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Author(s)	Norton, Daniel
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Estimating the value of the benefits of the Marine Strategy Framework Directive

by

Daniel Norton, B.E., P.Grad.Dip., M.Eng.Sc, M.Econ.Sc.

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From

J.E. Cairnes School of Business and Economics

The National University of Ireland, Galway

Supervisor

Dr. Stephen Hynes

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Abstract

The European Union introduced the Marine Strategy Framework Directive (MSFD) to ensure that Europe's seas are healthy, clean and productive. To meet these goals, decisions will have to be made and cost and benefits weighed against each other. Many of the benefits that the MSFD aims to create are not captured in the marketplace. This thesis estimated the value of these benefits using a variety of market and non-market valuation methodologies. The thesis initially captured the attitudes of the general public to the marine environment. This was done to understand what motivates the general public's values and understanding towards ensuring a sustainable and healthy marine environment. The first valuation method used is an ecosystem services approach using market data and value transfer to identify, quantify and value the different benefits that Ireland derives from its marine and costal environments. Then to estimate the non-use value of the Irish public, two stated preference techniques are used. The first, a contingent valuation approach provides a holistic value for the benefits to society from the achievement of good environmental status, as envisaged under the MSFD, in Irish marine waters. Using the results of the contingent valuation approach in conjunction with value transfer allows for the estimation of the benefits of meeting the goals of the MSFD in the North-East Atlantic for EU member states. The estimated value of achieving good environmental status in the North East Atlantic was €2.3 to €3.6 billion per annum. This work also demonstrated the estimation issues associated the 'modifiable unit areal problem' for the first time using value transfer. The second approach employed to valuing non-use value, a choice experiment approach, allows policymakers to target parts of the MSFD that will bring the most benefit to Irish society and also demonstrated the heterogeneity of values amongst the Irish public. Overall, the results show that the Irish public will gain from having Irish marine waters that are healthy, clean and productive and that they are willing to pay towards achieving those goals.

Declaration of work

I, **Daniel Norton**, certify that the Thesis is all my own work and that I have not obtained a degree in this University or elsewhere on the basis of any of this work.

Signed: ________________________________ Date: __________________

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Finally, I would like to thank my parents, Donal and Patricia, my brother Simon and my sister Eleanor, and all my family for, without them, I would not be where I am today.

Do seo go léir agus níos mó, a rá liom, go raibh maith agat.

Dedication

I dedicate this thesis to my mother, Patricia Norton who was taken too soon. She gifted me with decency, fairness and a joy of learning. I am eternally indebted to her and all she taught me.

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Acronyms and Abbreviations

AIC	Akaike information criterion
AER	annual environmental reports
ASC	alternative specific constant
BIC	Bayesian information criterion
BIM	Bord Iascaigh Mhara
BOD	biochemical oxygen demand
BSA	Biologically Sensitive Area
BT	benefit transfer
CBA	cost-benefit analysis
CBD	Convention on Biological Diversity
CBI	Central Bank of Ireland
CE	Choice experiment
CICES	Common International Classification of Ecosystem Services
CIS	Common Implementation Strategy
CL	Conditional Logit
CLAMER	Climate change and marine ecosystem research
CME	coastal, marine and estuarine
CO2	Carbon dioxide
COP	Conference of Parties
CORINE	Co-ORdinated INformation on the Environment
CS	consumer surplus
CSO	Central Statistics Office
CVM	contingent valuation method
DAFM	Department of Agriculture, Food and the Marine
DCE	discrete choice experiment
DECLG	Department of the Environment, Community and Local Government
EA	ecosystem approach
EAP	Environment Action Programme
EBM	Ecosystem based management
EC	European Commission
EC-DGE	European Commission - Directorate-General for Environment
EEA	European Environmental Agency
EEC	European Economic Community

EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EPA	(Irish) Environmental Protection Agency
ERSI	Economic and Social Research Institute
ES	ecosystem services
ESA	economic and social analysis
ESB	Electricity Supply Board
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GES	Good Environmental Status
GIS	Geographic Information System
GoI	Government of Ireland
GVA	gross valued added
HAB	harmful algae blooms
HELCOM	Helsinki Commission, also known as Baltic Marine Environment Protection Commission
HOOW	Harnessing Our Ocean Wealth
ICES	International Council for the Exploration of the Sea
IID	identically distributed
IMP	Integrated Marine Plan
INE	Instituto Nacional de Estadística
INFOMAR	Integrated Mapping for the Sustainable Development of Ireland's Marine Resource
INSEE	Institut national de la statistique et des études économiques
IPCC	Intergovernmental Panel on Climate Change
LCM	Latent class model
LL	Log-likelihood
MARNET	Marine Socio Economic Network
MAUP	modifiable area unit problem
MEA	Millennium Ecosystem Assessment
MCA	multi-criteria analysis
MCZ	marine conservation zones
MI	Marine Institute
MPA	Marine Protected area
MSPD	Maritime Spatial Planning Directive

MS	Member State
MSCG	Marine Strategic Co-ordination Group
MSFD	Marine Strategy Framework Directive
MSY	Maximum sustainable yield
MW	Megawatt
N	nitrogen
NE	North East
NISRA	Northern Ireland Statistics and Research Agency
NMCI	National Maritime College of Ireland
NRS	National Records of Scotland
NUI	National University of Ireland
NUTS	Nomenclature of territorial units for statistics
OLS	Ordinary Least Squares
ONS	Office for National Statistics
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
P	phosphorous
PC	Producer cost
PE	population equivalent
POPs	persistent organic pollutants
PPP	purchasing power parity
PS	producer surplus
PTE	Portuguese Escudo
QSR	Quality Status Report
RITZ	rocky intertidal zones
RP	revealed preference
RPL	Random Parameters Logit
RUM	random utility maximization
RV	Research vessel
SA	Small Area
SCV	standard compensating variation
SEA	Strategic Environmental Assessment
SEMRU	Socio-Economic Marine Research Unit
SFPA	Sea Fisheries Protection Authority
SMART	Strategic Marine Alliance for Research and Training

SP	stated preference
SS	Steamship
SSE	Scottish and Southern Energy
STECF	Scientific, Technical and Economic Committee for Fisheries
TAC	Total Allowable Catch
TBT	tributyltin
TEEB	The Economics of Biodiversity and Ecosystems
TEV	Total economic Value
TC	travel cost
UK	United Kingdom
UKNEA	UK National Ecosystem Assessment
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
US	United States
UWWTD	Urban Wastewater Treatment Directive
VAT	Value Added Tax
VT	value transfer
WG-ESA	Working Group on Economic and Social Assessment
WFD	Water Framework Directive
WTA	willingness to accept
WTP	willingness to pay

Chapter 1

Introduction

1.1. Introduction

For most of history the oceans were seen as a boundless source of food and raw materials especially by the fisheries and whaling industries (Roberts, 2010). The sea's vastness, covering 71% of the earth's surface and containing 90% of its biosphere (EC, 2006), made it seem as if it was an unlimited sink for waste from the shore and a source of inexhaustible resources. Thomas Henry Huxley, in the inaugural address at the Fisheries Exhibition, London in 1883 stated;

"Are there any sea fisheries which are exhaustible, and, if so, are the circumstances of the case such that they can be efficiently protected? I believe that it may be affirmed with confidence that, in relation to our present modes of fishing, a number of the most important sea fisheries, such as the cod fishery, the herring fishery, and the mackerel fishery, are inexhaustible. And I base this conviction on two grounds, first, that the multitude of these fishes is so inconceivably great that the number we catch is relatively insignificant; and, secondly, that the magnitude of the destructive agencies at work upon them is so prodigious, that the destruction effected by the fisherman cannot sensibly increase the death-rate (Huxley, 1883)"

The growth in technology and its impact on both terrestrial and marine environments was unforeseen and it wasn't until the late 20th century that it came to be realised that there are limits and humankind was beginning to test them (Meadows et al., 1972, Jackson, 2001).

The increased exploitation of marine resources due to a combination of technological progress and population increase was also amplified by a lack of assigned property rights (Wyman, 2008). This lack of assigned property rights means that the oceans are subject to the over-exploitation due to the 'tragedy of the commons' (Hardin, 1968). Hardin (1998) noted that this was caused by the shibboleth, *"the freedom of the seas"* and that now nations were moving to regulate their marine resources. Traditionally, nations only claimed the marine waters three nautical miles from their coastline as their territorial waters. However, post-world war two several nations began to extend their maritime boundaries, some to 12 nautical miles and others to 200 nautical miles or to the edge of the continental shelf. This was done to prevent use of resources within the marine territory by foreign vessels and also to protect nations from pollution from foreign ships operating close to their coastlines (Long, 2007). In an effort to prevent conflict between nations over various claims, the United Nations (UN) in 1956 held its first Conference on the Law of the Sea (UNCLOS I), which resulted in four treaties in 1958. These were in turn superseded by UNCLOS III which took place from 1973 to 1982 and was ratified in 1994 (Long, 2007).

UNCLOS III codified many nations' marine territorial claims and also set up legal framework for making of new marine territorial claims (Wyman, 2008). Broadly, this has created three levels of marine territorial boundaries; a 12 nautical mile zone known as the territorial waters where the coastal nation can legislate and regulate as it sees fit and has exclusive rights over marine resources; a further 12 nautical mile zone (24 nm from the coastline) known as the contiguous zone, where a state can enforce laws in relation to certain areas including customs, taxation, immigration and pollution if the infringement will impact on the coastal nation's territorial waters; and finally a 200 nautical mile zone out from the coastline known as exclusive economic zones (EEZs) where the coastal nation has exclusive rights over all natural resources. Additionally, UNCLOS III covers other issues including navigation and transit regimes, deep seabed mining and the exploitation regime, scientific research, settlement of disputes and protection of the marine environment (DOALOS, 2012). In relation to the marine environment, UNCLOS III places an obligation on all states to protect and preserve the marine environment both within their EEZs and in the high seas. It also focuses on protecting the environment through the prevention of marine pollution within the coastal nation's EEZ and from that nation's vessels wherever they are (DOALOS, 2012). In an effort to further protect marine fisheries in the high seas adjacent to EEZs from over-exploitation the Conference adopted the 1995 Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks which adopted a precautionary approach for exploiting fisheries and expanded powers for nations aimed at proper management of fisheries resources in the high seas (Juda, 1997).

In Europe, following an oil spill from the tanker, SS Torrey Canyon, in 1967 off the South-West coast of the UK, there was a drive for an international agreement to protect the marine environment (Harrison and Sewell, 1979). The first agreement reached was known as the "Bonn Agreement" or the Agreement for Cooperation in Dealing with Pollution of the North Sea by Oil (Bonn Agreement, 1983) which deals with oil spill management and was signed by eight North Sea nations in 1969 but was not activated until the late 1970's following two more oil spills. It was revised in 1983 to cover "other harmful substances" and allowed the EEC (now the EU) to join. It has been revised since then to allow aerial surveillance and to allow Ireland join. The original "Bonn Agreement" was followed by two conventions on protecting the marine environment. The first was the "Oslo Convention" or the *Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft* (1972) that provided further international legal protection for the marine environment from dumping at sea. It covered the Atlantic and Arctic Oceans (but excluded the Baltic and Mediterranean) and came into force in 1974. It was signed by 7 nations which were joined by 6 others by 1985. A second similar convention was the "Paris Convention" or *Convention for the Prevention of Marine Pollution from Land-Based Sources* (1974). It came into force in 1978 and aimed to protect the marine environment from discharges of harmful substances from coastal sources including watercourses and pipelines in the same sea areas covered by the "Oslo Convention".

In 1992, the 14 nations signed up to the "Oslo Convention" and the "Paris Convention", along with Switzerland and representatives of the European Commission (EC), adopted a new convention, the Convention for the Protection of the Marine Environment of the North-East Atlantic (1992) or the *OSPAR Convention*. This convention came into force in 1998. The OSPAR Convention contains a series of Annexes which deal with various specific areas, namely:

- Prevention and elimination of pollution from land-based sources: Annex I;
- Prevention and elimination of pollution by dumping or incineration: Annex II;
- Prevention and elimination of pollution from offshore sources: Annex III;
- Assessment of the quality of the marine environment: Annex IV and
- On the protection and conservation of the ecosystems and biological diversity of the maritime area: Annex V.

However, measures related to fisheries in the north east Atlantic and the North Sea are not covered by the "OSPAR Convention" but instead are managed by the International Council for the Exploration of the Sea (ICES) (1902). Additionally, the *OSPAR Convention* only covers the north east Atlantic (including the North Sea) and Arctic but excludes other European marine areas of the Baltic Sea, Mediterranean Sea and the Black Sea. These are covered by other international marine protection frameworks. In the case of the Baltic Sea, this is the Protection of the Marine Environment of the Baltic Sea Area, or the *Helsinki Convention* (1992). This convention is implemented by the Baltic Marine Environment

Protection Commission - Helsinki Commission (HELCOM), while in the Black Sea, the *Bucharest Convention* (Convention on Protection of the Black Sea Against Pollution) (1992) is implemented by the "Black Sea Commission" which also implements the Black Sea Strategic Action Plan. Finally, in the Mediterranean, there is the *Barcelona Convention* (the Convention for the Protection of the Mediterranean Sea Against Pollution) (1976) which was amended in 1995 and renamed the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (although it is still known as the Barcelona Convention).

The OSPAR Commission is the body responsible for implementing the *OSPAR Convention* and as part of its obligation related to Annex IV, released its first Quality Status Report (QSR) on the state of the marine environment in the OSPAR maritime area in 2000 (OSPAR, 2000) that was followed up by another in 2010 (OSPAR, 2010). The most recent QSR, QSR 2010, (OSPAR, 2010), examined eight areas related to the marine environment;

- Climate change and ocean acidification
- Eutrophication
- Hazardous substances
- Radioactive substances
- Offshore oil and gas industry
- Fishing
- Other human uses and impacts
- Biodiversity and ecosystems

In three of the areas the report noted that generally the situation had improved, two areas had mixed results and there were negative environmental trends for three areas. For eutrophication, in previous problem areas, nutrient inputs had greatly decreased since 1985 with up to 85% lower phosphorus and up to 50% lower nitrogen inputs. However, the goal of no eutrophication by 2010 had not been met and some areas in the North Sea and inshore areas in the Celtic Seas and off the French coast still had eutrophication issues. For radioactive substances the situation had improved with lower levels of radioactivity in all the OSPAR regions since 1995. There was also positive trends reported for the offshore oil and gas industry with oil discharges falling on average by 20% in the OSPAR area since 2000 beating the stated goal of a 15% reduction (OSPAR, 2010).

The two areas where there are mixed trends were for hazardous substances and fishing. It is expected that by 2020, a third of the OSPAR's priority groups of chemicals will be phased out and monitored chemicals concentrations have generally fallen, particularly heavy metals, but are still above acceptable concentrations in certain coastal areas. For example, tributyltin (TBT), which was subject to a global ban in 2008, is still persistent in large areas of the OSPAR region, particularly in high shipping areas. Another example of a legacy chemical are polychlorinated biphenyls (PCBs) that despite production being banned during the 1980's in Europe are still entering the OSPAR region and in conjunction with other persistent organic pollutants (POPs) are accumulating in high level predators such as cetaceans causing reproductive failure and increased susceptibility to diseases (Tanabe et al., 1994, OSPAR, 2010).

Fishing in the OSPAR region (UN FAO major fishing area 27, Atlantic, Northeast) covers 4% of the world's ocean surface area and accounts for 10% of the world's capture fisheries (OSPAR, 2009) making it the second most productive area in the world after the Northeast Pacific (UN FAO major fishing area 61, Pacific, Northwest) (FAO, 2012). Production measured as tonnes of fish was at its highest in 1976 at c.13 million tonnes (OSPAR, 2009) decreasing to c.8.1 million tonnes in 2012 (FAO, 2012). In relation to fishing, the QSR 2010 reports that there continues to be impacts on marine ecosystems despite improvements in management. Different fishing regimes for different species can have varying physical impacts on the benthos but the report noted that there had been an improvement in the protection of deep-sea cold water corals (CWCs) from deep water fishing. Other negative impacts on the marine environment noted by the report are due to discards which was estimated at 1.4 million tonnes during the 2000's during which fisheries production fell from 11.1 million tonnes in 2001 to 8.7 million tonnes in 2010 (FAO, 2006, FAO, 2012) and the effect of fisheries on community structure and marine food webs (OSPAR, 2010). It was also noted that over 80% of stocks were being exploited beyond maximum sustainable yields (MSYs) within the OSPAR region (OSPAR, 2010) but this is a declining trend with an increase in stocks fished at MSY from 2005 – 2009 (OSPAR, 2009).

The three areas that OSPAR 2010 identified with negative trends were climate change, biodiversity and ecosystems and lastly other human uses and impacts. For the latter, other human impacts and uses, there are a variety of activities which are putting pressure on the marine environment. Increases in activity associated with offshore renewables, particularly wind farms, mineral extraction and coastal defence works can physically alter the marine environment and compete for space with natural ecosystems. Using offshore wind energy as an example, Ashley et al. (2014) in a review of the literature of the effects of offshore windfarms and the potential of their co-location with marine protected areas (MPAs) found mixed effects. It has been theorised that offshore windfarms act as no-take zones for fisheries and would act as a de-facto MPA. In their review, Ashley et al (2014) found that offshore windfarms favoured hard substrate species including commercial species such as mussels (*Mytilus trosullus*) and edible crab (*Cancer pagarus*). The numbers of these species were found to have increased with weaker evidence of an increase in pollock (*Pollachius pollochius*) and cod (*Gadus morhua*). However, negative effects were noted on soft substrate benthic habitats and species such as flat fish species (*Pleuronectidae sp.*). It was concluded that there is a possibility of co-locating both offshore windfarms and MPAs but the success may be habitat dependent.

For the protection of biodiversity and ecosystems, OSPAR is one of the main processes for implementing the UN Convention on Biological Diversity (CBD) (1992) in the North East Atlantic region. The QSR 2010 (OSPAR, 2010) found that throughout many regions the pressures on biodiversity and ecosystems are still present and increasing despite efforts made to the contrary such as a growing network of MPAs. The report finds that there is still very limited knowledge on the ecosystem functioning and status of species and habitats in the seas below 200m which cover 83% of the OSPAR area. The most affected species and habitats are those that are slow growing or have slow reproduction cycles, such as deep sea cold water corals (*Lophelia pertusa*), the common skate (*Dipturus batis*) which can be impacted by bottom trawling and the blue whale (*Balaenoptera musculus*) which despite 40 years of protection from commercial whaling are still at low numbers and recovering very slowly. There are also a lot of differences across habitats within the OSPAR region especially between coastal areas and offshore areas. The type of threats also varies between the offshore and coastal habitats with coastal habitats and species at risk from a variety of increasing human impacts such as pollution, developments along the coast, dredging works or works to combat sea level rise while future threats include introduction of non-native species. Offshore in the shelf seas, the main pressure is fishing which affects certain target species such as Atlantic cod (*Gadus morhua*) and Atlantic bluefin tuna (*Thunnus thynnus*). Certain fishing practices, such as bottom trawling, also have severe impact on certain types of benthic habitats. Fishing also affects the deep sea environment which may be exasperated with the possible future development of deep sea mining. The most severe future threat for biodiversity, ecosystems and fisheries within the North East Atlantic that the report identified was climate change.

The most recent IPCC report, The Fifth Assessment Report (Stocker et al., 2013) has found that climate change and the warming of the planet and its oceans is unequivocal and it is clear that this is due to human activities. Climate change manifests itself in the oceanic environment as an increase in water temperature, a corollary rise in sea levels and reduction in the area and amount of sea ice in polar regions. Additionally, the absorption of CO_2 by the seas and oceans has increased acidity levels, a process known as ocean acidification. Oceanic warming dominates the mechanism through which increased energy is stored in the climate, systems accounting for 90% of the increase in the period 1971- 2010 (Stocker et al., 2013) and has led to an average 0.19m rise in sea levels from 1901 to 2010. Alongside the uptake in heat energy, the absorption of CO_2 into the oceans has increased acidity by 26% (measured as hydrogen ion concentration) and decreased average surface water pH by 0.1 (Stocker et al., 2013). It is also expected that effects of climate change on the oceans will continue and worsen (Stocker et al. 2013).

The QSR 2010 (OSPAR, 2010) found that climate change was having an effect on the North East Atlantic region, especially in the Arctic Ocean and North Sea regions. Despite this the report noted that there was still limited understanding between various mechanisms of climate change and how its effects will manifest themselves (due to uncertainty of the rate, magnitude and in some cases the direction of changes) on North East Atlantic ecosystems and species including commercial fisheries. The report finds that the physical effects of climate change that have been observed include an overall increase of between 1°C - 2°C in surface water temperature across the North East Atlantic (that is particularly pronounced in the North Sea) over the period 1985-2010.

On the biological side, the QSR 2010 (OSPAR, 2010) notes that over the past 50 years, there has been observed a northwards movement of plankton species, in some cases up to 1000km and changes in the timing of annual plankton blooms. This northward migration has also been observed for some species of fish such as silvery John Dory (*Zenopsis conchifer*) and red mullet (*Mullus* spp.) in waters around the British Isles. Additionally, the report noted that the decrease in Atlantic cod (*Gadus morhua*) in the North Sea cannot be explained by over fishing alone suggesting that northward migration of the species may also be taking place. According to the QSR 2010 (OSPAR, 2010), the most severe threat to the marine environment in the North East Atlantic region comes from ocean acidification. It observes that the current change in oceanic carbon chemistry is more than 100 times more rapid than in the last 100,000 years and will lead to major effects on plankton and other species that depend on calcium carbonate for building their skeletons and shells which in turn will undermine whole food webs and ecosystems which dependent upon these species.

OSPAR 2010 concludes that understanding the cumulative and interactive impacts of various types of human uses of the marine environment is still limited and advocates building on the international cooperation within OSPAR in achieving an improvement in the marine environment in the North East Atlantic region both through advancing marine spatial planning and in the implementation of the EU Marine Strategy Framework Directive (MSFD) (EC, 2008). The five North-East Atlantic MSs have 188 million people (37% of EU population), a GDP of 5,778 billion (42% of EU GDP) and an EEZ covering over 5.8 million km^2 (74% of EU EEZ). How these member states implement the MFSD will affect a large proportion of the EU's people and economy and most significantly its marine area. More recently, the European Environmental Agency (EEA, 2015) undertook an assessment of Europe's seas with a focus on EU-marine waters. The report paid particular attention to the initial assessments carried out by the EU MSs as part of their obligations under Article 8 of the MSFD (EC, 2008). The report found that despite implementation of certain policy instruments the current use of the marine resources (its natural capital) is not sustainable and that greater efforts were required in monitoring the impacts of human activity on the delivery of marine ecosystem services.

1.2. Theoretical background: Economics and policy behind managing the marine environment

For conventional goods and services, which are both excludable and rivalrous, markets facilitate the allocation of these and readily discoverable prices are an outcome of the matching of supply and demand. However, for public goods, which are both non-excludable and non-rivalrous, and are not traded in conventional markets due to these attributes and consequently do not have readily discoverable prices, alternative methods of valuation are required for the estimation of the prices and surpluses attached to non-market or public goods and services.

The term ‘value of nature’ has many different meanings across many different disciplines including philosophy, sociology and economics (Foster, 2001). This thesis will focus on the economic perspective of the value of nature or the environment. This is defined by Turner et al. (2003) as viewing nature ”*as an asset providing a flow of goods and services, physical as well as aesthetic, intrinsic, and moral*”. However, there are limitations to this approach, such as the impossibility in translating certain values into monetary amounts such as spiritual values, symbolic values or other cultural services related to the natural world (Turner, 2000). Despite these limitations, society continues to make decisions which can affect either the flow of goods and services from environmental assets (also known as ecosystem services) or affect the underlying asset itself such as the destruction of all or part of an ecosystem (Turner et al., 2003). The reason for this is that a market failure occurs since *“the market does not allocate scarce resources to generate the greatest social welfare”* (Hanley et al., 2003).

Market failures related to the environment generally occur because one or more of the following situations arise in relation to environmental assets or the goods and services that they generate (Hanley et al., 2003);

- Many environmental assets are affected by externalities. This means that one actor’s decisions or actions affect other actors, who neither pay for any benefit gained nor received any compensation for damage done.
- Property rights related to environmental assets and the flow of goods and services from them are often poorly defined or non-existent.
- Many environmental assets are common pool resources or public goods, that is, they are non-excludable. This means that it is either too costly or technically impossible to deny open access to an environmental resource.

This often leads to decision makers placing a monetary value of zero on many environmental goods and services when making a decision. Every decision made involves a trade-off. Whether this trade off occurs implicitly (decision maker makes a choice) or explicitly (using a framework used to make decision such as cost-benefit analysis (CBA) or multi-criteria analysis (MCA)), placing a zero value on nature will ensure that the net change to social welfare will be miscalculated. Monetary valuation of nature, while not a panacea, provides decision makers with better information in their decision making process and helps to avoid or lessen the market failure (Hanley & Barbier, 2009). It has been noted that valuation studies related to the marine environment are lacking (Turner et al., 2003) particularly for offshore ocean environment (Hanley et al., 2014). Often valuation studies are motivated by legislative changes and this can be seen in relation to several studies which are associated with such at both national and supra-national level (e.g. EU legislation).

A neoclassical framework assumes that the market price and quantity of goods supplied and demanded are outcomes of the interactions of demand curves and supply curves for a market good. The demand curve is the aggregate of all the consumers demand schedules where a demand schedule is the willingness to pay (WTP) of the consumer for each quantity of the good. Similarly, the supply curve is the aggregate of all the producers supply schedules where a supply schedule is the willingness to accept (WTA) compensation by the producer for producing each quantity of the good. The framework also assumes that producers ultimately face diminishing marginal returns meaning that each additional (or marginal) unit of output costs more than the previous unit. This leads to a positive slope in the supply curve. For the consumer, they are assumed to have diminishing returns to their utility for each additional unit of good consumed leading to decrease in WTP for each additional unit of good. This means that the demand curve has a negative slope (Krugman and Wells, 2009). A simplified graphical representation of this is shown in Figure 1.1.

Figure 1.1 also shows the differences between market value and economic value. The market value or total consumer expenditure (multiplying the market price by the total quantity consumed of the good) is sometimes used to represent the value of market good or service. This is represented by summing areas, ‘PS’ (producer surplus) and ‘PC’ (producers cost) as bounded by the dotted lines. The producer cost represents the actual costs incurred to produce the equilibrium amount of the market good (Q_{eq}) and the producer surplus represents the monetary value that producers gained above their costs. However, this ignores the consumer surplus (CS), the area represented by ‘CS’, which represents the monetary value that consumers gain from acquiring the market good for a price (P_{eq}) less than their WTP for that good. Aggregating the market value (PS + PC) plus the CS gives the total benefit value of a good to society or the aggregate WTP for a good.

For non-market goods and services produced by an environmental asset or ecosystem, the producer (e.g. nature) is not incentivised by price, therefore there is only a quantity of good supplied (no supply schedule or supply curve) and the economic value is solely determined by the demand curve and is represented by the CS or the total WTP for the non-market good or service (Hanley et al., 2007). This is shown graphically in Figure 1.2 in which the supply curve is just a line along the quantity of the good supplied and the total economic value (TEV) is the CS under the demand curve.

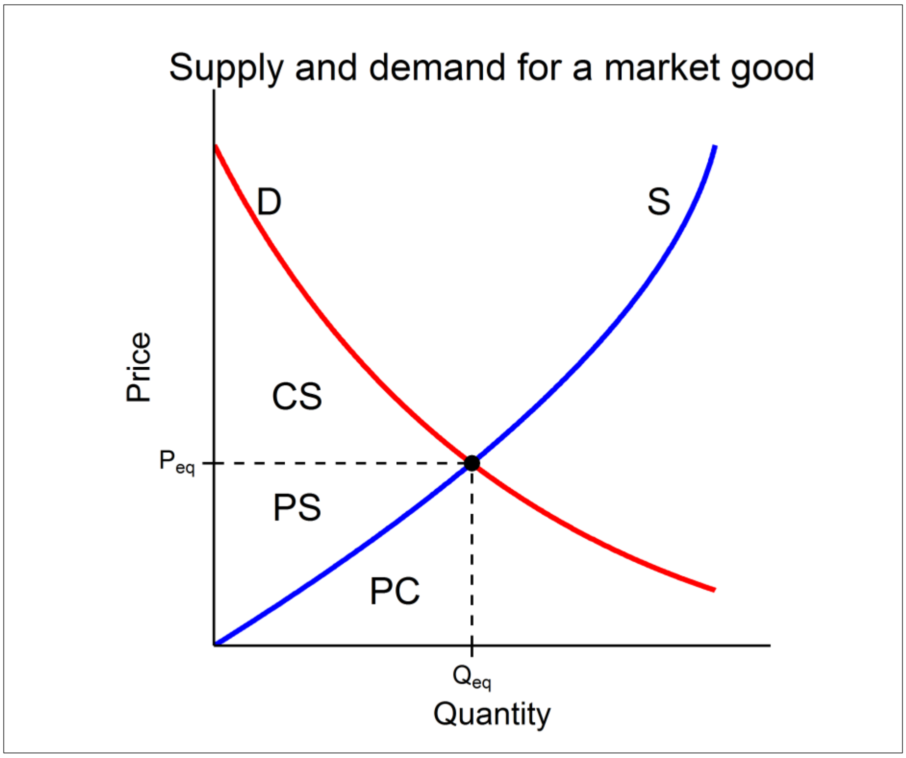

Figure 1-1. Supply and demand for a market good where the market price is P_{eq} (the equilibrium price) and Q_{eq} is the equilibrium quantity.

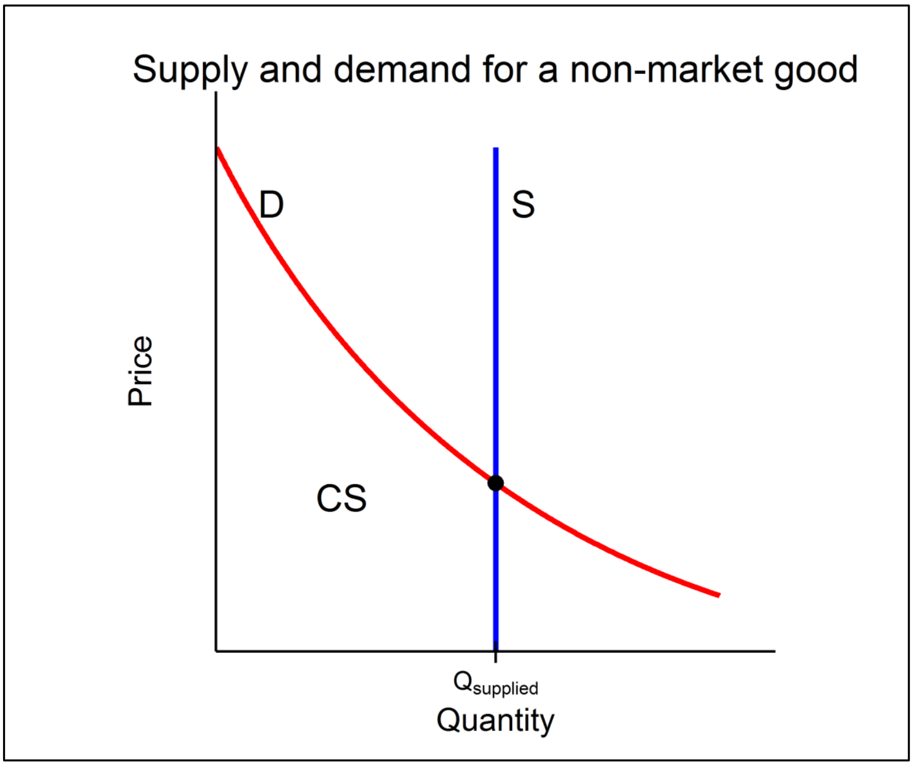

Figure 1-2. Supply and demand for a non-market good

Valuation or value is the change in economic value which is measured as the amount of goods or services (typically measure in monetary terms) someone is willing to give up to accept a change in an ecosystem service (willingness to pay (WTP)) or the amount that are willing to receive to avoid a change in an ecosystem service (willingness to accept (WTA)). In a market situation the amount that is actually paid by a consumer may be less than the amount that that consumer is WTP and the excess value that they did not pay is known as the Consumer Surplus (CS). The economic value of a good is therefore the WTP or where there is a market price, it is the market price plus the CS[1].

While it is theoretically straight forward to derive monetary values for benefits accruing from commercial ocean economy activities, such as fisheries and mineral extraction, different approaches must be taken to provide economic values for services with less obvious links to economic activity such as aesthetic services, waste assimilation services, recreation pursuits, etc. There are a variety of methods available to estimate the economic values of the various types of ecosystem services. The type of methodology used depends on the types of

[1] For an in-depth discussion of the theory behind environmental valuation and the methods used the interested reader is directed to "Hanley and Barbier (2009).

services, whether the benefit being valued has use value or non-use value and if there is the data to use a revealed or stated preference technique. The different types of values to be considered are shown in figure 1-3.

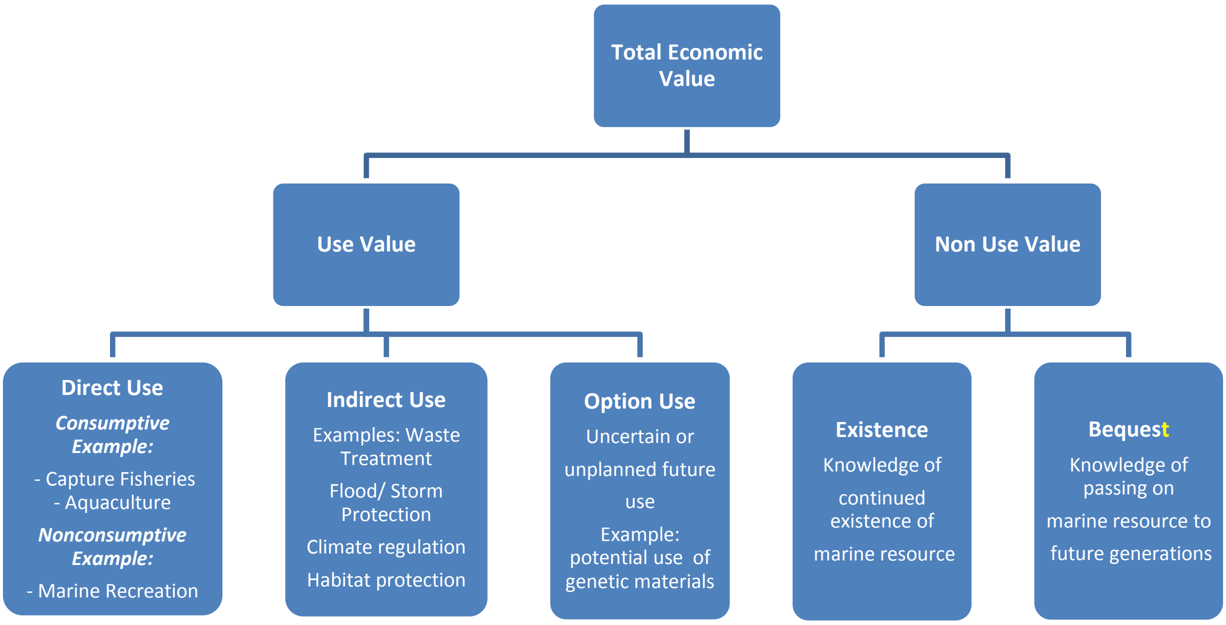

Figure 1-3. Total Economic Value (TEV) Framework

Proxies are often used to estimate the economic value of the non-market goods and services. These proxies serve in the absence of formal markets and give some signals of value. Even in the case where we do have market prices as is the case for provisioning goods, these do not reflect the true economic values as they omit the CS element of value and may be affected by taxes or subsidies. As outlined in table 1.1, there are two primary valuation typologies: revealed preference (RP), and stated preference (SP) techniques.

RP techniques are used where people's choices can be observed and related back to market prices or where CS can be estimated from their 'revealed' behaviour. SP techniques are often used to estimate non-use values or where choices cannot be observed. They are based on constructed hypothetical markets through which individuals are asked to express their willingness to pay for environmental goods and services. The main RP and SP approaches used in the valuation of marine ecosystem services are listed in table 1.1. These primary valuation methods can often be time consuming and/or expensive. Therefore interest has been growing amongst valuation practitioners in a secondary methodology known as value transfer (Johnston et al., 2015). Using this method values are taken from the literature and ‘transferred ‘from the original study site (where the primary research has taken place) to the policy site (where the value of the benefits are trying to be estimated). While often the values can be adjusted for differences between the sites (income differences, temporal differences, differences in affected population, etc.) there is still the possibility of an error in the value which is estimated. However the method can still provide a broad estimate of the value of the benefits delivered by ecosystem services (Johnston and Rosenberger, 2010).

Table 1-1. Main methodologies for estimating marine ecosystem service values

Type and methods	**Notes**	**Where used in this thesis**
Revealed preference methods	***Methods based on values for ecosystem services that are ‘revealed’ by behaviour in associated markets.***	
Market prices	Market prices are rarely equal to values. Prices do not generally reveal the ‘consumer surplus’, (the value to the consumer over and above the price paid). They can also be distorted by taxes and subsidies.	Capture fisheries, aquaculture, algae/ Seaweed harvesting (chapter 5)
Production functions	Production functions are statistical models which relate how changes in some ecosystem function affect production of a marketed good or service	Not used
Avoided costs/ Replacement costs	Avoided or replacement costs are a measure of the value of a service based on the cost to replace the ecosystem function or service.	Waste services, climate regulation, coastal defence (chapter 5)
Non-market revealed preference techniques	*Methods based on values for ecosystem services that are revealed by behaviour in associated markets.*	
Travel cost	The travel cost method is used to estimate the value of sites which people travel to (i.e. for recreation) based on the theory that the time taken and travel costs represents the price of access to the site.	Recreational services (chapter 5)

Hedonic pricing	Hedonic pricing is a statistical modelling technique which estimates the implicit price paid for environmental characteristics of the area or for a pleasing sea view through the variation in the property prices in different areas.	Aesthetic services (chapter 5)
Stated preference methods	*Methods based on surveys in which respondents give valuation responses in hypothetical situations*	
Contingent valuation	Contingent valuation is a holistic method of valuing a single change to an environmental good or service where the change is described and the respondent is asked their WTP/WTA.	Non-use values (chapter 6)
Choice experiments	Choice experiments estimate values from the choices respondents make between options with different specified attributes of an environmental good.	Non-use values (chapter 6)
Other methods		
Value transfer(VT)	A secondary valuation methodology that uses existing value evidence to be applied to new cases without the need for primary valuation studies.	Recreational services (chapter 5), non use values (chapter 6)
Point, function and meta-analysis transfer methods	Point VT transfers a single value or mean of value which may or may not be adjusted. Function transfer a function which has be estimated using a primary valuation method. Meta-analysis pools similar primary studies together to generate statistically robust function for use in VT.	

