecklonia maxima) Debris in a Sandy Beach Microcosm. *Marine Ecology Progress Series Halstenbek,* 7 (3), pp. 315.

Koop. (1982) Microbial regeneration of nutrients from the decomposition of macrophyte debris on the shore. *Marine Ecology Progress Series Halstenbek,* 9 (1), pp. 91.

Koop, K. and Lucas, M.I. (1983) Carbon flow and nutrient regeneration from the decomposition of macrophyte debris in a sandy beach microcosm. *Sandy beaches as ecosystems.* Netherlands: Springer, pp. 249-262.

Koop, K., Newell, R. and Lucas, M. (1982) Microbial regeneration of nutrients from the decomposition of macrophyte debris on the shore. *Marine Ecology Progress Series.Oldendorf,* 9 (1), pp. 91-96.

Kumar, M. and Kumar, P. (2008) Valuation of the ecosystem services: a psycho-cultural perspective. *Ecological Economics,* 64 (4), pp. 808-819.

Lack, P. (2010) *The atlas of wintering birds in Britain and Ireland.* A&C Black.

Latimer, H. (1981) Consumer and producer surpluses in tourism. *International Journal of Tourism*, September 1981, pp. 147-161.

Lee, J.A. and Ignaciuk, R. (1985) The physiological ecology of strandline plants. *Ecology of Coastal Vegetation.* pp. 319-326.

Lee, T.D. (1988) Patterns of fruit and seed production. *Plant Reproductive Ecology: Patterns and Strategies.Oxford University Press, New York.* pp. 179-202.

Leppäranta, M. and Myrberg, K. (2009) *Physical oceanography of the Baltic Sea.* Springer Science & Business Media.

Lindenmayer, D.B., Likens, G.E., Krebs, C.J. and Hobbs, R.J. (2010) Improved probability of detection of ecological "surprises". *Proceedings of the National Academy of Sciences of the United States of America,* 107 (51), pp. 21957-21962.

Llewellyn, P.J. and Shackley, S.E. (1996) The effects of mechanical beach-cleaning on invertebrate populations. *British Wildlife,* 7, pp. 147-155.

Long, S.C. and Freese, J. (2006) *Regression Models for Categorical Dependent Variables Using Stata.* Third ed. Texas: Stata Press.

Louviere, J.J., Hensher, D.A. and Swait, J.D. (2000) *Stated choice methods: analysis and applications.* Cambridge University Press.

Lucrezi, S., Saayman, M. and Van der Merwe, P. (2015) Managing beaches and beachgoers: Lessons from and for the Blue Flag award. *Tourism Management,* 48, pp. 211-230.

Luisetti, T., Turner, R.K., Bateman, I.J., Morse-Jones, S., Adams, C. and Fonseca, L. (2011) Coastal and marine ecosystem services valuation for policy and management: Managed realignment case studies in England. *Ocean & Coastal Management,* 54 (3), pp. 212-224.

Maddock, A. (2008) UK Biodiversity Action Plan; Priority Habitat Descriptions. *UK Biodiversity Action Plan, 94pp.*

Mann, K.H. (1986) The Role of Detritus at the land-sea boundary. , pp. 123.

Marine Conservation Society - Beach Watch Report. (2013)

Mascia, M.B., Brosius, J.P. and Dobson, T.A. (2003) Conservation and the social sciences. . *Conservation Biology,* 17, pp. 649-650.

Mattson, S., Eriksson, E., Vahtras, K. and Williams, E. (1949) Phosphate relationships of soil and plant. I. Membrane equilibria and phosphate uptake. *Ann.Agr.Coll.Sweden,* 16, pp. 457-484.

Maun, M.A. (2009) *The biology of coastal sand dunes.* Oxford University Press.

Maun, M. (1998) Adaptations of plants to burial in coastal sand dunes. *Canadian Journal of Botany,* 76 (5), pp. 713-738.

McFadden, D. (1974) The measurement of urban travel demand. *Journal of Public Economics,* 3 (4), pp. 303-328.

McKenna, J., Williams, A.T. and Cooper, J.A.G. (2011) Blue Flag or Red Herring: Do beach awards encourage the public to visit beaches? *Tourism Management,* 32 (3), pp. 576-588.

McLachlan, A. (1983) Sandy beach ecology—a review. *Sandy beaches as ecosystems.* Springer, pp. 321-380.

McLachlan, A. and Brown, A.C. (2006) *Ecology of sandy shores.* Academic Press.

McLachlan, A. and McGwynne, L. (1986) Do sandy beaches accumulate nitrogen. *Mar.Ecol.Prog.Ser,* 34, pp. 191-195.

Meehl, G.A., Stocker, T.F., Collins, W.D., Friedlingstein, P., Gaye, A.T., Gregory, J.M., Kitoh, A., Knutti, R., Murphy, J.M. and Noda, A. (2007) Global climate projections. *Climate Change,* 3495, pp. 747-845.

Mellbrand, K., Lavery, P., Hyndes, G. and Hambäck, P. (2011) Linking Land and Sea: Different Pathways for Marine Subsidies. *Ecosystems,* 14 (5), pp. 732-744.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Current State and Trends, vol 1. Island Press, Washington, DC.

Mora, C., Tittensor, D.P., Adl, S., Simpson, A.G. and Worm, B. (2011) How many species are there on Earth and in the ocean? *PLoS Biol,* 9 (8), pp. e1001127.

Mouat, J., Lozano, R.L. and Bateson, H. (2010) *Economic impacts of marine litter.* Kommunenes Internasjonale Miljøorganisasjon.

Nelson, C. and Botterill, D. (2002) Evaluating the contribution of beach quality awards to the local tourism industry in Wales—the Green Coast Award. *Ocean & Coastal Management,* 45 (2), pp. 157-170.

Nelson, C., Morgan, R., Williams, A.T. and Wood, J. (2000) Beach awards and management. *Ocean & Coastal Management,* 43 (1), pp. 87-98.

Nordstrom, K.F., 1994. Beaches and dunes of human-altered coasts. Progress in physical Geography, 18(4), pp.497-516.

Nordstrom, K.F., Lampe, R. and Vandemark, L., M. (2000) Reestablishing Naturally Functioning Dunes on Developed Coasts. *Environmental Management,* 25, pp. 37-51.

Nordstrom, K.F., 2004. Beaches and dunes of developed coasts. Cambridge University Press.

Olabarria, C., Lastra, M. and Garrido, J. (2007) Succession of macrofauna on macroalgal wrack of an exposed sandy beach: effects of patch size and site. *Marine Environmental Research,* 63 (1), pp. 19-40.

ONS. Office for National Statistics. Availale at (http://www.ons.gov.uk) [Accessed September 2015)

Orr, M., Zimmer, M., Jelinski, D.E. and Mews, M. (2005) Wrack Deposition on different beach types: spatial and temporal variation in the pattern of subsidy. *Ecology,* 86 (6), pp. 1496-1507.

Pakeman, R.J. and Lee, J.A. (1991) The Ecology of the Strandline Annuals Cakile Maritima and Salsola Kali. I. Environmental Factors Affecting Plant Performance. *Journal of Ecology,* 79 (1), pp. pp. 143-153.

Pearce, D., Atkinson, G. and Mourato, S. (2006) *Cost-benefit analysis and the environment: recent developments.* Organisation for Economic Co-operation and development.

Pemedasa, M.A., Greig-Smith, P. and Lovell, P.H. (1974) A quantitative description of the distribution of annuals in the dune system at Aberffraw, Anglesey. . *Journal of Ecology,* 62, pp. 379-402.

Perman, R., Ma, Y., Common, M., Maddison, D. and McGilvray, J. (2011) *Natural resource and environmental economics. .* 4th ed. Pearson Education Limited.

Perman, R. (2003) *Natural resource and environmental economics.* Pearson Education.

Phillips, M. and Jones, A. (2006) Erosion and tourism infrastructure in the coastal zone: Problems, consequences and management. *Tourism Management,* 27 (3), pp. 517-524.

Pooley, S.P., Mendelsohn, J.A. and MILNER-GULLAND, E. (2014) Hunting down the chimera of multiple disciplinarity in conservation science. *Conservation Biology,* 28 (1), pp. 22-32.

Provoost, S., Jones, M.L.M. and Edmondson, S.E. (2011) Changes in landscape and vegetation of coastal dunes in northwest Europe: a review. *Journal of Coastal Conservation,* 15 (1), pp. 207-226.

Purvis, A. and Hector, A. (2000) Getting the measure of biodiversity. *Nature,* 405 (6783), pp. 212-219.

Queffelec, B., Cummins, V. and Bailly, D. (2009) Integrated management of marine biodiversity in Europe: Perspectives from ICZM and the evolving EU Maritime Policy framework. *Marine Policy,* 33 (6), pp. 871-877.

Quilliam, R.S., Jamieson, J. and Oliver, D.M. (2014) Seaweeds and plastic debris can influence the survival of faecal indicator organisms in beach environments. *Marine Pollution Bulletin,* 84 (1), pp. 201-207.

Randall, A. (2002) *Benefit cost considerations should be decisive when there is nothing more important at stake.* Blackwell Publishing, Oxford.

Redpath, S.M., Young, J., Evely, A., Adams, W.M., Sutherland, W.J., Whitehouse, A., Amar, A., Lambert, R.A., Linnell, J.D. and Watt, A. (2013) Understanding and managing conservation conflicts. *Trends in Ecology & Evolution,* 28 (2), pp. 100-109.

Rees, G. (1997) Lies, damned lies and beach awards. *Current Issues,* 1, pp. 1-2.

Salisbury, E.J.S. (1952) *Downs and Dunes. Their plant life and its environment.* London: G. Bell & Son Ltd.

Salzman, J., Thompson Jr, B.H. and Daily, G.C. (2001) Protecting ecosystem services: Science, economics, and law. *Stan.Envtl.LJ,* 20, pp. 309.

Scarpa, R., Gilbride, T.J., Campbell, D. and Hensher, D.A. (2009) Modelling attribute non-attendance in choice experiments for rural landscape valuation. *European Review of Agricultural Economics,* 36 (2), pp. 151-174.

Schlacher, T.A., Dugan, J., Schoeman, D.S., Lastra, M., Jones, A., Scapini, F., McLachlan, A. and Defeo, O. (2007) Sandy beaches at the brink. *Diversity and Distributions,* 13 (5), pp. 556-560.

Schlacher, T.A., Schoeman, D.S., Dugan, J., Lastra, M., Jones, A., Scapini, F. and McLachlan, A. (2008) Sandy beach ecosystems: key features, sampling issues, management challenges and climate change impacts. *Marine Ecology,* 29, pp. 70-90.

Sen, A. (1973) Behaviour and the Concept of Preference. *Economica,* New Series, Vol. 40, No.159, pp 241-259.

Smith, V.K. and Desvousges, W.H. (1985) The generalized travel cost model and water quality benefits: a reconsideration. *Southern Economic Journal,* pp. 371-381.

Smyth, R.L., Watzin, M.C. and Manning, R.E. (2009) Investigating public preferences for managing Lake Champlain using a choice experiment. *Journal of Environmental Management,* 90 (1), pp. 615-623.

Spash, C.L. and Aslaksen, I. (2012) Re-establishing an Ecological Discourse in the Debate over the Value of Ecosystems and Biodiversity.

Surfers Against Sewage. *Marine Litter Report. (2014)*

Tarr, J. and Tarr, P. (1987) Seasonal abundance and the distribution of coastal birds on the northern Skeleton Coast, South West Africa/Namibia. *Madoqua,* 15, pp. 63-72.

Ter Heerdt, G., Verweij, G., Bekker, R. and Bakker, J. (1996) An improved method for seed-bank analysis: seedling emergence after removing the soil by sieving. *Functional Ecology.* pp. 144-151.

Thompson, K. (2000) The functional ecology of soil seed banks. *Seeds: The Ecology of Regeneration in Plant Communities,* 2, pp. 215-235.

TNS Travel and Tourism*. Bathing water use in Scotland.* Edinburgh: Scottish Executive Social Research. (2004)

Tudor, D.T. and Williams, A.T. (2006) A rationale for beach selection by the public on the coast of Wales, UK. *Area,* 38 (2), pp. 153-164.