(Adapted from UNEP-WCMC, 2011)

The main aim of marine ecosystem service valuation is therefore to provide information to policy makers that can assist in deciding on the best options to pursue using an ecosystem based management approach. There are also numerous other reasons for valuing marine ecosystem services. Firstly, the valuation of marine ecosystem service benefits can help to promote sustainable development by providing policymakers with information about the value of market and non-market marine ecosystem services, and the potential costs if these services are lost. They can also be used for demonstrating and communicating the importance of marine ecosystems to the wider public. Additionally, Champ et al. (2013)

listed broad areas where valuation is useful as a guide to improve decisions in a variety of processes. These include;

- public policies (at the local, regional, or national level) which includes cost-benefit analysis even if underlying decision is based on precautionary principle,
- resource allocation and priorities in order to ensure that resources are targeted by budget holders to maximizes benefits,
- compensation for losses and to estimate a monetary value for damage assessments,
- design of environmental market such as new markets for non-market goods (e.g. carbon markets) or designing initiatives (e.g. payment for ecosystem services (PES))

1.3. Non-market valuation techniques

In the previous section, table 1.1 briefly highlights the different valuation methodologies. This section will explore these techniques in more detail giving an introduction to the methods, examples of their application, a discussion of their pros and cons and the challenges and issues facing practitioners in this field.

What is meant by valuation or values is that the change in economic value which is measured as the amount of goods or services (typically measured in monetary terms) someone is willing to give up to accept a change in an ecosystem service or the amount that are willing to receive to avoid a change in an ecosystem service. The former willingness to give up an amount is known as willingness to pay (WTP) and the latter is known as willingness to accept (WTA). In a market situation the amount that is paid by a consumer may be less than the amount that that consumer is WTP and the excess value that they did not pay is known as the Consumer Surplus (CS). The economic value of a good is therefore the WTP or where there is a market price, it is the market price plus the CS (Hanley and Barbier, 2009).

To find the economic values of various types of ecosystem services, there are a variety of methods available. The type of methodology used depends on the types of services, whether the benefit being valued has use value or non-use value and if there is the data to use a revealed or stated preference technique. As many ecosystem services are non-market goods and services, we have to use proxies to estimate the economic value of those.

These proxies serve in the absence of formal markets and give some signals of value. Even in the case where we do have market prices as is the case for provisioning goods, these do not reflect the true economic values as they omit the consumer surplus element of value and may be affected by taxes or subsidies. There are three main types of valuation techniques: market based, revealed preference, and stated preference techniques.

Examining first the revealed preference methods, the most readily available valuation method used is the market price. This is often used for valuation by multiplying the flow of ecosystem service by the price per unit flow. Market based techniques are based on data relatively readily available in the form of established market prices. The market price is a measure of exchange value and does not include all consumer surplus, therefore it does not include the total WTP for an ecosystem services or change in environment. In theory, market prices reflect perfect competitive markets with easy entry and exit, in practice they may be distorted by government taxes and subsidies or markets may be non-competitive for other reasons (Badura et al, 2016). Additionally, ecosystem services may only comprise a portion of the value of inputs along with others such as labour, social capital, etc. Not adjusting market values to try and take into account these issues will lead to biased estimates. In practice this is not always done with many studies (Kroeger & Casey, 2007, Bateman et al., 2013). Although market prices do not include consumer surplus they are more readily available compared to the non-market based prices and serve as good proxy for the change in value of certain ecosystem service; in particular the provisioning ecosystem types. One method to tease out the contribution of ecosystem services to a marketed good is through a production function approach.

Production functions are statistical models which relate how changes in some ecosystem function affect production of another good or service. This method may be able to account for non-linearity in the relationship between ecosystem functioning and services. The main challenge to this method is the need for good enough data describing the relationship and even with such data it can be very site specific. Foley et al. (2010) applied the production function approach to estimate the value lost from a reduction of redfish (*Sebastes spp.)* caught in Norwegian waters due to a decrease in coverage of cold water coral (*Lophelia pertusa*), a nursery habitat for the redfish. It was estimated that a 1km^2 reduction in cold water coral would lead to an annual loss of 68 to 110 tonnes in the redfish harvest resulting in a loss of US$ 70,000 - 120,000. It was estimated that between 30-50% of

Norway's cold water coral habitat has been damaged or highly degraded which has led to an annual loss of between US$2.7 - 7.4 million per annum.

Another alternative is to use costs. Although to be avoided in most cases, it may give some concept of the value placed on an ecosystem service. Avoided costs is a measure of the value of a service which an ecosystem provides often for free which if it wasn't would have to be borne by human society. An extreme example would be the cost to pay someone to pollinate fruit if no bees or other pollinators were available. However, without the WTP there is no way to see if there is demand for such a service. This is closely related to replacement costs which are an estimate of how much it would cost to replace a service which an ecosystem had previously provided for free. The use of cost data to estimate values is highly conversional (Badura et al., 2016) due to fact that it does not measure demand or WTP and should only be used to as a last resort where there is a lack of data or in an effort to highlight the possible cost to society if an ecosystem and the ecosystem services it generates are lost or destroyed. Despite this it has been used. Chong (2005) used this method to value the cost of replacing mangroves using physical barriers for the ecosystem service of storm protection while Beaumont et al., (2010) used it similarly to value the same service for saltwater marshes.

Non-market revealed preference (RP) techniques are used where people's choices can be observed and related back to market prices or where CS can be estimated from their behaviour. The travel cost method is used to estimate the value of sites which people travel to for recreation (including hunting and fishing and wildlife viewing). It is based on the theory that travel costs represents the price of access to the site. Traditional travel cost methods can be broken into two types of approaches: the zonal travel cost and individual travel cost approaches. The zonal travel cost approach is the most inexpensive technique because it primarily uses secondary data with just a small amount of simple primary data collected directly from visitors and it is only appropriate for valuing a site as a whole instead of valuing changes in the characteristics of a site. An alternative which has been used by Hynes et al, (2006) is the random utility model which allows changes in welfare to be estimated and offers a better way of dealing with site characteristics. One of the main issues is the opportunity cost of time although Fezzi et al., (2014) showed that indeed it seems to be close to the wage rate.

Hedonic pricing is a statistical modelling technique which is most commonly used with house or land prices to determine the values of the surrounding environmental levels such as air quality, distance to amenities or a clean water body and estimate the value of changes in these ecosystem services to the change in value of the house or land. Getting data of sufficient quality and reliability is the often the biggest problem with using this technique in addition to a plethora of econometric issues related to spatial regression and omitted variable bias.

Stated preference techniques are often used to estimate non-use values. For example an individual may gain utility from the knowledge that the blue whale is protected and be willing to pay towards that protection even though they may never even see or use a blue whale themselves. Stated preference techniques are based on constructed hypothetical markets through which individuals are asked to express their willingness to pay for environmental goods and services. Contingent valuation is a stated preference method of valuing a single change to an environmental good or service. The change is described and the respondent is asked to pay via a charge or tax (the respondent is asked either their WTP for the change if is a positive change or their WTA if it is negative change).

In a review of valuation of coastal and marine environments in the Black Sea and Mediterranean, two of the regions designated by the MSFD, Remoundou et al. (2009) found that CVM was the most common valuation methodology used, being used in six of the thirteen studies reviewed. CVM has been also used by others to values changes in coastal and marine environments. Nunes and van den Bergh, (2004) used a joint travel cost (TC) - CVM survey to estimate the value in preventing harmful algae blooms (HAB) for the Dutch coastline. The programme valued the treatment of ballast water for ships to prevent establishment of invasive algae species. The TC method was used to estimate the value of recreational users while the CV was targeted at valuing indirect and non-use values. Using the TC method the authors estimated an annual gross recreation benefit per individual of €55. The CVM using a double-bounded dichotomous choice question estimated the WTP for preventing HABs was €76 per respondent. Carson et al. (2003) used CVM to estimate the non-use value or passive value of an oil spill in Alaska and estimated a mean WTP of $79.20 based on a modified Weibull distribution.

An alternative to the CV method, and the tool used in chapter 7, is the choice experiment(CE) approach where instead of a change in one attribute, the good is broken down into several attributes, each with their own levels (Haab and McConnell, 2002) . Respondents are then asked to choose between different sets of these attribute levels. By including a price attribute within the choice sets, the value of a change between different levels of an attribute can be estimated.

The use of the CE methodology originated within the spheres of marketing and transport research (Louviere and Woodworth, 1983; Louviere, 1988) but has spread to other policy areas including environmental economics (Hanley et al., 1998). The CE methodology is based upon the concept known as "the characteristics theory of value" (Lancaster, 1966) where a good may be thought of as being composed of several characteristics or attributes, which the respondent values independently, rather than valuing the good as a whole. The theoretical framework behind the analysis of CE data is random utility maximization (McFadden, 1974). Further details of this methodology are detailed in section 7.3 of this thesis. An example of the use of this approach for marine water quality was that by Doherty et al. (2014) that used a discrete choice experiment (DCE) to explore the preferences of residents in the Republic of Ireland for a number of ecosystem services provided by Irish water bodies. The authors estimated the welfare impact on the Irish population associated with moving from the lowest ecosystem service levels of certain attributes to the highest level of the attributes. The attributes in question were aquatic ecosystem health, water clarity and smell, access to recreational activities and condition of banks or shoreline. They found that the total value of a policy change that ensures the highest standards is reached for all attributes in marine water bodies was associated with a welfare impact of €95 per person per year. Assuming a population over the age of 16 of 3,439,565 this translates to a total welfare impact of €327 million. The study also found that residents had the highest WTP for the water quality and smell attribute followed by the health of the ecosystem and the conditions of shoreline attributes. The lowest valued attribute was associated with recreational access.

These stated and revealed primary valuation methods can take time to implement and are often expensive to conduct. However, there is a secondary methodology known as value transfer that is both time and cost efficient (Brouwer, 2000). In this method, values are taken from the literature and their value is 'transferred 'from the original study site (where the primary research has taken place) to the policy site (where the value of the benefits are trying to be estimated). While often the values can be adjusted for differences between the sites (income differences, temporal differences, differences in affected population, etc.) there is still the possibility of an error in the value which is estimated. However, it can still provide a broad estimate of the value of the benefits delivered by ecosystem services (Johnston and Rosenberger, 2010).

For further information and a deeper examination of non-market valuation methods in particular, Hanley and Barbier, (2009) is recommended.

1.4. The ecosystem approach and the precautionary principle

Two other concepts underpinning the management of the marine environment via the MSFD are the ecosystem approach and the precautionary principle. The ecosystem approach (EA) has been variously described as a more holistic or systems perspective style of planning for and managing the natural environment or a strategy for the integrated management of ecosystems to ensure a sustainable and equitable use of the resources generated by them (Kidd et al., 2011). The MSFD defines the ecosystem approach as management of human activities, ensuring that the collective pressure of such activities is kept within levels compatible with the achievement of good environmental status and that the capacity of marine ecosystems to respond to human-induced changes is not compromised, while enabling the sustainable use of marine goods and services by present and future generations (EC, 2008).

The EA is based on several principles namely;

- sustainability of economic systems and quality of human life is inevitably dependent on the maintenance of healthy ecosystems,
- humans are an integral part of ecosystem rather than separate from them,
- a sectorial approach to management is generally insufficient to deal with the complex interrelationships and diverse stakeholder priorities that exist in the real world (Kidd et al., 2011).

These principles line up well alongside those mentioned by McLeod et al. (2009) who noted that rather than traditional approaches that address single concerns, the ecosystem approach or ecosystem based management is a spatial approach that acknowledges connections, cumulative impacts and multiple objectives.

A formal definition and one of the most frequent cited is offered by Decision 2000 V/6 of the Conference of Parties (COP) to the Convention on Biological Diversity (CBD) which defined EA as *"A strategy for the integrated management of land , water and living resources which promote conservation and sustainable use in a an equitable way."*(CBD COP, 2000, V/6). This was further underpinned by 12 principles (Malawi Principles for the Ecosystem Approach) which guide the EA namely;

- Management objectives are a matter of societal choice.
- Management should be decentralized to the lowest appropriate level.
- Ecosystem managers should consider the effects of their activities on adjacent and other ecosystems.
- Recognizing potential gains from management there is a need to understand the ecosystem in an economic context, considering e.g. mitigating market distortions, aligning incentives to promote sustainable use, and internalizing costs and benefits.
- A key feature of the ecosystem approach includes conservation of ecosystem structure and functioning.
- Ecosystems must be managed within the limits to their functioning.
- The ecosystem approach should be undertaken at the appropriate scale.
- Recognizing the varying temporal scales and lag effects which characterize ecosystem processes, objectives for ecosystem management should be set for the long term.
- Management must recognize that change is inevitable.
- The ecosystem approach should seek the appropriate balance between conservation and use of biodiversity.
- The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.
- The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Elliott et al. (2006) noted that the first five principles relate to social, economic and management rather than ecological diversity and in particular number 4 of the principles exemplifies the need for valuation of environmental costs and benefits for inclusion in policy making. It has been noted by some (Borja et al., 2010, Long, 2011) that the MSFD represents the first time that an EA has been taken with respect to an EU directive.

The second concept underpinning the management of the marine environment via the MSFD is the precautionary principle. The precautionary principle is one method of dealing with the problem of weighing up protecting the environment (and/or human health) versus maintenance or intensifying of economic activities. This is particularly relevant for incomplete understanding and uncertainty in the understanding between cause and effect relationships (Brooks et al., 2002). One often cited definition is that offered by principle 15 of the Rio Declaration (1992) that notes: *"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."* However, some have argued that there is a difference between the precautionary principle and the precautionary approach, the latter seen as weaker due to application dependent on a state's capabilities and the inclusion of cost-effective measures, meaning that some sort of cost effective analysis is needed (Garcia, 1995). Additionally, while there could be 'false positives' where government regulation was undertaken based on precaution but later turned out to be unnecessary which would be a net cost to society, Harremoës, (2013) found that most case studies they looked at were instead 'false negatives' — instances where early warnings existed but no preventive actions were taken.

Within the EU the PP is enshrined in EU law and is the basis for EU environmental law under the Treaty of the European Union 1992. Within the MSFD, it states that the programmes of measures and subsequent action for the achievement of good environmental status (GES) should be based on an ecosystem-based approach and devised on the basis of the precautionary principle. Additionally, the new thresholds devised under the Commission Decision (2017) on measuring GES states that these threshold values should also be set on the basis of the precautionary principle. Using an ecosystem services framework and the precautionary principle may act as a decision tool in the achievement of the goals of the ecosystem approach to management of the marine environment The need to take account of the precautionary principle is an important part of using an ES framework as the complexity and high level of uncertainty associated with all ecosystems, and marine ecosystems in particular, means that decisions may often have to take place without full knowledge or information available.

1.5. Overview of research objectives

The main research objective of this thesis is to estimate the value of the benefits of achieving the objectives of the Marine Strategy Framework Directive, (namely Good Environmental Status (GES), in Irish waters. To achieve this objective, a variety of valuation methodologies were used, which offer policy makers alternative approaches to the value of our protecting our marine environment.

Initially, to gain an understanding of the general public's attitudes to the marine and coastal environment, attitudinal questions were included in a nationwide survey of the Irish general public. The survey instrument also included the valuation questions and collected socio-demographic information. Examining the attitudes of the public to the marine and coastal environment was considered important, as the public's attitudes can affect what values society places on the marine environment and impact the decisions that are made by policy makers.

Following the attitudinal analysis, four different methodologies for valuing the marine environment were undertaken. The first was an ecosystem services assessment which used the CICES framework to classify the various ecosystem services provided by the marine environment in Irish coastal, marine and estuarine waters. The second was based on a contingent valuation question in the survey instrument that was used to estimate the value of achieving GES in Ireland. Thirdly a spatial value transfer exercise was undertaken based on the contingent valuation exercise to estimate the value of GES for the five Northeast Atlantic member states and finally a choice experiment was undertaken to estimate the value placed on different attributes of GES by the Irish public.

1.6. Structure of thesis

The main body of the thesis consists of four separate empirical chapters. However, these are preceded by chapter 2 which presents the Marine Strategy Framework Directive. This piece of legislation is the key link between the empirical chapters of the thesis. The chapter provides a background to the Directive, an overview of how it will work and reviews progress to-date on the implementation of the Directive. Additionally, how economic valuation is dealt with in the implementation of the Directive will also be explored.

Chapter 3 gives an introduction into the design, development and application of the survey. The following four chapters are the basis for the three papers and report produced from this PhD.

Chapter 4 presents the results of a nationwide survey in Ireland that explored the values, concerns and preferences of individuals towards the Irish marine environment. The results of the Irish survey are also compared to the results from similar surveys carried out in other maritime countries in the EU. The views of the Irish public towards the seas and oceans around the Irish coast are relatively unknown. This is although Ireland has sovereign rights over 900,000km^2 of seabed (an area 10 times the size of the land area of Ireland). The results of the Irish survey demonstrate a reasonable level of knowledge of the main threats facing Ireland's marine environment and of the importance of non-market as well as market ecosystem services provided by the seas around the Irish coast. The results also suggest that the Irish public are sceptical of the ability of government and private industry to manage the Irish marine economy but instead place a large amount of trust in the competency of scientists. The perception of whether or not they consider where they live as being a coastal area would also suggest that the Irish public hold a much more narrow view of what constitutes a coastal area than that held by statistical agencies such as Eurostat.

Following on from examining the attitudes of the Irish public, the next chapter (Chapter 5) uses an ecosystem services framework known as the Common International Classification of Ecosystem Services (CICES) framework to identify, quantify, map and estimate the value of the marine and coastal ecosystems around the island of Ireland providing benefits to the Irish economy and society. While the value of some these goods such as fish and aquaculture are somewhat easier to measure, the value of many other benefits such as carbon sequestration, waste treatment and recreation are not captured in any market. Therefore, non-market techniques including the use of value transfer method is explored in this chapter. The results of this chapter which are broken down into the three ecosystem services of provisioning, regulating and cultural ecosystem services may not only be used for valuing changes arising achieving good (marine) environmental status (GES) under the MSFD but also feed into other EU policies including the 2020 Biodiversity Strategy aims to protect, value and where necessary restore nature both for biodiversity's intrinsic value and for its contribution to human wellbeing and economic prosperity through ecosystem services.

The next chapter, Chapter 6 is the first of two chapters exploring stated preference techniques, often used to value non-use values, which for the marine are expected to be a significant contributor to the TEV arising from changes to the marine environment. This chapter uses a combination of the contingent valuation method (CVM) and value transfer (VT) to estimate the value of non-market benefits associated with the achievement of GES as specified in the EU Marine Strategy Framework Directive (MSFD) for Atlantic member states. The increased use of geographic information systems in VT means that many VT exercises now include spatial elements such as distance decay and population density. This chapter explores the impact of distance decay on welfare estimates as well as the impact from the modifiable area unit problem (MAUP) when population density is included as an explanatory variable. These issues can have a large effect on a VT estimate. In this study the overall value for achieving GES for Atlantic member states varied between €2.37 billion and €3.64 billion. It was found that the different distance decay specifications changed values between -3% and 82% with a mean absolute difference of 25% and by adjusting the spatial scale in an effort to overcome the MAUP changed aggregate values between 13% and 25% with a mean of 17%.

The final chapter of the main body (Chapter 7) demonstrates an alternative stated preference approach, the choice experiment methodology, using it to estimate the value of the non-market benefits associated with the achievement of GES as specified in the EU MSFD. The MSFD requires that the "costs of degradation" (the benefits foregone if GES is not achieved) be considered within a broader 'Economic and Social Assessment' of the marine environment by EU member states. Assessing the costs of degradation as defined by the MSFD implies that changes in marine ecosystem services provided in each State should be analysed. The results show that there are high values attached with changes to the state of the marine environment by the Irish general public. The results of a random parameters logit model also demonstrate that preferences are heterogeneous, with changes in certain marine attributes generating both positive and negative utility.

Finally, Chapter 8, provides an overview of the main findings of the thesis and highlights the key issues that arose during the work undertaken. Also, suggestions for future work to be undertaken in this area are addressed and limitations associated with the thesis are outlined. The chapter concludes the thesis with recommendations for how to integrate the findings of the thesis into policy particularly in relation to the achievement of GES in all EU marine waters.

1.7. Thesis outputs

There have been a number of outputs arising from work done for this thesis and these are listed below. The first two papers are published and the third is currently in press. The results of chapter 4 have also been externally reviewed by a panel of experts on behalf of the Irish Environment Protection Agency (EPA) and is forthcoming as a national EPA report. I am primary author for papers 1 and 3 and the report (4). For the second paper (Investigating societal attitudes towards the marine environment of Ireland), I jointly conceived the concept of the paper before design and deployment of the survey (Chapter 3). In addition, I was primary author on two sections, Section 4.2, the questionnaire design and Section 4.3, the results section and contributed partially towards the rest of the paper.

1.7.1. *Papers and Reports*

1. Valuing the non-market benefits arising from the implementation of the EU Marine Strategy Framework Directive. Ecosystem Services, 10, 2014, p.84-96 (with Hynes. S.)
2. Investigating societal attitudes towards the marine environment of Ireland. Marine Policy, 47, 2014, p.57-65 (with Hynes. S. and Corless, R.)
3. Estimating the Benefits of the Marine Strategy Framework Directive in Atlantic Member States: A Spatial Value Transfer Approach (Ecological Economics) (In press) (with Hynes. S.)
4. Valuing Ireland's Blue Ecosystem Services, Irish Environmental Protection Agency Report 2017 (accepted and forthcoming) (with Hynes, S., and Boyd, J.)

1.7.2. *Presentations*

Norton, D. 2012. Valuing the benefits of the Marine Strategy Framework Directive, Environment Camp on Environmental Valuation Methods for Ecosystem Services, 4^{th} – 6^{th} Sept, Stirling University

Norton, D. 2013. Valuing the benefits of the Marine Strategy Framework Directive, ESAI Environ Conference, 30^{th} Jan – 1^{st} Feb, NUI Galway

Norton, D. 2013. Valuing the benefits of the Marine Strategy Framework Directive, 4th Annual Beaufort Marine Socio-Economic Workshop, 27th August, NUI Galway

Norton, D. 2014. Estimating the value of achieving GES for North East Atlantic Member States: A Value Transfer Approach 5th Annual Beaufort Marine Socio-Economic Workshop - 21st October, Galway

Norton, D. 2015. Using Contingent Valuation and Value Transfer to estimate the value of achieving GES under the MSFD in EU Atlantic states. ESAI Environ Conference, April 8th to 10th, Sligo IT

Norton, D. 2015. An international value transfer to estimate the value of achieving Good Environmental Status in North-East Atlantic, Irish Economic Association 2015, May 7th to 8th, Dublin

Norton, D. A Spatial Value Transfer to Estimate the Value of Marine Strategy Framework Directive in EU Atlantic Member States. European Association of Environmental and Resource Economists 21st Annual (EAERE 21) Conference, 24th - 27th June, 2015, Helsinki, Finland

Norton, D. 2015. VIBES: Valuing Ireland's Blue Ecosystem Services. Ryan Institute Research Day, 25th September, Galway

Norton, D. 2015. Spatial issues arising from a value transfer exercise for environmental quality of marine waters. 150th Seminar of European Association of Agricultural Economists, 22nd -23rd, October, Edinburgh, Scotland

Norton, D. 2015. VIBES: Valuing Ireland's Blue Ecosystem Services. THREESIS competition final, 29th October, Galway

Norton, D. Hynes, S. & Boyd, J., 2015. VIBES: Valuing Ireland's Blue Ecosystem Services. The 6th Annual Beaufort Marine Socio Economic Workshop, 24th November, Galway

Norton, D. 2016. VIBES: Valuing Ireland's Blue Ecosystem Services. ESAI Environ Conference, April 8th to 10th, University of Limerick

Norton, D. 2015 VIBES: Valuing Ireland's Blue Ecosystem Services. Whitaker Institute Day, April 13th, NUI Galway

Norton, D., 2016. VIBES: Valuing Ireland's Blue Ecosystem Services. 30th Annual Irish Economic Association Conference, 5th - 6th May 2016, NUI Galway

Norton, D. 2016. The Role of Economics in Marine Ecosystem Based Management in the EU: An Irish perspective. 26th May 2016, Ocean Networks Canada, Victoria, Canada

1.8. Chapter summary

The former part of this chapter gave an overview of the state of the marine environment in Europe including the governance and environmental policies and was focused mainly on the North-East Atlantic and Irish marine waters. This places the MSFD in the context of the history of protecting the marine environment in the EU. Additionally some theoretical context is given for the economic valuation of non-market goods and services and details on the principles underlying other parts of the MSFD including the ecosystem approach and the precautionary principle. The latter part of this chapter then gave an overview of the research objectives, the structure of thesis and the thesis outputs to date.

Chapter 2

Overview of the Marine Strategy Framework Directive

2.1. Introduction

This section offers an overview of the MSFD. Section 2.2 goes through the road to the MSFD from the 6th Environment Action Programme (EAP) to the latest EU Commission (2017) directive on a new approach to assessing GES. This section also covers some of the economic aspects of the MSFD. Section 2.3 then examines the current state of EU marine waters based on the initial assessments carried out under the MSFD by the 23 member states with marine waters (the five member states with no marine waters are Austria, Czech Republic, Luxembourg, Hungary and Slovakia). The section examines the implementation of the MSFD at an EU level and also reviews the initial assessment carried out by Ireland. The final section briefly summarises this chapter.

2.2. The road to implementing the MSFD

The European Union (EU) and its precursor organisations, the European Community (EC) and the European Economic Community (EEC), have long recognised the value of its member state's marine resources. Within the original Treaty of Rome (1957), the founding member states adopted a common policy in the sphere of agriculture (Article 3 (d)) with fisheries defined as 'agricultural products' included within this policy (Article 38 (1)). Following the first United Nations Conference on the Environment (UN COE) in 1972 in Sweden, the European Commission presented a first Environment Action Programme (EAP) in 1973 on the basis of the commitments it made at the UN COE in 1972 (Jordan, 2012). In the same year of the first EAP, Ireland joined the EEC and since then policy and legal instruments from Europe have been the main driver of marine environmental protection for Ireland and many of the other member states.

Since 1973, there have been seven EAPs with the latest, the 7th EAP, adopted in November 2013 mentioning that the EU *"has agreed to achieve good environmental status in all marine waters of the Union by 2020"* referencing the Marine Strategy Framework Directive (MSFD) which was adopted in June 2008. This directive is the zenith of the EU efforts to protect and preserve the marine environment in EU waters to date.

The need for an integrated approach to protect the marine environment, and to ensure its sustainable use can be traced back to the 6th EAP (2002-2012) which had four key environmental priorities namely;

- climate change;
- nature and biodiversity;
- environment and health and quality of life;
- natural resources and wastes.

Article 6 of the 6th EAP entitled 'Objectives and priority areas for action on nature and biodiversity' including the aim of conserving and where appropriate restoring the marine and coastal environment to ensure its sustainable use. The EAP noted that this aim would be pursued through the following actions;

- greater integration of environmental considerations in the Common Fisheries Policy;
- a thematic strategy for the protection and conservation of the marine environment taking into account the obligations of marine Conventions, and the need to reduce emissions and impacts of sea transport and other sea and land based activities;
- promotion of the integrated management of coastal zones;
- promotion of the use of protected marine areas including through the Natura 2000 network,

and that the ecosystem approach, as adopted in the Convention on Biological Diversity (CBD), should be applied whenever appropriate. Concurrent to the objectives of the 6th EAP, the EU Commission issued a communication to the Council and the European Parliament (COM (2002) 539) entitled "*Towards a strategy to protect and conserve the marine environment*" that found that there was a need for an overall and integrated policy for marine protection at EU level. The communication (COM (2002) 539) noted that there were threats to marine biodiversity arising from fishing, invasive species, increasing intensity of human activities along the coast, pollution and climate change. It also noted that there was a wide range of policies and legislative instruments dedicated to protecting the marine environment, mainly through a sectorial approach although there have been deficiencies in implementing some of these measures. Data gaps that were needed to be filled to achieve an ecosystem approach were also detailed in the communication but it did note that certain organisations were making progress (e.g. HELCOM in the Baltic Sea). The communication suggested that any strategy for achieving the objective of sustainable use of the seas and conserving the marine environment should include the following activities;

- development of a coherent marine policy by moving towards an ecosystem-based approach building on the existing policies;
- improving implementation and enforcement of both existing and new legislation in an integrated way;
- mechanisms and actions aimed at facilitating the co-ordination of these measures and the co-ordination of the different organisations and other stakeholders;
- initiatives to improve knowledge, on past trends in and likely future scenarios for the quality status of European seas and the procedures and methodologies to assess this information;
- promotion of the use and improvement of the co-ordination between the different funding instruments towards the protection of the marine environment;
- application of these strategic elements both regionally and globally.

Under Article 4 of the EAP, the EU was required to develop and present ‘Thematic strategies’ to implement the aims of the 6th EAP. These strategies had to be developed by the midterm review of the EAP (2005). As a result, seven strategies had been developed relating to:

- Air quality;
- The marine environment;
- The sustainable use of resources;
- Waste prevention and recycling;
- Pesticides;
- Soil quality;
- The urban environment.

The outcome of this approach in relation to the marine environment lead to the EU Commission producing three documents from the EU Directorate-General for the Environment which provided a basis for beginning of the legislative journey of the MSFD. These were:

- A Communication from the Commission to the Council and the European Parliament entitled “Thematic Strategy on the Protection and Conservation of the Marine Environment” (COM(2005)504 final)
- A Proposal for a Directive of the European Parliament and of the Council establishing a Framework for Community Action in the field of Marine Environmental Policy (Marine Strategy Directive) (COM(2005)504 final)
- Commission staff working document - Annex to the Communication from the Commission to the Council and the European Parliament - Thematic Strategy on the Protection and Conservation of the Marine Environment and Proposal for a Directive of the European Parliament and of the Council establishing a Framework for Community Action in the field of Marine Environmental Policy (Marine Strategy Directive) - Impact Assessment (SEC(2005) 1290)

Examining the three documents together it is clear that the EU Commission believes that the marine environment, both within EU marine waters and globally are under threat and that to achieve the overall aim of the Thematic Strategy i.e. ("to promote sustainable use of the seas and conserve marine ecosystems") requires effective EU action. This is a reiteration of the “Towards a strategy to protect and conserve the marine environment” (COM (2002) 539) but it more forcefully states that part of the failure to achieve the aims of both communications are due to an inadequate institutional framework for management of the seas. In particular it is noted that measures that exist that may be useful operate at a sectoral level but that many were not designed with protecting the marine environment in mind. Therefore the Commission felt that a new approach was needed and proposed a Marine Strategy Directive that would complement current EU policies related to marine protection and bolster the fragmented (i.e. sectoral and regional) approaches taken to date.

The Commission considered several policy options to achieve the aims of the strategy. Rejected options included limited improvement in existing instruments, a prescriptive legislative instrument that was deemed too rigid and finally voluntary cooperation between Member States and the regional sea conventions. Ultimately, the Commission proposed the Marine Strategy Framework Directive (a binding legal agreement) as the best approach to achieve the Strategy’s objectives in a flexible manner; meeting the EU's general principle of subsidiarity.

The Commission stated that member states would have to work together to achieve good environmental status of the marine environment by 2021 (the initial proposed year for achievement of GES), noting that the marine environment does not accord with existing geo-political boundaries and therefore requires co-operation and common principles. Applying a purely national approach to the marine environment would mean that the achieving the objectives of the Marine Strategy Framework Directive is *"doomed to fail"* (Juda, 2007).

Examining the economics of the implications of meeting the Directive's objectives the Commission expected that there would be social and economic costs in the short-term, but in the medium and long-term, social and economic benefits would outweigh these costs by a considerable amount. In addition, the commission estimated that the administrative burden of the Directive would be approximately €90 million per annum for the EU as a whole in the first two years and €70 million thereafter. (EU Comission, 2005)

After it progressed through the legislative procedure of the relevant EU institutions[2], the main changes from the proposal to the final directive were;

- Changes in suggested timelines, most significantly a change from the year in the prosed Marine Strategy Directive from 2021 to 2020 in the MSFD;
- The use of a framework directive to avoid additional costs and increased bureaucracy;
- The inclusion of the Black Sea as a regional sea;
- More emphasis on application of the directive at the sub-regional level rather than just at regional level;
- More emphasis on achieving consistency between MSs undertaking assessment and monitoring in the same region/ sub region.

Mee et al. (2008) was critical of the passage of the Directive through the legislative process noting that some of the attempts by the Parliament to strengthen the MSFD were rejected by the European Council. Several marine NGOs perceived this as a "watering down" of the directive.

[2] The relevant EU institutions that reviewed and altered the proposal through the ordinary legislative procedure until it was adopted were the Economic and Social Committee, Committee of the Regions, the Council of the European Union and the European Parliament.

2.2.1. *Marine Strategy Framework Directive*

The European Union (EU) adopted the Marine Strategy Framework Directive (MSFD) (2008/EC/56) in February 2008. Comprising of five chapters and 28 articles, the Directive is aimed at achieving, maintaining, or where possible restoring good environmental status (GES) of Europe's marine and coastal waters by 2020. GES is measured using 11 descriptors and when all 11 descriptors are at good status then the marine region/ sub-region will have achieved GES. Achieving GES will be met by protecting, maintaining and preventing deterioration of the marine ecosystems and also by preventing polluting inputs being introduced into the marine environment. This target is to be achieved by developing and implementing measures that will manage human activities to ensure a balance between sustainable use of the waters and conservation of marine biodiversity (Long, 2011).

The MSFD builds on previous EU legalisation in the environmental area such as the Water Framework Directive (WFD) (2000/60/EC). The MSFD complements the efforts of the WFD within coastal water bodies where the two Directives overlap by allowing for interaction of management plans but this does not apply to transitional waters which are solely covered by the WFD. This process may not be seamless though. Borja et al (2010) have identified some potential conflicts between the two directives due to issues of spatial application (e.g. Borja et al., 2010) question should transitional waters with a large marine influence be omitted from the MSFD), different terminology of the goals of the Directives (Good Ecological Status (GEcS) versus Good Environmental Status (GES)), different levels of measurement for GEcS/ GES status (WFD having 5 levels, MSFD having 2) and different indicator measures of GEcS/ GES.

As pointed out by Turner et al. (2010), the MSFD is 'informed' by the Ecosystem Management Approach, with GES interpreted in terms of ecosystem functioning and services provision. It is considered to be the first attempt to undertake an ecosystem management approach to protect and maintain the marine environment while ensuring that marine based activities are sustainable (Long, 2011). This ecosystem approach can also be considered a more holistic approach toward water body management compared to what has been perceived as a more prescriptive approach taken by previous water body related directives such as the EU Water Framework Directive (WFD), (EC 2000) Bathing Water Directive (CEC, 1976) and the Urban Waste Water Directive (CEC, 1991) (Borja et al. 2010).

The MSFD established several marine regions / sub-regions (Article 4) on the basis of geographical and environmental criteria (Suárez de Vivero et al., 2009). There are four regions; North-East Atlantic Ocean, the Mediterranean Sea, the Baltic Sea, and the Black Sea. These regions are further divided into several sub-regions as shown in figure 2.1. Figure 2.2[3] shows the regions with EU MSs EEZs. Table 2.1 gives the estimated area for each regional/sub-regional sea.

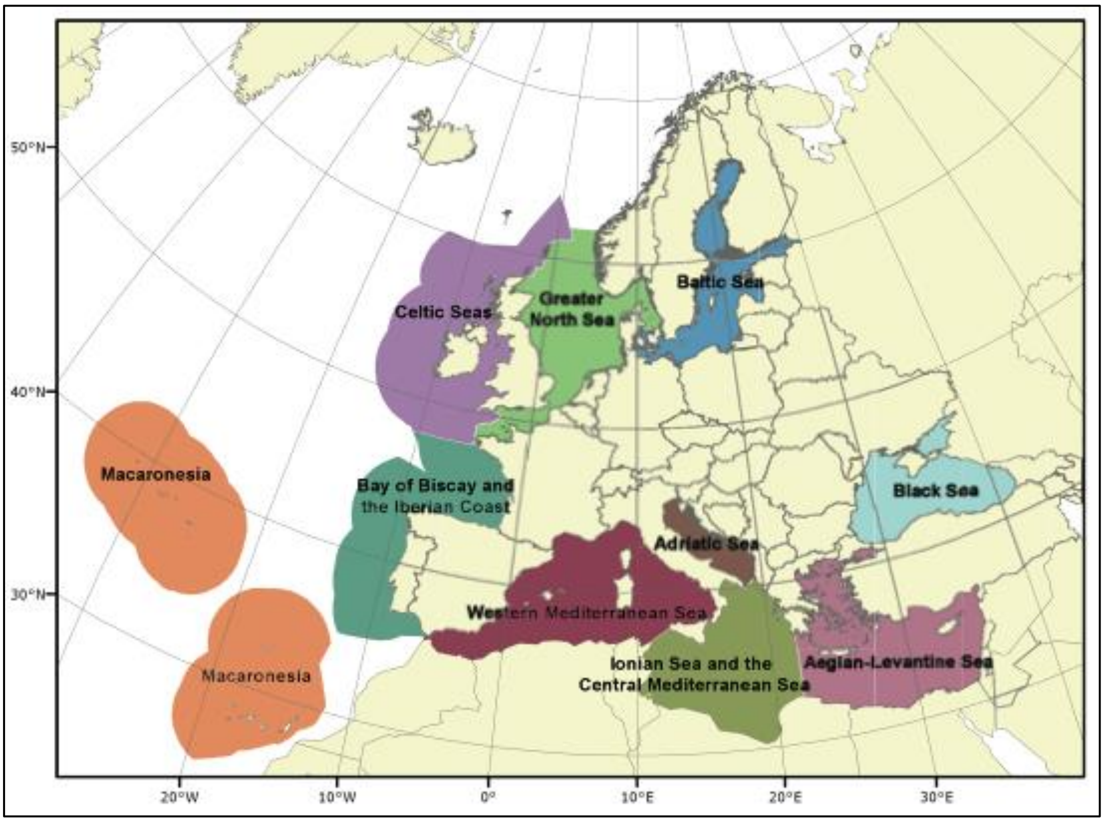

Figure 2-1. MSFD Regions (Source: PISCES, 2012, EEA, 2012)

[3] Note that these images are for illustrative purposes only and should not be taken as definitive instruments for boundaries of nations or their territorial claims.