Turner, R.K., Paavola, J., Cooper, P., Farber, S., Jessamy, V. and Georgiou, S. (2003) Valuing nature: lessons learned and future research directions. *Ecological Economics,* 46 (3), pp. 493-510.

Van den Bergh, J.C.J.M. (2001) Ecological economics: themes, approaches, and differences with environmental economics. *Regional Environmental Change*, 2, pp13-23.

Viscusi, W.K., Magat, W.A. and Huber, J. (1991) Pricing environmental health risks: survey assessments of risk-risk and risk-dollar trade-offs for chronic bronchitis. *Journal of Environmental economics and management*, 21(1), pp.32-51.

Ward, F.A. and Beal, D. (2000) *Valuing nature with travel cost models.* Edward Elgar.

Wardman, M. and Bristow, A.L. (2004) Traffic related noise and air quality valuations: evidence from stated preference residential choice models. *Transportation Research Part D: Transport and Environment,* 9 (1), pp. 1-27.

Wattage, P., Glenn, H., Mardle, S., Van Rensburg, T., Grehan, A. and Foley, N. (2011) Economic value of conserving deep-sea corals in Irish waters: A choice experiment study on marine protected areas. *Fisheries Research,* 107 (1-3), pp. 59-67.

Wellenreuther, M. and Connell, S.D. (2002) Response of predators to prey abundance: separating the effects of prey density and patch size. *Journal of Experimental Marine Biology and Ecology,* 273 (1), pp. 61-71.

Whitehead, J.C. (1992) Measuring use value from recreation participation. *Southern Journal of Agricultural Economics,* 24 (02), pp. 113-119.

Wickham, H. (2009) *ggplot2: elegant graphics for data analysis.* Springer Science & Business Media.

Wieland, R.C. and Horowitz, J. (2007) Estimating the recreational consumer surplus at Maryland's state-owned forests. *Report for Harry R.Hughes Center for Agro-Ecology, University of Maryland.*

Williams, J.A. (1978) The annual pattern of reproduction of Talitrus saltator (Crustacea: Amphipoda: Talitridae). *Journal of Zoology,* 184 (2), pp. 231-244.

Williams, P.H. and Gaston, K.J. (1994) Measuring more of biodiversity: can higher-taxon richness predict wholesale species richness? *Biological Conservation,* 67 (3), pp. 211-217.

Willis, A.J. (1965) The Influence of Mineral Nutrients on the Growth of Ammophila Arenaria. *Journal of Ecology,* 53 (3), pp. pp. 735-745.

Wilson, E.O. (1996) The current state of biological diversity. In: M.L. Reaka-Kudla and E. Wilson, eds. *Biodiversity II: understanding and protecting our biological resources.* Joseph Henry Press, pp. 3-18.

Wilson, E.O. (1998) Cosilience. Alfred Knopf, New York.

Zemke-White, W.L., Speed, S.R. and McClary, D.J. (2005) *Beach-cast seaweed: a review. Ministry of Fisheries.* .

Zhang, F., Wang, X.H., Nunes, P.A. and Ma, C. (2015) The recreational value of gold coast beaches, Australia: An application of the travel cost method. *Ecosystem Services,* 11, pp. 106-114.

Zuur, A., Ieno, E., Walker, N., Saveliev, A. and Smith, G. (2009) Mixed effects models and extensions in ecology with R. Gail M, Krickeberg K, Samet JM, Tsiatis A, Wong W, editors. *New York, NY: Spring Science and Business Media.*

Appendix A

Chapter 3: Adult plant species list

Ammophila arenaria	Marram Grass
Leymus arenarius	Lyme Grass
Epilobium angustifolium	Rosebay Willowherb
Taraxacum officinale	Dandelion
Agropyron pungens	Couch Grass
Aster spp.	Aster Spp.
Hieracium perpropinquum	Hawkweed
Cirsium arvense	Creeping Thistle
Cirisium vulgare	Spear Thistle
Poa annua	Annual Bluegrass
Senecio jacobaea	Silver Ragwort
Lamium album	White dead nettle
Bromus sterilis	Barren brome
Galum aparine	Sticky willy
Urtica dioica	Stinging nettle
Alliaria petiolata	Garlic mustard
Achillea millefolium	Yarrow
Angelica sylvestris	Wild angelica
Honckenya peploides	Sea sandwort
Atriplex patula	Common orache
Trifolium ornithopodioides	bird's foot clover
Hippophae rhamnoides	Sea buckthorm
Tussilago farfara	Coltsfoot
Erodium cicutarium	Common Stork's-bill

Rumex obtusifolius	Dock
Senecio vulgaris	Ragwort
Solanum dulcamara	Bittersweet woody nightshade
Montia perfoliata	Miner's lettuce
Silene dioica	Red Campion
Carex arenaria	Sand sedge
Saxifraga tridactyles	Nailwort
Agropyron sp.	wheatgrass
Sonchus arvensis	Beaked Hawksbeard
Geranium molle	Soft cranesbill
Myrrhis odorata	Sweet Cicely
Myosotis sp	forget me not
Sonchus arvensis	Sow corn thistle
Cakile maritima	Sea Rocket
Atriplex laciniata	Frosted Orache
Rumex crispus	Curled dock
Holcus lanatus	Yorkshire Fog
Atriplex littoralis	Thin atriplex
Rosa canina	Dog Rose
Festuca ovina	Sheeps fescue
Elymus farctus	Sand couch
Poa pratensis	Smooth meadow grass
Vicia cracca	Purple Vetch
Vicia hirsuta	Hairy Tare
Trifolium repens	Clover
Draba incana	Hoary Whitlowgrass
Festuca rubra	Red Fescue
Lolium multiflorum	Italian rye grass
Lotus corniculatus	Bird's foot trefoil

Myosotis arvensis	Field forget-me-not
Bellis perennis	Daisy
Thalictrum minus	Lesser Measdow rue
Hypochaeris glabra	Small dandelion
Cirisium Spp.	Melancholy thistle
Heracleum sphondylium	Hogweed
Cochlearia danica	Common scurvy grass
Gnaphalium Sp	Cudweed
Aira praecox	Early Hairgrass
Dactylis glomerata	Cocksfoot
Poa annua	Annual Meadow Grass
Agrostis stolonifera	Creeping Bent Grass
Cerastium diffusum	Sea Mouse-Ear
Lolium perenne	Perennial Ryegrass
Anthyllis vulneraria	Kidney Vetch
Silene vulgaris	Bladder Campion
Filipendula ulmaria	Meadow Sweet
Vicia lutea	New Vetch
Kniphofia spp.	Red Hot Poker
Hypochaeris radicata	Hairy Hawk
Catapodium marinum	Stiff Sand Grass
Poa compressa	Flattened Meadow Grass
Atriplex glabriscula	Babingtons Orache
Triplspermum maritimum	Sea Mayweed
Daucus carota	Wild Carrot
Picris echioides	Bristly Oxtongue
Torilis japonica	Upright Hedge Parsley
Echium vulgare	Viper's Bugloss
Plantago lanceolata	Ribwort Plantain

Crepis vesicaria	Beaked Hawksbeard

Senecio jacobea	Ragwort
Senecio cineraria	Silver Ragwort
Angelica sylvestris	Wild Angelica
Artemisia norvegica	Mugwort

Chapter 3: Seedbank species list

Gallium aparine	Sticky Willy
Cardamine hirsuita	Hairy bittercress
Urtica dioica	Common nettle
Tussilago farfara	Coltsfoot
Cochlearia officinalis	Common Scurvygrass
Atriplex patula	Spear Orache
Tripleurospernum inodurum	Wild chamomile
Taraxacum officinale	Dandelion
Atriplex glabriscula	Babington's Orache
Atriplex littoralis	Grass-leaved Orache
Rumex obtuifolius	Bitter Dock
Atriplex laciniata	Frosted Orache
Sonchus arvensis	Corn Sowthistle
Ammophila arenaria	Marram Grass
Sonchus asper	Prickly Sow Thistle
Lactuca virosa	Wild Lettuce
Leymus arenarius	Lyme Grass
lactuca serriola	Milk Thistle
Carlina vulgaris	Carline Thistle
Crepis taraxacifolia	Beaked Hawk's Beard

Potenetilla anserina	Silverweed
Senecio jacobea	Ragwort
Agrostis stolonifera	Creeping Bentgrass
Hieraceum sp.	Hawkweed
Senecio vulgaris	Common Groundsel
Crepis sp.	hawksbeard
Rumex crispus	Curly Dock
Cakile maritima	European Searocket
Triplospernum maritimum	Sea Mayweed
Honkenya peploides	Sea Sandwort
Catabrosa aquetia	Water Whorl-grass
Agropyron pungens	Sea Couch Grass
Poa bulbosa	Bulbous Bluegrass
Elymus farctus	Sand Couch Grass
Festuca rubra	Red Fescue

Appendix B

Chapter 4: Choice experiment questionnaire 1

UNIVERSITY OF STIRLING

Beach Questionnaire 1

Introduction

We are currently carrying out some research about beaches in Scotland and you have been randomly selected from the electoral roll as someone who can help us. Because you live at or near to the coast we are asking for your help with our research into how people would like their beaches to be managed. We are based at the University of Stirling and this project is a joint venture between the School of Biological and Environmental Sciences and the Economics Department.

We are keen to find out your views on a number of different factors which you may consider when choosing which beach to visit. The information that you give to us will help inform beach managers meaning that your opinions will be used to influence how your beaches are managed.

This survey is completely anonymous and we can ensure that your contribution and views will remain anonymous in any of the reports or publications that we will produce. We will not share any of your personal details with any third party. Data will be stored on secure servers managed in accordance with the Data Protection Act 1998.

Once you have completed the survey, please post it back to us in the pre-paid, pre-addressed envelope. As an incentive to do so, if we receive your survey you will be placed in a draw with the chance of winning a £100 Amazon voucher.

If you would rather fill out this survey online then please visit the web address below:
http://www.survey.bris.ac.uk/stirling/beach

If you have any further questions about the survey, please contact Caroline Griffin here at Stirling University at c.m.griffin@stir.ac.uk or phone 01786 466544

Thank you very much for your time.

Explanatory notes for Beach Questionnaire

We all dislike litter on beaches but how local councils manage it can affect local wildlife and beach habitats. Some councils remove litter and also seaweed that has been washed up on the beach by grooming using a tractor and heavy mechanical equipment. This equipment removes any material that has been washed up or left on the beach. Other councils adopt handpicking to remove litter and others simply leave litter and other material in place.

This survey aims to identify how important beach awards, litter and beach management are to beach goers, in order to help councils decide on the best management options for their beaches This means that by letting us know your preferences you could have a say in how your beaches are managed.

On the following pages we will ask you to pick your favourite beach from a number of alternatives. These options are related to choices you make when choosing a beach to visit. Below you will find information on the choices you will face. Please read through this information which will give you further guidance on what exactly the differences between the beaches are.

1. Beach Awards

In Scotland two different levels of award can be given to beaches. The most prized award is the European Blue Flag. Blue flag beaches must adhere to 26 specific criteria including bathing water quality, environmental education and information and environmental management

The second type of award is the Seaside Award. This award scheme runs only in Scotland, Wales and Northern Ireland and is divided into resort and rural categories. The main difference is that resort beaches offer additional facilities such as toilets and cafés.

Beach Managers can apply for these awards if their beaches meet the specified criteria. It is a desirable feature for a beach to have an award as beach managers believe that they attract larger numbers of tourists.

We ask you to consider 2 options:

- **The beach has an award**
- **The beach has no award**

- ## 2. Price £

Managing beaches costs money. This cost is mainly met by the public through their council taxes. We are asking how much extra you would be prepared to pay per year on your council tax towards beach management, if you could be certain that any increase would indeed go to better beach management.

- **No extra cost. Beach management is either non-existent or at such a level that it does not lead to an increase in council tax.**
- **An increase of £5 per year is added on to the council tax**
- **An increase of £10 per year is added on to the council tax**
- **An increase of £25 per year is added on to the council tax**
- **An increase of £40 per year is added on to the council tax.**

3. Litter Management Practice

Litter is obviously unsightly and at times can pose a health risk. This litter can either be removed by handpicking or mechanical grooming. Handpicking can target litter whereas mechanical grooming is indiscriminate and will remove other natural material washed ashore, such as seaweed. Below we give you 3 options for your preferred choice of litter management.