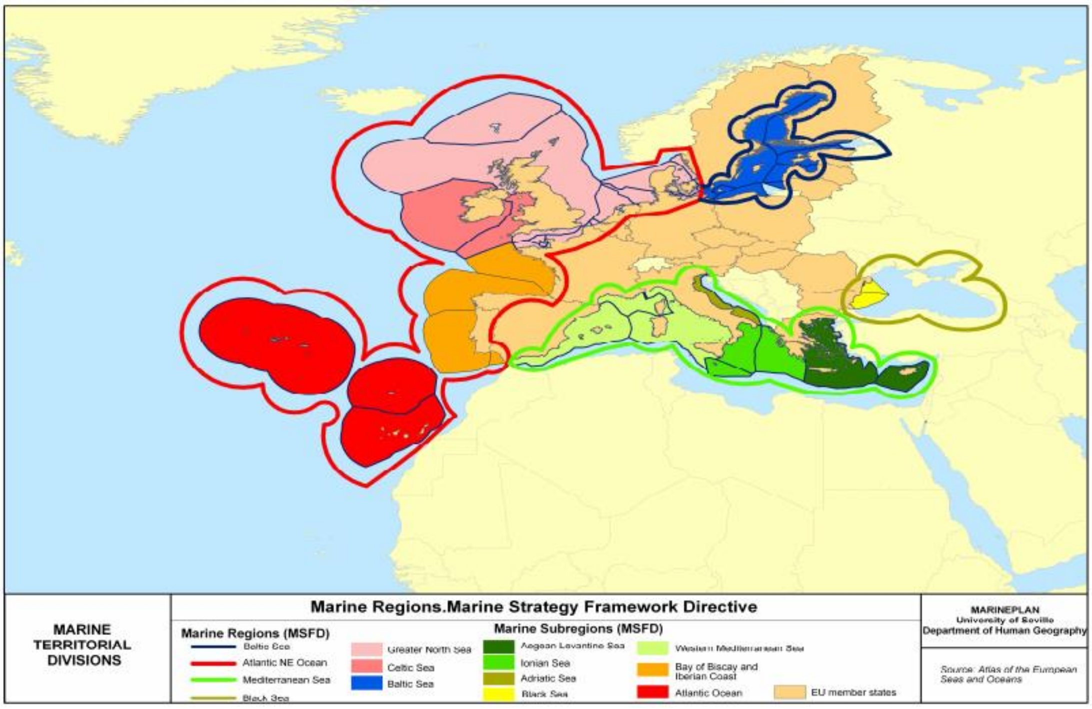

Figure 2-2. Map of MSFD Regions and EU MS EEZs (Source: Freire-Gibb et al., 2014)

Table 2-1. EU MSFD Marine Regions and associated sub-regions (Adapted from Suárez de Vivero et al., 2009)

Marine Regions	Area (km^2)	Marine sub-regions	Area (km^2)
Atlantic NE Ocean	4,673,125	Greater North Sea	1,359,539
		Celtic Sea	518,672
		Bay of Biscay and Iberian Coast	821,374
		Atlantic Ocean	1,973,540
Baltic Sea	349,644	Baltic Sea	349,644
Black Sea	55,908	Black Sea	55,908
Mediterranean Sea	1,533,098	Western Mediterranean Sea	693,550
		Ionian Sea	359,906
		Aegean Levantine Sea	418,819
		Adriatic Sea	60,823

The MSFD requires Member States to undertake marine strategies for each region or sub-region that its marine waters cover (Article 5). A marine strategy involves the following;

- the preparation of an initial assessment of current environmental status of the regions/sub-region and the impact of human activities on said region/sub-region (Article 8)
- the determination of what GES is for the region/sub-region (Article 9) and the establishment of environmental targets and associated indicators (Article 10)
- setting up of a monitoring programmes for the region/sub-region (Article 11)
- developing by 2015 a programme of measures to achieve or maintain GES by 2020 and implementing such measures by 2016 (Article 13)

In developing a marine strategy for a particular region, cumulative and synergetic effects of impacts on the marine ecosystem should be considered in addition to the sustainable use of marine goods and services by present and future generations. However, MS may not be required to undertake measures where there is no significant risk to the marine environment, or where the costs would be disproportionate. However, under article 192.5 of The Treaty on the Functioning of the European Union, derogations from implementation of the MSFD are temporary as MSs should look to access financial support from the Cohesion Fund.

The MSs are to cooperate with other Member States in designing and implementing marine strategies for each marine region (Article 6) (Long, 2011). However, a recent report (EC, 2014) by the EU Commission on the implementation of the MSFD has found many deficiencies in the manner that MSs developed marine strategies. The Commission pointed to the lack of co-ordination between MSs leading to a lack of coherence in what GES is, even within the same regions/sub-regions and noting the lack of ambition in the programme of measures announced to-date. This could be considered a fulfilment of the concerns highlighted by some (Long, 2011, Van Leeuwen, 2012) of the willingness of MSs to implement the MSFD and improve the status of their marine waters.

As the MSFD is a framework directive it aims to contribute to the coherence between numerous other EU directives, policies and international agreements. These include

- Common Fisheries Policy
- Integrated Maritime Policy
- Common Agricultural Policy
- Natura 2000 Directive
- Birds Directive
- Habitats Directive
- Water Framework Directive
- Nitrate Directive
- REACH Directive
- The International Convention for the Prevention of Pollution from Ships (MARPOL)
- International Convention on the Control of Harmful Anti-fouling Systems on Ships
- International Convention for the Control and Management of Ships‟ Ballast Water and Sediments
- The Helsinki Convention (HELCOM)
- The Oslo Paris Convention (OSPAR)
- The Barcelona Convention
- The Bucharest Convention
- The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter

The concept of environmental status should account for the structure and functioning (including processes) of the marine ecosystems together with natural physiographic, geographic and climatic factors in addition to human induced conditions affecting the physical and chemical characteristics of the marine waters (Borja et al., 2011). Environmental status within the MSFD is defined by 11 descriptors (table 2.2). These descriptors have been further defined by Commission Decision (2010/477/EU) which broke down those descriptors into 29 associated criteria that are measured using 56 indicators including biological, physio-chemical indicators as well as pressure indicators (Borja et al., 2013).

The MSFD defines GES as "*the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are intrinsically clean, healthy and productive, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations*" (European Commission, 2008). This definition has left open what GES really is as none of these objectives are mentioned in the descriptors, criteria or indicators. For the WFD, a coastal water body is said to be at GES when all descriptors are at favourable levels. This follows the "one out, all out" approach where the status of the worst element, used in the assessment, determines the final status (Borja et al., 2010). However, the same approach is not being adopted for the MSFD as a whole but may be adopted for individual descriptors (Borja et al., 2013).

Table 2-2. MSFD Descriptors of GES

1.	Biological diversity is maintained, including sufficient quality and quantity of habitats and species.
2.	Marine food webs occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of each species.
3.	Healthy stocks of all commercially exploited fish and shellfish which are within safe biological limits.
4.	Contaminants in fish and other seafood for human consumption do not exceed unhealthy levels.
5.	Concentrations of contaminants are at levels not giving rise to pollution effects.
6.	Human-induced eutrophication is minimised.
7.	Marine litter does not cause harm to the coastal and marine environment.
8.	Non-indigenous species introduced by human activities have minimal affect on native ecosystems.
9.	Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded.
10.	Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.
11.	Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

A recent report from the commission (EC, 2014) assessed the first phase of implementation during which MSs were undertaking and reporting on the state of their seas (the initial assessment), defining what they (MSs) consider to be GES of their marine waters and the targets set to achieve GES by 2020 in their marine waters. The report found that the "*quality of reporting varies widely from country to country, and within individual Member States, from one descriptor to another*". Additionally, knowledge gaps were found across many countries in relation to data relevant to the 11 GES descriptors. The report also highlighted a lack of data which could provide a baseline in which to measure change towards GES. Amongst its recommendations, the EU Commission report indicated a need to review and improve the current Commission Decision Document 2010/477/EU by 2015 to produce a clearer, more coherent and comparable set of GES criteria that could also include the impact of climate change on GES.

After a review of the progress made in the first assessment by the EU Commission in 2014, as was required under Article 12 of the MSFD, the Commission decision of 2010 on descriptors was revisited and superseded by the Commission Decision 2017 (2017/848) while Annex III in the MSFD was amended by a new Directive 2017 (2017/845). Both the Commission decision 2017 and the amendment to Appendix III (Indicative lists of characteristics, pressures and impacts) by the Directive 2017 attempts to improve member states progress towards achieving GES by adopting a new approach aimed at a clearer, simpler, more concise, more coherent and comparable set of GES criteria and methodological standards. Table 1 and Table 2 of Appendix III has been simplified and now links directly to descriptors which was not the case before. Additionally a new table (Table 2b) has been included which includes a list of human activities affecting the marine environment which need to assessed and considered in marine strategies to attain GES. See Appendix D for Appendix III of the Commission decision 2017.

The 2017 Decision states that to determine whether GES is being achieved or not, member states are required to set up threshold values for each of the criteria being used. The decision also lays out the criteria and methodological standards to be used when determining a set of characteristics for GES. It includes requirements that primary criteria are to be used and giving member states the option to use secondary criteria. There is now 27 primary criteria and 15 secondary criteria to be examined for GES in the next cycle of the MSFD. The Decision states that the "*number of criteria that Member States need to monitor and* *assess should be reduced, applying a risk-based approach to those which are retained in order to allow Member States to focus their efforts on the main anthropogenic pressures affecting their waters*" (EU Com, 2017). This statement includes the concept of a risk-based approach which is also allowed in setting thresholds meaning member states have more flexibility than the previous decision which as stated above had 29 associated criteria that were measured using 56 indicators.

2.2.2. *Economic aspects of the Marine Strategy Framework Directive*

The need to estimate the value of the benefits from achieving GES is driven by several elements required under the MSFD. Bertram and Rehdanz (2012) identified the four main requirements for the valuation of ecosystem service benefits within the MSFD. These are:

- Initial assessment of a Member States' marine waters, including economic and social analysis (ESA) of the use of those waters, and of the cost of degradation of the marine environment (Art.8.1(c) MSFD).
- Establishment of environmental targets and associated descriptors describing GES, including due consideration of social and economic concerns (Art.10.1 in connection with Annex IV, No. 9 MSFD).
- Identification and analysis of measures needed to be taken to achieve or maintain GES, ensuring cost-effectiveness of measures and assessing the social and economic impacts including cost-benefit analysis (Art.13.3 MSFD).
- Justification of exceptions to implement measures to reach GES based on disproportionate costs of measures taking account of the risks to the marine environment (Art.14.4 MSFD).

The MSFD also refers to the "costs of degradation", which has been taken to mean the benefits foregone if the MSFD is not implemented (WG-ESA, 2010). With respect to the programme of measures that may need to be introduced to achieve GES, Bertram and Rehdanz (2012) note that the MSFD requires that these measures should be cost-effective and MSs will have to assess the social and economic impacts of new measures which may include conducting cost-benefit analyses. MSs may delay or not achieve GES, if the cost of the measures needed are disproportionate. Additionally, the MSFD calls for a social and economic analysis as part of the initial assessment and consideration of social and economic impacts when setting environmental targets. While costs are thought to be easier to estimate for measures, many of the benefits generated by the MSFD will be non-market goods and services.

To help achieve the aims of the MFSD, the Marine Directors established an organisation structure for a Common Implementation Strategy (CIS) and set up the Marine Strategic Co-ordination Group (MSCG). The MSCG co-ordinates the different working groups and all main activities under the CIS and this led to the establishment of the Working Group on Economic and Social Assessment (WG-ESA) which in 2016 was renamed the Working Group on Programmes of Measures and Economic and Social Assessment (WG-ESA) 2016). One of the main outputs from the WG-ESA was the publication of a guidance document (WG-ESA, 2010) for member states on how to undertake socio-economic analysis with respect to two objectives;

- The economic and social analysis of the use of MSs waters,
- The cost of degradation of the marine environment.

The WG-ESA (2010) report proposed two different approaches to the first; the economic and social analysis of the use of member states waters. These were the Ecosystem Services approach and Marine Water Accounts approach but the document did leave open the door to several other approaches such as a ‘Thematic Approach’.

The Ecosystem Services approach is more in line with the aims of the MSFD in taking an ecosystem-based approach to management of the marine environment. It consists of identifying the ecosystem services in a member states waters using a classification system in cooperation with the analysis of status (Art. 8.1 (a)) and the analysis of pressures and impacts (Art. 8.1(b)). Then the welfare derived from the ecosystem services should be quantified and/or valued using appropriate economic methodologies that allow for the valuation of both market and not-market benefits. Additionally, the report suggested that the drivers and pressures affecting the ecosystem services should also be identified.

If the above approach was in theory the best approach that fitted with an ecosystem-based approach to management of the marine environment the Marine Water Accounts approach was the more practicable approach. This approach was included based on the experiences in Netherlands from using a similar approach for the Water Framework Directive called NAMWA (National Accounting Matrix including Water Accounts) (Brouwer et al., 2005, Van der Veeren et al. 2004) and was based on the regional economic accounts. The accounts included the following five indicators:

- Production
- Use of intermediary products (at purchase prices)
- Gross value added (at market prices)
- Employers' wages
- Labour force size

The approach identifies the regions and boundaries for each region, then identifies and describes the economic sectors using the marine waters. Once this has been done, the economic benefits derived from the economic sector's use of marine waters using the five indicators describe above are quantified and, if possible, the impacts generated by these sectors (e.g. pollutants, CO_2 emissions, capture fisheries production) are also identified. The list below offers an outline of suggested sectors to include in the Marine Water Accounts.

- Aquaculture and mariculture
- Shipping construction and transport
- Coastal defence and flood protection
- Defence - Military
- Fisheries
- Tourism
- Mining (gravel, sand and shell extraction)
- Oil and Gas
- Cables (e.g. Power transmission, Telecommunications, Pipelines - interconnectors)
- Renewable energy (e.g. wind farms)
- Storage (of gases e.g. CO2, CCS)
- Water abstraction
- Water transport
- The use of the marine water for waste and wastewater disposal (agriculture, industry, households etc.)
- Supporting infrastructure (e.g. ports, marinas, navigation aids)

The WG-ESA (2010) report also examines several different approaches to valuing the "costs of degradation". It offers the Business As Usual (BAU) approach to measuring the economic gap between BAU and achievement of GES as the "costs of degradation" where BAU is defined as follows: "*A baseline, or a Business As Usual (BAU) scenario, describes the anticipated evolution in the environmental, social, economic and legislative situation in the marine environment over the agreed time horizon in the absence of the policy under consideration (i.e. if the MSFD is not implemented).*" This represented graphically for the MSFD in Figure 2.3 below with the economic benefits foregone due to the gap between BAU and GES in Figure 2.3 representing the "costs of degradation".

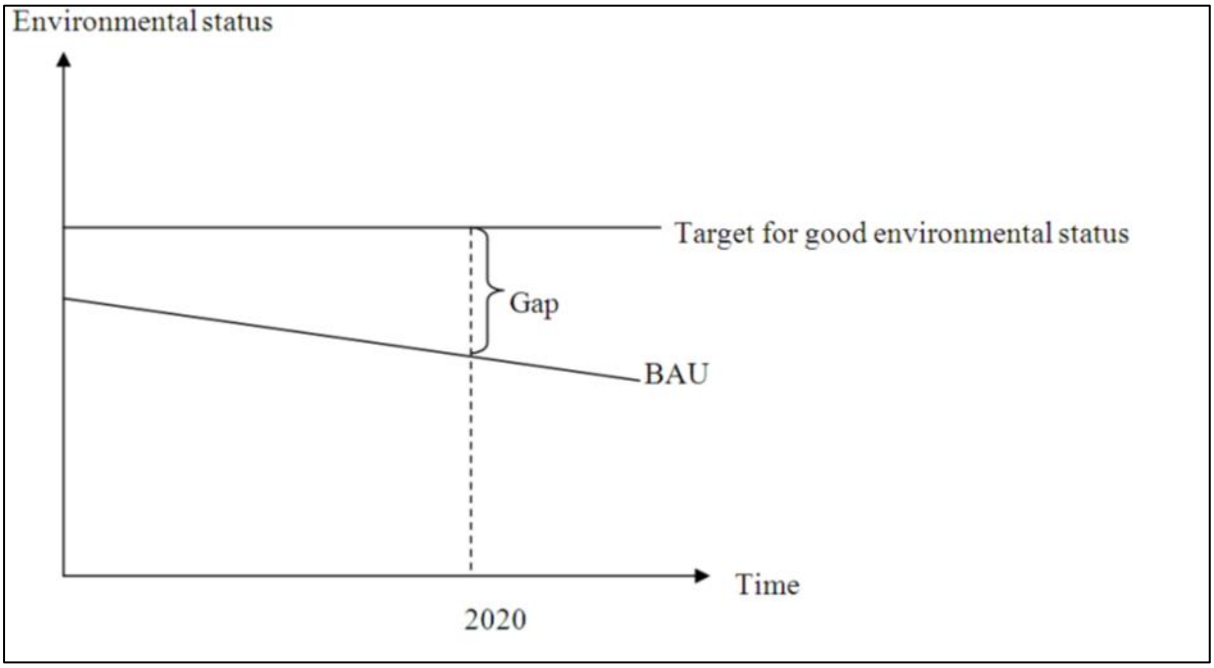

Figure 2-3. Graph demonstrating the 'gap' between BAU and GES

The different approaches that the WG-ESA (2010) report offered to value the "costs of degradation" were;

- The Ecosystem Service Approach,
- The Thematic Approach,
- The Cost-based Approach

The Ecosystem Services Approach breaks down the changes in the marine environment by the different ecosystem services that are impacted, such as provisioning services (e.g. fish and aquaculture), regulating services (e.g. waste treatment and carbon sequestration) and cultural services (e.g. recreation and aesthetic values) and follows a similar approach to that described above for the Ecosystem Services approach for the economic and social analysis of the use of

MSs waters. The Thematic Approach uses currently reported national economic data from sectors that would be impacted by the changes arising from achieving GES in the marine waters and only assesses the current cost of degradation. The results from this approach are expected to more qualitative rather than quantitative.

The Cost Based Approach considers only the costs of meeting the GES targets and could be considered a cost effectiveness approach rather than the cost-benefit analysis (CBA), which the MFSD requires. The advantages of both the Cost-Based and the Water Accounts approaches are that both the costs and thematic data are more readily available compared to measuring both the benefits and costs under the ecosystem based approach. However, given that the MSFD is framed in the context of the Ecosystem Approach, with GES being interpreted in terms of ecosystem functioning and services provision it seems more appropriate to follow the same approach when attempting to estimate the costs of degradation to the marine environment should the MSFD not be implemented in full.

2.3. Progress since implementation of the MSFD

It has been mentioned that the EU Commission's reviews of assessments and monitoring programmes were inadequate overall and some progress at the EU level has been under Commission Decision 2017 (2017/848) and amendments to Annex III in the MSFD by a new Directive 2017 (2017/845). Therefore this section will examine member states approach to carrying out the socio-economic analysis and cost of degradation required under the Article 8(c).

The lack of available information and the existence of data gaps were acknowledged by the majority of Member States (EU Com., 2014). For the socio-economic analysis required for the initial assessment the EU commission found that most Member States have used the Water Accounts approach. Two Member States (Latvia and the UK) applied the Ecosystem Services approach and another two (Lithuania, Sweden) have used a mixture of the Water Accounts and Ecosystem Services approaches. Ireland mostly used the Water Accounts approach except for wastewater where it used the Ecosystem Services approach. For those using the Marine Accounts Approach the marine uses most commonly described included fisheries, shipping, tourism, port operations, aquaculture, defence, marine research activities and renewable energy production (Figure 2.4).

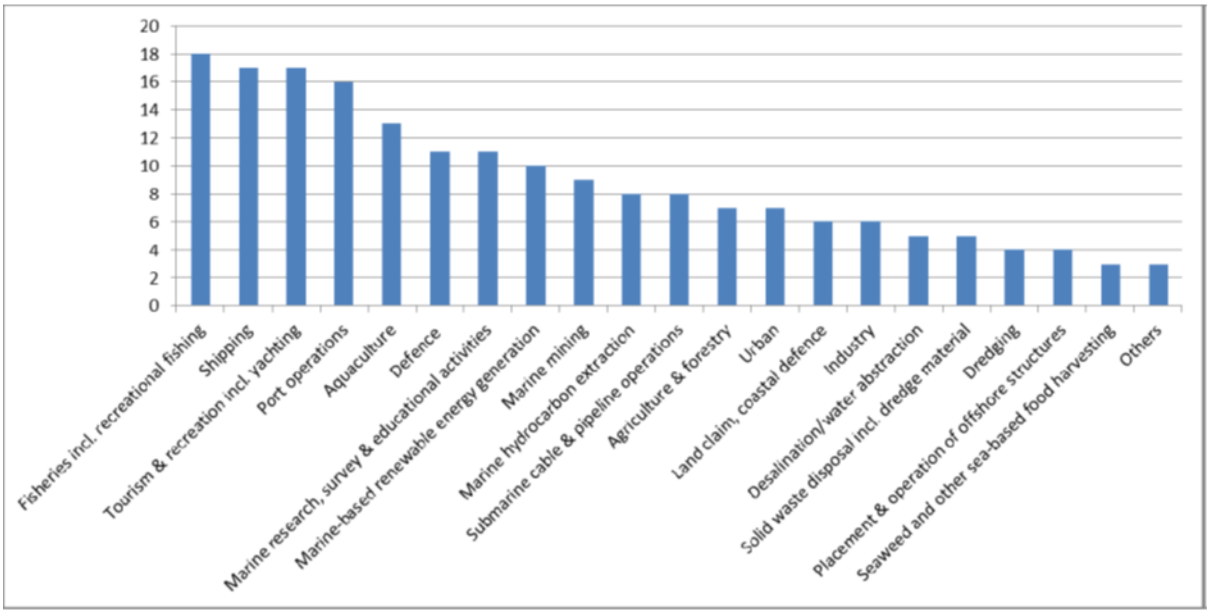

Figure 2-4. Uses and activities were most often included in the economic and social analysis of Member State's Initial Assessments (figures refer to the number of member states which included each use/activity).

For the analysis of the cost of degradation, the approaches used were more diverse than the approaches used for the economic and social analysis for the initial assessment. Over half of the Member States used the cost-based approach. Five Member States (Ireland, Latvia, Sweden, Slovenia and the UK) used the Ecosystem Services approach, two member states (Belgium and Estonia) used the Thematic approach. Finally, two more (Germany and Lithuania) used a mixed approach, using different methods to estimate the cost of degradation in their marine waters. For Bulgaria, the approach used was not clear. The approaches used are summarised in Figure 2.5.

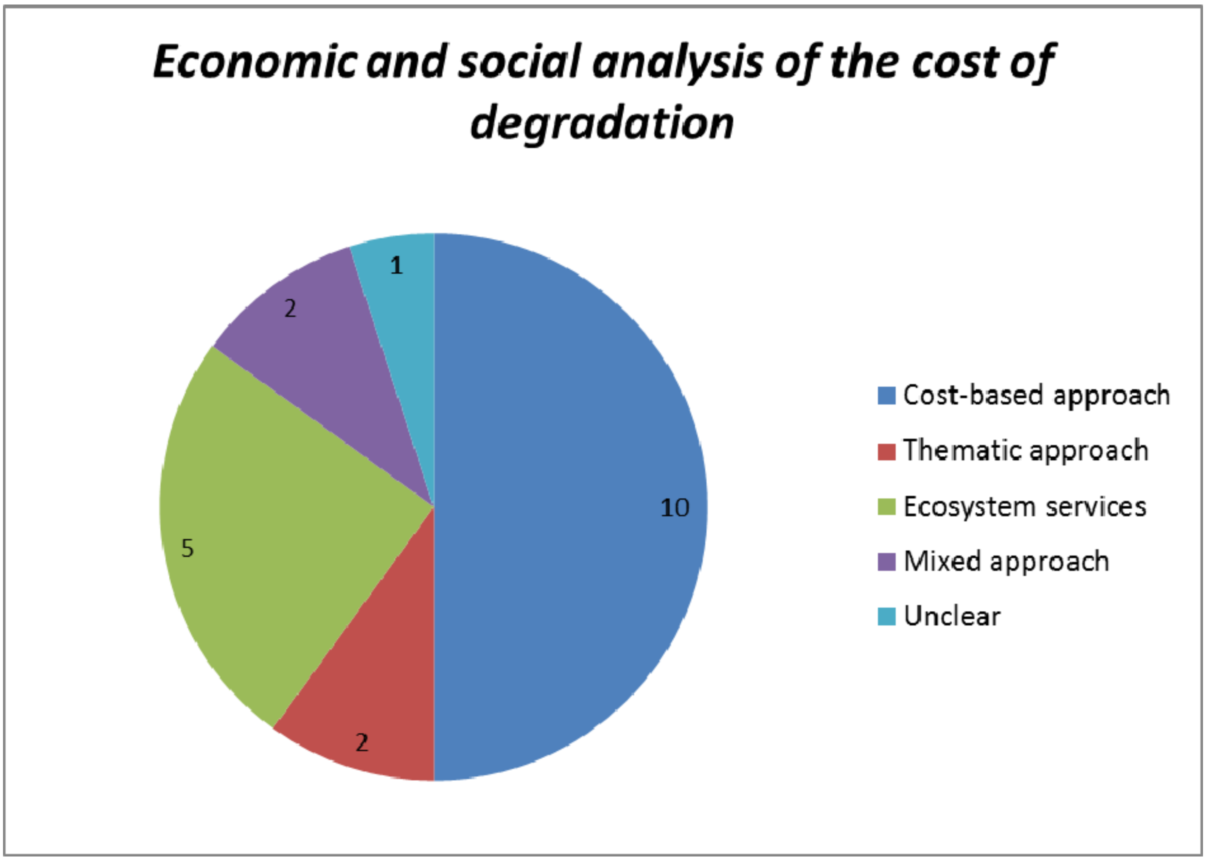

Figure 2-5. Methods most often used in the analysis of the cost of degradation in Member State's Initial Assessments (figures refer to the number of member states which used each approach).

Oinonen et al. (2016a) noted that studies from Spain, the Netherlands and France show that the cost of degradation is €1.5-2 billion annually for those nations based on the cost approach but said that these are the current costs and should be taken as a lower bound estimate for the costs of degradation. The same report also noted the knowledge gaps in the initial assessment and to help develop theoretically sound and practically useful conduction of economic analyses for the MSFD offered a set of five detailed recommendations. These were:

- Develop a multi-step approach for the economic analysis used in the identification and prioritization process for the development of the PoMs
- Develop objectives and response functions in a coordinated and interdisciplinary way
- Focus effort on those descriptors that are not covered by other policies
- Create common data collection and analysis platforms at the regional seas level and between countries sharing marine waters

- Provide guidelines for the use and interpretation of numerical outputs of economic analyses

2.3.1. *Implementing the Marine Strategy Framework Directive in Ireland*

Ireland transposed the MSFD into Irish law in June 2011 using S.I. No. 249/2011 - European Communities (Marine Strategy Framework) Regulations 2011 which were further amended by S.I. No. 265/2017 - European Communities (Marine Strategy Framework)(Amendment) Regulations 2017 which allowed the revision of timetables by the Irish government. The spatial scope of the MSFD in Irish marine waters is the EEZ plus an area of continental shelf abutting the Porcupine Abyssal Plain (Area 2, Figure 2.6). The MSFD region in Ireland also includes coastal waters, as defined by the WFD, with a landward boundary set at the high water mark (HWM), but excludes WFD transitional waters. The reason for the omission of the rest of the continental shelf claimed by Ireland is due to unresolved maritime boundary issues (Areas 3 and 4, Figure 2.6) (DECLG, 2013). The areas under the MSFD is shown in Figure 2.6 (Area 1 and Area 2).

The first task was the initial assessment required under Article 8. The conclusion of Ireland's assessment (DECLG, 2013) was that the overall quality of Ireland's marine environment is good with the limited amount of trend information related to the marine environment suggesting steady improvements in most areas through the action of national and European legislation and other international agreements. However, the existence of significant knowledge gaps in both in the quality of Ireland's marine ecosystems and the status of the pressures acting upon them was acknowledged and the power these gaps had on checking rapid progress towards GES was noted. The report also highlighted that international cooperation has been limited during the initial stages of MSFD implementation, despite the requirements within the MSFD to work together at a regional seas level.

Within the Irish initial assessment the economic and social analysis required under Article 8(c) was mostly carried out using the Marine Water Accounts methodology based on figures produced for the Ocean Economy Report 2007 (Morrissey et al., 2010) apart from the Wastewater sector. The value for the Wastewater sector followed an ecosystem service approach based on the same methodology used in Section 5.5.1 of this thesis. Additionally, the cost of degradation reported for Ireland was based on initial results of chapter 6 of this thesis.

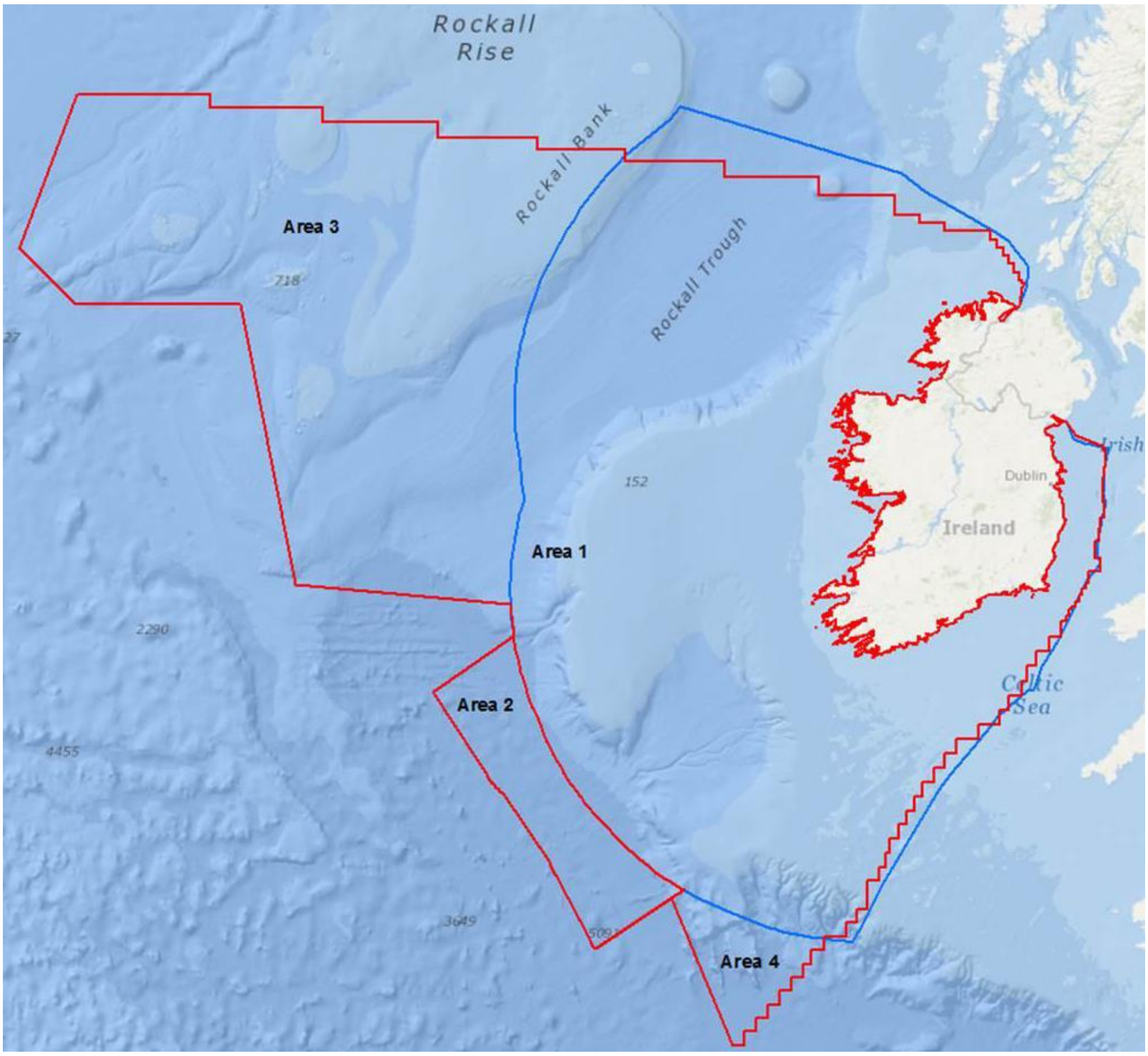

Figure 2-6. Ireland's EEZ (Area 1) and continental shelf claims (Areas 2, 3, 4)

This initial assessment by Ireland was assessed by the EU Commission (EU Com., 2014) in 2014 as required under Article 12 of the MSFD. The report found a story similar to other member states initial assessments, i.e. large knowledge gaps existed, that there are many inadequacies in member states' submissions, that there was insufficient definitions of GES and/or the targets to achieve GES. In particular for Ireland, the report was critical of:

- a single assessment area for all Ireland's marine waters,
- lack of a clear measurable definition of GES with no descriptors being assessed as adequate,
- generally limited assessment of impacts from pressures,
- and that environmental targets were often not sufficiently clear or SMART to be measurable.

In addition the report noted that there was insufficient detail to adequately assess the economic and social analysis in the reporting sheets which provided the basis for their assessment.

On a positive note however, the report did highlight some areas of strength for Ireland's initial assessment. These included

- efforts towards regional coordination with the UK and France through OSPAR, ICES and bilateral arrangements,
- use of existing EU requirements and standards and those of regional sea convention (OSPAR),
- that the main pressures and their sources have been identified and new assessment undertaken for marine litter on the back of the implementation of MSFD,
- targets for Descriptor 5 (eutrophication) was adequate and measurable,
- and there is a good level of consistency between GES, the initial assessment and the environmental targets for most descriptors.

The assessment concluded that Ireland should strengthen the its GES definition of the biodiversity descriptors, aim to make GES measurable in conjunction with OSPAR members, address knowledge gaps, improve its assessment capacity toward quantitative rather than qualitative measures of descriptors and impacts and ensure that the targets cover all relevant pressures, are SMART (i.e. Specific, Measurable, Achievable, Realistic and Time-bound) and sufficiently ambitious to achieve the requirements and timelines of the MSFD.

In a more recent assessment on the monitoring programmes for the MFSD, the EU Commission's (EU Com., 2017) conclusion on Ireland's monitoring programmes per descriptor, under Article 11(3) of the MSFD, was "*Overall, the monitoring programme of*

Ireland constitutes a partially appropriate framework to meet the requirements of Directive 2008/56/EC and to measure progress towards the achievement of good environmental status (GES)". Its noted that while some parts of the monitoring programme have been in place since 2014, most of it will not be in place till 2020. The report found that similar to other EU member states, Ireland relies on existing monitoring programmes from other Union policies as part of its MSFD monitoring programme. Only two of the eleven descriptor categories are described as sufficient (eutrophication (Descriptor 5) and contaminants in seafood (Descriptor 9)) and despite Ireland identifying monitoring gaps and outlining its plans to address the gaps, the report noted that Ireland has not established targets for birds, mammals and the water column (Descriptors 1, 4). Overall, the report suggested that Ireland needed to move faster with it plans to implement the full monitoring programme.

The problems with Ireland's implementation of the MSFD is mirrored by many other EU states, that of lack of decent definition of GES, lack of quantifiable targets for certain descriptors, lack of ambition in the speed of implementation and most significant the large knowledge gaps that need to be filled before GES targets are SMART. It is only when targets for GES at each descriptor level are SMART that adequate programmes of measures will be introduced.

2.4. Summary

This chapter gave an overview of the history of the MSFD and how it functions in creating a marine strategy to achieved or maintain GES by 2020 in EU waters. It also assessed the economic elements which require either CEA or CBA, the latter of which requires estimating the value of the benefits of achieving GES. A brief overview of the economic approaches recommended by the Commission to carry out the initial assessment by each member state was presented and Ireland's progress in achieving GES was also reviewed. Figure 2.7 gives a brief guide to the main reports and legal instruments discussed in this chapter.