- **Litter is removed**
- **Litter and seaweed are removed**
- **Nothing is removed**

4. Level of health risk 

In order to comply with European standards of bathing water quality there are certain criteria which must be adhered to.

Human waste (sewage) and waste from animals and birds can promote the growth of harmful bacteria in the sea. These bacteria are always present in sea water but more accumulate where untreated waste enters the sea. The bacteria can cause health risks such as ear infections and stomach upsets. Risks are generally higher for children, the elderly and the immunosuppressed. New water quality standards are coming into place from 2015 based upon levels of these bacteria and are much stricter than current standards.

We ask you to consider three levels of **health risk** associated with **swimming, paddling or water sports where you are actually getting wet:**

- **10% Risk - Sufficient Water Quality. This is the highest level of risk a beach is permitted in order to still achieve status as a designated European bathing water. There is a 10% risk of stomach upsets or ear infections.**

- **5% Risk – Good Water Quality achieved with a somewhat reduced risk of stomach upsets and ear infections generally although still a risk in particular to vulnerable groups such as children.**

- **Very Little Risk - Excellent Water Quality achieved with a larger reduction in the risk of stomach upsets and ear infections.**

5. Wildlife and the Environment

The number of different plants and animals found in the environment is known as the BIODIVERSITY of that environment. We want to find out about how important wildlife and biodiversity are to you. In this example we use the numbers of different bird populations and health of the sand dunes as a way to measure levels of biodiversity.

We ask you to consider 3 levels of biodiversity on the beach:

- **There has been major disruption to the natural environment, loss of bird populations and sand dune erosion. Low levels of biodiversity**
- **Disruption to the environment is reduced but bird and dune plant numbers are still likely to be affected to some extent. Moderate levels of biodiversity**

- **Healthy bird populations and dune systems. High levels of biodiversity**

The Choice Cards

The survey consists of 12 choice cards. Each one gives a choice of three imaginary beaches which differ in the 5 different aspects outlined above. You are asked to choose which of the beaches you would prefer to visit given a choice between the three.

An Example:

Imagine you are thinking of making a day trip to a beach in your area. You might think about all the features of different beaches you could visit. In the example choice task below, we ask people taking part to decide which type of beach they would be most likely to choose to visit by choosing from A,B or C.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	Award	Award	No Award
B. The extra cost on your council tax for this beach would be £	£40	£25	No extra cost
C. Litter management practice 	Remove both	Remove only litter	Remove neither
D. Level of water quality 	Very little risk	5% risk	10% risk
E. Diversity of birds on the beach and health of the dunes 	High numbers of many different species of birds and healthy dune systems. **High biodiversity**	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**
Please pick the ONE option you prefer	☑	☐	☐

In this example the person would choose to visit the beach which has been managed with management type **A**, the combination of attributes is the one they prefer.

Some people may not be concerned about beach awards and simply want the cheapest option. In this case they would opt for beach management type **C**.

Alternatively people may want to see more birds and healthier dunes and prefer to visit the beach which has managed its beach using management type **B** which encourages a higher level of these but with only a small addition to their council tax.

There are no right or wrong answers! The results of this research aim to impact upon how beaches are managed in the future. We therefore want to understand what is important to you. Take the opportunity to have a say in how your beaches are managed, both now and for future generations.

1.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	No Award	Award	Award
B. The extra cost on your council tax for this beach would be £	£0	£10	£40
C. Litter management practice 	Remove neither	Remove only litter	Remove both
D. Level of water quality 	Very little risk	10% risk	5% risk
E. Number and diversity of birds on the beach and health of the dunes 	High numbers of many different species of birds and healthy dune systems. **High biodiversity**	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

2.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	No Award	Award	Award
B. The extra cost on your council tax for this beach would be £	£5	£5	£25
C. Litter management practice 	Remove only litter	Remove neither	Remove both
D. Level of water quality 	10%	Very little risk	5% risk
E. Number and diversity of birds on the beach and health of the dunes 	High numbers of many different species of birds and healthy dune systems. **High biodiversity**	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

3.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	Award	No Award	Award
B. The extra cost on your council tax for this beach would be £	£0	£25	£25
C. Litter management practice 	Remove only litter	Remove neither	Remove both
D. Level of water quality 	Very little risk	5% risk	10% risk
E. Number and diversity of birds on the beach and health of the dunes 	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**	High numbers of many different species of birds and healthy dune systems. **High biodiversity**	High numbers of many different species of birds and healthy dune systems. **High biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

4.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	No Award	Award	No Award
B. The extra cost on your council tax for this beach would be £	£10	£5	£10
C. Litter management practice 	Remove neither	Remove only litter	Remove both
D. Level of water quality 	5% risk	10% risk	Very little risk
E. Number and diversity of birds on the beach and health of the dunes 	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**	High numbers of many different species of birds and healthy dune systems. **High biodiversity**	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

5.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	Award	Award	No Award
B. The extra cost on your council tax for this beach would be £	£25	£10	£0
C. Litter management practice 	Remove both	Remove neither	Remove only litter
D. Level of water quality 	Very little risk	5% risk	Very little risk
E. Number and diversity of birds on the beach and health of the dunes 	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**	High numbers of many different species of birds and healthy dune systems. **High biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

6.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	Award	No Award	Award
B. The extra cost on your council tax for this beach would be £	£25	£5	£5
C. Litter management practice 	Remove both	Remove only litter	Remove neither
D. Level of water quality 	5% risk	Very little risk	10% risk
E. Number and diversity of birds on the beach and health of the dunes 	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**	High numbers of many different species of birds and healthy dune systems. **High biodiversity**	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

In making your choices which of the attributes in the choice cards did you consider to be important or unimportant?

	Important	Unimportant
Beach Award	☐	☐
Cost	☐	☐
Litter management	☐	☐
Health Risk	☐	☐
Biodiversity	☐	☐

FURTHER INFORMATION ABOUT YOUR HOUSEHOLD

It would be really helpful if you could let us know some information about your household so we can make sure we are getting information from a wide and varied range of the population. All of this information is confidential and will not be used for any purpose other than this study.