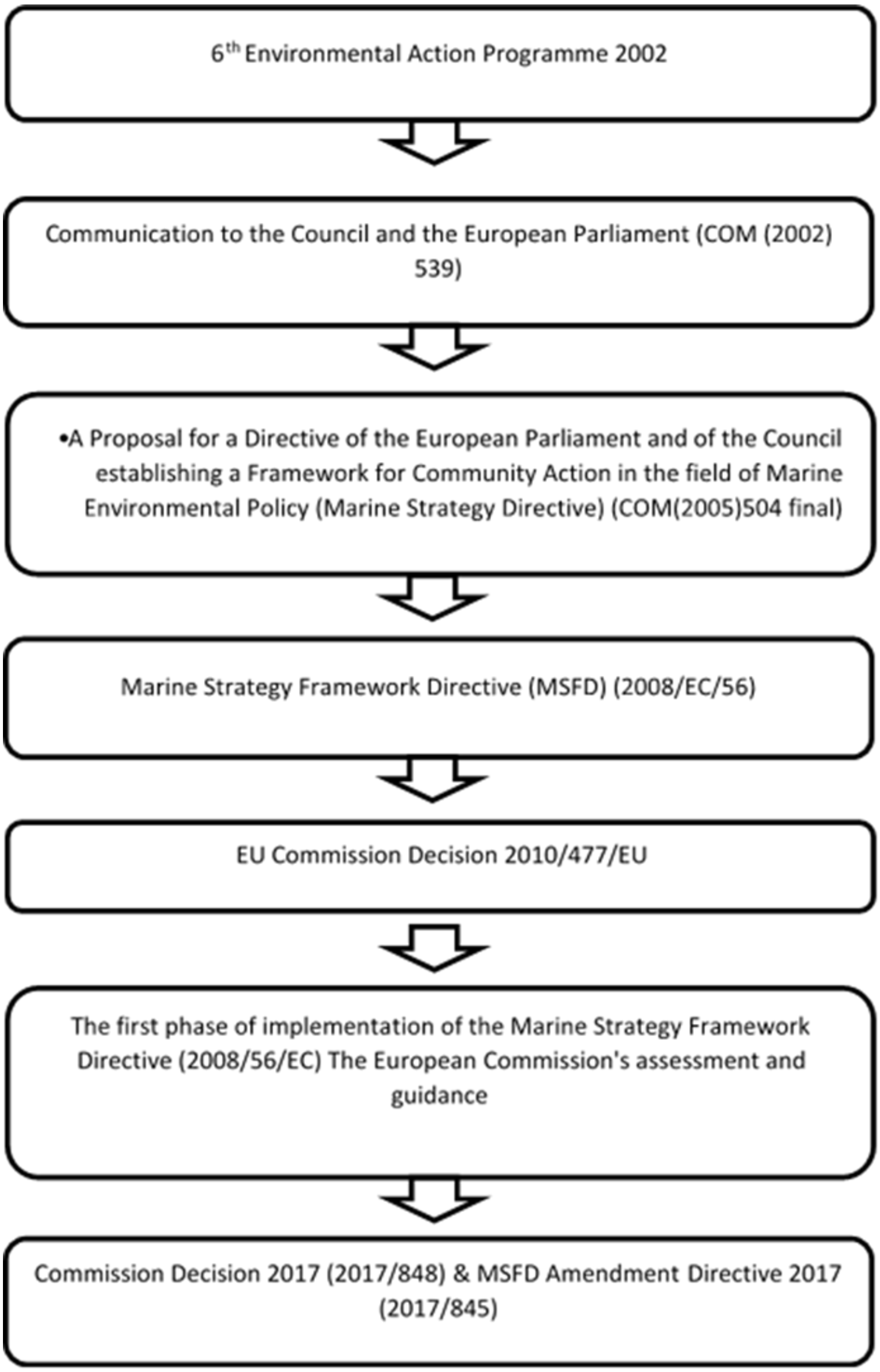

Figure 2-7. Outline of main legal instruments and policy reports for the MSFD

Chapter 3

Survey Design and Development

3.1. Introduction

The main data source for this PhD was a survey designed and developed by myself. It comprised of a 30 minute questionnaire covering respondent's knowledge of the marine environment, their activities in the marine environment and stated preference questions (choice experiment and contingent valuation question). This chapter gives an overview of the design, development and application of the survey.

In what follows, Section 3.2 gives details of the conception and design of the survey. Section 3.3 presents an overview of the survey testing and results from the pilot. Section 3.4 gives a brief overview of the final survey sample while section 3.5 provides some concluding discussion on lessons learnt.

3.2. Questionnaire Design

The survey was originally conceived of as choice experiment related to valuing the attainment of GES in Irish marine waters but grew to include other sections related to the marine environment in Ireland. It was considered by the author and his supervisor that the manner in which the marine environment was broken down into a number MSFD descriptors offered an elegant way to apply a choice experiment to the Irish general public. During the literature review phase of the PhD it was also noted that a study by Potts et al. (2011) on attitudes towards issues related to the marine environment had not been undertaken in Ireland but had in other EU member states. Following on from previous work from his masters on adjusting WTP values for culture and attitudes in value transfer, it was felt that inclusion of the same questions would contribute to knowledge in this area and allow both comparisons with the results of Potts et al. (2011) and allow for any value transfer estimates to be adjusted for different attitudes between MS with particular focus on the EU Atlantic States.

Respondents were first presented with a general statement on the marine environment in Irish seas and the uses to which this environment was being put and were then asked how much of this information they were already aware of. This opening preamble did not just seek to set the context for the survey, but it was hoped that it might also provide a useful indication of the knowledge of the respondents in relation to the state of the seas around the coast of Ireland. Interestingly, 55% of the sample indicated that they knew nothing or "very little" of the information provided. Only 1.2% knew everything.

Information was collected on respondent's attitudes towards different aspects of the marine environment. This was obtained by reading out a number of statements and asking the respondents to indicate the extent to which they agreed or disagreed with them. These statements were developed with the assistance of marine specialists in the Ryan Institute, National University of Ireland Galway and through dialogue in several focus groups before survey design. Several of the questions asked were also adopted from a similar attitudinal survey by Potts et al. (2011) to allow comparisons from the Irish sample to the responses by representative population samples in UK, Spain, Portugal, Poland, Italy, Germany and France[4]. While some questions related to the actions of marine stakeholders, others were aimed at determining individuals' support for policies aimed at marine planning and protection.

Following on from other work by Hynes and Farrelly (2012) on the range of definitions available for coastal zone boundaries, it was found that in Ireland there had not been any work done on the public's perception of the coastal zone and therefore it was decided to include a question to ask respondents in the survey if they considered where they lived as being in a coastal area. They were also asked how far they approximately lived from the coast.

Despite previous work undertaken by the ERSI (1996, 2003), it was felt that there was a lack of recent information on use of the coast and marine for recreational activities. Therefore a number of questions related to number of visits, visitation sites and types of activities undertaken was included in the survey.

For estimating the non-use ecosystem service benefits associated with the achievement of GES as specified in the MSFD, the CE was thought to be an appropriate method as the overall goal (achieving GES by 2020) was already defined by several

[4] It should be noted however that the Potts et al (2011) study used an on-line sampling procedure and excluded persons over the age of 65 whereas the survey reported in this chapter used a face to face survey and included persons over the age of 65. Potts et al. did reweight their samples however to be nationally representative of the population in each of the countries analysed.

descriptors (See Table 3.1), which could be used as attributes in the choice cards presented to the public. This differs from the more common approach where the attributes of a choice card used within a CE are generated after reviewing the literature and/or followed by consultations with experts or stakeholders through the use of focus groups. In the CE presented, the attributes are based directly on the policy text. Having said that, it was decided that 12 attributes (11 descriptors and a price attribute) would be too difficult cognitively for respondents to be able to effectively trade off the attributes against each other. It was therefore decided to combine related descriptors into single attributes. Willis et al. (2005) stated that in a CE, respondents cannot trade off too many attributes without adopting some heuristic rule. They noted that Miller (1956) suggested that in accurately being able to rank attributes, seven (plus or minus two) was the limit of most people's cogitative abilities. Willis et al. (2005) suggested that four or five be the maximum number of attributes used.

Table 3-1. MSFD Descriptors of GES

1.	Biological diversity is maintained, including sufficient quality and quantity of habitats and species.
2.	Marine food webs occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of each species.
3.	Healthy stocks of all commercially exploited fish and shellfish which are within safe biological limits.
4.	Contaminants in fish and other seafood for human consumption do not exceed unhealthy levels.
5.	Concentrations of contaminants are at levels not giving rise to pollution effects.
6.	Human-induced eutrophication is minimised.
7.	Marine litter does not cause harm to the coastal and marine environment.
8.	Non-indigenous species introduced by human activities have minimal affect on native ecosystems.
9.	Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded.
10.	Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.
11.	Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

Table 3-2. Combination of the MSFD descriptors to create the CE attributes

	MSFD descriptor of GES	CE Attribute
1.	Biological diversity is maintained including sufficient quality and quantity of habitats and species.	*Biodiversity and Healthy Marine Ecosystem*
2.	Marine food webs occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of each species.	
3.	Healthy stocks of all commercially exploited fish and shellfish which are within safe biological limits.	*Sustainable fisheries*
4.	Contaminants in fish and other seafood for human consumption do not exceed unhealthy levels.	
5.	Concentrations of contaminants are at levels not giving rise to pollution effects.	*Pollution levels in sea*
6.	Human-induced eutrophication is minimised.	
7.	Marine litter does not cause harm to the coastal and marine environment.	
8.	Non-indigenous species introduced by human activities have minimal affect on native ecosystems.	*Non-native species*
9.	Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded.	*Physical Impacts to the Sea*
10.	Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.	
11.	Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.	

Based on consultation with experts in the field of marine science and following testing with focus groups, certain MSFD descriptors were combined to create joint attributes (shown in Table 3.2). This was done to lower the cognitive burden on respondents. Six attributes were eventually decided upon, including a price attribute. Table 3.2 shows which MSFD descriptors were combined to generate the attributes used in the choice card.

In order to make sure the survey would be understood by the general public, it was pretested on two focus groups. The first focus group was members of the general public from Galway City, a city on the western coast of Ireland, and some students from the local university, NUI Galway (14/6/2012). The second focus group was all female members of a library book group in Portarlington, a town in Co. Laois in the midlands of Ireland which was generally older than the Galway focus group (19/6/2012). The use of focus groups is important in better phrasing and communication of survey questions and for a choice experiment ensuring that the good, its attributes and the levels of the attributes are understood in order for a proper measure of changes in utility. The use of one coastal population and one non-coastal population in addition a general age difference between the two groups was to get a wide diversity of views of people which has been highlighted a preference for focus groups over representation of the final sample (Fowler, 1995). Following the focus groups, a number of changes were made to the text describing the attributes to the respondents and the CE design;

- Changing the term “Non-indigenous species” to “Non-native species”
- Terms related to eutrophication or nutrient enrichment were removed as respondents thought nutrients could only be positive. It was felt that trying to further explain this concept in the short time/space was confusing. Eutrophication was included in general pollution.
- Finally, in light of an increasing amount of taxes and charges being imposed on the Irish general public at the time of conducting this CE, the focus groups felt that the highest payment level presented should not be more than €100 as this was the standard charge for an unpopular household charge at that time. Therefore the maximum amount chosen for inclusion as a payment level was €70. The values used were reassessed following the pilot study but given no issues arose; the values were kept the same for the main survey. Regarding the CVM, however, the focus groups felt there was enough choice in the CVM payment card that giving higher payment options was acceptable.

The final description given to the respondents of the attributes used in the CE are shown in Box 3.1 on the changes that implementing GES would involve in terms of the MSFD descriptors (description of the current state, expected change and potential threats).

Box 3.1. Description of Irish Marine Environment

a) Marine Biodiversity and Healthy Ecosystem

High levels of biodiversity are often a sign of a healthy well-functioning ecosystem. An area has high biodiversity if there are high numbers of different species (especially high level predators), high numbers of those species and the areas in which they live are protected from damage. Biodiversity and healthy ecosystems in Irish waters are known to be under threat from a variety of human activities (i.e. fishing, pollution, marine construction, etc). Currently, most of the seas and oceans around Ireland are rated as at good status with some areas of moderate and poor status; without protection, it is expected that biodiversity will decrease (less species) and there will be a reduction in the area and number of healthy ecosystems.

b) Sustainable and healthy fisheries

The sea provides a variety of fish species which are both nutritious and tasty. In Irish seas while some fisheries are currently have stable populations (e.g. it is sustainable to harvest them) and are safe to eat, other fisheries have been overfished and no longer produce the same yield as in previous years (e.g. it is unsustainable to harvest them). Providing sustainable fisheries may mean closing some fisheries in the short term to allow fish stock to replenish so that they are available both for us in the longer term and for future generations. Management may also be required to ensure fish are healthy and safe to eat.

c) Pollution levels in sea

A variety of polluting substances and litter are known to be entering the seas around Ireland. These pollutants can cause damage to marine environment (e.g. oil slicks), can affect humans by being absorbed through eating fish and can cause harmful algae blooms (e.g. red tides) which can close bathing areas and cause shellfish poisoning. Marine litter can look unsightly and cause damage to marine life. Preventive measures will be needed to reduce the levels of pollution and litter in Irish seas.

d) Non-native species

Marine non-native species are animals and plants that humans transport to Ireland either on purpose or accidently (attached to ships or in ballast water of ships).There are small numbers of marine non-native species in Irish marine waters currently. Non-native species are known to cause damage to oyster beds and disrupt ecosystems. Without preventative measures, these species could spread and new non-native species could travel to Irish waters.

e) Physical impacts on the sea

Physical altering the seabed and changing flows can cause damage to habitats on which various marine species depend and also may cause pollution by stirring up pollutants which were buried in the seabed. Different human activities in the sea and on the coast can change the sea bed and the flows of tides and currents. Underwater noise caused by sonar, ships propellers and construction within the marine environments can also cause disturbance to fish populations and induce stress in marine mammals that use sonar like whales and dolphins. It is expected that some of these activities will increase in the future which is expected to cause more changes to the sea bed and flows. Management of these activities will be needed to prevent significant damage to the marine environment.

For the CE the cost attribute was described as follows;

If you choose the alternative, there will be an amount that you as an individual would have to pay annually for the next 10 years to help protect the Irish marine environment under *this alternative. Payment is expected to be made through a ring fenced tax dedicated to protecting the marine environment either through your income tax or VAT. Please consider how much money is available in your budget considering all your other expenses before making your decision".*

The respondent was then asked *" Based on all the information you have heard so far and again remembering your income and budget, what would be the most that you would be willing to contribute as an annual cost towards achieving good environmental status in the seas around Ireland? "* and the respondents were presented with a series of 12 choices cards from either block 1 (See Appendix B) or block 2 (See Appendix C).

At this point the description of each attribute in the choice experiment was presented (as shown in box 3.1) and a sample choice card (see figure 3.1) was worked through with each respondent. The levels of the attributes were described using qualitative measures rather than quantitative measures due to fact that for Irish marine waters there is currently insufficient quantitative evidence related to the main descriptors of the MSFD to develop any meaningful measures. The levels used for each of the attributes are shown in Table 3.3.

Table 3-3. Levels and brief description of the attributes as per choice cards

Attributes	***Option C Level (status quo)***	***Alternative Levels***	
Biodiversity and Healthy Marine Ecosystem	Biodiversity decreases	Biodiversity maintained at current levels	Biodiversity increases
Sustainable fisheries	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*
Pollution levels in sea	Pollution increases	No change in pollution	Pollution decreases
Non-native species	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	Irish waters are virtually free of non-native species *(Ecosystem unaltered)*	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*
Physical Impacts to the Sea	Wide scale damage	Moderate damage	Limited damage
Tax	€0	€5 €10 €20	€30 €45 €70

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity increases	Biodiversity maintained at current levels	Biodiversity decreases
Non-native species	Irish waters are virtually free of non-native species*(Ecosystem unaltered)*	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Sustainable fisheries	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution decreases	No change in pollution	Pollution increases
Physical Impacts to the Sea	Limited damage	Moderate damage	Wide scale damage
Tax you have to pay	€70	€20	€0

Figure 3-1. Final Sample Choice Card

Following a tender process, the contract to undertake the survey was awarded to RED C Research & Marketing. The survey was undertaken throughout the Republic of Ireland and was carried out on a face to face basis.

3.2.1. *Designing the choice experiment*

The choice experiment was a main part of this PhD and much of the results from this part of the survey are detailed in Chapter 7. This section details how the choice cards were designed for the choice experiment.

As noted in Chapter 2 of this thesis, there was and is a lack of available information related to the marine environment in the EU with the existence of major data gaps being acknowledged by the majority of Member States (EU Com., 2014). Ireland was no different when work began on this survey. After consultation with marine ecologists and fisheries scientists at NUI Galway and Marine Institute, it was decided that for most of the attributes a qualitative approach in terms of increasing, decreasing and no-change scenarios was the best approach. However, for the *Non-native species* attribute, there was some evidence (Lützen et al. 2011) that some marine non–indigenous species can alter an ecosystem by 20% so this was also presented as the extreme level along with a general description. The *Sustainable and healthy fisheries* attribute combined the two fisheries related descriptors in the Directive. The attribute had three possible levels (sustainable & healthy to eat, sustainable and unhealthy to eat, or unsustainable and unhealthy to eat). The unhealthy to eat level was assumed to be as a result of the fish being contaminated. Contaminates are often as a result of high pollution and this attribute was expected to be correlated with the pollution attribute. This was one of the reasons that the random parameters mixed logit model was preferred as it can take correlation between attributes into account. [5]

The price attribute used was based on a ten year ring fenced tax that the respondent would have to pay, a common instrument in the environmental valuation literature. While the aim of this survey is to estimate the "cost of degradation" the question is framed as "paying for improving the environment" through the medium of a tax increase. This approach was taken as a tax is the most realistic payment method that can be used for a public good. Also the "costs of degradation" is interpreted here as the benefits foregone if GES is not achieved and the willingness to pay via taxation for marine ecosystem service benefits should reflect the value in the loss of such services under any scenarios considered. The fact that environmental ring fenced taxes are already used in Republic of Ireland (Convery et al., 2007) also meant the respondents would be familiar with this payment method. The tax is meant to allow the respondent make a payment that will assist in changing the current trend of degradation of the marine environment, which the raison d'être for the implementation of the MSFD in the first place. Dunlap et al. (2002) have described how environmental problems have generally tended to become more geographically dispersed, less directly observable, and more ambiguous in origin which may lead to the belief that people cannot

[5] This expectation was borne out in our results (See appendix H) as the correlation between the unsustainable and unhealthy to eat level of the Sustainable Fisheries attribute is correlated with both the pollution attributes levels (Increasing pollution; 0.37 , Pollution at current levels; 0.66)

understand a trend towards a deteriorating environment. However, other studies (Gifford et al., 2009, Dunlap et al., 1993) have found that there is temporal pessimism for the environment i.e. that things are getting worst over time with Gifford et al. (2009) noting " awareness of environmental deterioration seems to be so strong that it overrides the default bias towards optimism". With this in mind, we consider that the any framing issues related to the use of tax as a payment vehicle within the survey should be slight.

The CE initially employed a Bayesian design based on expected qualitative results with a 1, 0,-1 standing for changes associated with increased, no-change and decreasing utility. Following the pilot a conditional logit parameter estimates (shown below in figure was used to generate priors and the Bayesian efficient design was updated. This created 24 initial profiles that were used to generate the choice cards for the main survey. The initial 24 marine policy profiles were blocked into 2 versions of 12 choice cards, each containing three marine environment alternatives: option A, option B and a status quo. The status quo alternative represented a continuation of current levels in all the marine attributes and therefore a zero additional tax (price) was associated with the status quo alternative. Generic alternatives A and B contained variations in the attribute levels, but with a positive tax price, representing modification to current policy support. The software Ngene was used to generate the Bayesian efficient design based upon minimising the Db-error criterion (Louviere et al., 2000)[6].

3.3. Pilot Stage

A pilot survey of 56 individuals living in Ireland was conducted in the period August-September in 2012. A quota controlled sampling procedure was followed to ensure that the survey was nationally representative for the population aged 18 years and above. Quota sampling sets demographic quotas on the sample based on known population distribution figures. The quotas used here were based on known population distribution figures for age, sex, occupation and region of residence taken from the 2011 National Census of Population. Interviews were spread across different days of the week and across different times of day to ensure all population sub groups had an equal chance of being interviewed.

[6] The interested reader is directed towards Scarpa and Rose (2008) for an outline and discussion of the efficient experimental design literature.

Pilot testing of the survey instrument was conducted in the field by RED C Research & Marketing. This allowed the collection of additional information and amendment of the survey instrument which, along with expert judgment and observations from earlier focus group discussions, was used to refine how the questions were asked and the addition of some new questions. The pilot survey was undertaken during the month of August 2012 and consisted of 56 interviews.

Although there was limited sample it was compared to the Irish Census 2011 on basis of age, education and gender. These results are shown in table 3.4 and show close alignment with the characteristics of the Irish general public.

Table 3-4. Characteristics of the pilot survey versus Census 2011

	This survey (n=56)	Census 2011 – Republic of Ireland
Average Age (Years)	45.4	44.8
Gender (% Male)	46	49
Nationality (%Irish)	90	86
Education (% To primary level)	18	16
Education (% To secondary level)	54	53
Education (% To third level)	29	31

Note that that Census values refer to population aged 18+.

Not many changes were made to the survey from the pilot. An number of exceptions to this include the number of activities that were asked about in the main survey was increased from 14 to 19 to include the following activities which were specified in the other category. These were

- Whale/ Dolphin Watching
- Sunbathing
- Picnicking
- Family Day Trip
- Gathering Shellfish

Additionally, although it was quite a limited sample, a conditional logit model was used to generate priors for the coefficients for Bayesian efficient design of the choice cards. The results are shown in table 3.5.

Table 3-5. Conditional logit results from the pilot

		Conditional Logit – AI	
		C.E.	S.E.
No change in biodiversity	μ	**0.30****	(0.15)
Increase in biodiversity	μ	**0.18**	(0.37)
No change in invasive species	μ	**0.11**	(0.17)
No invasive species	μ	**0.35***	(0.19)
Non sustainable fisheries	μ	**1.05*****	(0.18)
Healthy & sustainable fisheries	μ	**1.01*****	(0.19)
No change in pollution	μ	**-0.07**	(0.15)
Decrease in pollution	μ	**-0.70*****	(0.17)
Moderate physical impact	μ	**0.08**	(0.16)
Limited physical impact	μ	**-0.47*****	(0.17)
Irish Sea	μ	**-0.65*****	(0.2)
Celtic Sea	μ	**-0.46****	(0.19)
Atlantic Ocean	μ	**-0.63*****	(0.2)
Cost		**-0.03*****	(0.01)

Additionally the pilot results were presented at a workshop (Environment Camp on Environmental Valuation Methods for Ecosystem Services) at Stirling University in September 2012 and the comments at this workshop were used to further refine the choice experiment element of the survey. The main change was to omit an area element attribute (See figure 3.2) which was included in earlier iterations of the CE survey as there were difficulties in defining a status quo and it was thought by some at the workshop that the CE had too many attributes. Instead to examine spatial preference for targeting funds the main survey incorporated a separate question to the CV question asking respondents if they would prefer to allow policymakers/scientists (Question 29) to decide how to spatially allocate funds or if they wanted to spatially target funds themselves between three areas, Irish Sea, Celtic Sea or Atlantic Ocean (See question 29 in survey; Appendix A). In addition those who chose themselves to spatially target the funds were shown a map to aid their decision making (Appendix E).

Attribute	Choice A	Choice B	Choice C (Status Quo)
Biodiversity and Healthy Marine Ecosystem	**Biodiversity increases** *(more abundance and diversity of fish, sea mammals and birds)*	**Biodiversity maintained at current levels** *(no change)*	**Biodiversity Decreases** *(less abundance and diversity of fish, sea mammals and birds)*
Non-native species	**Irish waters are virtually free of non-native species** *(Ecosystem unaltered)*	**No new non-native species but existing non-native species remain** *(Ecosystem altered by 5%)*	**New non-native species invade Irish waters in addition to existing non-native species** *(Ecosystem altered by 20%)*
Sustainable fisheries	**Healthy fish stock** *(stocks sustainable, no contaminant in fish and other seafood)*	**Healthy but Non-sustainable fish stock** *(stock is over-fished but no contaminants present in fish and other seafood)*	**Unhealthy fish stock** *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	**Decrease** *(Concentration of pollutants decrease)*	**No change** *(Concentration of pollutants unchanged)*	**Increase** *(Concentration of pollutants increase)*
Physical Impacts to the Sea	**Small Impact** *(minor impact on the sea bed and marine ecosystems)*	**Moderate Impact** *(limited damage to the physical sea bed and marine ecosystems)*	**Large Impact** *(wide scale damage to the sea bed and marine ecosystems)*
Marine Areas	Atlantic Ocean	Celtic Sea	All Irish Waters
Amount you have to pay	€70	€20	€0

Figure 3-2. Pilot Stage Sample Choice Card including area attribute

3.4. Final Survey details and sample details

The final survey was applied to 812 individuals living in Ireland and was conducted in the latter half of 2012, between September and November. Similar to the pilot survey, a quota controlled sampling procedure was followed to ensure that the survey was nationally representative for the population aged 18 years and above. Characteristics of this survey versus Census 2011 are shown in table 3.6. Based on these characteristics the survey respondents are considered to be representative of the general public in the Republic of Ireland. In the next chapters the responses to the main survey are analysed, the results of each section are presented and further discussed.

Table 3-6. Characteristics of the final survey versus Census 2011[1]

	This survey (n=812)	Census 2011 – Republic of Ireland
Average Age (Years)	44.6	44.8
Gender (% Male)	49.8	49
Nationality (%Irish)	90	86
Education (% To primary level)	10	16
Education (% To secondary level)	56	53
Education (% To third level)	34	31
Marital Status (% Single)	29	27
Marital Status (% Married)	53	51
Marital Status (% Other)	18	12
Income[2] (€ per year)	33,300	36,138

1 Note that that values refer to population aged 18+.
2.Estimated income was only estimated for those working who reported their personal income (n=185) for the sample in order to make similar comparison to available national data which was based on average earnings for third quarter, 2012 (CSO, 2012).

3.5. Discussion and lessons learnt

This chapter covered the design, development and deployment of both the pilot and main survey instrument used in this thesis especially for chapters 4, 6 and 7. With the benefit of hindsight, both undertaking the survey and the analysis of the results the main lessons learnt are that is highly likely that there was too much complexity in the CE with a large number of cards and two options apart from the status quo in each choice card in addition to too many attributes. In addition, the concept of basing the choice set design for GES on policy rather than let respondents decide the choice sets may be one of the reasons that insignificant and surprising changes in direction of utility change emerged during the analysis of the choice data in relation to the attributes of invasive species and biodiversity. New guidelines have been put in place recently (Johnston et al., 2017) which suggest that lowering choice options to a binary choice option is now best practice. Additionally, they place more emphasis on qualitative pretesting with a rough minimum of four to six focus groups recommended, with larger numbers recommended for new, unfamiliar, or difficult-to-quantify goods which would be the case in this PhD. I agree with this and the two focus groups used although very useful were limited and more should have been undertaken. Despite these limitations, the undertaking of a large survey covering many different topics, attitudes, understanding and use of the marine sector and environment and two stated preference techniques has allowed me to developed my skillset in this PhD and given me resources for future work as detailed in section 8.4.

Chapter 4

Investigating Societal Attitudes towards the Marine Environment of Ireland

4.1. Introduction

Many people in Ireland rely upon the sea and its resources for their livelihood either directly or indirectly, while for others Irish seas and coasts are important for recreation. In 2007, the direct economic value of the Irish ocean economy was €1.44 billion, with a combined direct and indirect value of the sector of €2.4 billion (Morrissey et al., 2011). However, the views of the Irish public towards the seas and oceans around the Irish coast are relatively unknown. This is despite the fact that that Ireland has sovereign rights over 900,000km^2 of seabed (which is an area 10 times the size of the land area of Ireland).

While the positions of organised stakeholder groups are often captured through responses to policy consultations such as those provided for the recently launched Integrated Marine Plan for Ireland, the opinion of the 'ordinary person in the street' is difficult to include in the decision making process. However, it is the collective choices made by communities through the marine and coastal resources they use, the coastal areas they visit or reside in that drive many pressures on the marine environment. The viewpoint of the Irish public on the seas and oceans around Ireland will also play an important role in supporting policies such as the Integrated Marine Plan for Ireland and the EU Marine Strategy Framework Directive and for policies aimed at the deployment of marine renewable, large scale aquaculture projects, and marine protected areas that have considerable social and economic consequences.

The marine environment policy agenda in Europe is moving forward as a result of directives such as the European Marine Strategy Framework Directive, the Bathing Waters Directive and through regional seas strategies such as the Atlantic Strategy. Across other areas of marine activity, such as planning and maritime development, policy is being driven by the Integrated Maritime Strategy; and for fisheries through the reform of the Common Fisheries Policy (Potts et al., 2011; Hanley et al., 2003). Indeed, the adoption of the Marine Strategy Framework Directive is an opportunity for a comprehensive policy for protecting, improving and sustainably using Europe's environmentally degraded seas. It calls for an ecosystem-based approach to management where humans are regarded as a key system component (Mee et al., 2008).

The ever increasing and diverse use of the marine environment is leading to human induced changes in marine life, habitats and landscapes, making necessary the development of marine policy that considers all members of the user community and addresses current, multiple, interacting uses. In recent times, the governance of the marine environment has also evolved from being primarily top down and state directed to being more participatory, inclusive and community based. Democracies respond to the views of it citizens and this work will help those within governance understand the views of the general public and not only interested stakeholders. Coupled with this fact is recent research that points to higher levels of citizen involvement in the management of the marine environment would greatly benefit the marine environment (Atkins et al., 2011; McKinley & Fletcher, 2010).

In what follows, Section 4.2 will briefly review previous studies that have examined public attitudes to the marine environment. Section 4.3 will then present an analysis of the survey responses while section 4.4 provides some concluding discussion. This chapter provides the context for the rest of the valuation work (chapters 5, 6 and 7) in this thesis. Attitudes are important part in creating preferences (McFadden, 2000) that in turn feeds into how people and in turn society makes trade-offs in the marine sector, which is basis of this thesis.

4.2. Previous studies that have examined public attitudes to the marine environment

Several previous research studies have examined the public awareness, attitudes and perceptions to the marine environment using public surveys to attain their results (Buckley et al., 2011; Cocklin et al., 1998; EU Commission, 2009; Whitmarsh et al., 2009; Brody et al., 2008; Steel et al., 2005; Sant, 1996).

Hamilton and Safford, (2015) reported the results of coastal and marine related questions from the Community and Environment in Rural America (CERA) initiative, a series of telephone surveys in selected rural regions around the United States between n 2009–2012 with 9,000 residents in 19 counties of eight regions. Overfishing was only seen as the highest threat in one region (SE Alaska) and was one of the lowest in the Gulf of Mexico regions. They also noted that political affiliation was a significant factor in relation to perception of environmental problems related to the marine and coastal areas with

Democrats are more likely than Republicans to see environmental problems as a serious threat. In other work in the USA, Steel et al., (2005) in a survey of over 1200 respondents found that coastal residents had higher ocean literacy than those inland.

Closer to Ireland, Fletcher et al., (2009) assessed the awareness of marine environmental issues of visitors to the National Maritime Museum in the UK. Using a face-to-face interview survey they interviewed a sample of 138 respondents. In terms of ocean literacy and awareness, the top two responses that were most commonly mentioned were 'pollution' (16.1%) and 'marine life' (12.9%). This mirrors other work which tends to show low levels of environmental awareness related to the marine environment among the general public (Spruill and Dropkin 2001). In terms of threats to the marine environment the only topics mentioned by more than 10% of interviewees were pollution (40.8%), climate change (17.3%) and over-fishing and stock depletion (16.8%).

A recent European briefing report carried out by Potts et al. (2011) explored the values, concerns and aspirations of the ordinary person regarding the marine environment. It was important to gain the views of the public as they play an important role in supporting reforms. A large sample across seven countries was taken. The findings revealed that the public had a good understanding of the marine environment, especially in relation to ocean and atmospheric systems; that the importance placed on the marine environment for scenery provides a justification for further incorporation of ecosystem services into the decision making process; and in terms of environmental issues that immediate problems, such as the cost of living, health and pollution, were of greater concern to the public than more abstract elements of sustainability. The survey presented an optimistic picture for support for marine planning and protection at the national scale, with considerable goodwill in the public mind for the development of marine planning initiatives.

In 2011 the FP7 project CLAMER (Climate change and marine ecosystem research) prepared a report (Buckely et al., 2011) that discussed what the European public knows and cares about in relation to marine climate change risks and impacts. The survey spanned 10 European countries and was undertaken as a result of the perceived gap between what is known through research and what policy makers and the public knows and understands about the impacts of climate change in the oceans and seas around Europe. The EU Commission conducted a similar report in 2009 in preparation for the United Nations Climate Change

Conference in Copenhagen that was aiming to reach a follow-up agreement to the Kyoto Protocol (EU Commission, 2009). The results from both reports show that the public cares about climate change, ranking it second overall from a list of major global issues, and almost everybody polled believed climate change is at least partly caused by humans. It also showed that estimates provided by the public for rates of sea level rise and temperature change matched well with scientific consensus, suggesting some fundamental messages are getting through to the public domain. However for some issues, especially ocean acidification, public awareness was extremely low. Potts et al. (2011) also highlighted a split between the public and the scientific community over their respective perceptions of environmental problems in the sea. Elsewhere, research by Cobham Resource Consultants (1996) on the attitudes and aspirations of people towards the marine environment of Scotland with respect to its uses, controls and conservation importance concluded that both the public and marine stakeholders appear to have a restricted understanding of the full range of uses and importance of marine resources. However they found that generally, stakeholders had a better knowledge of the environmental issues such as pollution, waste disposal and impact of overfishing.

Several broader socio-demographic themes also emerge from the literature. Staying longer in education, higher income and use of the internet has an impact on people's opinions of the marine environment (EU Commission, 2009). Several studies comparing responses between genders found that women were more concerned about the issues facing the marine environment than men (Cobham Resource Consultants, 1996; EU Commission, 2009; Wester & Eklund, 2011). Additionally, the proximity to the sea and perceived level of risk to the marine environment has also been found to shape the perceptions of the public towards the marine environment (Brody et al., 2008).

Research has also shown that by enhancing public awareness and knowledge of oceans can lead to increased public support for ocean restoration efforts (Steel et al., 2005). The literature suggests that there has already been some degree of effective communication between policy makers and the public in relation to the marine environment, although there still remains a gap between public and scientific understanding about many of the threats to marine ecosystems. Steel et al. (2005) conclude that the public is not well informed on the environmental terms and knowledge about ocean issues. The survey conducted by the authors found that coastal residents say that they are slightly more knowledgeable than those residing in non-coastal areas, however both sets of respondents had trouble identifying important terms and answering ocean related quiz questions, implying that both coastal and non-coastal communities need access to better information that is delivered in an effective manner.

More recently, Ahtiainena et al. (2013) contributes to the expanding literature on social preferences for marine ecosystem services by assessing recreational usage and perceptions of the condition of the Baltic Sea from the perspective of the general public within the coastal states surrounding the Baltic. They find that citizens of coastal countries are concerned over the state of the Baltic Sea, especially in Finland, Russia and Sweden and that the Poles, Danes and Finns have the most positive attitude towards contributing financially to improving the state of the Baltic Sea. Other research that has examined the attitudes, values, concerns and aspirations of individuals regarding aspects of the marine environment include work that has focused on climate change (Lorenzoni and Pidgeon, 2006; Featherstone et al. 2009), environmental quality and beach use (Pendleton et al. 2001), cetacean conservation issues (Scott and Parsons, 2005) and off shore wind farms (Haggett, 2008; Portman, 2009).

This chapter adds to the above body of research by reporting on the results of a nationwide survey in Ireland that explored the values, concerns and preferences of individuals regarding the Irish marine environment. The results of the Irish survey are also compared to the results from similar surveys carried out in other maritime countries in the EU. The results of this study also feed into the emerging literature on ‘Ocean literacy’ where an ocean-literate person can be defined as one that understands the influences of the ocean on society and society’s influence in turn on the ocean, can communicate ocean related information, and is able to make informed decisions that affect the ocean. As Steel et al. (2005) point out; with an understanding of the depth and breadth of ocean understanding held by the general public, more effective public education and marine and ocean information dissemination efforts may be targeted. With this in mind, the depth and breadth of ocean and marine knowledge held by the Irish general public is investigated through the use of a survey (See Chapter 3 of this thesis for further details on the survey) and reported on in the following sections.

4.3. Results

Respondents were first asked the extent to which they thought the overall environmental state of both coastal and the deep oceans around Ireland was poor or good using a five point Likert scale. As shown in figure 4.1., the first notable difference between respondents' assessment of the Irish marine waters condition is that they are more uncertain about the condition of the offshore marine waters (24% unsure) compared to conditions for those coastal waters closer to the shore and beaches (7%). After removing those who are unsure, the public's assessment of the conditions of the marine and coastal environment is quite similar. Approximately 15% (coastal and beach: 17%, offshore: 14%) of the sample believed that the general environmental state of the Irish coastal and ocean waters was very poor or poor, 17% (coastal and beach: 16%, offshore: 18%) believed it was neither poor nor good and the remaining 68% (coastal and beach: 67%, offshore: 68%) believed that it was good or very good. This is interesting in the context of the variety of marine related water management schemes put in place over the last 20 years such as the Water Framework Directive, the Bathing Waters Directive and more recently, the Marine Strategy Framework Directive. These measures coupled with Ireland's geographical location on the edge of the Atlantic, which supplies Ireland with it fresh maritime climate, may explain the Irish general population's positive perception of the state of the country's marine environment.

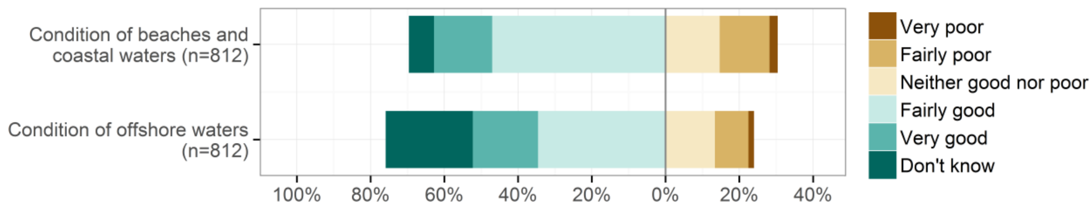

Figure 4-1. The rating of the environmental condition of coastal waters and beaches in Ireland and the rating of the environmental condition of the oceans around Ireland by the Irish general public.

Respondents were next asked how concerned, if at all, they were about different issues facing society in Ireland today. As shown in figure 4.2., health issues and the cost of living were rated as being the most important issues facing Irish society, closely followed by the economy and education. Only terrorism and species loss ranked lower than ocean health in terms of being an important or very important issue of concern. Interestingly, the Potts et al. (2011) study showed a very similar pattern of concerns for other European countries (figure 4.3) with ocean health being further down the concerns list. It is also worth nothing however that while the pattern is similar, the Irish sample appear to have a much higher tendency to rate each issue as being important or very important.

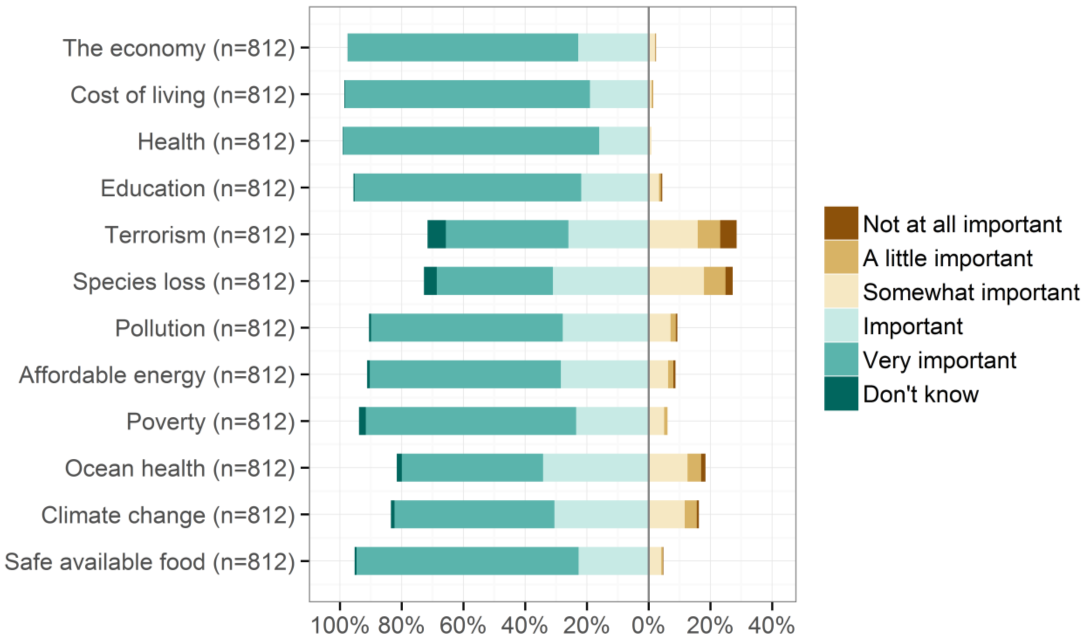

Figure 4-2. A comparison of issues of concern which are individually scored.

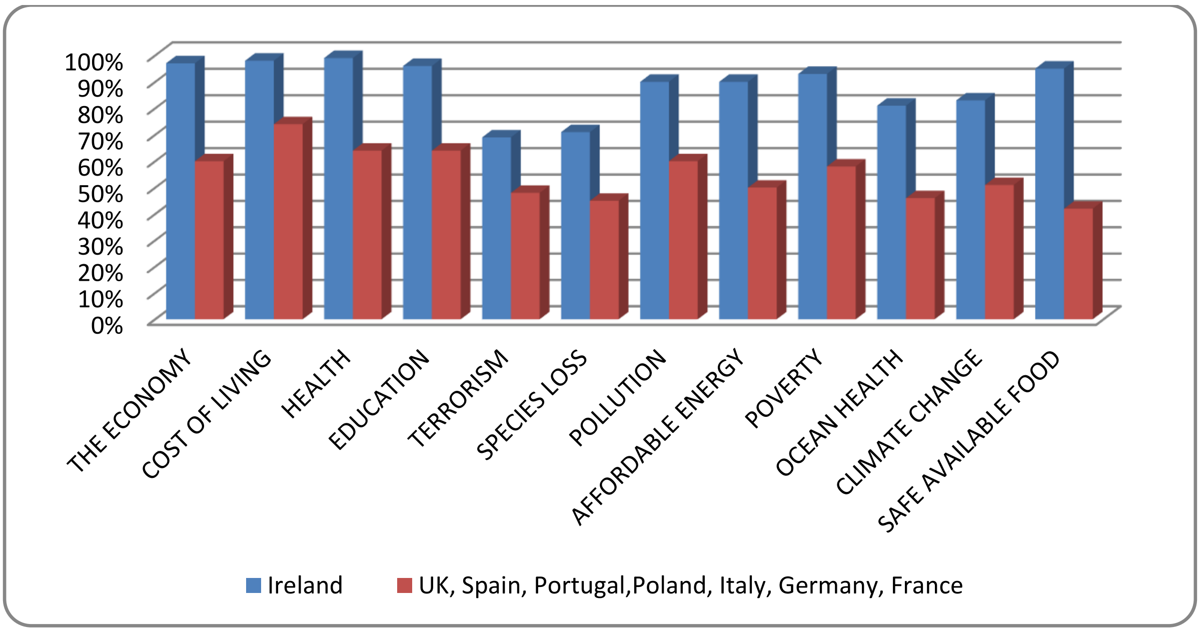

Figure 4-3. Prioritisation of issues of concern by Irish general public compared to the average response from individuals across UK, Spain, Portugal, Poland, Italy, Germany and France. (A score of 4-5 on a 5 point scale where 1 means it is not at all important and 5 means it is very important.)

The next question in the survey asked respondents to rank on a scale of 1 to 5 how important they felt various functions of Irish seas and oceans were to them personally (1 being least important and 5 being most important). The results of this question are presented in figure 4.4. *The seas as a source of food* were given a rank of 4 or 5 (i.e. seen as important or very important) by approximately 91% of all respondents. This was closely followed by "*for the regulation of weather and climate" and "recreation and tourism"* which were given a rank of 4 or 5 by 87% and 86% of respondents respectively. The importance of Irish seas for *culture and identity* and for *creativity* had the lowest 4 or 5 rankings albeit at a still high at 73% and 71% respectively. The latter finding is somewhat surprising given that Ireland is an island nation on the fringes of Europe but having said that the fact that Ireland has tended to turn her back on her marine resources and heritage has been commented on previously (MacLaughlin, 2011; Fahy, 2013).

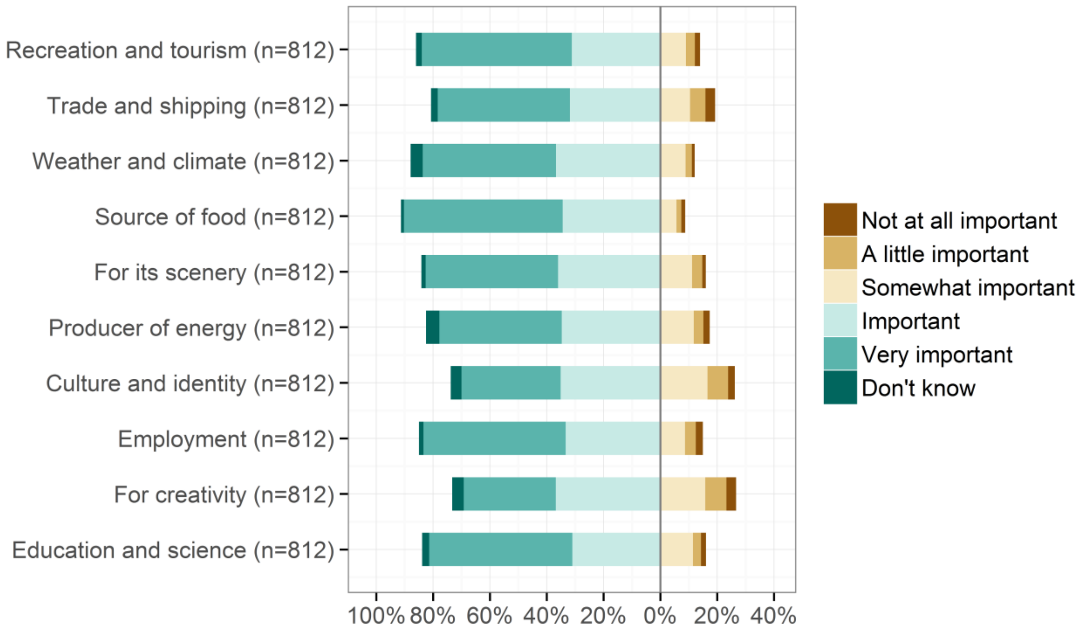

Figure 4-4. The value of the oceans to individuals across Ireland.

While Irish residents emphasise the practical uses of the seas as being important (food source, trade, employment and education) it is also interesting to note that the non-market ecosystem services (climate, recreation, scenery) are rated as important as marine functions and activities. It is often debated whether the general public have enough knowledge in relation to the non-provisioning ecosystem services provided by the marine environment to be in a position to state their value to them personally (Kumar, 2010; Jobstvogt et al., 2014) but the attitudes expressed by the Irish general public would suggest that they are aware of their importance and that the inclusion of non-market and non-use ecosystem services in decision making is something that should be happening as standard rather than on an ad-hoc basis. Once again individuals from across the UK, Spain, Portugal, Poland, Italy, Germany and France would appear to have a similar pattern of preferences to the Irish as well as the same appreciation for the non-market as well as the marketed ecosystem services from the marine environment, although once again the Irish are more generous with their ratings in each case (see figure 4.5).

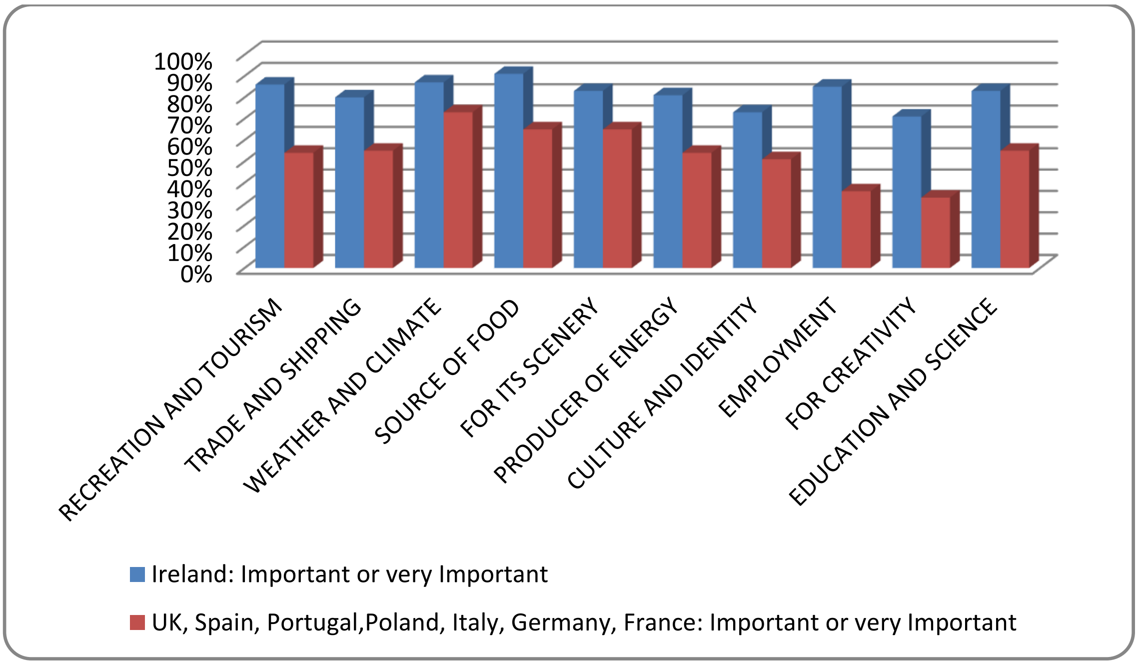

Figure 4-5. The value of the oceans to individuals across Ireland compared to the average response from individuals across UK, Spain, Portugal, Poland, Italy, Germany and France. Scores shown as percentage of responses rated as 'important or very important' (A score of 4-5 on a 5 point scale where 1 means it is not at all important and 5 means it is very important.)

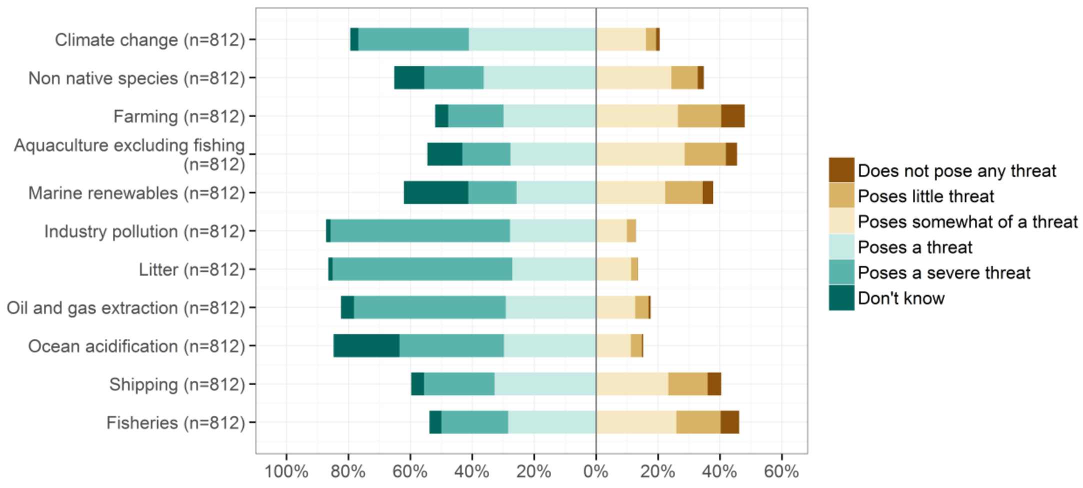

Figure 4-6. Rankings of perceived threats to the marine environment by the Irish Public.

Respondents were then asked to indicate how much of a threat different issues posed for Ireland's marine environmental (see figure 3.4.). The factors that were deemed to be the most of a threat were industry pollution (87%) followed by litter (86%). Interestingly an additional 11% of those on lower annual incomes (less that €40,000) consider that litter poses a significant threat (i.e. give litter a ranking of 5) than those who earn more. Oil and gas extraction and ocean acidification was a close third with 81% and 80% of the sample rating them as posing a threat or severe threat to Ireland's marine environment. The perceived threat of non-native (invasive) species by the Irish general public is relatively high at 60%. While invasive species have been shown to have major impacts on marine ecosystem services (Oguz et al 2008), invasive species in Irish marine waters has not been a major problem to date. The perceived threat of oil and gas is surprisingly high considering the extensive nature of such activity in Irish waters but may reflect exposure to the long running media coverage of the conflict between a local community groups and the Shell oil company over construction of a natural gas pipeline and refinery at a site in Co. Mayo.

Less than 50 % of all citizens considered farming or aquaculture as posing a threat or severe threat to Ireland's marine environment and only approximately 52% of respondents felt that fishing posed any significant threat. This is an interesting finding given that the Irish Environmental Protection Agency (EPA, 2008) identified the discharge of nutrients and other contaminants (much of which is likely to come from farming), marine litter, commercial fishing, aquaculture and the effects of climate change as key pressures on Ireland's marine waters. Indeed, eutrophication driven by agriculture has been shown to pose a major threat on the marine environment, causing hypoxia, anoxia and mass benthic die-off (Mee et al 2005). It would appear that except for marine litter, what the scientific community/experts see as the most significant threats on Ireland's marine environment are not fully in line with that perceived by the general public. The low perceived threat of fisheries may explain the surprise expressed by Fahy (2013, p19) that the public is not more effective in obtaining a change in what the author sees as poor fisheries management policy in Ireland. Fahy also comments on the fact that "*commercial fishing has a warm spot in the people's hearts and the way it operates is profoundly misunderstood*".

Also, in an international survey of the perceptions of scientists in relation to threats to the ocean, Halpern et al. (2006) found that climate change and commercial fishing are the two chief causes of concern for scientists. It is also surprising that fishing, farming and aquaculture do not rank higher given the significant media coverage often given to these sectors impact on the marine environment relative to many of the other categories that are perceived to be of a higher threat. Once again however the general pattern of perceptions of threats would appear to be very similar to those held by citizens in the UK, Spain, Portugal, Poland, Italy, Germany and France where the factors that were deemed to be the most of a threat were the same as in Ireland; industry pollution and marine litter (see figure 4.7). These may be perceived to be the most significant threats by the public as perhaps they see litter on the beaches and the spread of industry on the coasts, where as they may not see as readily commercial fishing activity that takes place off shore or the impacts of nutrient run-off from farming.

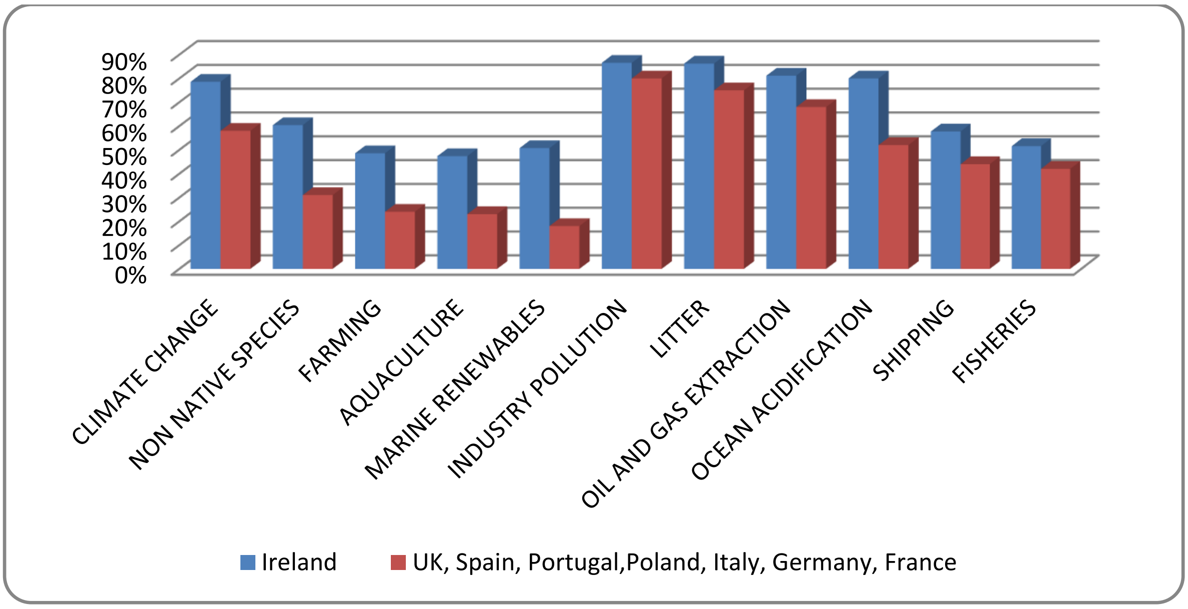

Figure 4-7. Rankings of perceived threats to the environment by the Irish general public compared to the average response from individuals across UK, Spain, Portugal, Poland, Italy, Germany and France (A score of 4-5 on a 5 point scale where 1 means it poses no threat and 5 means it poses a significant threat.)

The next question in the survey asked respondents how competent they felt a number of different groups were when it came to managing and protecting Ireland's ocean environment. As can be seen from figure 4.8 only 25% and 27 % of respondents felt that local government or national government, respectively, were competent or highly competent (score of 4 or 5) when it came to the management of the marine environment (after removing don't knows). Indeed even private industry was seen as being more competent than these institutions when it comes to marine management. It should be noted that these questions were asked only shortly after the Irish government put in place the first Integrated Marine Plan for Ireland and as such the attitudes of the general public may have altered in regard to this institution's competency since then. It would appear that the many marine and coastal related policies and Directives the EU has drafted in recent years have made some impact in terms of the perceived competency of this institution with 40% of respondents believing that this level of government is competent or highly competent when it comes to the management of the marine environment.

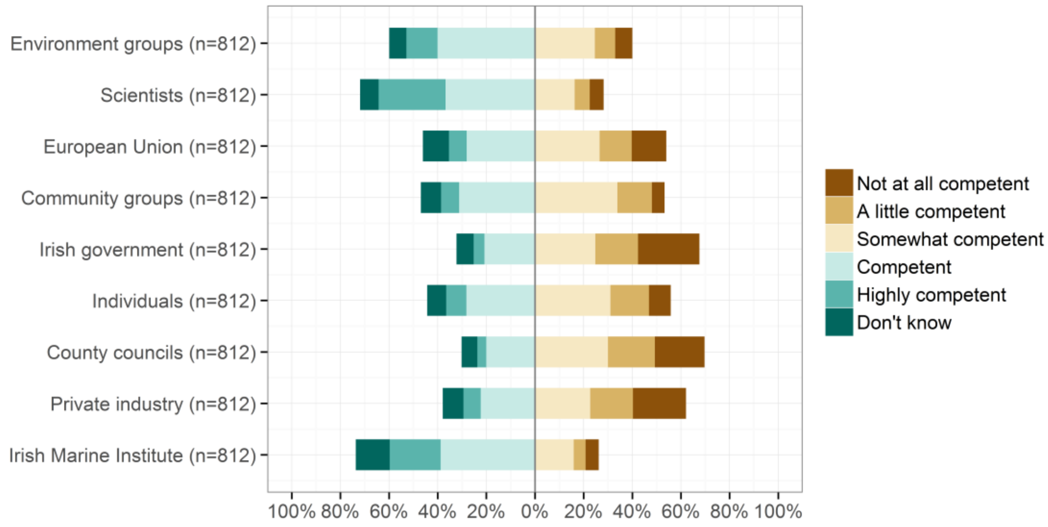

Figure 4-8. Perceived competence of different groups to manage the marine environment.

The one group that the public would appear to have some faith in when it comes to the management of the marine environment are the scientist where after removing don't knows, 69% of respondents believe that this group are competent or highly competent when it comes to the management of the marine environment. This high level of faith in the ability of a group to manage the marine environment (69% after removing don't knows) is also shown for the Irish Marine Institute which is the national agency responsible for marine research, technology development and innovation[7]. Once again a very similar pattern of rankings is shown for the different groups across the countries in the Potts et al. (2011) study as well (see figure 4.9). As Potts et al. (2011) point out the apparent mistrust of government organisations and industry with the management of the marine environment may reflect the public's discontent at environmental problems in general (even when not ocean related) and the failure of government policy to tackle such problems.

[7] While there are many other agencies in Ireland with a marine related remit such as the Environmental Protection Agency, Bord Iascaigh Mhara, Sea Fisheries Protection Authority, etc., only the Marine Institute was included in the question as this is the agency with the widest remit when it comes to the management of the Irish marine environment and would be the most recognisable marine related agency to the general public.

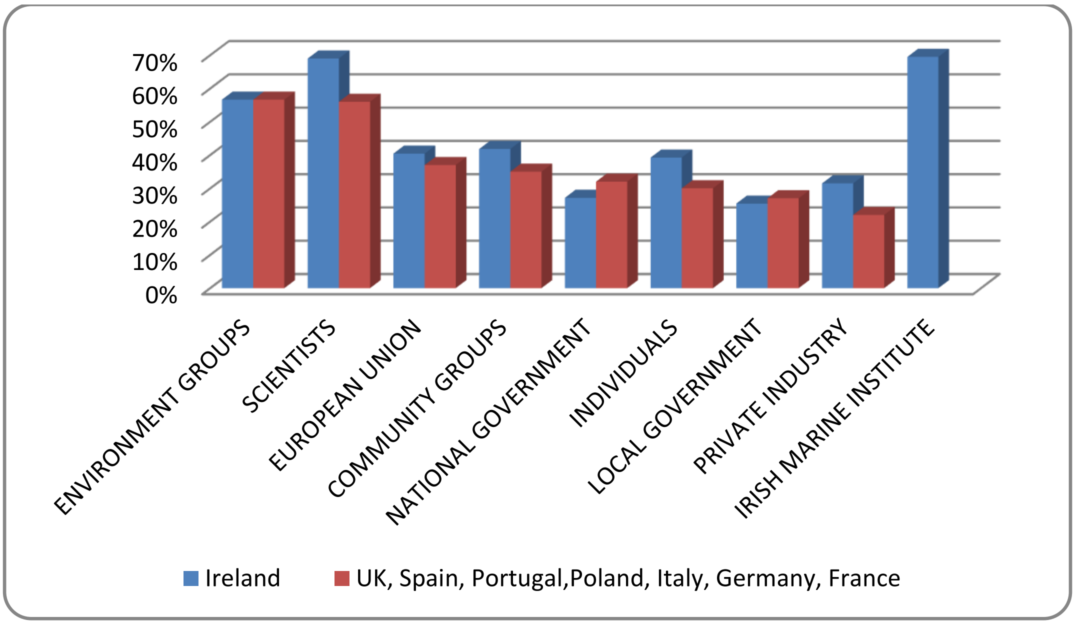

Figure 4-9. Perceived competence of different groups to manage the environment by Irish general public compared to the average response from individuals across UK, Spain, Portugal, Poland, Italy, Germany and France. Scores shown as percentage of responses rating 'competent or highly competent' (A score of 4-5 on a 5 point scale where 1 means it is not at all competent and 5 means highly competent.)

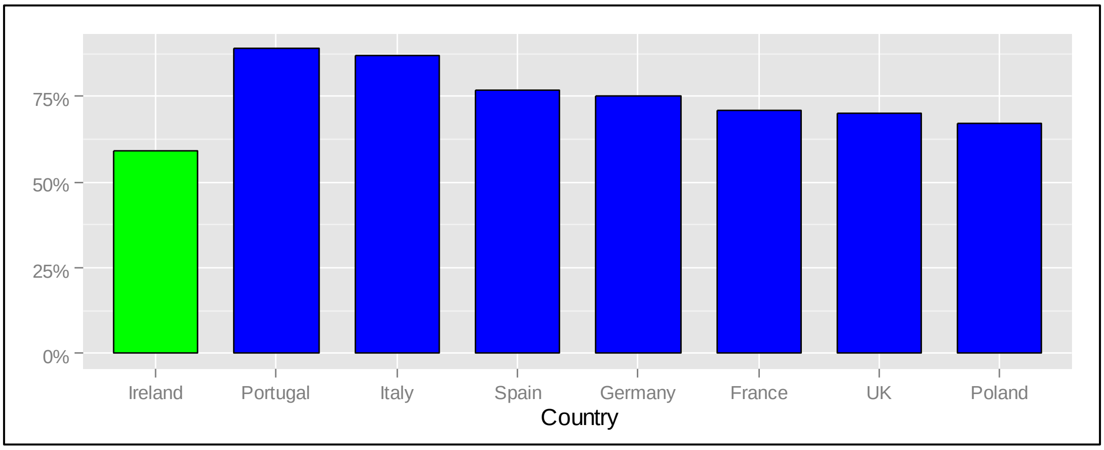

Figure 4-10. Rankings of national responses to marine spatial planning. Shown as percentage of responses rated as 'agree or strongly agree' by the Irish general public compared to the rated response from individuals across UK, Spain, Portugal, Poland, Italy, German[8]

[8] Score of 4 or 5, from a scale of 1 to 5 where 1 means strongly disagree and 5 is strongly agree.

The next two questions in the survey were asked to gauge the support from the general public for marine planning and protection. As Pomeroy and Douvere (2008) point out management of the marine environment is a matter of societal choice and "*involves decision making in terms of allocating parts of three-dimensional marine spaces to specific uses to achieve stated ecological, economic and social objectives*". People are central to this decision-making process and are the agents for the use change of the marine resources. As such, the attitudes of the general public to marine management and planning are vital to the success of any form of marine spatial planning.

The respondents were first told that it had been suggested that governments should make plans that specify the different activities that can happen and where they can happen in the sea. Respondents were then asked to what extent they agreed or disagreed with this idea on a scale of 1 to 5 where 1 meant strongly disagree and 5 is strongly agree. As can be seen from figure 4.10 there was relatively low agreement to this statement from the Irish general population relative to that in the countries from the Potts et al. (2011) study. This may be related to the perceived competency of the government by the general public in relation to the management of the marine environment.

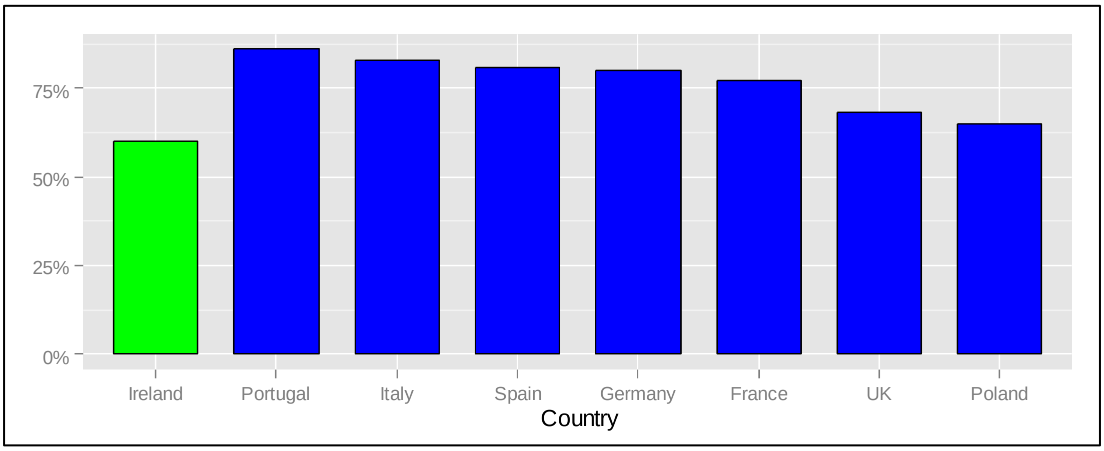

Figure 4-11. Designation of marine protected areas. Percentage of responses rated as 'agree or strongly agree' by the Irish general public compared to the rated response from individuals across UK, Spain, Portugal, Poland, Italy, Germany and France[9]

Similarly, the following question then informed the respondents that some people have suggested that governments should designate parts of the ocean as protected areas, in the same way that they do with national parks on land, while others have said this is not a

[9] Score of 4 or 5, from a scale of 1 to 5 where 1 means strongly disagree and 5 is strongly agree.

good idea. The respondents were then asked to what extent they agreed or disagreed with this suggestion. Once again, and as can be seen from figure 4.11, there was relatively low agreement to this statement from the Irish general population relative to that in the countries from the Potts et al. (2011) study. This is all the more interesting result given that the Irish sample consistently gave higher rankings across all the other questions before these two questions compared to the UK, Spain, Portugal, Poland, Italy, Germany and France samples.

While marine protected areas (MPAs) do exist in Irish waters they have a much narrower definition than what is used internationally. In Ireland MPAs are designated specifically for the protection of habitats and species under the Birds and Habitats Directives. The existence of the Irish Conservation Box off the south west coast of Ireland also represents a kind of MPA in Irish waters, but its main purpose is for the management of commercial fish stocks. Also seven marine sites have been identified as being of significant ecological importance and were proposed by the Irish government as Special Marine Areas of Conservation in 2012. As Johnson et al. (2008) point out; the designation of marine SACs or MPAs in Irish waters presents opportunities for marine conservation and has the potential to bring wider benefits to society. However, evidence from the response to the last question suggests that Irish society may not be aware of these benefits as there does not appear to be a high level of support for marine spatial planning or designated protected areas in general

In light of the surprising low number of respondents that ranked fisheries as threat (52%) (Q16, Appendix A), it was decided to explore the relationship between this result and the trust in two of the institutions responsible for management of the fish stocks, scientists and government. Both of these are partially responsible for the setting of quota through total allowable catches (TACs) which is the main instrument used in the Common Fisheries Policy. The Commission prepares the proposals, based on scientific advice on the stock status from advisory bodies such as ICES and STECF and these can be considered the scientists. In turn, final decision is made of December of each year with the TAC set annually for most stocks (every two years for deep-sea stocks) by the Council of fisheries ministers. These can be considered the government. Trust is measured using the level of competency that the respondents judged the different institutions have in managing and protecting the ocean environment (See Q15, Appendix A). Additionally, these three variables were measured against respondents' agreeableness to both marine protected area

(Q17, Appendix A) and a management plan (MPA) for the marine environment (the MSFD in effect).

To analysis the data, each question was reduced to a binary variable. For competency (proxy for trust), those who chose competent or highly competent were given a 1, otherwise a zero. A similar approach was taken for those who considered fisheries a threat or severe threat for fisheries threat and those who agreed or strongly agreed with MPA or MFSD. Don't knows were excluded and made up between 4% - 10% of respondents depending on the pair of questions being compared. Two-way tablets were used to examine the direction of a relationship between each pair of variables, if any. A chi-square test was used to see if there was a statistically significant relationship between pairings. The result of the direction of the relationship is shown below (table 4.1) with chi-square result and the associated p-value in brackets.

Table 4-1. Chi-square test results for comparing fisheries threat to the marine environment (Statistical significant: * - 10% level, ** - 5% level, * - 1% level**

Binary Variable	Fisheries are a threat to the marine environment	Competent government	Competent scientists	Agree with MPA
Competent government	None 0.48 (0.49)			
Competent scientists	Positive 5.46 (0.02)**	Positive 49.02 (0.00)***		
Agree with MPA	Positive 26.48 (0.00)***	Positive 7.22 (0.01)**	Positive 37.99 (0.00)***	
Agree with MSFD	Positive 14.69 (0.00)***	Positive 5.805 (0.02)**	Positive 32.94 (0.00)***	Positive 465.51 (0.00)***

All results bar one have a positive relationship which is as expected. The strongest relationship is between those agreeing with MPA and MSFD. The only pairing which did not produce a result is that between government competency and fisheries as threat to the marine environment.

Finally, respondents in the survey were also asked if they considered where they lived as being in a coastal area. They were also asked how far they approximately lived from the coast. As discussed by Hynes and Farrelly (2012) the range of definitions available for coastal zone boundaries raises difficulties between those who prefer to use an ecological-natural system based boundary to those who prefer a legal/administrative/economic boundary consistent with government jurisdictions. Often these definitions do not coincide with communities own perceptions of living in a coastal area. For example, Eurostat defines EU coastal regions as standard statistical regions (NUTS level 3), which have at least half of their population within 50 km of the coast (Eurostat, 2009). In Ireland's case NUTS level 3 regions are represented by almost the entire country except for four counties in the centre. The results of this survey would indicate that this is a much broader definition than peoples own perceptions of whether the area they live in is coastal or not.

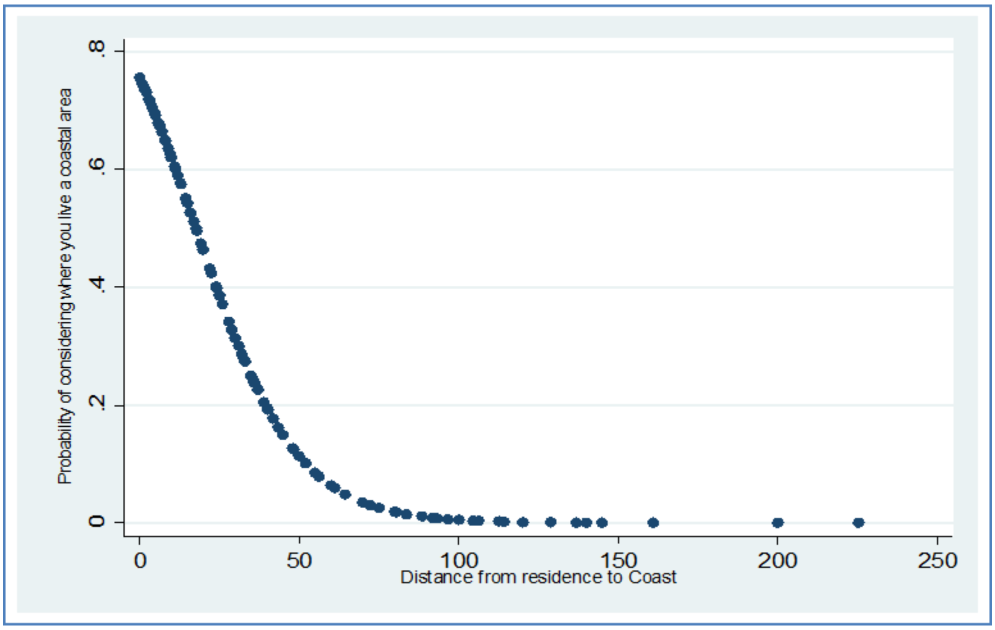

Figure 4-12. The probability of considering where you live a coastal area as a function of the distance of residency (km) from the coast (probability based on a simple logit model of the response 'yes' (1) or 'no' (0) as a function of distance)

In total, 41% of the sample considered where they live as being coastal. More interestingly, the average distance to the coast of those who considered themselves as living in a coastal region was reported at 9.4km but ranging from 0 to 80km. A simple binary logit model was also used to estimate the probability that someone considers where they live is in a coastal zone as a function of their reported distance to the coast. The results are graphed in figure 4.12 and figure 4.13 and indicate that a person has a 0.5 probability of considering themselves living in the coastal zone if they are within 15km of the coast. This is significantly below the inland boundary distance for a coastal region in Ireland as defined by Eurostat.

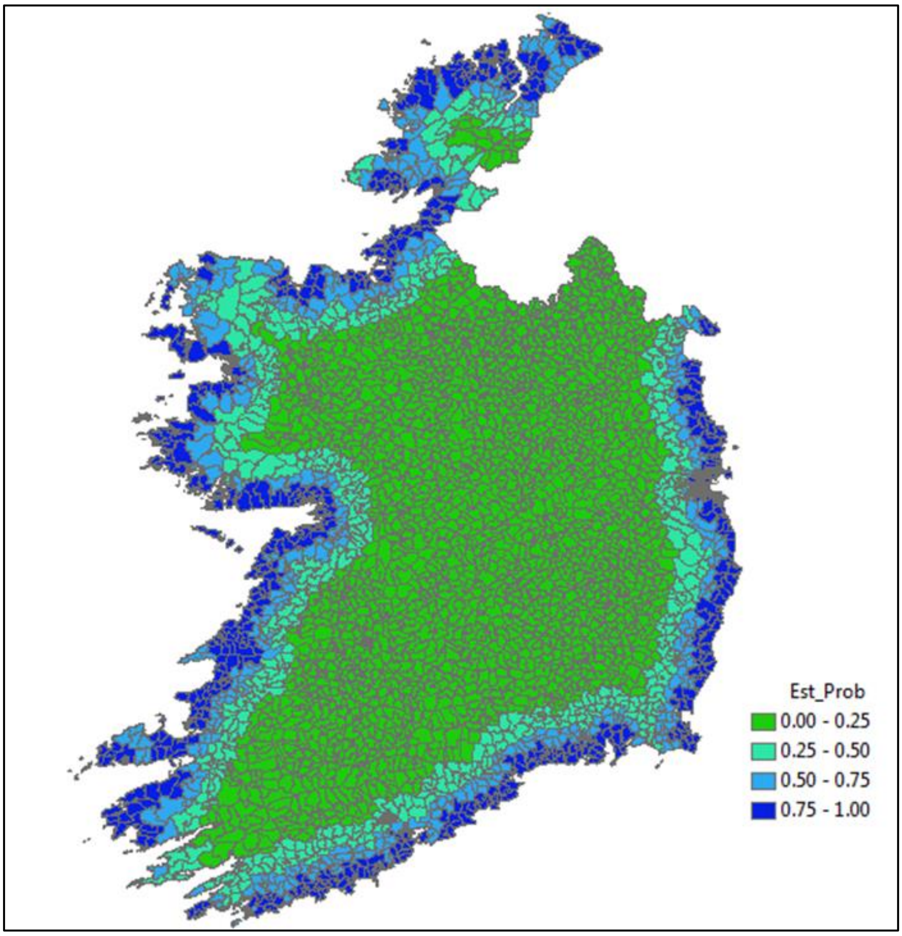

Figure 4-13. Mapping the probability of considering where you live a coastal area as a function of the distance of residency (km) from the coast (probability based on a simple logit model of the response 'yes' (1) or 'no' (0) as a function of distance)

4.4. Discussion and Conclusions

The general public's demands for new functions from the marine environment are continuously changing. Society increasingly utilises the marine environment for a variety of purposes and its protection is now seen as much more important by modern consumers.