How many adults live in your household? ___________

How many children live in your household? __________

Do you own a dog? Yes ☐ / No ☐

How old are you?

Under 18 ☐

18-29 ☐

30-49 ☐

50+ ☐

<u>Please tick the appropriate box</u>

Gender: Male ☐ Female ☐

Are you a member of a conservation group Yes ☐
(e.g. RSPB, WWF, National Trust) No ☐

Which of the following best describes your level of education?
School only ☐ College ☐ University ☐

What is your current occupation?

____

What is your approximate annual household income? *(Sum of all people in the house before tax)*

Under £15,000 ☐ £15,000 to £30,000 ☐ £30,000 to £50,000 ☐

£50,000 to £75,000 ☐ Over £75,000 ☐

Thank you for helping us with our research at the University of Stirling!

If you wish to be put forward for the prize draw for the £100 Amazon voucher please leave your email address or phone number below so we can contact you if you win:

THANK YOU!

Appendix C

Chapter 5: Choice experiment questionnaire 2.

Beach Questionnaire 2

Introduction

We are currently carrying out some research about beaches in Scotland and you have been randomly selected from the electoral roll as someone who can help us. Because you live at or near to the coast we are asking for your help with our research into how people would like their beaches to be managed. We are based at the University of Stirling and this project is a joint venture between the School of Biological and Environmental Sciences and the Economics Department.

We are keen to find out your views on a number of different factors which you may consider when choosing which beach to visit. The information that you give to us will help inform beach managers meaning that your opinions will be used to influence how your beaches are managed.

This survey is completely anonymous and we can ensure that your contribution and views will remain anonymous in any of the reports or publications that we will produce. We will not share any of your personal details with any third party. Data will be stored on secure servers managed in accordance with the Data Protection Act 1998.

Once you have completed the survey, please post it back to us in the pre-paid, pre-addressed envelope. As an incentive to do so, if we receive your survey you will be placed in a draw with the chance of winning a £100 Amazon voucher.

If you would rather fill out this survey online then please visit the web address below:
http://www.survey.bris.ac.uk/stirling/beachsurvey

If you have any further questions about the survey, please contact Caroline Griffin here at Stirling University at **c.m.griffin@stir.ac.uk** or phone **01786 466544**

Thank you very much for your time.

Explanatory notes for Beach Questionnaire

We all dislike litter on beaches but how local councils manage it can affect local wildlife and beach habitats. Some councils remove litter and also seaweed that has been washed up on the beach by grooming using a tractor and heavy mechanical equipment. This equipment removes any material that has been washed up or left on the beach. Other councils adopt handpicking to remove litter and others simply leave litter and other material in place.

This survey aims to identify how important beach awards, litter and beach management are to beach goers, in order to help councils decide on the best management options for their beaches This means that by letting us know your preferences you could have a say in how your beaches are managed.

On the following pages we will ask you to pick your favourite beach from a number of alternatives. These options are related to choices you make when choosing a beach to visit. Below you will find information on the choices you will face. Please read through this information which will give you further guidance on what exactly the differences between the beaches are.

1. Beach Awards

In Scotland two different levels of award can be given to beaches. The most prized award is the European Blue Flag. Blue flag beaches must adhere to 26 specific criteria including bathing water quality, environmental education and information and environmental management

The second type of award is the Seaside Award. This award scheme runs only in Scotland, Wales and Northern Ireland and is divided into resort and rural categories. The main difference is that resort beaches offer additional facilities such as toilets and cafés.

Beach Managers can apply for these awards if their beaches meet the specified criteria. It is a desirable feature for a beach to have an award as beach managers believe that they attract larger numbers of tourists.

We ask you to consider 2 options:

- **The beach has an award**
- **The beach has no award**

2. Price £

Managing beaches costs money. This cost is mainly met by the public through their council taxes. We are asking how much extra you would be prepared to pay per year on your council tax towards beach management, if you could be certain that any increase would indeed go to better beach management.

- **No extra cost. Beach management is either non-existent or at such a level that it does not lead to an increase in council tax.**
- **An increase of £5 per year is added on to the council tax**
- **An increase of £10 per year is added on to the council tax**
- **An increase of £25 per year is added on to the council tax**
- **An increase of £40 per year is added on to the council tax.**

3. Litter Management Practice 

Litter is obviously unsightly and at times can pose a health risk. This litter can either be removed by handpicking or mechanical grooming. Handpicking can target litter whereas mechanical grooming is indiscriminate and will remove other natural material washed ashore, such as seaweed. Below we give you 3 options for your preferred choice of litter management.

- **Litter is removed**
- **Litter and seaweed are removed**
- **Nothing is removed**

4. Level of health risk 

In order to comply with European standards of bathing water quality there are certain criteria which must be adhered to.

Human waste (sewage) and waste from animals and birds can promote the growth of harmful bacteria in the sea. These bacteria are always present in sea water but more accumulate where untreated waste enters the sea. The bacteria can cause health risks such as ear infections and stomach upsets. Risks are generally higher for children, the elderly and the immunosuppressed. New water quality standards are coming into place from 2015 based upon levels of these bacteria and are much stricter than current standards.

We ask you to consider three levels of **health risk** associated with **swimming, paddling or water sports where you are actually getting wet:**

- **10% Risk - Sufficient Water Quality. This is the highest level of risk a beach is permitted in order to still achieve status as a designated European bathing water. There is a 10% risk of stomach upsets or ear infections.**

- **5% Risk – Good Water Quality achieved with a somewhat reduced risk of stomach upsets and ear infections generally although still a risk in particular to vulnerable groups such as children.**

- **Very Little Risk - Excellent Water Quality achieved with a larger reduction in the risk of stomach upsets and ear infections.**

5. Wildlife and the Environment

The number of different plants and animals found in the environment is known as the BIODIVERSITY of that environment. We want to find out about how important wildlife and biodiversity are to you. In this example we use the numbers of different bird populations and health of the sand dunes as a way to measure levels of biodiversity.