Similar to terrestrial based ecosystems there are numerous push and pull factors that can lead to significant changes in marine ecosystem processes and outputs. The push factors are connected with trends in marine related commercial activities such as shipping or fishing, which can result in intensification of the use of the marine space as well as new functions such as off-shore energy production and marine tourism. The pull factors relate to what the consumer rather than the direct marine stakeholders want from the marine environment. With increased urbanization and improved infrastructure allowing even quicker access to the coastline, there is increasing demands for recreational activities and nature conservation from the modern consumer. Given these multiple dynamics the sustainability of any particular marine activity may only be guaranteed through the commitment of all the parties involved: fishermen, shipping operators, marine policymakers, recreationalists, spatial planners, and perhaps most importantly society in general (who are also the taxpayers funding the marine policy initiatives).

While food security was a dominant concern for consumers at the time of the formation of the European Union, concerns surrounding the environmental impacts of human activity on the environment are now as important to citizens of the EU. Citizens are now more aware that certain marine related activities can have negative impacts on, among other things, biological diversity, water quality and seascape and habitats (Shackeroff et al., 2009; Ahtiainena et al. 2013; Hynes et al. 2013). Marine environmental management and legislation has also moved away from management efforts organized around particular uses such as fishing or tourism, resulting in separate governance regimes for each sector, towards an ecosystem based management approach which recognizes that plant, animal and human communities and activities are interdependent and interact with their physical environment to form distinct ecological units called ecosystems. This approach to management also allows policy makers to include societal values for marine ecosystem services into the decision making processes where the trade-off between economic use and marine protection can be fully assessed.

With these issues in mind, this chapter presented the results of a nationwide survey in Ireland that explored the values, concerns and preferences of individuals regarding the Irish marine environment. Many of the questions asked on the marine environment of the Irish sample were also asked in a similar survey in other maritime countries in the EU by Potts et al. (2011). The results of both of these surveys would suggest similar attitudes toward the marine environment across Ireland, the UK, Spain, Portugal, Poland, Italy, Germany and France, although the Irish respondents tended to give a higher ranking on many of the questions asked. Previous to this survey being carried out the views of the Irish public towards the seas and oceans around the Irish coast were relatively unknown. This is despite the fact that that Ireland has sovereign rights over 900,000km^2 of seabed (which is an area 10 times the size of the land area of Ireland).

The results of the Irish survey demonstrate a reasonable level of knowledge of the main threats facing Ireland's marine environment and of the importance of the non-market as well as market ecosystem services that the seas around the Irish coast provide. The results also suggest that the Irish public are sceptical of the ability of government and private industry to manage the Irish marine economy but instead place a large amount of trust in the competency of scientists. This would imply that a greater, more transparent role for scientists in marine policy formation and the decision making process would result in marine policy measures receiving greater support from the public than measures that are perceived to be mainly driven through government departments. Indeed this increased role for scientists (including social scientists!) is already becoming more evident in policies such as the EU Marine Strategy Framework Directive with its integrated assessment approaches which incorporates the viewpoints of many stakeholders and the current reforms of the Common Fisheries Policy which is attempting to boost participatory decision making and co-management (Farrell et al. 2012).

Interpreting the results above in light of the CFP, while there is a positive relationship between the perceived level of competency in both scientists and government (table 4.1), scientists are perceived to be more competent to manage the marine environment than the government (figure 4.8). This suggests more weight should be put on scientific advice in setting TACs. Interestingly though, in terms of countering the fisheries threat to the marine environment, there is no relationship between those who perceive fisheries is a threat to the marine environment and trust in the government, but there is a positive relationship although weaker than some of the other relationships measured between those who perceive fisheries is a threat to the marine environment and trust in the scientists. In terms of actions in to further protect the marine environment through management (MSFD) or the introduction of MPAs, the results from table 4.1 show that it seems the more trust in institutions, the more likely people are to agree to these changes.

The Irish public's response to marine special planning and designation of MPA's by the government was less enthusiastic than their European counterparts. This may be related to the perceived competency of the government by the Irish general public in relation to the management of the marine environment. With the establishment of MPAs and the use of marine spatial planning likely to increase in the coming years the relevant Irish authorities will need to find a way to communicate the importance of such marine planning and protection approaches to the Irish public and to educate them on the flow of benefits that could flow from any further MPA designations in Irish waters; benefits from both an economic and social as well as a conservation perspective. The differences between the public and scientific perception of the main threats to the marine environment also suggests that better communication between the relevant authorities and the public on marine issues and policies is needed. Finally, the perception of whether or not they consider where they live as being a coastal area would also suggest that the Irish public hold a much more narrow view of what constitutes a coastal area than that held by statistical agencies such as Eurostat.

Given the increased impetus on marine spatial planning for commercial and environmental sustainability regulation in areas such as fisheries, marine energy, and aquaculture, national governments and marine policy makers are in need of a range of social and economic indicators for the sector, including information on the opinions and preferences of the persons and communities using Ireland's coastal and marine resources. While the positions of organised stakeholder groups are often captured through responses to policy consultations, the opinion of the 'ordinary person in the street' is difficult to include in the decision making process. However, it is the collective choices made by communities through the marine and coastal resources they use, the coastal areas they visit or reside in that drive the many pressures on the marine environment. The viewpoint of the Irish public on the seas and oceans around Ireland will also play an important role in supporting policies such as the Marine Strategy Framework Directive, the deployment of marine renewable devices, large scale aquaculture projects, and marine protected areas that have considerable social and economic consequences. Ultimately, management of the marine environment is a matter of societal choice and knowing what the values, concerns and preferences of individuals regarding the marine environment are is the first step in ensuring that policy decisions are broadly in line with society's wishes.

Chapter 5

An initial investigation of the value of Ireland's marine and coastal ecosystem services

5.1. Introduction

Decision making frameworks such as cost-benefit analysis or multi-criteria analysis offer a more open, objective method of choosing between alternative projects. However, any methodology which fails to include all the costs and all the benefits of a project may lead to poor choices. For much of history this has been the case; failure to account for societies' effects on the environment has stretched and in some cases breached our planetary boundaries (Steffen et al., 2015) to such a degree that some claim has resulted in a new geological epoch, the anthropocene (Zalasiewicz et al., 2008). In the marine sphere, this failure also led to the perception of the oceans as boundless source of food and raw materials from its fisheries and whaling industries leading to near collapse of many populations (Roberts, 2010).

Traditionally, public environmental policy has generally just used 'environmental policies' to protect the environment. This can be seen within the European Union. Earlier directives focused on protecting the environment directly, through such directives as the Birds Directive (EC, 1979) and the Habitats Directive (EC, 1992) or indirectly by preventing or limiting specific pollutants entering the environment from society (UWWT Directive, EC 1991) or industry (IPPC Directive, EC 1996, Dangerous Substances Directive, EC, 1967, Nitrates Directive, EC, 1991). However, there has been a shift from just protecting the environment for its intrinsic value to realisation that nature produces important benefits for humankind and that failing to account for these in policy making means that overall, human kind will be worst off. This realisation led to the concept of 'ecosystem services' (Erlich and Erlich, 1982, Krutilla and Fisher, 1975). There have been various definitions of ecosystem services (De Groot, 1987, 1992, Daily, 1997, Boyd and Banzhaf, 2009) but one of the most succinct was offered by the Millennium Ecosystem Assessment (MEA, 2005) that defines ecosystem services as "the benefits humans derive from nature". Initiated in 2001 to assess the effects of ecosystem change for human well-being, it provided evidence at a global level for actions needed to protect ecosystems, their ecosystem services and demonstrated that human well-being is dependent on those ecosystem services (MEA, 2005).

More recent directives in the EU have also recognised that there is a need to internalise external environmental costs of society. This is demonstrated by the inclusion of water-pricing in the WFD (Riegels et al., 2013) and the requirement for economic valuation of costs and benefits related to the degradation of the marine environment by the MSFD (Bertram and Rehdanz, 2012). Long (2011) states that the MSFD is the first EU directive to take an ecosystem approach and Borja et al. (2010) notes that this ecosystem approach is a more holistic approach compared to what has been perceived previously as a more prescriptive approach by the EU in protecting the aquatic environment. While the MSFD does not explicitly mention ‘ecosystem services’, it does note that “demand for marine ecological services are often too high” and states that one of the objectives of marine strategies is to ensure “sustainable use of marine goods and services” which would include ecosystem services (Elliott 2011, Berg et al. 2015). Additionally according to the Working Group on Economic and Social Assessment for the MSFD, an ‘Ecosystem Services Approach’ is the preferred methodology for assessing the economic and social analysis of the use of marine waters and measuring of the cost of degradation of the marine environment (EC-DGE, 2011).

Often it is policies which drive protection of our environment or the incorporation of environmental values into decision making. At the global level the main policy driver for protection of biodiversity is the Strategic Plan arising from the tenth meeting of the Conference of Parties (COP10) to the Convention on Biological Diversity (CBD). The outcome of this Strategic Plan was 20 targets (Aichi Targets) (Cardinale et al. 2012). The targets were in addition to previous targets (Balmford, 2005) to protect and conserve global biodiversity and added protection of ecosystem services within three of the targets (Target 11, Target 14, Target 15).

At a European level, the European Commission (EC) aims to protect, value and where necessary restore nature both for biodiversity's intrinsic value and for its contribution to human wellbeing and economic prosperity through ecosystem services (EU Commission, 2011). This commitment has led to the EU 2020 Biodiversity Strategy. The strategy runs to 2020 and by that time aims to halt the loss of biodiversity and ecosystem services in the EU member states. This chapter contributes to achievement of Target 2 in Ireland of the strategy. Target 2 aims for the maintenance and restoration of ecosystems and their services by 2020. Under Action 5 of Target 2, each member state will map their ecosystems and their services by 2014 and assess the economic value of such services by 2020. Mapping these values will allow spatially explicit prioritisation and problem identification of threats to ecosystem services. They are also useful for communication between different stakeholders and will allow up- or down-scaling of values from national level to local level and vice versa (Maes et al., 2013). This will help to integrate these values into policy making decisions. The integration of ecosystem service values into accounting and reporting systems at EU and national level by 2020 is required by the EU 2020 Biodiversity Strategy.

Additionally the EU also aims to protect the marine environment and ensure sustainable use of it in the future through the Marine Strategy Framework Directive (MSFD) (2008). The overriding aim of the MSFD is to achieve "good environmental status" (GES) in all EU marine and coastal waters, as measured by 11 descriptors (Table 5.1), by 2020. It is considered to be the first attempt by an EU directive to undertake an ecosystem approach to protect and maintain the marine ecosystems (Long, 2011). As can be seen in Table 5.1, many of the descriptors relate to ecosystem services provided by marine ecosystems such as provision of food (descriptors 3 and 4), regulating ecosystem services such as waste treatment (descriptors 5, 6, 7 and 11) or relate to the overall achievement of maintaining biodiversity and functioning ecosystems upon which ecosystem services depend (descriptors 1 and 2).

Table 5-1 MFSD Descriptors of GES

1.	Biological diversity is maintained, including sufficient quality and quantity of habitats and species.
2.	Marine food webs occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of each species.
3.	Healthy stocks of all commercially exploited fish and shellfish which are within safe biological limits.
4.	Contaminants in fish and other seafood for human consumption do not exceed unhealthy levels.
5.	Concentrations of contaminants are at levels not giving rise to pollution effects.
6.	Human-induced eutrophication is minimised.
7.	Marine litter does not cause harm to the coastal and marine environment.
8.	Non-indigenous species introduced by human activities have minimal effect on native ecosystems.
9.	Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded.
10.	Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.
11.	Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

Concurrently, Ireland is implementing the MSFD. Many of its aims overlap the EU 2020 Biodiversity Strategy and the output of this thesis may contribute to helping policy makers in their assessment of the measures needed to achieve good environmental status as required by the MSFD while ensuring the sustainable use of marine goods and services by present and future generations.

In 2012 the Irish government launched an integrated marine plan for Ireland, "Harnessing Our Ocean Wealth" (HOOW, 2012). The plan's primary goal is to develop a sustainable marine and maritime economy and to grow the Irish blue economy to increase its contribution to Ireland's GDP. However, it also aims to do this in a sustainable manner to ensure that Ireland's marine biodiversity and ecosystems are protected. One of the key actions, which this chapter will contribute towards, is Action 15 within the HOOW. Action 15 is to "*Promote further research into economic values of marine biodiversity and ecosystem services to ensure best practice planning and management of the ocean resource*" to ensure delivery of the goals of HOOW.

Several national ecosystem assessments have been undertaken already across the EU. The most well-known and comprehensive of these is the UK National Ecosystem Assessment (UK NEA, 2011) while Ireland has also undertaken work on assessing the value of our biodiversity and ecosystem services (Bullock et al., 2008). However, Brouwer et al. (2013) in their review of ecosystem assessments across the EU member states noted that "*Marine ecosystem services are relatively less well explored*", while at national level in Ireland a recent report by the National Economic and Social Council (NESC, 2014) highlighted the large data gap for environmental and economic data in the area of the marine especially lack of environmental data. There has been some work to overcome this including work done as part of the initial assessment undertaken for the MSFD and there is spatial data available in online atlases especially Ireland's Marine Atlas [http://atlas.marine.ie] developed by the Marine Institute for Ireland's reporting for the MSFD and the Marine Irish Digital Atlas (MIDA) [http://mida.ucc.ie/] (Dwyer, 2003). The lack of marine spatial data relating to marine ecosystem services is not just a challenge within Ireland but is found in other countries also (Townsend et al., 2014).

5.2. Ecosystem Services

The ecosystem services (ES) framework offers a way of understanding the indirect effects of decisions that affect the natural environment on human welfare. The term was first coined by Erlich and Erlich (1982) but the concept had been previously explored by others (Carson, 1962, Krutilla and Fisher, 1975, Westman, 1977). The concept gained prominence in the late 1990s, particularly following a paper published in Nature by Constanza et al. (1997) which attempted to estimate the value of the earth's ecosystem services. This was in the same period as several papers started articulating the need for integrating ecosystem services into policy and decision making (De Groot, 1987, 1992, Daily, 1997)[10]. In turn a number of ES frameworks were proposed (Daily 1997, Boyd and Banzhaf, 2009, Constanza, 2008) which could be used in policy circles. Many differing definitions of ecosystem services emerged (Fisher et al. 2009), the most common and succinct definition was that offered by the MEA (MEA, 2005) which defined ecosystem services as *"the benefits humans derive from nature"* although there are other differing definitions and frameworks (Nahlik et al., 2012).

The Millennium Ecosystem Assessment (MEA) was initiated in 2001 following a call by the United Nations Secretary-General Kofi Annan. The objective of the MEA was to assess the effects of ecosystem change on human well-being and then to provide evidence for action needed to protect ecosystems, their ecosystem services and consequently human well-being dependent on those ecosystem services (MEA, 2005). As well as data on the linkage between biodiversity, conservation and ecosystem services and their linkages to social welfare, it also provided a framework for classifying ecosystem services into four broad groups. The first three - provisioning services, regulating services and cultural services, are all underpinned by the fourth, supporting services. Following on from The Economics of Biodiversity and Ecosystems (TEEB) (Kumar, 2010), it was noted that only the first three types of ecosystem services could be valued as to do otherwise would risk double-counting (Fu et al. 2011) The types of ecosystem services that can be valued can be described as:

- Provisioning services – These ecosystem services are tangible goods and there is often a direct connection between the ecosystem and the provision of these ecosystem

[10] For further discussion of the history of the development of the ES concept the interested reader is directed towards Gómez-Baggethunet al. (2010).

services. Examples of the provisioning ecosystem services generated by Irish marine and coastal ecosystems are the marine fish and seaweed harvested and also the aquaculture resources around our coasts.

- Regulating and maintenance services – These ecosystem services regulate natural functions and processes in the world around us and often are consumed indirectly. Examples of these ecosystem services include carbon sequestration which helps to mitigate climate change, treatment of our wastewater and its return to the hydrological cycle and flood and storm protection by sand dunes and saltmarsh which lessens the damage done by winter storms.
- Cultural services – The cultural ecosystem services refer to the physical, psychological and spiritual benefits that humans obtain from contact with nature. Examples of the cultural ecosystem services in the Irish marine and coastal zones include recreational activities such as walking along the beach, surfing and also the added value that having a sea view from your house has on your well-being.

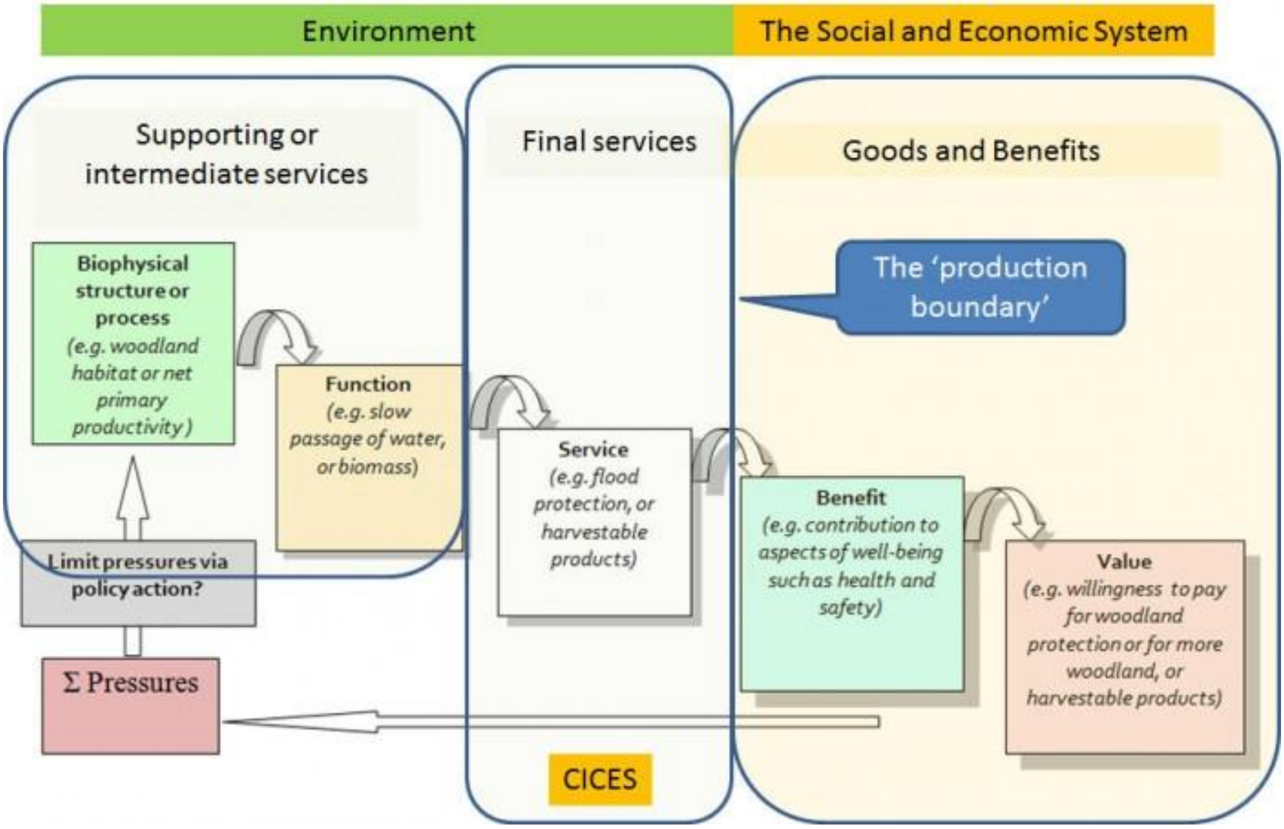

Figure 5-1 An example of ecosystem service cascade (Adapted from Potschin and Haines-Young (EEA), 2011)

A thorough understanding of ecosystem functioning and how these functions provide benefits is needed in order provide a variety of indicators for the different ecosystem services. In turn these indicators can be used in conjunction with the value that the population places on changes in the supply or quality of these ecosystem services to estimate the values that they produce. Böhnke-Henrichs et al. (2013) emphasised the need to differentiate between different elements of the ecosystem service cascade (processes - functions - services - benefits - values) (Figure 5.1) in order that different elements are not confused, noting that one service can deliver multiple benefits and confusing services and benefits could lead to double counting. This is why a framework is needed for the assessment of ecosystem values in addition to the need to classify ecosystem services and identify gaps in knowledge. In many cases each new study develops its own concepts and classifications or develops a variation on a previously used ES framework. However, the UN et al. (2014) has advocated a move towards a standard approach for environmental-economic assessment frameworks especially for integrating environmental accounts with national accounts. This has lead in recent years to a proposed new international framework known as the Common International Classification of Ecosystem Services (CICES) framework (Haines-Young and Potschin, 2010).

The CICES framework was originally proposed by Haines-Young and Potschin (2010). Although it was originally envisaged as a method to facilitate the construction of ecosystem accounts, the hierarchical and flexible structure built on the three main ES types (provisioning, regulating and cultural) make it an ideal framework for assessment of ESs (Maes et al., 2013). Since the original report it has been updated as part of the revision of the System of Environmental-Economic Accounting (SEEA) by the United Nations Statistical Commission (UN et al., 2014). This process has led to debate within the review process reflecting the wider literature on aspects of measuring and valuing ecosystem services. Such topics include defining the boundary between abiotic and biotic services, the role of water as a service, if ecosystem services are benefits or contribute to benefits.

This chapter will use CICES 4.3, the most up to date version of the framework to classify the ES to be valued in this chapter. There are three main ecosystem services, provisioning, regulation and maintenance and cultural. Figure 5.2 shows an example of how the hierarchical nature of CICES works for the breakdown of the provisioning ecosystem services. CICES is built upon the previous frameworks of MEA and TEEB and this allows comparability between frameworks used.

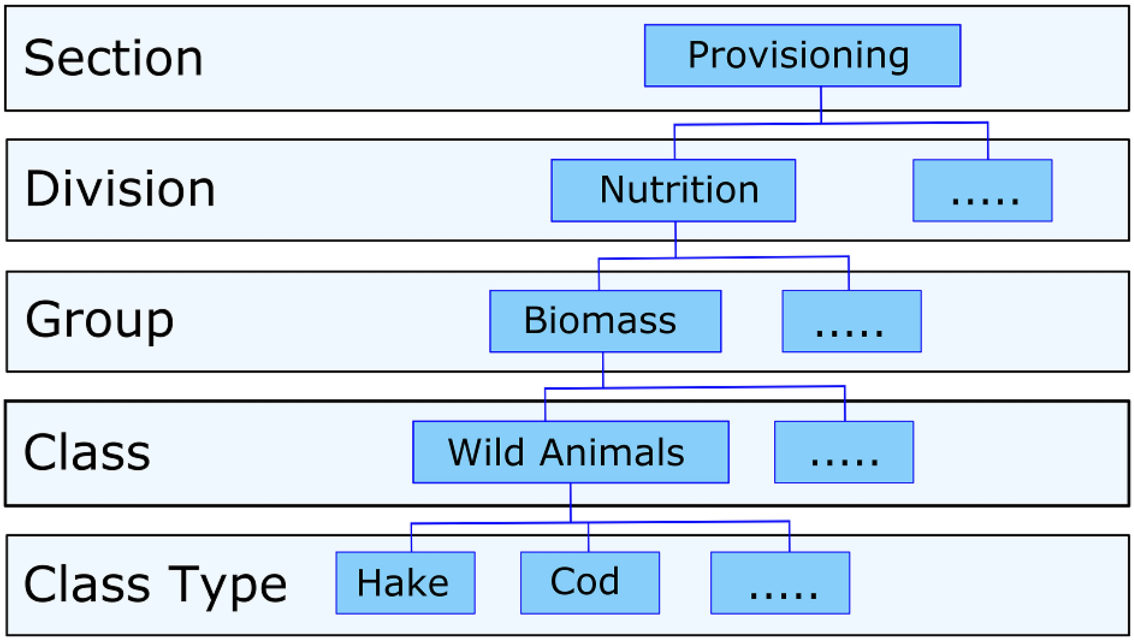

Figure 5-2 Example of hierarchical structure of the provisioning ES (adapted from Haines-Young and Potschin (EEA) 2012)

In the tables below (5.2, 5.3, 5.4), all CICES classifications are shown to class level. Highlighted in italics are the ecosystem services examined in this thesis with those further highlighted in bold being the ecosystem services valued, the difference between the two being the level of data available to value the ecosystem service. The reason that other CICES classes were not examined was that in some cases they were not relevant in a marine context (e.g. pollination, soil formation), were not currently significant in Ireland (e.g. Plants and algae from in-situ aquaculture) or there was insufficient evidence or data on suitable indictors, either for quantities of the ecosystem service flow or valuation work.

A description of the differences between the hierarchies are as follows:

- Section: This column lists the three main categories of ecosystem services
- Division: This column divides section categories into main types of output or process.
- Group: The group level splits division categories by biological, physical or cultural type or process.
- Class: The class level provides a further sub-division of group categories into biological or material outputs and bio-physical and cultural processes that can be linked back to concrete identifiable service sources.

Table 5-2. CICES Provisioning Ecosystem Services

CICES Framework			
Section	**Division**	**Group**	**Class**
Provisioning	Nutrition	Biomass	Cultivated crops
			Reared animals and their outputs
			Wild plants, algae and their outputs
			Wild animals and their outputs
			Plants and algae from in-situ aquaculture
			Animals from in-situ aquaculture
		Water	Surface water for drinking
			Ground water for drinking
	Materials	Biomass	***Fibres and other materials from plants, algae and animals for direct use or processing***
			Materials from plants, algae and animals for agricultural use
			Genetic materials from all biota
		Water	*Surface water for non-drinking purposes*
			Ground water for non-drinking purposes
	Energy	Biomass-based energy sources	Plant-based resources
			Animal-based resources
		Mechanical energy	Animal-based energy

Table 5-3. CICES Regulation and Maintenance Ecosystem Services

CICES Framework			
Section	**Division**	**Group**	**Class**
Regulation & Maintenance	***Mediation of waste, toxics and other nuisances***	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems
			Dilution by atmosphere, freshwater and marine ecosystems
			Mediation of smell/noise/visual impacts
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates
			Buffering and attenuation of mass flows
		Liquid flows	Hydrological cycle and water flow maintenance
			Flood protection
		Gaseous / air flows	***Storm protection***
			Ventilation and transpiration
	Maintenance of physical, chemical, biological conditions	***Lifecycle maintenance, habitat and gene pool protection***	Pollination and seed dispersal
			Maintaining nursery populations and habitats
		Pest and disease control	Pest control
			Disease control
		Soil formation and composition	Weathering processes
			Decomposition and fixing processes
		Water conditions	Chemical condition of freshwaters
			Chemical condition of salt waters
		Atmospheric composition and climate regulation	***Global climate regulation by reduction of greenhouse gas concentrations***
			Micro and regional climate regulation

Table 5-4. CICES Cultural Ecosystem Services

CICES Framework			
Section	**Division**	**Group**	**Class**
Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	***Physical and experiential interactions***	Experiential use of plants, animals and land-/seascapes in different environmental settings
			Physical use of land-/seascapes in different environmental settings
		Intellectual and representative interactions	*Scientific*
			Educational
			Heritage, cultural
			Entertainment
			Aesthetic
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	*Symbolic*
			Sacred and/or religious
		Other cultural outputs	*Existence*
			Bequest

5.3. Valuing Ecosystem Services

While more primary valuation studies need to be undertaken for all ecosystem typologies, at a global scale terrestrial ecosystems have been studied more than coastal and marine ecosystems. There is often a clearer relationship between terrestrial ecosystem and the benefits they produce compared to marine or some coastal ecosystems which tend to involve more nonlinear relationships (i.e. more complex) between ecosystem functioning and the benefits they produce. Ecosystems services, their benefits and the relationships between ecosystem functioning and the benefits produced have been extensively studied for terrestrial ecosystems such as forests (Garrod and Willis, 1992, Cullinan et al. 2011) and wetlands (Bateman and Langford, 1997, Ghermandi et al., 2008).

Despite there being a low number of marine and coastal valuation studies relative to those on terrestrial ecosystems, there have been increased attempts to put values on the benefits generated by marine and coastal ecosystem services in recent years. One of the first attempts was a paper by Costanza et al. (1997). They made an attempt to value the ecosystem services provided by all the ecosystems in the world and estimated a total value of US$33 trillion^{1997} per year. They estimated that the 'total economic value' of coastal and marine ecosystems was $20.9 trillion^{1997} and accounted for 63% of the world's ecosystems 'total economic value' of which coastal systems alone contributed $10.6 trillion^{1997}.

More recently, Barbier et al (2011) undertook a review of five different estuarine and coastal ecosystems (coral reefs, seagrass beds, salt marshes, mangroves, and sand beaches and dunes) and showed numerous examples of the various benefits produced by the ecosystems. In another study, coral reefs were estimated to generate US$15–45 000 km^{-2} of healthy coral reef in Philippines from sustainable fish production (White et al. 2000) while in the Seychelles, an estimate of US$88,000 total consumer surplus was generated for 40,000 tourist visits to its marine parks (Mathieu et al. 2003). Examining salt marshes, King and Lester (1995) estimated UK£15.27 ha^{-1} yr^{-1} net income from livestock grazing in the UK while another study examining the ecosystem service of lifecycle maintenance in US salt marsh estimated values of US$6471 acre^{-1} and $981 acre^{-1} for recreational fishing for the east and west coasts, respectively, of Florida (Bell, 1997) and a marginal value product of US$0.19–1.89 acre^{-1} in a Gulf Coast blue crab fishery (Freeman 1991). For sand beaches and dunes, Huang et al. (2007) estimated a willingness to pay (WTP) of US$4.45 household^{-1} for an erosion control program to preserve 8 km of beach in Maine and New Hampshire. For recreation, a value of US$166 trip^{-1} or US$1574 household^{-1} year^{-1} was estimated for North Carolina beaches, USA (Landry and Liu 2009). This review showed that the various ecosystem services provided by marine and coastal ecosystems have high values associated with the benefits they produce.

Brenner et al. (2010) undertook a benefit transfer for the coastal zone of the Catalan coast which examined four coastal and marine ecosystem types which covered 22% of the area under consideration. The yearly ecosystem value was estimated to be US$3.2 billion (2004) for the coastal area of Catalan. In the UK, Lusetti et al. (2011) considered the value of managed coastal realignment scenarios (Humber estuary and Blackwater estuary) from an ecosystem services perspective. For the Humber estuary the study found that the current business as usual (BAU) scenario offered the lowest costs (UK£70.4 million) based on net present value over 25 years using a declining discount rate. Under the same assumptions the best scenario for the Blackwater estuary was a deep greening scenario which involved the creation of 10 times as much intertidal habitat (much of it saltmarsh). This was estimated to produce net benefits of UK£74.83 million compared to the BAU scenario of costs of UK£1.88 million.

Looking at non-use values, Eggert and Olsson (2009) used a CE with the attributes of coastal cod stock levels, bathing water quality levels, and biodiversity levels to estimate the values traded off between these aspects of a marine ecosystem. McVittie and Moran (2010) also used a CE to estimate the non-use values associated with the introduction of marine conservation areas within the UK. The McVittie and Moran study (2010) attributes included biodiversity, environmental benefits (such as CO2 sequestration, water treatment and recreation) and restrictions to fishing and marine extractive industries. They also argued that non-use values compose a large segment of the values associated with changes to the marine environment due to their spatial remoteness relative to other ecosystems.

Also in the UK, Beaumont et al. (2010) included an economic valuation of the benefits of many marine and coastal ecosystem services as part of the UK National Ecosystem Assessment (UK NEA). For carbon sequestration it was estimated that the current (2010) value is UK£19.9 million per year for ecosystems within the coastal margin and for the marine waters in 2004 it is estimated to be worth UK£6.7 billion per year. For fisheries the estimated value was UK£596 million per year in 2008, although it was cautioned that it is difficult to extract the value of ecosystem service versus the capital to extract the benefits, while recreational services were worth UK£17 billion based on 2002 data.

In Ireland, Bullock et al. (2008) undertook a valuation of mainly terrestrial ecosystem services particularly related to biodiversity but did include a section on the marine and coastal ecosystems. Bullock et al. (2008) examined the provisioning services of fisheries noting that although the amounts of landings were declining, the value of landings had been maintained at c. €180 million. In the same report the provisioning services of aquaculture production was valued (€125 million) but while seaweed and mäerl production and the regulating service related to the prevention of harmful algae blooms were commented on, no value specific to an Irish context was available. Hynes et al. (2012) undertook a valuation exercise for Galway Bay which used value transfer combined with an ecosystem approach to estimate the value of different ecosystems and the services they provide. The paper included a novel cultural adjustment approach which showed the lowest transfer error was 50% of the tests when the cultural adjustment was combined with a gross national income (GNI) adjustment. This study showed that the sea and beaches were the two most valuable ecosystems at €137.6 million and €45.3 million respectively using the combined GNI and cultural adjustment. The study also estimated using the combined approach for the benefit transfer that waste treatment (€136.8 million), non-use value (€34.8 million) and recreation (€34.5 million) were the most valuable ecosystem services for the area studied.

However, caution must be urged with these single figure estimates which suggest a degree of confidence in these measurements that may be misplaced. In particular, these single figure studies such as Costanza et al. (1997) and Beaumont et al. (2008) do not take into account the changes over time, the condition of the underlying natural capital (or environmental asset) or of the flow of these ecosystem services is sustainable. The Costanza et al. (1997) paper in particular, adopted a now invalid approach of up-scaling site specific per hectare estimates and applying them on a global scale. This is not the approach adopted here. Newer techniques relate values back to demand for each ecosystem service. More data and research is needed to generate time series of flows of ecosystems services and their values, on applying techniques to a large area while taking into account as many site conditions and spatial and ecosystem heterogeneity as possible. However, as noted by Bouma and Van Beukering (2015) single estimate valuation studies may be useful as an advocacy tool highlighting that all ecosystem services have some value, improving decision making by making what were pervious implicit valuations more explicit and as in this case can give an overview of the data available and provide a starting point for critique of methods hopefully to be replaced by both better data and better valuation methodologies.

In what follows, an assessment of Ireland's marine and coastal ecosystem services and their values are presented. Using the CICES framework as a guide, estimates for the quantity and value of provisioning, regulating and cultural ecosystem services were generated. In each case those service benefits that can be valued are presented under the headings of data source, methodology used and results. Those ecosystem services in this chapter where insufficient data is available to estimate the quantity of the ecosystem service or the value are not reviewed.

5.4. Ireland’s Provisioning Marine Ecosystem Services

5.4.1. *Offshore capture fisheries*

Ireland is located in UN FAO major fishing area 27 (Atlantic, Northeast), which covers 4% of the world’s ocean surface area and accounts for 10% of the world’s capture fisheries making it the second most productive area in the world (OSPAR Commission, 2009). The capture fisheries ecosystem service is measured in tonnes of fish landings and valued using market price data.[11]

5.4.1.1. Data Source

The main data source for the capture fisheries is from the Scientific, Technical and Economic Committee for Fisheries, (STECF) which is the advisory body for the EU Commission on fisheries management. The STECF in conjunction with the Joint Research Centre and member states under the Data Collection Framework (DCF) collect, manage and make available a wide range of fisheries data needed for scientific advice. This disseminated data collected for the evaluation of the fishing effort regimes is the main source of data for the analysis of offshore capture fisheries and can be downloaded from DCF Data Dissemination for Fisheries Dependent Information: [Available online: https://datacollection.jrc.ec.europa.eu/data-dissemination]

It is also noted that the STECF dataset only covers data for EU landings. To look at non-EU fisheries taking place in the Irish EEZ, the ICES data for ICESs areas VI and VII was examined using the ICES data set on catch statistics: ICES Official Nominal Catches 2006-2013 dataset. [Available online: http://www.ices.dk/marine-data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx]

5.4.1.2. Methodology

There are several STECF datasets which cover the north east Atlantic area and include Ireland. The data is available across various EU member states and is spatially available at

[11] Again as in section 1.3, it is noted that market prices are not a perfect method for valuation of ecosystem services as they may be distorted by taxes and subsides, does not include consumer surplus and the ecosystem service component may only form part of the value of the good or service (e.g. the value which covers the cost of transporting the good to market).

the spatial scale of ICES statistical rectangles (0.5° latitude by 1.0° longitude). As there is spatial overlap between datasets and they cannot be aggregated together, it was decided to follow the approach taken by Gerristen and Lordan (2014).

The data used for the ICES Statistical Areas VIa and VIIa were taken from the Annex IIa dataset and the data used for ICES Statistical Areas VIb and VIIb-k were taken from the Western Waters dataset. The Western Waters data was stripped of the BSA (Biological Sensitive) data to avoid double counting. Due to concern about the quality of data from boats under 15 m which traditionally were not required to have Vessel Monitoring Systems (VMS) (used to allocate landings data across the rectangles) and boats under 10m are not required to log their landings, only data from boats over 15 m was used for the offshore capture fisheries only used. Boats under 15m are known as the inshore fleet and the vast majority work in Irish territorial waters (<12nm from the coast). The prices are based on those reported in Gerristen and Lordan (2014) and the Marine Institute Stock Book (2015). The reference year used is 2014. The Irish EEZ and the ICES rectangles used to estimate the Irish wild fisheries ES can be seen in figure 5.3 and it is noted that some of these straddle the EEZ border between Ireland and the UK and this might lead to a slight overestimate of the offshore capture fisheries caught by boats >15m in the Irish EEZ.

For non-EU fisheries, the total tonnage for all offshore capture fisheries for ICESs areas VI and VII was examined in 2014 and is estimated at 1,690,622 tonnes. The EU took 1,138,595 tonnes and the non-EU states (Russia, Norway, Faroe Islands, Iceland and Greenland) took 546,076 tonnes. Of this 546,076 tonnes, 538,977 tonnes were for blue whiting (Micromesistius poutassou, FAO code WHB), making up 99% of non-EU catch in ICES Areas VI & VII. No other species was therefore considered.

To estimate the non-EU blue whiting catch within the Irish EEZ, maps of where blue whiting were caught showed that the vast bulk of the activity that occurred within the Irish EEZ was in ICES rectangles VII c2 and VI b2. ICES data for these areas showed the only non-EU fishing nation catching blue whiting was Norway. From this data, it is estimated that circa. 80,000 tonnes of blue whiting was caught by Norway in the Irish EEZ in 2014. Note that non-EU catches are not accounted for in the maps in this chapter which rely on STECF data alone.

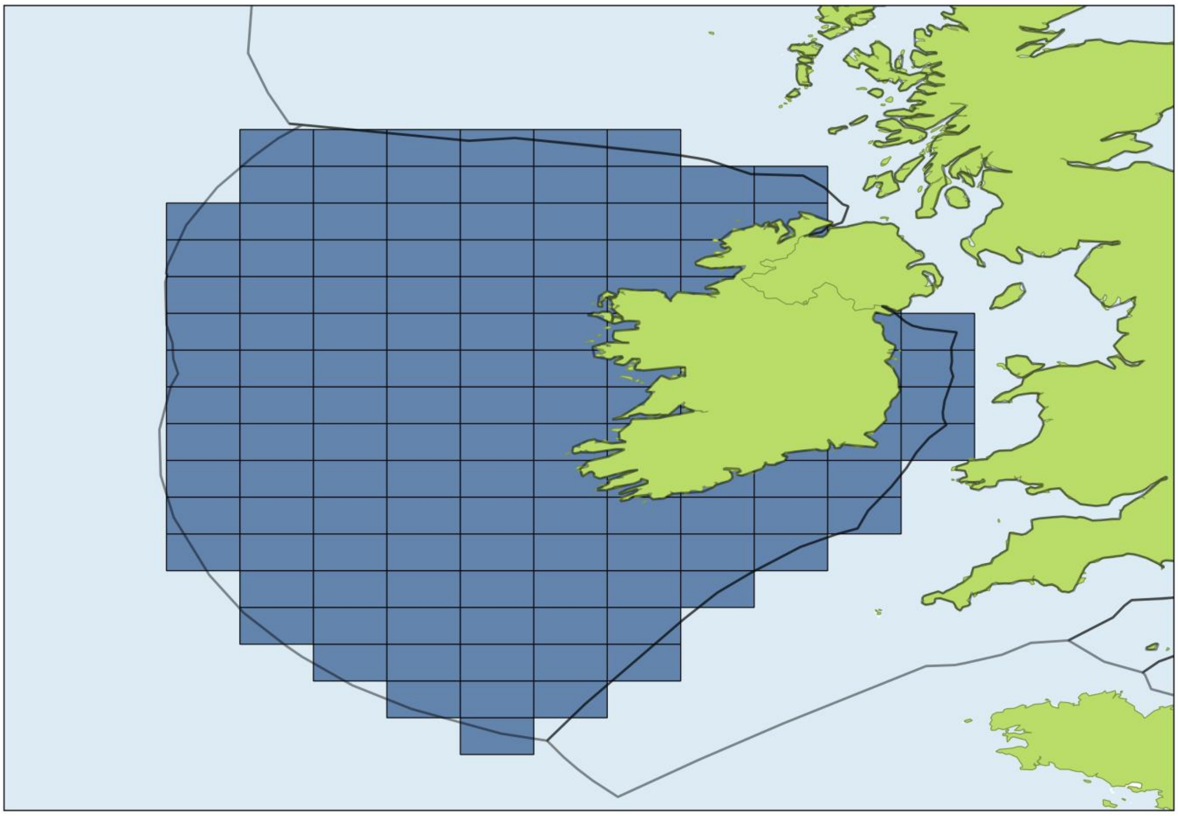

Figure 5-3. The dark blue rectangles show which ICES rectangles were included in estimating the value of the Ireland's offshore fisheries

5.4.1.3. Results

Table 2.1 shows a breakdown of the species landed from waters within the Irish Exclusive Economic Zone (EEZ) for all vessels greater than 15m, ordered by value. As there was no individual level prices available for some species these were aggregated with "other species" from the STECF data, which means that 'other species' is not included in the value of landings. This group makes up less than 0.3% of the offshore capture fisheries by landings and its value would be expected to be less than 2% of the total value of the offshore capture fisheries by boats greater than 15m. It is estimated that the top ten valued species make up over 90% of the total value.

Table 5-5 Estimated annual landings and value for capture fisheries within the Irish EEZ for vessels greater than 15m.

Species	Landings (tonnes)	Estimated Value (€)
Hake	33,496	€81,033,688
Blue whiting	159,398	€77,784,715
Mackerel	101,522	€75,123,471
Nephrops	9,639	€52,459,978
Anglerfish/ Monkfish	15,757	€51,296,108
Horse mackerel	67,266	€42,684,084
Megrim	8,098	€24,379,551
Albacore tuna	9,864	€18,279,184
Whiting	7,415	€8,439,412
Haddock	4,718	€7,818,730
Herring	19,111	€5,749,079
Cod	1,868	€4,518,946
Scallop	1,357	€2,683,604
Saithe	1,196	€2,196,076
Witch	1,064	€2,093,086
Ling	1,696	€2,074,902
Boarfish	16,491	€2,020,027
Sole	221	€1,973,941
Rays and skates	1435	€1,850,055
Turbot	194	€1,535,826
Lemon sole	518	€1,363,738
Pollack	783	€1,255,350
Squid	539	€870,419
Plaice	386	€709,622
Sprat	2,381	€433,247
Black scabbardfish	496	€343,286
Blackbelly rosefish	429	€331,057
Conger eel	261	€286,869
Grenadiers	155	€130,964
Blue ling	86	€73,230
Crab	483	€739,204
Tusk	13	€10,468
Other species	1,399	-
Totals	469,735	€472,541,917

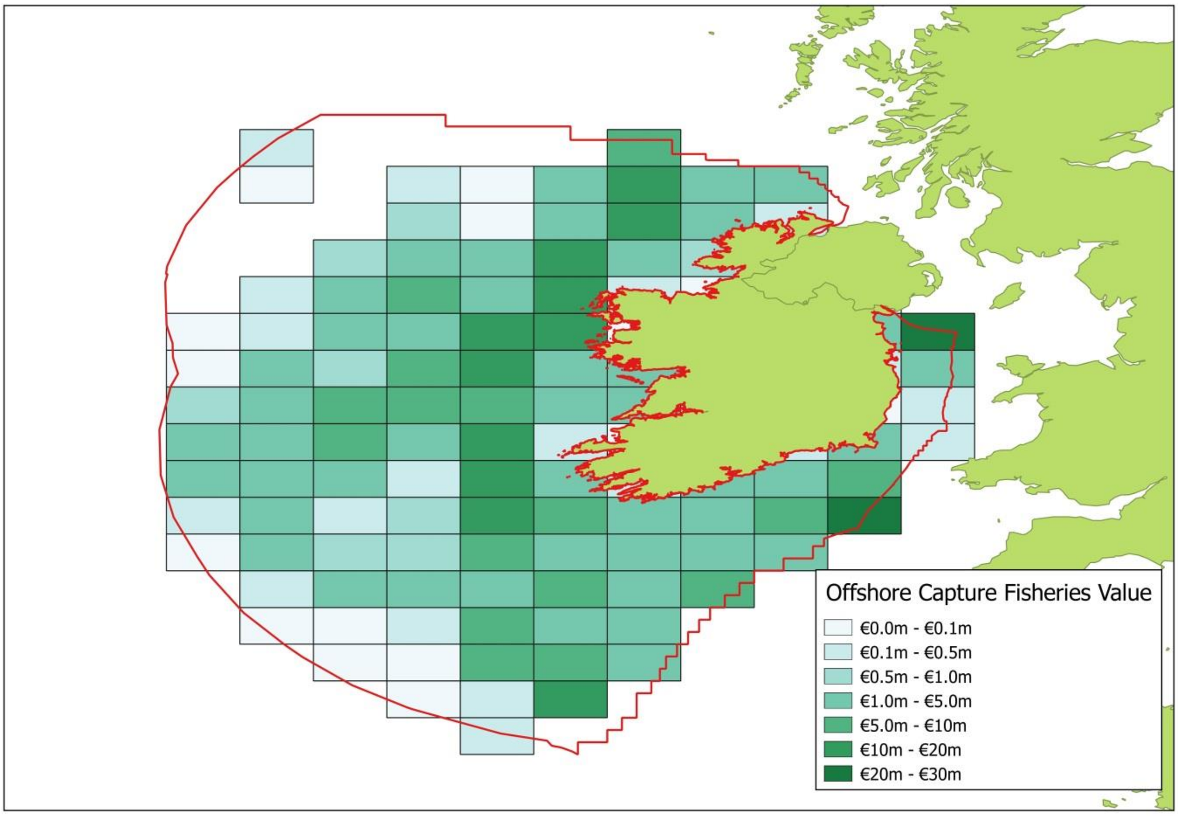

Figure 5-4 The total capture value per ICES rectangle in millions of euro.

As shown in table 5.5 and in the map of ICES rectangle values (figure 5.4) there is significant heterogeneity in the value each species contributes. Looking at ICES rectangle value maps of some of the top ten species by value (figure 5.5), patterns can be distinguished for certain species, which is linked back to their characteristics and the characteristics of the ecosystem types they inhabit. For example, megrim is predominantly landed from the southern Irish EEZ while blue whiting is more commonly caught in the North West area of the EEZ[12]. Nephrops are also very region specific with major resources to the west of the Aran Island, the South East and in Dublin Bay while albacore tuna is mostly caught far off the south-western shores of Ireland. Table 5.6 shows the main beneficiaries from this provisioning service in terms of member state share in the resource by value and landings.

[12] Note that only blue whiting caught by EU nations is mapped.

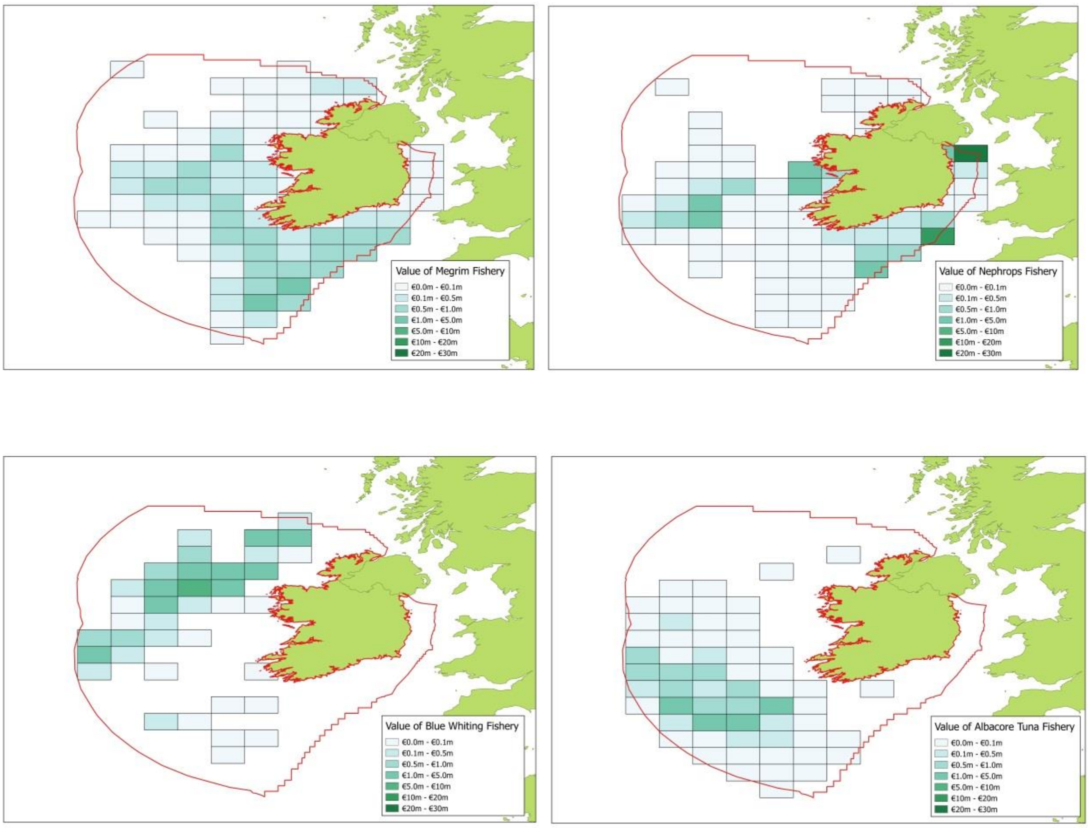

Figure 5-5 (From left to right, top to bottom) Megrim Value Map, Blue Whiting Value Map, Nephrops Value Map, Albacore Tuna Value Map

Table 5-6 Off-shore landings and value by Member State fishing in Irish EEZ, 2014

	Estimated Landings (tones)	Estimate Value of Landings	% of total value	% of total landings
Belgium	417	€1,546,003	0.3	0.1
Denmark	22,375	€12,758,888	2.7	4.8
England	16,523	€24,183,039	5.1	3.5
Spain	23,239	€55,057,710	11.7	4.9
France	41,704	€86,720,080	18.4	8.9
Germany	27,981	€18,551,512	3.9	6.0
Ireland	156,735	€155,879,060	33.0	33.4
Netherlands	34,453	€20,774,560	4.4	7.3
Northern Ireland	7,765	€14,014,175	3.0	1.7
Scotland	58,543	€44,017,690	9.3	12.5
Total EU	389,735	€433,502,717	91.7	83.0
NON-EU	80,000	€39,039,200	8.3	17.0
Total	469,735	€472,541,917	100	100

5.4.2. *Inshore capture fisheries*

The inshore capture fisheries are mainly based in the territorial waters which extend out to 12nm from the coast and are mainly composed of boats less than 15m. The vast majority of these are targeting the shellfish stocks (MI & BIM, 2015).

5.4.2.1. Data source

The data for the shellfish and crustacean fisheries are based on the Shellfish Stocks and Fisheries Review 2014 (MI & BIM, 2015), using figures for the year 2013. This chapter focuses on selected shellfish and crustacean stocks in Ireland that are mainly distributed inside the national 12 nm territorial limit (except for crab and scallop which are also fished outside the 12 nm limit) and that are nearly all targeted by vessels less than 13m.

5.4.2.2. Methodology

The figures for the latest year with complete data (2013) were reproduced from the Shellfish Stocks and Fisheries Review 2014 (MI & BIM, 2015).

5.4.2.3. Results

Table 5-7 Estimated landings and value for the selected inshore fisheries in Ireland.

Common name	2013 Tonnes	2013 Price per tonne	2013 Value
King Scallop	2,584	€5,900	€15,245,600
Edible crab	6,510	€1,490	€9,699,900
Lobster	374	€12,720	€4,757,280
Whelk	2,660	€1,200	€3,192,000
Shrimp	157	€16,430	€2,579,510
Razor clams	723	€3,540	€2,559,420
Crayfish	34	€35,000	€1,190,000
Native oyster	214	€4,000	€856,000
Velvet crab	365	€1,990	€726,350
Queen scallop	285	€1,700	€484,500
Periwinkle	218	€2,040	€444,720
Spider crab	229	€1,080	€247,320
Surf clam	37	€3,000	€111,000
Shore crab	31	€620	€19,220
Total	14,421		€42,112,820

Source: MI and BIM. 2015. Also note that these values do not represent the total amounts or total value of Ireland’s inshore fishery as finfish capture by the inshore fleet is not recorded.

Table 5.7 shows the estimated landings and value of those landings at 2013 prices for the Irish inshore capture fisheries with estimated inshore landings of 14,421 tonnes valued at €42,112,820. Crayfish and lobster are the most valuable per tonne, with King Scallop being the most valuable overall. Edible crab is the largest fishery by landings.

5.4.3. *Aquaculture*

The aquaculture sector is an important sector particularly in rural areas of the west of Ireland. Most of the aquaculture output produced relates to salmon, oyster and mussel farming and is mainly based on the west coast of Ireland. Salmon farming is generally carried out using cages suspended in the water. Oyster and mussel aquaculture operations are usually either grown using bottom production methods (on the low shoreline or seabed), or, for mussels, via suspended rope cultures.

5.4.3.1. Data source

The main data source for the aquaculture fisheries is the BIM Annual Aquaculture Survey 2016 (BIM, 2016). It has data for both production and market price for aquaculture species in Ireland.

5.4.3.2. Methodology

The figures for the latest year with complete data (2015) are reproduced from the BIM Annual Aquaculture Survey 2016 (BIM, 2016).

5.4.3.3. Results

As can be seen from table 5.8, Atlantic salmon is the most valuable farmed marine species in Ireland while the pacific oyster is the most valuable farmed shell fish even though the quantity of blue mussels farmed is approximately double that of pacific oysters.

Table 5-8. Irish Aquaculture Production and Value 2015

Common Name	Production (tonnes)	Value (€)
Atlantic salmon	14,004	97,111,893
Pacific cupped oyster	9,018	35,252,032
Blue mussel	16,009	12,846,147
European flat oyster	471	2,583,000
Great Atlantic scallop	50	233,550
Other marine species	173	742,500
Total	39,725	148,769,122

Source: BIM 2016, BIM Annual Aquaculture Survey 2016.

Figure 5.6 shows the distribution of salmon, oyster and mussel aquaculture by county around the coast of Ireland. (BIM, 2016). These figures are presented in table 5.9 and demonstrate the importance of this provisioning service to counties on the west coast in particular.

Table 5-9. Aquaculture by type and county.

County	Atlantic salmon (tonnes)	Pacific cupped oyster (tonnes)	European flat oyster (tonnes)	Blue mussel (tonnes)
Donegal	2,873	2,002	200	855
Sligo		142		
Mayo	2,128	1,128	16	1,286
Galway	5,371	323	80	1,043
Clare		240		20
Limerick		15		
Kerry		533	175	2,948
Cork	3,601	816		6,193
Waterford		2,969		
Wexford	31	432		2,211
Louth		418		1,453
Totals	14,004	9,018	471	16,009

Source: BIM 2016, BIM Annual Aquaculture Survey 2016

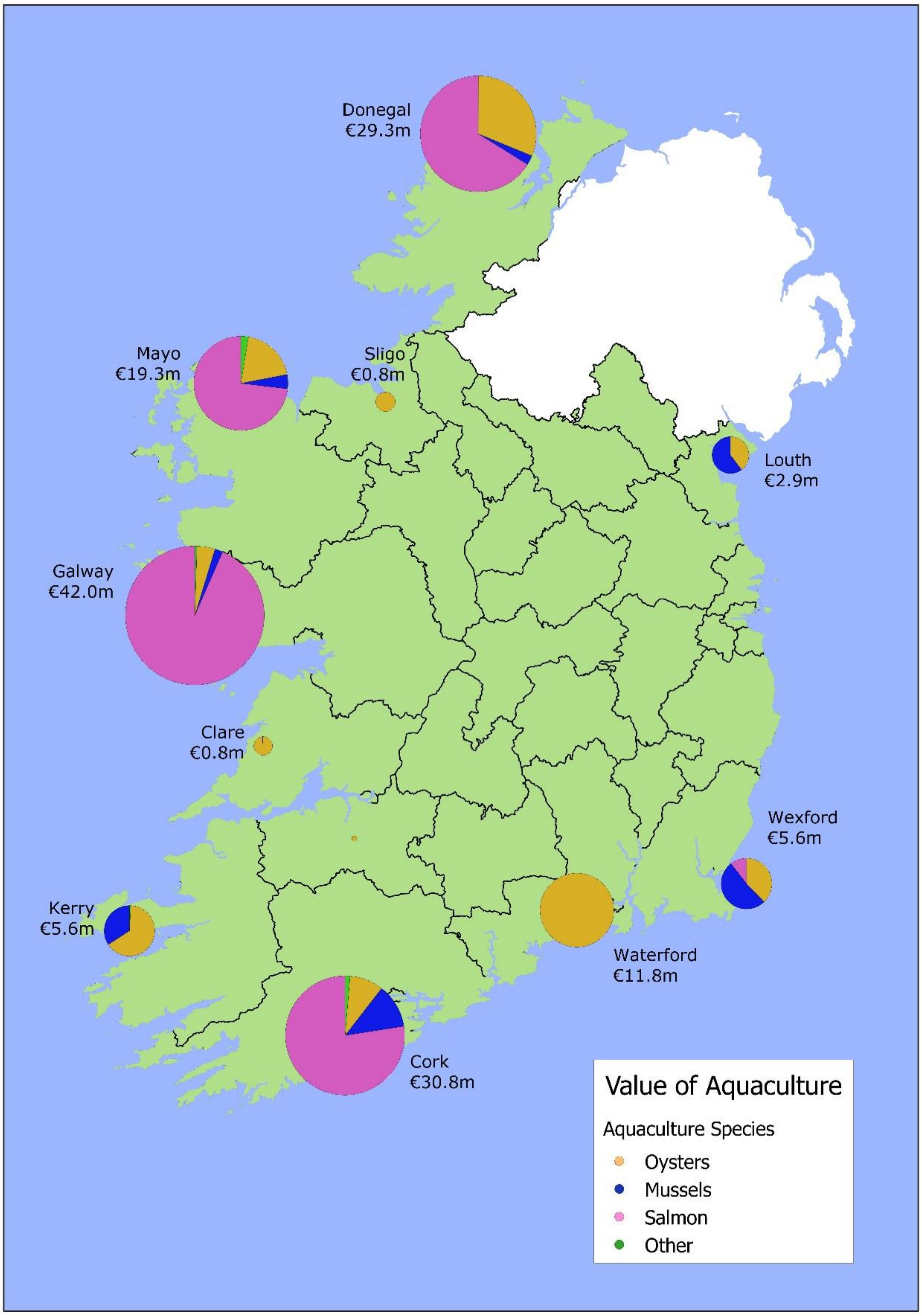

Figure 5-6. Value of Irish aquaculture activity by county

5.4.4. *Algae/seaweed harvesting*

Seaweeds, also known as macro-algae are plant-like marine species and are generally found attached to hard substrates along the coast. They can be categorised on the basis of colour into three divisions: brown algae (Phaeophyceae), red algae (Rhodophyta) and green algae (Chlorophyta). In Ireland, seaweed is mainly harvested on the western seaboard of Ireland, focused mainly on the counties of Donegal, Sligo, Mayo, Galway, Clare and Cork. There are many uses of the seaweed harvested in Ireland, but following processing it is primarily used as a food additive, for agriculture and aquaculture feed, as fertiliser and as an additive in the cosmetics industry (O'Toole & Hynes,2014).

5.4.4.1. Data source

There are a variety of estimates for the volume of seaweed production in Ireland. It is estimated that there is annual harvesting of approximately 30,000 tonnes of seaweed in Ireland (O'Toole and Hynes, 2014, FAO, 2014) but it could be as high as 36,000-40,000 tonnes (Morrissey et al., 2011, JCECG, 2015). For this chapter the estimated harvest for the main types of seaweed based on the Food and Agriculture Organization of the United Nations (FAO) estimates for 2012 (FAO, 2014) and the value is estimated for 2012 based on the figures from O'Toole & Hynes (2014).

5.4.4.2. Methodology

Figures for the estimated harvest for the main types of seaweed were reproduced from the Food and Agriculture Organization of the United Nations (FAO) estimates for 2012 (FAO, 2014) and the value was estimated based on figures reproduced from the values produced by O'Toole & Hynes (2014).

5.4.4.3. Results

The main species harvested is Ascophyllum nodosum (brown algae) and its main areas of production are in the western bays and islands of Galway, Rutland Island and Sound in Donegal, and Clew Bay in Mayo (O'Toole and Hynes, 2014). The other less harvested species are Fucus serratus (brown algae), Laminaria digitata (brown algae), Chondrus crispus (red algae) and Palmaria palmate (red algae). Table 5.10 shows the estimated harvest production and value for the main types of seaweed for 2012.

Table 5-10. Estimated seaweed harvest in Ireland

Species	2012 Production (tonnes)	2012 Value (€)
Ascophyllum nodosum	28,000	3,706,000
Laminaria hyperborea	1,400	23,000
Red seaweeds	100	185,000
Total	29,500	3,914,000

5.4.5. *Water for non-drinking purposes*

The most significant type of non-drinking use for marine water identified by coastal, marine and estuarine ecosystems was the use of water for cooling a number of electricity generating stations in several estuaries around Ireland. Six power plants were identified as using cooling water in estuaries in Ireland.

5.4.5.1. Data source

Six power plants were identified as using cooling water in estuaries in Ireland. Data for each was based on Annual Environmental Reports (AER) from the EPA (EPA, 2015a), Inspector reports by the EPA, grey literature on certain plants and some calculations by the author of this thesis. Details of the source for each plant are described in more detail in the methodology section (Section 5.4.5.2).

5.4.5.2. Methodology

The method and further details for each power plant are given below.

5.4.5.2.1. Aghada Generating Station

The value for cooling water for Aghada Generating Station was estimated from the 2012 AER (http://www.epa.ie/licences/lic_eDMS/090151b280493736.pdf) which was the only year cooling water volumes were detailed in an AER. It was based on discharges from PE4 and PE19, which were identified in Aghada Generating Station Integrated Pollution Prevention and Control (IPPC)/Waste Licensing Review Form and Guidance Note for the purposes of EC Environmental Objectives (Surface Waters) Regulations 2009 (http://www.epa.ie/licences/lic_eDMS/090151b2804250a8.pdf) as Cooling Water Outfall (Unit 1) and Condenser Cooling Water respectively. In 2012 the discharge of cooling water from PE4 was 57,840,000m^3 and from PE19 was 173,780,000m^3 giving a total of 231, 620,000m^3 which is below the ELV (Emission Limit Value) trigger value of 280,320,000m3.

5.4.5.2.2. Poolbeg Generating Station

The value for cooling water for Poolbeg Generating Station was estimated from the 2015 AER (http://www.epa.ie/licences/lic_eDMS/090151b28059c3e4.pdf). It is based on discharges from SW1 which was identified as discharge for condenser cooling water in Inspectors report on a review of the licence in September 2012 (http://www.epa.ie/licences/lic_eDMS/090151b28045faf0.pdf). The value for 2015 was 50,642,736m^3.

5.4.5.2.3. Dublin Bay Power Plant

The value for cooling water for Dublin Bay Power Plant was estimated from the 2015 AER (http://www.epa.ie/licences/lic_eDMS/090151b2805acaaa.pdf). It is based on discharges from SW1 which was identified as cooling water emission point in Inspectors report on a review of the licence in June 2012 (http://www.epa.ie/licences/lic_eDMS/090151b2804446b8.pdf). The value for 2015 was reported as a daily value of 584,618m^3 day^{-1} which was multiplied by 365 to give an annual estimate of 213,385,570m^3.

5.4.5.2.4. Tarbert

There was insufficient information available to estimate the cooling water used by Tarbet generating station.

5.4.5.2.5. Great Island

The value for cooling water for Great Island was estimated based on running hours and estimate of cooling water used per hour from an EIS for the new Combined Cycle Gas Turbine (CCGT) power plant. This was because there were no volumetric values reported for the volume of cooling water used in any recent AER. The estimated volume of cooling water used per hour was based on values reported in table 14.8 in the EIS for the CCGT power plant (http://www.epa.ie/licences/lic_eDMS/090151b28035fbfd.pdf). For the existing heavy fuel oil (HFO) power plant units it was reported that Condenser Cooling Water used was 50,170m^3 hr^{-1} and for the newer CCGT plant it was 25,000m^{3}hr^{-1}. In the 2015 AER (http://www.epa.ie/licences/lic_eDMS/090151b2805b5cd1.pdf) the running hours for the HFO plant was 146 hours and for the CCGT plant was 4132 hours. Multiplying these figures by the estimates from table 14.8 of the EIS gives an estimate of 89,964,820m3 of cooling water used in 2015.

5.4.5.2.6. Moneypoint Generating Station

The value for cooling water for Dublin Bay Power Plant was estimated based on running hours and estimate of cooling water used per hour from a report by Connolly and Rooney (1997). The Inspectors report on a review of the licence in October 2012 (http://www.epa.ie/licences/lic_eDMS/090151b2804610f2.pdf) identified discharge point SW8 as the discharge point for cooling water. However there were no volumetric values reported for the volume of cooling water used in any recent AER. Therefore it an estimate for the volume was estimated based on average running hours output (7261.7 hours) for the three units reported for 2015 from their AER (http://www.epa.ie/licences/lic_eDMS/090151b2805b804d.pdf) and a figure of 83,160 m^3 hr^{-1} cooling water used when Moneypoint was generating based on a report by Connolly and Rooney (1997) . This produced an estimate of 603,880,200m^3.

5.4.5.3. Results

Table 5.11 shows the estimated amount of cooling water used by each of six power plants in estuaries in Ireland. The total amount of water used was estimated at nearly 1,200 million cubic metres.

Table 5-11. Details of water abstraction for cooling in Irish estuaries

Station Name	Operator	Estimated Maximum Output (MW)	Cooling Water Source	Estimated Volume (m^3)
Aghada Generating Station	ESB	960	Cork Harbour Estuary	231,620,000
Poolbeg Generating Station	ESB	463	Liffey Estuary	50,642,736
Dublin Bay Power Plant	Synergen Power Limited	403	Liffey Estuary	213,385,570
Tarbert	SSE Generation Ireland Limited	626	Shannon Estuary	Not Estimated
Great Island	SSE Generation Ireland Limited	240	Barrow/Suir Estuary	89,964,820
Moneypoint Generating Station	ESB	849	Shannon Estuary	603,880,200
Estimated total				1,189,493,326

5.5. Ireland's Regulating Marine Ecosystem Services

5.5.1. *Waste services*

Wastewater discharged from urban wastewater treatment plants is used as a part-measure of the ecosystem services of waste treatment in Irish coastal and estuarine waters. Wastewater is not the only waste that is discharged to Irish coastal and estuarine waters and urban wastewater treatment plants are not the only source but they are the source with the most available information. Wastewater is treated to different levels before discharge to the aquatic environment where it undergoes dilution and further biological processes to clean the water of pollutants such as organic waste, nitrogen and phosphorus. Too much of these pollutants can lead to excess algae growth and in turn anoxic conditions in the water. It is noted that there are limits to what the aquatic environment can process in terms of our wastewater and it is noted that when thresholds are exceeded ecosystems and the services they generate can decline or cease. The replacement cost approach is taken here which not an ideal method but due to lack of data and a predictive model on the relationship between amount of wastewater discharged for each site, the water quality, other waste sources and the how water quality benefits are valued by the relevant population, it will give some indicative idea of range of values related to this ecosystem service. Section 1.3 provides further discussion of issues related to this method.

5.5.1.1. Data source

The data for wastewater treatment were based mainly on AERs for 2015 and where there wasn't enough data from the AERs, EPA inspector reports and applications for wastewater discharge licences were used to estimate the population equivalent of the agglomerations and estimates were generated as detailed in the methodology section (Section 5.5.1.2.). The source for each of the 143 agglomerations is available in Appendix F. Estimated values are shown in italics in Appendix F.

The method of valuing this ecosystem service is based on the cost avoided if society had to provide the same water treatment services (i.e. the removal of pollutants (BOD, N, P) from the wastewater). In their review of the shadow prices of pollutants, Zhou et al., (2014) found of 40 studies, 6 related to waste-water and only one (Hernandez-Sancho et al. (2010))was in the EU with the same treatment standards as Ireland. Hernandez-Sancho et al. (2010)

estimated the shadow price of treating a kilogram of each of the examined pollutants to a level suitable for reuse of the water. The values have been adjusted for inflation and are shown in table 5.12. Note that these values are based on operating costs and do not include capital expenditure.

Table 5-12. Shadow prices of removing a kg of each pollutant. Hernández-Sancho et al. (2010)

Pollutant removed	Shadow Price (€ per kg removed) (2015 prices)
Biochemical Oxygen Demand (BOD)	€0.07/kg
Nitrogen (N)	€30.93/kg
Phosphorous (P)	€93.63/kg

5.5.1.2. Methodology

Using the Water Framework Directive (WFD) defined coastal and transitional water bodies and the EPA urban wastewater treatment spatial databases (EPA, 2015b) those wastewater treatment plants near to the coast that had wastewater discharge licences (required for agglomerations over 500 population equivalent (PE)) or had applied for licences were chosen and this produced 182 agglomerations. An examination of their licence application files, EPA inspector's reports and annual environmental reports (AERs) [available online: http://www.epa.ie/terminalfour/wwda/index.jsp] reduced the number directly discharging into coastal and estuarine waters to 143 agglomerations (See figure 5.7). Details of these agglomerations are shown in Appendix F with the estimated effluent flows and estimates of the yearly BOD_5 (a measure of organic waste), total nitrogen and total phosphorous with the receiving WFD waterbody and type of waterbody (coastal or estuarine).

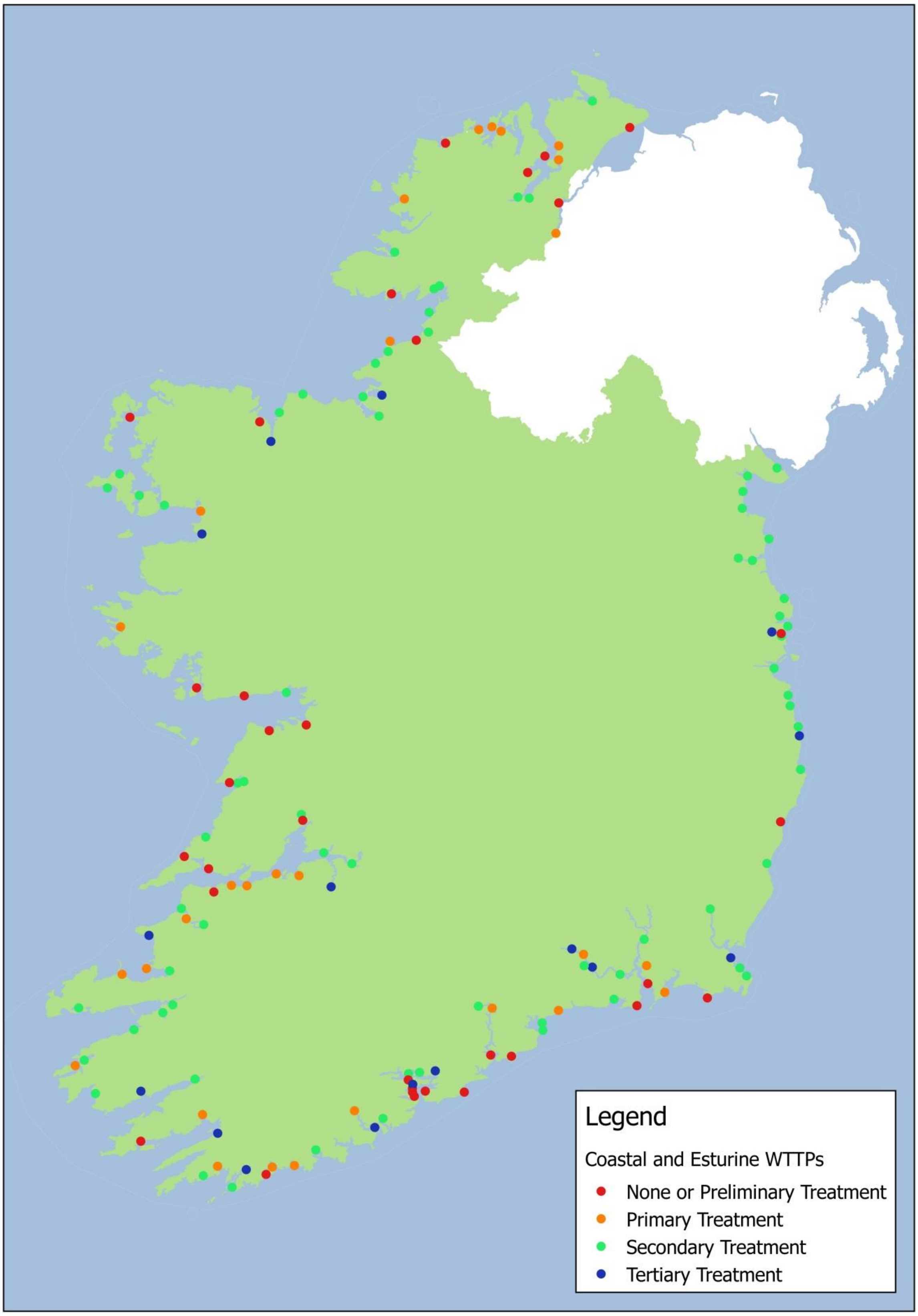

Figure 5-7. Coastal and Estuarine WTTPs in Ireland

For those agglomerations with no or only preliminary treatment the figures in table 5.13 (based on Kiely, 2007) were used to estimate the yearly emissions based on population equivalent reported in the AER, application or EPA inspectors report. For those agglomerations with primary treatment the figures in table 5.14 were used which assumes, as per Kiely (2007), that BOD is reduced by 30%, and total nitrogen and total phosphorous are reduced by 10%.

Table 5-13. Assumptions for untreated wastewater discharges quantities (Kiely, 2007)

Pollutant	kg PE^{-1} day^{-1}
cBOD	0.06
N	0.01
P	0.002

cBOD - carbonaceous biochemical oxygen demand

Table 5-14. Assumptions for primary treated wastewater discharges quantities (Kiely, 2007)

Pollutant	kg PE^{-1} day^{-1}
cBOD	0.042
N	0.009
P	0.0018

For the agglomerations treated to secondary and tertiary levels, regressions analysis were used to estimate the emissions for total nitrogen and total phosphorous based on population equivalent and BOD emissions for the year. This lead to six regressions detailed below. The data for each was based on the details gathered through the AERs and were separated into 3 groups based on the level of treatment; secondary treatment, tertiary nitrogen removal and tertiary nitrogen and phosphorous removal and finally, tertiary phosphorous removal.

The emissions of total nitrogen and total phosphorous were estimated for Sneem WWTP (License D0285) based on an OLS regression analysis using the information from other plants with tertiary phosphorous removal (table 5.15 and table 5.16) and without an intercept term. The results are shown below.