We ask you to consider 3 levels of biodiversity on the beach:

- **There has been major disruption to the natural environment, loss of bird populations and sand dune erosion. Low levels of biodiversity**

- **Disruption to the environment is reduced but bird and dune plant numbers are still likely to be affected to some extent. Moderate levels of biodiversity**

- **Healthy bird populations and dune systems. High levels of biodiversity**

The Choice Cards

The survey consists of 12 choice cards. Each one gives a choice of three imaginary beaches which differ in the 5 different aspects outlined above. You are asked to choose which of the beaches you would prefer to visit given a choice between the three.

An Example:

Imagine you are thinking of making a day trip to a beach in your area. You might think about all the features of different beaches you could visit. In the example choice task below, we ask people taking part to decide which type of beach they would be most likely to choose to visit by choosing from A,B or C.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	Award	Award	No Award
B. The extra cost on your council tax for this beach would be £	£40	£25	No extra cost
C. Litter management practice 	Remove both	Remove only litter	Remove neither
D. Level of water quality 	Very little risk	5% risk	10% risk
E. Diversity of birds on the beach and health of the dunes 	High numbers of many different species of birds and healthy dune systems. **High biodiversity**	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**
Please pick the ONE option you prefer	☑	☐	☐

In this example the person would choose to visit the beach which has been managed with management type **A**, the combination of attributes is the one they prefer.

Some people may not be concerned about beach awards and simply want the cheapest option. In this case they would opt for beach management type **C**.

Alternatively people may want to see more birds and healthier dunes and prefer to visit the beach which has managed its beach using management type **B** which encourages a higher level of these but with only a small addition to their council tax.

There are no right or wrong answers! The results of this research aim to impact upon how beaches are managed in the future. We therefore want to understand what is important to you. Take the opportunity to have a say in how your beaches are managed, both now and for future generations.

1.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	Award	No Award	No Award
B. The extra cost on your council tax for this beach would be £	£0	£40	£5
C. Litter management practice 	Remove only litter	Remove both	Remove neither
D. Level of water quality 	10% risk	Very little risk	5% risk
E. Number and diversity of birds on the beach 	High numbers of many different species of birds and healthy dune systems. **High biodiversity**	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

2.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	Award	Award	No Award
B. The extra cost on your council tax for this beach would be: £	£40	£0	£5
C. Litter management practice 	Remove both	Remove neither	Remove only litter
D. Level of water quality 	Very little risk	10% risk	5% risk
E. Number and diversity of birds on the beach 	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**	High numbers of many different species of birds and healthy dune systems. **High biodiversity**	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

3.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	No Award	Award	No Award
B. The extra cost on your council tax for this beach would be £	£40	£0	£10
C. Litter management practice 	Remove both	Remove only litter	Remove neither
D. Level of water quality 	5% risk	Very little risk	10% risk
E. Number and diversity of birds on the beach 	High numbers of many different species of birds and healthy dune systems. **High biodiversity**	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

4.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	No Award	No Award	Award
B. The extra cost on your council tax for this beach would be £	£10	£25	£0
C. Litter management practice 	Remove only litter	Remove both	Remove neither
D. Level of water quality 	10% risk	5% risk	Very little risk
E. Number and diversity of birds on the beach 	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**	High numbers of many different species of birds and healthy dune systems. **High biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

5.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	No Award	No Award	Award
B. The extra cost on your council tax for this beach would be £	£5	£0	£40
C. Litter management practice 	Remove neither	Remove both	Remove only litter
D. Level of water quality 	5% risk	10% risk	Very little risk
E. Number and diversity of birds on the beach 	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**	Only one or two different species of birds and dunes in poor health with few plants and lots of erosion. **Low biodiversity**	High numbers of many different species of birds and healthy dune systems. **High biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

6.

Attribute	Management type **A**	Management type **B**	Management type **C**
A. Does the beach have a Beach Award? 	Award	No Award	No Award
B. The extra cost on your council tax for this beach would be £	£5	£40	£0
C. Litter management practice 	Remove neither	Remove both	Remove only litter
D. Level of water quality 	Very little risk	10% risk	5% risk
E. Number and diversity of birds on the beach 	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**	A few different species of birds found on the beach and dunes are relatively healthy but with some erosion. **Moderate biodiversity**
Please pick the ONE option you prefer	☐	☐	☐

In making your choices which of the attributes in the choice cards did you consider to be important or unimportant?

	Important	Unimportant
Beach Award	☐	☐
Cost	☐	☐
Litter management	☐	☐
Health Risk	☐	☐
Biodiversity	☐	☐

FURTHER INFORMATION ABOUT YOUR HOUSEHOLD

It would be really helpful if you could let us know some information about your household so we can make sure we are getting information from a wide and varied range of the population. All of this information is confidential and will not be used for any purpose other than this study.

How many adults live in your household? ___________

How many children live in your household? __________

Do you own a dog? Yes ☐ / No ☐

How old are you?

Under 18 ☐

18-29 ☐

30-49 ☐

50+ ☐

<u>Please tick the appropriate box</u>

Gender: Male ☐ Female ☐

Are you a member of a conservation group Yes ☐
(e.g. RSPB, WWF, National Trust) No ☐

Which of the following best describes your level of education?
School only ☐ College ☐ University ☐

What is your current occupation?

____

What is your approximate annual household income? *(Sum of all people in the house before tax)*

Under £15,000 ☐ £15,000 to £30,000 ☐ £30,000 to £50,000 ☐

£50,000 to £75,000 ☐ Over £75,000 ☐

Thank you for helping us with our research at the University of Stirling!

If you wish to be put forward for the prize draw for the £100 Amazon voucher please leave your email address or phone number below so we can contact you if you win:

THANK YOU!

Appendix D

Chapter 5: Travel Cost Model Beach Questionnaire

Beach___________________________

Date _______________________________

The University of Stirling are currently carrying out research into peoples' opinions about different types of beach management. We would like to find out peoples' thoughts and feelings about how and why they visit beaches in this area. This information will be used to feedback to beach managers (i.e. local councils) and could influence how these beaches are managed in the future.

Please could you take a few moments to help us with our research and fill in the questions below?

1. Why have you chosen to visit this particular beach today?

Close to home	
Clean bathing Water	
No litter	

Good facilities	
To see wildlife/birds	
Beach Award	
Water sports	
Walking	
Dog Walking	
On Holiday staying nearby	
Good Location	
Other (please specify)	

2. What activities do you do at the beach usually? Tick as many as apply.

Dog walking	
Beach combing	
Walking/jogging	
Playing with my kids/picnic	
Paddling	
Bathing/Swimming	
Watch wildlife/birds	
Relaxing	

Windsurfing	
Sea Kayaking	
Surfing	
Kite surfing	
Other (please specify)	

3. How did you travel here?

Car	
Bus	
Train	
On foot	
Bike	

4. How many people, including yourself, have you travelled here today with?

____

5. How long did it take you to get here?

____

6. Did you travel from home today or are you on holiday?

____

7. If you are on holiday how far is this beach from your accommodation?

____

8. How far is it in miles from your home?

____

Can you please let us know your postcode so that we can work out exactly how far you have travelled to get to this beach? This will be used only for the purposes of this study and will not be passed on to anyone else. This cannot be traced straight to your house. If the full postcode is given then it will be narrowed down to about 30 houses. If the last letter is left out then this then changes to within 300 houses.

Postcode: ____

9. In the last 12 months how often have you visited this particular beach?

10. Is your trip today exclusively to visit the beach or are you planning on other activities in this area?

11. How important is bathing water quality to you in deciding on which beach to visit? (Please tick one)

- **Extremely important**
- **Quite important**
- **Not sure**
- **Not important at all**

12. How would you rate the levels of man-made litter on this beach normally (e.g. crisp packets, drinks bottles, fishing gear etc.)? Please circle one.

None/small amount/ considerable amount/Large amount

13. How acceptable do you find the levels of man-made litter on this beach? (Please tick one level)

- **Acceptable**
- **Not too bad**
- **Not sure**
- **Unacceptable**

14. How would you rate the levels of seaweed which have been washed up on the beach? (Circle one)

None/small amount/considerable amount/Large amount

15. How acceptable do you find the levels of seaweed?

- **Acceptable**
- **Not too bad**
- **Not sure**
- **Unacceptable**
-

16. How important is the natural environment, wildlife and biodiversity to you?

- **Very Important**
- **Quite important**
- **Not sure**
- **Not important at all**

17. Do you know if this beach has an award?

- **No**
- **Yes. Which one?**

FURTHER INFORMATION ABOUT YOUR HOUSEHOLD

It would be really helpful if you could let us know some information about your household so we can make sure we are getting information from a wide and varied range of the population. All of this information is confidential and will not be used for any other purpose than this study.

How many adults live in your household? ___________

How many children live in your household? __________

Do you own a dog? Yes ☐ / No ☐

How old are you?

Under 18 ☐

18-29 ☐

30-49 ☐

50+ ☐

<u>Please tick the appropriate box</u>

Gender: Male ☐ Female ☐

Are you a member of a conservation group Yes ☐
(e.g. RSPB, WWF, National Trust) No ☐

Which of the following best describes your level of education?
School only ☐ College ☐ University ☐

What is your current occupation?

What is your approximate annual household income? *(Sum of all people in the house before tax)*

Under £15,000 ☐ £15,000 to £30,000 ☐ £30,000 to £50,000 ☐

£50,000 to £75,000 ☐ Over £75,000

Thank you for helping us with our research!

Appendix E

Design syntax for choice cards

MNL efficiency measures

D error	0.120713
A error	0.151279
B estimate	93.94407
S estimate	135.0764

Prior	b2	b3	b4	b5	b6
Fixed prior value	0.1	-0.1	0.1	0.1	0.1
Sp estimates	135.0764	16.02276	46.4786	45.81056	47.18777
Sp t-ratios	0.168642	0.489652	0.287495	0.289583	0.285326

Design

Choice situation	alt1.a	alt1.b	alt1.c	alt1.d	alt1.e	alt2.a	alt2.b	alt2.c
1	0	0	0	2	2	1	2	2
2	0	1	2	0	2	1	1	0
3	1	0	2	0	2	0	4	1
4	1	4	1	2	1	1	0	0
5	1	0	2	2	0	0	3	0
6	0	4	1	1	2	1	0	2
7	0	2	2	0	0	0	3	1
8	0	2	0	1	1	1	1	2
9	1	3	1	0	1	1	2	0
10	1	3	1	1	0	0	1	2
11	0	1	0	1	0	0	0	1
12	1	1	0	2	1	0	4	1

Choice situation	alt2.d	alt2.e	alt3.a	alt3.b	alt3.c	alt3.d	alt3.e	Block
1	0	0	1	4	1	1	1	1
2	2	1	1	3	1	1	0	1
3	2	1	0	1	0	1	0	2
4	0	2	0	1	2	1	0	2
5	1	2	1	3	1	0	2	1
6	2	0	0	2	0	0	1	2
7	1	1	1	0	0	2	2	2
8	0	2	0	2	1	2	0	1
9	1	0	0	0	2	2	2	1
10	2	2	1	1	0	0	1	1
11	0	0	1	4	2	2	2	2
12	1	1	0	0	2	0	1	2

MNL utilities

Choice situation	alt1	alt2	alt3
1	0.4	0.1	0
2	0.3	0.3	0
3	0.5	0	0
4	0.1	0.3	0.2
5	0.5	0	0.1
6	0	0.5	-0.1
7	0	0	0.5
8	0	0.4	0.1
9	0	0	0.6
10	0	0.5	0.1
11	0	0.1	0.3
12	0.3	-0.1	0.3

MNL
probabilities

Choice situation	alt1	alt2	alt3
1	0.414742	0.307248	0.27801
2	0.364855	0.364855	0.270291
3	0.451863	0.274069	0.274069
4	0.30061	0.367165	0.332225
5	0.439203	0.26639	0.294407
6	0.281408	0.463963	0.254629
7	0.274069	0.274069	0.451863
8	0.27801	0.414742	0.307248
9	0.261635	0.261635	0.47673
10	0.26639	0.439203	0.294407
11	0.289433	0.319873	0.390694
12	0.374487	0.251026	0.374487