Table 5-15. Regression for estimating nitrogen emissions for plants with tertiary phosphorous removal

Dependent Variable: kg N yr^{-1}				
Coefficients	**Estimate**	**Std. Error**	**t-value**	**p-value**
Pop. Equiv.(2015)	3.7763	0.5552	6.802	0.00244
kg BOD yr-1	-1.025	0.3308	-3.099	0.03627
Adjusted R-squared:	0.9466			
F-statistic:	54.16			
n:	6			

Table 5-16. Regression for estimating phosphorous emissions for plants with tertiary phosphorous removal

Dependent Variable: kg P yr^{-1}				
Coefficients	**Estimate**	**Std. Error**	**t-value**	**p-value**
kg BOD yr-1	0.41336	0.06608	6.255	0.00333
Pop. Equiv.(2015)	-0.11086	0.03937	-2.816	0.04803
Adjusted R-squared:	0.938			
F-statistic:	46.42			
n:	6			

The emissions of total nitrogen and total phosphorous were estimated for Midleton WWTP (License D0056), Ballyheigue(License D0186) and Bantry (D0168) based on an OLS regression analysis using the information from other plants with tertiary nitrogen removal and tertiary nitrogen and phosphorous removal and without intercept term (table 5.17 and table 5.18). The results are shown below.

Table 5-17. Regression for estimating nitrogen emissions for plants with tertiary nitrogen removal

Dependent Variable: kg N yr^{-1}				
Coefficients	**Estimate**	**Std. Error**	**t-value**	**p-value**
Pop. Equiv.(2015)	-0.08292	0.22136	-0.375	0.7233
kg BOD yr-1	2.56201	0.687	3.729	0.0136
Adjusted R-squared:	0.9784			
F-statistic:	159.2			
n:	7			

Table 5-18. Regression for estimating phosphorous emissions for plants with tertiary nitrogen removal

Dependent Variable: kg P yr^{-1}				
Coefficients	**Estimate**	**Std. Error**	**t-value**	**p-value**
Pop. Equiv.(2015)	0.05247	0.05517	0.951	0.395
kg BOD yr-1	-0.01382	0.17129	-0.081	0.94
Adjusted R-squared:	0.7574			
F-statistic:	10.37			
n:	6			

The emissions of total nitrogen and total phosphorous were estimated for 15 wastewater treatment plants missing data for secondary treatment based on an OLS regression analysis using the information from other wastewater plants treating to secondary treatment level and without the intercept term (table 5.19 and table 5.20). The results are shown in italics in Appendix F.

Table 5-19. Regression for estimating nitrogen emissions for plants with secondary treatment level

Dependent Variable: kg N yr^{-1}				
Coefficients	**Estimate**	**Std. Error**	**t-value**	**p-value**
Pop. Equiv.(2015)	1.1008	0.2365	4.655	0.0000234
kg BOD yr-1	0.2911	0.1198	2.429	0.0187
Adjusted R-squared:	0.9746			
F-statistic:	1016			
n:	53			

Table 5-20. Regression for estimating phosphorous emissions for plants with secondary treatment level

Dependent Variable: kg P yr^{-1}				
Coefficients	**Estimate**	**Std. Error**	**t-value**	**p-value**
Pop. Equiv.(2015)	0.105243	0.013491	7.801	0
kg BOD yr-1	0.105919	0.006836	15.494	0
Adjusted R-squared:	0.9976			
F-statistic:	10990			
n:	53			

5.5.1.3. Results

Based on the AERs shown in Appendix F and including the missing data as estimated above (Section 5.5.1.2) the estimated totals for pollutants discharged into Irish coastal and estuarine waters for 2015 is shown in table 5.21.

Table 5-21. Estimated totals for pollutants discharged into Irish coastal and estuarine waters for 2015

Pollutant	kg
Biochemical Oxygen Demand	9,350,642
Total Nitrogen	6,834,783
Total Phosphorous	1,118,739

The shadow prices of Hernandez-Sancho et al. (2010) were used as an estimate of the cost avoided by not having to bring the discharged water from these water treatment services up to full re-use quality. By multiplying the shadow prices represented in table 5.12 above by the total amount of wastewater pollutants discharged (table 5.21) the value of the ecosystem service of waste water treatment in Irish waters is estimated as shown in table 5.22.

Table 5-22. The value of the waste treatment ecosystem service for each pollutant

Pollutant removed	Total amount discharged (kg)	Estimated value of ecosystem service (€)
Biochemical Oxygen Demand (BOD)	9,350,642	€638,252
Nitrogen (N)	6,834,783	€211,377,302
Phosphorous (P)	1,118,739	€104,751,290
Total		**€316,766,844**

It should be noted that the values estimated in table 5.22 are likely to be an underestimate of the value of the waste treatment service performed by the coastal and marine ecosystems due to other sources of wastewater including agricultural runoff, septic tanks in rural coastal areas and discharges from rivers. It should also be noted that there are many other types of waste that are discharged to the seas such as accidental spillage of chemicals and litter not accounted for in this analysis.

5.5.2. *Coastal defence*

The ecosystem service of coastal defence (also known as mediation of flows under CICES) is the preventative or moderating effect certain ecosystems can have on infrequent natural hazards thus reducing the level of harm imposed on life, health or property. For coastal areas these natural hazards often take the form of storms, storm surges and/or flooding. Many ecosystems can act as physical barriers to damp or reduce the energy hitting the inland portion of the seashore. Such ecosystems include reefs, seagrasses, kelp beds/forests, dunes and saltmarshes.

5.5.2.1. Data source

Based on CORINE data (EPA, 2015c) 81 saltmarsh area was available for those saltmarshes larger than 25ha[13]. Sixty four sites were identified from the CORINE dataset and using QGIS software, the land-use of the land bordering each of the sixty four saltmarsh sites was measured to determine the defensive length of the saltmarsh. Where saltmarsh bordered water or intertidal flats no coastal protection service was deemed to be present. In addition, four sites were deemed not to provide a coastal defence ecosystem service as they were adjoining coastal lagoons and were not exposed directly to the coast. Another site was also omitted on Inishmurray Island off Sligo, as there were no inhabitants on the island. This left 59 sites (Details of each of these sites is shown in table 5.23.)

[13] King and Lester's (1995) values are based on a minimum saltmarsh width of 80m. In the analysis presented here no saltmarshes was found to be have an average width less than 80m but some smaller saltmarshes not classified using the CORINE either in area (due to the linear nature of saltmarsh creation) or in width may still provide valuable coastal defence ecosystem service in certain areas. This is highlighted as a limitation to the methodology used here and as an area for future research.

Table 5-23. Breakdown of estimated protected length of CORINE landcover types by saltwater marsh in Ireland

CORINE_ID	County	Location	Area (Ha)	Estimated Protected Length (m)	Protected CORINE Code	Protected CORINE length (m)	Protected CORINE Code	Protected CORINE length (m)	Protected CORINE Code	Protected CORINE length (m)
IE_4754	Cork	Inchydoney	43	2003	231	2003				
IE_4755	Cork	Lislevane	61	4365	231	4365				
IE_4756	Kerry	Waterville	97	4045	231	3476	412	569		
IE_4757	Cork	Cork City, Tivoli	41	3620	243	1393	211	1085	122	891
IE_4758	Kerry	Cahersiveen	26	1594	231	953	243	641		
IE_4759	Kerry	Killorglin	58	3954	231	3954				
IE_4760	Kerry	Killorglin	60	2449	243	1895	231	554		
IE_4761	Kerry	Cromane	29	524	231	524				
IE_4762	Kerry	Inch Beach	163	6847	331	4498	331	2348		
IE_4763	Kerry	Tralee Bay	59	3306	231	3306				
IE_4764	Kerry	Tralee Bay	122	413	231	413				
IE_4765	Kerry	Tralee	53	2921	231	2551	112	371		
IE_4766	Kerry	Fenit	56	3579	231	1684	331	1295	211	443
IE_4767	Kerry	Ballylongford	33	2890	231	2890				
IE_4768	Kerry	Ballylongford	26	2003	324	1207	231	797		
IE_4769	Clare	Carrigaholt	29	1990	112	1066	231	924		
IE_4770	Clare	Querrin	75	2117	231	2117				
IE_4771	Limerick	Limerick City	128	7133	231	7133				
IE_4772	Clare	Termon	137	8794	231	7658	243	1136		
IE_4773	Clare	Moyasta	97	4508	231	4508				
IE_4774	Clare	Two Mile Inn	149	9869	231	9254	122	615		

IE_4775	Clare	Shannon	27	1925	231	1925				
IE_4776	Clare	Shannon	194	4839	231	2491	321	2146	243	202
IE_4777	Clare	Ballynacally	87	1358	231	1358				
IE_4778	Clare	Lisheen	71	6924	231	6924				
IE_4779	Clare	Clarecastle	328	4462	231	4462				
IE_4780	Clare	Latoon	37	2197	231	2197				
IE_4781	Clare	Lahinch	293	10834	231	9337	142	1497		
IE_4782	Galway	Kinvarra	45	3521	231	3521				
IE_4783	Galway	Kilcolgan	33	3849	231	3849				
IE_11172	Cork	Redbarn	183	8321	231	5773	112	1722	324	827
IE_11173	Cork	Youghal	69	2782	121	1079	112	937	231	766
IE_11174	Waterford	Clashmore	64	2878	231	2878				
IE_11175	Waterford	Ballinatray	38	2294	211	1289	311	1006		
IE_11176	Wexford	Ladys Island	72	0						
IE_11177	Wexford	Tacumshin	82	0						
IE_11178	Wexford	Mountpill	213	0						
IE_11179	Kilkenny	Rochestown	26	1535	231	1535				
IE_11180	Wexford	Castlebridge	78	3453	112	1715	231	1492	313	245
IE_11181	Wicklow	Wicklow Town	31	2092	231	1805	211	287		
IE_11182	Wicklow	Newcastle	161	5154	231	2673	211	1686	242	638
IE_11183	Dublin	Bull Island	108	4597	142	3572	331	1025		
IE_13837	Mayo	Murrisk	56	3223	243	2091	324	1132		
IE_13838	Mayo	Mullranny	25	952	243	952				
IE_13839	Sligo	Ballysadare	40	1805	231	1482	122	323		
IE_13840	Sligo	Ballysadare	49	1689	231	1689				
IE_13841	Mayo	Castlelacken	140	4957	231	4957				
IE_13842	Sligo	Drumcliff	35	1708	231	1708				

IE_13843	Sligo	Inishmurray	36	0						
IE_13844	Sligo	Mullaghmore	72	2671	231	2210	324	461		
IE_13845	Donegal	Ardara	75	3065	412	2107	231	688	331	271
IE_18754	Dublin	Portmarnock	65	3462	211	1160	142	1007	112	766
IE_18755	Dublin	Malahide	56	1400	142	1400				
IE_18756	Dublin	Lusk	77	3696	211	3696				
IE_18757	Louth	Drogheda	33	1294	313	374	211	818	112	101
IE_18758	Louth	Dromiskin	130	3049	211	3049				
IE_18759	Louth	Dundalk	220	4525	231	2833	211	1009	112	682
IE_18760	Louth	Dundalk	93	2517	231	2517				
IE_18761	Donegal	Ballyshannon	27	1421	331	775	231	646		
IE_18762	Donegal	Burnfoot	38	1651	231	1651				
IE_18763	Donegal	Derrybeg	36	2899	112	1529	242	1010	331	360
IE_18764	Donegal	Ards	39	2110	313	1822	243	287		
IE_18765	Donegal	Dunfanaghy	32	0						
IE_18766	Donegal	Ballyliffen	28	1799	231	1799				

5.5.2.2. Methodology

Following the approach taken by the Beaumont et al. (2010) only one ecosystem (saltmarsh) is examined in relation to its role in reducing disturbance related to waves and storms. Saltmarsh attenuates both waves and storm surges thereby reducing the energy hitting the seashore which in turn means that the flood defences needed are lower than those needed on an exposed shoreline. This method of valuation known as the 'replacement cost' approach as it assumes that the seashore defences would have to be replaced or upgraded to provide the same function as a saltmarsh protected seashore.

King and Lester (1995) estimated that a saltmarsh of minimum 80m width would reduce the capital cost of a seawall by between €400,000 to €800,000 per hectare (2015 prices) and maintenance costs of €8,000 per hectare (2015 prices). However, to multiply this by the total area of Irish saltmarsh as was done by Beaumont et al. (2010) would over estimate this ecosystem service as the average estimated width of the Irish saltmarsh for which data is available is circa 400m. Dividing 1 hectare (10,000m^2) by 80m gives 125m which divided by the per hectare figure above gives capital cost per linear metre of seashore protected by saltmarsh of €3,200 to €6,400. This compares to the King and Lester (1995) linear per metre costs of €3,500 to €6,200. Using the midpoint of these figures gives a value for capital cost (i.e. the value of the putting in coastal defences if there was no saltmarsh) of €4,800 and maintenance costs of €64 per metre length per year.

5.5.2.3. Results

Based on these 59 sites (table 5.23) with a total area of 4,744 ha, the total length of protected length was estimated at 201,830m with an average length of protected area of 3,420m. Table 5.24 shows the breakdown of the land-use protected by saltmarsh. The majority of land-use is extensive with agricultural and pastures making up 67% of the land-use protected.

Table 5-24. Land cover type protected by saltmarsh in Ireland

Land-use type protected (CORINE level 2 codes)	CORINE level 1 code	Estimated length of coast protected (m)	Percentage of total land-use type protected
Pastures (231)	Agricultural areas	134957	67%
Non-irrigated arable land (211)	Agricultural areas	14601	7%
Beaches, dunes, sands (331)	Forest and semi-natural areas	10630	5%
Discontinuous urban fabric (112)	Artificial surfaces	8938	4%
Land principally occupied by agriculture, with significant areas of natural vegetation (243)	Agricultural areas	8645	4%
Sport and leisure facilities (142)	Artificial surfaces	7517	4%
Transitional woodland-shrub (324)	Forest and semi-natural areas	3646	2%
Peat bogs (412)	Forest and semi-natural areas	2691	1%
Mixed forest (313)	Forest and semi-natural areas	2455	1%
Natural grasslands (321)	Forest and semi-natural areas	2158	1%
Road and rail networks and associated land (122)	Artificial surfaces	1839	1%
Complex cultivation patterns (242)	Agricultural areas	1657	1%
Industrial or commercial units (121)	Artificial surfaces	1085	1%
Broad-leaved forest (311)	Forest and semi-natural areas	1011	1%

Two types of protected land are considered; the first one considers CORINE level 1 'artificial surfaces' land-use type (a protected length of 19,379m) and the second is the CORINE level 1 'agricultural areas' (a protected length of 159,860m) with the 'artificial surfaces' giving a protected length of 179,239m.

Multiplying the above protected length estimate bordered by saltmarsh by the estimated values generated above for the capital costs gives a value of €860 million and multiplying the protected lengths by the value for maintenance costs gives an estimated reduction in the cost of maintaining coastal defences fronted by saltmarsh of €11.5 million per year.

5.5.3. *Lifecycle and habitat services*

Usages of certain habitats are temporally defined and only support a species for a specific stage of their lifecycle (e.g. as breeding or spawning areas for adults or as nursery areas juvenile animals). Failing to account for this when examining the value of an ecosystem may have potential negative effects for benefits arising in other ecosystems.

The Biologically Sensitive Area (BSA) is located off the southern Irish coast and is a limited marine protected area which aims to protect the nursery and spawning grounds of several commercial fish species particularly hake but also cod, haddock and herring. This protection is provided by the restriction of fishing effort within the BSA (Marine Institute, 2006). Another example is the EU Birds Directive (2009/147/EC) designated Special Protection Areas (SPAs) for the protection of endangered species of wild birds; particularly protecting migratory species. In Ireland there are many coastal SPAs including those protecting the breeding grounds of the Manx Shearwater and the Storm Petrel. The SPA's form part of the Natura 2000 protected sites and these are overlapped by Special Areas of Conservation (SACs) which provide protection to habitats and species under the EU Habitats Directive.

5.5.3.1. Data source

In Ireland 60 habitats and 25 species are protected under the Habitats Directive and there are 423 protected sites covering 1,355,624 hectares. While the BSA and SPAs are discussed, only SACs were used as a proxy indicator for the ecosystem service of lifecycle and habitat services to avoid double counting of protected areas. To identify SACs which offered protection to coastal, marine and estuarine ecosystems, habitat types associated with these based on Annex I of the EU Directive on the Conservation of Habitat, Flora and Fauna (92/43/EEC) were identified. These are shown in Table 5.25.

Table 5-25. Coastal, marine and estuarine habitat types based on Annex I of the EU Directive on the Conservation of Habitat, Flora and Fauna (92/43/EEC)

Habitat Code	Coastal, Marine or Estuarine habitat type protected under Annex I of habitats Directive
1210	Annual vegetation of drift lines
2150	Atlantic decalcified fixed dunes (Calluno-Ulicetea)
1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
1150	Coastal lagoons
2140	Decalcified fixed dunes with Empetrum nigrum
2170	Dunes with Salix repens ssp.argentea (Salix arenariae)
2110	Embryonic shifting dunes
1130	Estuaries
2130	Fixed coastal dunes with herbaceous vegetation (grey dunes)
2190	Humid dune slacks
1160	Large shallow inlets and bays
21a0	Machairs (* in Ireland)
1420	Mediterranean and thermo-Atlantic halophilous scrubs (Sarcocornetea fruticosi)
1410	Mediterranean salt meadows (Juncetalia maritimi)
1140	Mudflats and sandflats not covered by seawater at low tide
1220	Perennial vegetation of stony banks
1170	Reefs
1310	Salicornia and other annuals colonizing mud and sand
1110	Sandbanks which are slightly covered by sea water all the time
2120	Shifting dunes along the shoreline with Ammophila arenaria (white dunes)
1320	Spartina swards (Spartinion maritimae)
8330	Submerged or partly submerged sea caves
1230	Vegetated sea cliffs of the Atlantic and Baltic coasts

5.5.3.2. Methodology

Based on the Annex 1 habitat types in Table 5.25, a search of SAC sites which included these habitat types produced 126 sites that protect all or part of a coastal, marine or estuarine ecosystem listed below in table 5.26. The SAC search was based on sites listed in the NATURA 2000 Database for Ireland.

5.5.3.3. Results

An examination of sites that protect all or part of a coastal, marine or estuarine ecosystem identified 126 sites (30% of total sites) covering 844,383 hectares (62% of the total protected area) and are shown in Table 5.26.

Table 5-26. SAC Sitename protecting all or part of a coastal, marine or estuarine ecosystem

Site Code	SAC Sitename protecting all or part of a coastal, marine or estuarine ecosystem	Area (hectares)
IE0000020	Black Head-Poulsallagh Complex	7,805
IE0000036	Inagh River Estuary	391
IE0000077	Ballymacoda (Clonpriest and Pillmore)	487
IE0000091	Clonakilty Bay	508
IE0000097	Lough Hyne Nature Reserve and Environs	451
IE0000101	Roaringwater Bay and Islands	14,259
IE0000109	Three Castle Head to Mizen Head	342
IE0000111	Aran Island (Donegal) Cliffs	518
IE0000133	Donegal Bay (Murvagh)	1,810
IE0000138	Durnesh Lough	357
IE0000147	Horn Head and Rinclevan	2,344
IE0000154	Inishtrahull	471
IE0000164	Lough Nagreany Dunes	221
IE0000181	Rathlin O'Birne Island	812
IE0000189	Slieve League	3,926
IE0000190	Slieve Tooey/Tormore Island/Loughros Beg Bay	9,435
IE0000191	St. John's Point	1,079
IE0000194	Tranarossan and Melmore Lough	654
IE0000197	West of Ardara/Maas Road	6,739
IE0000199	Baldoyle Bay	539
IE0000202	Howth Head	375
IE0000204	Lambay Island	405
IE0000205	Malahide Estuary	810
IE0000206	North Dublin Bay	1,475
IE0000208	Rogerstown Estuary	586
IE0000210	South Dublin Bay	742
IE0000212	Inishmaan Island	793
IE0000213	Inishmore Island	14,666
IE0000268	Galway Bay Complex	14,409
IE0000278	Inishbofin and Inishshark	2,795
IE0000328	Slyne Head Islands	2,385
IE0000332	Akeragh, Banna and Barrow Harbour	1,204
IE0000335	Ballinskelligs Bay and Inny Estuary	1,629
IE0000343	Castlemaine Harbour	8,687
IE0000370	Lough Yganavan and Lough Nambrackdarrig	272
IE0000375	Mount Brandon	14,355
IE0000455	Dundalk Bay	5,236
IE0000458	Killala Bay/Moy Estuary	2,182
IE0000470	Mullet/Blacksod Bay Complex	14,066
IE0000472	Broadhaven Bay	9,075

IE0000484	Cross Lough (Killadoon)	57
IE0000500	Glenamoy Bog Complex	12,902
IE0000507	Inishkea Islands	1,230
IE0000516	Lackan Saltmarsh and Kilcummin Head	540
IE0000622	Ballysadare Bay	2,145
IE0000625	Bunduff Lough and Machair/Trawalua/Mullaghmore	4,389
IE0000627	Cummeen Strand/Drumcliff Bay (Sligo Bay)	4,919
IE0000665	Helvick Head	205
IE0000671	Tramore Dunes and Backstrand	753
IE0000696	Ballyteige Burrow	703
IE0000697	Bannow Bay	1,326
IE0000700	Cahore Polders and Dunes	265
IE0000704	Lady's Island Lake	540
IE0000707	Saltee Islands	15,809
IE0000709	Tacumshin Lake	559
IE0000710	Raven Point Nature Reserve	595
IE0000714	Bray Head	264
IE0000729	Buckroney-Brittas Dunes and Fen	321
IE0000764	Hook Head	16,940
IE0000781	Slaney River Valley	6,020
IE0001021	Carrowmore Point to Spanish Point and Islands	4,238
IE0001040	Barley Cove to Ballyrisode Point	795
IE0001058	Great Island Channel	1,443
IE0001061	Kilkeran Lake and Castlefreke Dunes	98
IE0001090	Ballyness Bay	1,236
IE0001141	Gweedore Bay and Islands	6,016
IE0001190	Sheephaven	1,842
IE0001195	Termon Strand	87
IE0001228	Aughrusbeg Machair and Lake	422
IE0001230	Courtmacsherry Estuary	735
IE0001257	Dog's Bay	141
IE0001275	Inisheer Island	552
IE0001309	Omey Island Machair	229
IE0001459	Clogher Head	24
IE0001482	Clew Bay Complex	11,987
IE0001497	Doogort Machair/Lough Doo	184
IE0001501	Erris Head	815
IE0001513	Keel Machair/Menaun Cliffs	1,616
IE0001529	Lough Cahasy, Lough Baun and Roonah Lough	301
IE0001680	Streedagh Point Dunes	630
IE0001741	Kilmuckridge-Tinnaberna Sandhills	86
IE0001742	Kilpatrick Sandhills	40
IE0001766	Magherabeg Dunes	75
IE0001932	Mweelrea/Sheeffry/Erriff Complex	20,983
IE0001957	Boyne Coast and Estuary	630
IE0001975	Ballyhoorisky Point to Fanad Head	1,293

IE0002005	Bellacragher Saltmarsh	17
IE0002012	North Inishowen Coast	7,069
IE0002034	Connemara Bog Complex	49,226
IE0002070	Tralee Bay and Magharees Peninsula, West to Cloghane	11,632
IE0002074	Slyne Head Peninsula	4,028
IE0002111	Kilkieran Bay and Islands	21,314
IE0002123	Ardmore Head	30
IE0002129	Murvey Machair	80
IE0002137	Lower River Suir	7,100
IE0002158	Kenmare River	43,290
IE0002159	Mulroy Bay	3,209
IE0002161	Long Bank	3,372
IE0002162	River Barrow and River Nore	12,373
IE0002165	Lower River Shannon	68,330
IE0002170	Blackwater River (Cork/Waterford)	10,150
IE0002172	Blasket Islands	22,712
IE0002187	Drongawn Lough	31
IE0002189	Farranamanagh Lough	28
IE0002193	Ireland's Eye	42
IE0002243	Clare Island Cliffs	355
IE0002249	The Murrough Wetlands	606
IE0002250	Carrowmore Dunes	443
IE0002259	Tory Island Coast	3,046
IE0002261	Magharee Islands	2,270
IE0002262	Valencia Harbour/Portmagee Channel	2,693
IE0002263	Kerry Head Shoal	5,797
IE0002264	Kilkee Reefs	2,916
IE0002265	Kingstown Bay	80
IE0002268	Achill Head	7,165
IE0002269	Carnsore Point	8,736
IE0002274	Wicklow Reef	1,533
IE0002280	Dunbeacon Shingle	42
IE0002281	Reen Point Shingle	7
IE0002283	Rutland Island and Sound	3,418
IE0002287	Lough Swilly	9,262
IE0002306	Carlingford Shore	526
IE0002327	Belgica Mound Province	41,162
IE0002328	Hovland Mound Province	108,956
IE0002329	South-West Porcupine Bank	33,121
IE0002330	North-West Porcupine Bank	71,941
	Total	**844,383**

5.5.4. *Climate regulation*

The oceans are helping to moderate the effects of climate change on the atmosphere and terrestrial ecosystems by absorbing circa 90% of excess heat input between 1961 and 2003 (Nolan et al, 2009) and also by absorbing greenhouse gases. The most important greenhouse gases are water vapour, carbon dioxide, methane and nitrous oxide. In this section, only the value of marine and coastal ecosystems absorbing carbon dioxide (CO_2) (also known as carbon absorption[14]) is examined.

5.5.4.1. Data source

Five ecosystems were examined with respect to carbon absorption.

The carbon absorbed per unit area (in this case per hectare) for each ecosystem is based on existing studies from elsewhere. Further details are given in the methodology section (Section 5.5.4.2). To value this ecosystem service the value of the carbon dioxide removed is based on the Irish carbon tax of €20 per tonne of CO_2 equivalent (Department of Finance, 2011). The valuation of this carbon absorption service uses the avoided damage method as the carbon absorbed avoids the social cost associated with the additional build-up of carbon in the atmosphere (the social cost of climate change).

5.5.4.2. Methodology

The methodology varied in relation to the type of ecosystem assessed. Further details on the method used for each is presented below.

5.5.4.2.1. Coastal ecosystems

The two coastal semi-terrestrial ecosystems examined in this report are saltmarsh and sand dunes. For the saltmarsh and sand dunes, the areas are based on CORINE data (Lydon & Smith, 2014). Note that the minimum area associated with the CORINE data is 25 ha and due to the linear nature of many coastal ecosystems, this most likely underestimates the area of saltmarsh and sand dune.

[14] Note that carbon absorption is different to carbon sequestration. The reason for use of absorption in this thesis is that CO2 transfer across the water/air boundary for some ecosystems was used to measure the removal of CO2 from the atmosphere. This CO2 is not locked away from the ecological system but instead contributes to ocean acidification which itself is an ecosystem disservice or cost

The carbon absorbed per unit area (in this case per hectare) for each coastal ecosystem is based on studies reported in by the UK NEA (Beaumount et al, 2010). The estimate for sand dunes of 0.58 (±0.26) tonnes carbon (C) per hectare per year is based on report by Jones et al. 2008 which was converted to CO_2 equivalent using a factor of 3.66 to give an estimate of 2.1 tonnes CO2 per hectare per year.

Sand dunes areas were based on the CORINE estimate for "Beaches, dunes and sand plains" for 2012 which was 12,013 hectares. This may be an overestimate of the area of dunes but it is also noted that the minimum area associated with the CORINE data is 25 ha and due to the linear nature of many coastal ecosystems, the data source may be an underestimate of the area of sand dune in some places. The area was multiplied by the value of 2.1 tonnes t CO_2 ha-1 yr-1by 12,013 hectares to generate an estimate of 26.4 kt CO_2.

A similar approach was used for the saltmarsh which covered an extent of 5,179 hectares based on CORINE data (Lydon & Smith, 2014). The estimate used for carbon absorption was 1.42 tC ha^{-1} yr^{-1} the midpoint of carbon absorbed by saltmarsh reported by Cannell et al. (1999) (0.64 – 2.19 tC ha^{-1} yr^{-1}) which was converted to CO_2 by multiplying by 3.66 to give a value of 5.2 CO2 ha-1 yr-1. Multiplying this value by the saltmarsh area of 5,179 hectares gives an estimate of 26.9 kt CO_2.

5.5.4.2.2. Estuaries

To estimate the carbon flux from Irish estuaries the mean of carbon flux from 14 estuarine environments in the NE Atlantic Region was taken from Chen and Borges (2009) as shown in table 5.27. The values reported in table 3.16 are in mols[15] C per m^2 per year and these were converted to tonnes of C per hectare by multiplying by 0.1201. In turn this was converted to tonnes (t) CO2 ha^{-1} yr^{-1} by multiplying by 3.66. Note that negative sign indicates that the estuarine environments are emitting carbon to the atmosphere.

[15] The mole (unit symbol mol) is defined as the amount of a chemical substance that contains as many elementary entities, e.g., atoms, molecules, ions, electrons, or photons, as there are atoms in 12 grams of carbon-12 (12C), the isotope of carbon with relative atomic mass 12.

Table 5-27. Carbon flux 14 estuarine environments in the NE Atlantic Region taken from Chen and Borges (2009)

Location	Carbon flux (in mols C m^{-2} yr^{-1})	Carbon flux (t CO_2 ha^{-1} yr^{-1})	Reference
Aveirolagoon(PT)	-12.4	-5.5	Borges and Frankignoulle (unpublished)
Douro (PT)	-76	-33.4	Frankignoulle et al.(1998)
Elbe (DE)	-53	-23.3	Frankignoulle et al.(1998)
Ems (DE)	-67.3	-29.6	Frankignoulle et al.(1998)
Gironde (FR)	-30.8	-13.5	Frankignoulle et al.(1998)
Guadalquivir(ES)	-31.1	-13.7	de la Pazetal.(2007)
Loire (FR)	-64.4	-28.3	Abril et al.(2003)
Randers Fjord(DK)	-2.2	-1.0	Gazeau et al.(2005)
Rhine (NL)	-39.7	-17.5	Frankignoulle et al.(1998)
Sado (PT)	-31.3	-13.8	Frankignoulle et al.(1998)
Saja-Besaya(ES)	-52.2	-22.9	Ortega et al.(2005)
Scheldt (BE/NL)	-63	-27.7	Frankignoulle et al.(1998)
Tamar(UK)	-74.8	-32.9	Frankignoulle et al.(1998)
Thames (UK)	-73.6	-32.4	Frankignoulle et al.(1998)
Mean	**-47.9**	**-21.1**	

The area of estuaries is based on that reported for transitional waters minus coastal lagoons for the Water Framework Directive and gave an estimate of 80,680 hectares. This was multiplied by the mean carbon flux of 14 NE Atlantic estuarine environments reported by Chen and Borges (2009) of -21.1 t CO_2 ha^{-1} yr^{-1} to give an estimate of 1,702 kt CO_2 per year being emitted from Irish estuaries.

5.5.4.2.3. Coastal Waters

To estimate the carbon flux from Irish estuaries the mean of carbon flux from three shallow and coastal marine environments in the NE Atlantic Region taken from Chen and Borges (2009) as shown in table 5.28 was used. The values reported in table 5.28 are in mols C per m^2 per year and these were once again converted to tonnes of C per hectare per year by multiplying by 0.1201. In turn this was converted to tonnes t CO_2 ha^{-1} yr^{-1} by multiplying by 3.66.

Table 5-28. Estimate of carbon flux is based on the mean of three shallow and coastal marine environments in the NE Atlantic Region taken from Chen and Borges (2009)

Location	Carbon flux (in mols C m^{-2} yr^{-1})	Carbon flux (t CO_2 ha^{-1} yr^{-1})	Reference
Bristol Bay	0.2	0.1	Borges et al. 2005
English Channel	0.15	0.1	Thomas et al, 2008, Borges and Frankignoulle (2003)
Galican Coast	2.2	1.0	Borges et al. 2005
Mean	**0.85**	**0.4**	

The area of coastal waters (including bays) is based on that reported coastal waters for the Water Framework Directive which gives an area of 1,314,374 hectares. This was multiplied by the mean of the values from table 3.17 (0.4 t CO_2 ha^{-1} yr^{-1}) to give an estimate of carbon absorption by Irish coastal waters of 525.7 kt CO_2 per year.

5.5.4.2.4. Offshore waters

For the offshore waters the carbon flux value was based on average for 2015 generated from two grid cells of the NOAA model of oceanic carbon flux (NOAA, 2016, available online : http://cwcgom.aoml.noaa.gov/cgom/OceanViewer/). The reason only these are used is that they cover the majority of the Irish EEZ. The grid cell Irish Coast South overs the area between 10 degrees and 15 degrees longitude west and between 50 degrees and 54 degrees latitude north. The grid cell Irish Coast North covers the area between 10 degrees and 15 degrees longitude west and between 54 degrees and 58 degrees latitude north. The monthly measurements of carbon flux for these two cells are shown in figure 5.8.

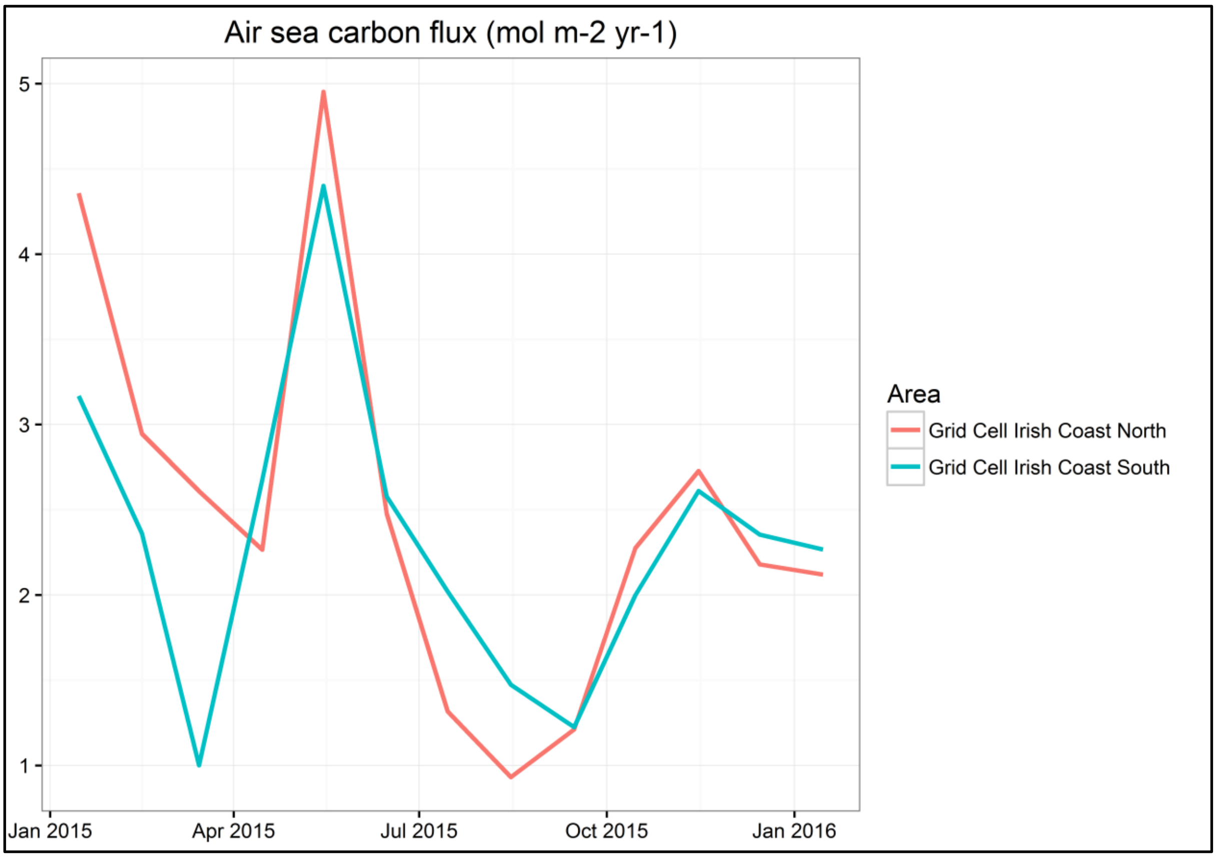

Figure 5-8. Air – sea carbon flux for grid cells off Irish western coast taken from NOAA model (Park et al., 2010)

These monthly estimates are generated from model data based on satellite measurements of sea surface temperature (SST) and wind speeds that can be used to estimate atmosphere to ocean carbon flux on empirical relationships between carbon flux, SST and wind speed. The model is explored in more detail by Park et al. (2010).

The mean of the grid cells from figure 5.8 is estimated to be 2.42 mols C per m^2 per year and this was converted to tonnes of C per hectare per year by multiplying by 0.1201. In turn this was converted to tonnes tCO_2 ha^{-1} $yr^{-1}$by multiplying by 3.66 to give a figure of 1.06 tCO_2 ha^{-1} yr^{-1}.

The area of offshore waters used in the calculation is based on the Irish EEZ (Seas around us, 2016) (409,929 km^2) and the WFD coastal waters and bays have been subtracted from this this value to produce a figure of 39,678,526 hectares. Multiplying this figure by 1.06 tCO_2 ha^{-1} yr^{-1} gives an estimate of 42,059 $ktCO_2$ yr^{-1}.

5.5.4.3. Results

Table 5.29 summarises the results from the methodology section and table 5.30 shows the estimates of the total amount of carbon dioxide absorbed per ecosystem and the total in aggregate within the Irish EEZ. Note that carbon absorbed is not the same as carbon sequestered, therefore only sequestered carbon is valued in Table 5.30. Estimating the linkages between different marine and aquatic ecosystems and the amount of carbon sequestered spatially is an important area of future research in this field.

Table 5-29. Irish coastal and marine ecosystem areas and estimated carbon absorption amounts

Ecosystem	Irish area (ha)	Carbon absorption (tCO_2/ha)[1]	References
Saltmarsh	5,179	5.2 (2.4, 8.0)	Cantell et al. (1999)
Sand dunes	12,013	2.1 (0.25, 4)	Jones et al. (2008)
Estuaries	80,680	-21.1 (-33.4 - -1.0)	Chen and Borges (2009)
Coastal waters and bays	1,314,374	0.4 (0.0 - 1.0)	Chen and Borges (2009)
Offshore waters	39,678,526	1.06	NOAA (2016)

For saltmarsh and sand dunes the confidence intervals is within brackets while range is reported in the brackets for the other ecosystems

Table 5-30. Estimated total amount of carbon absorbed and value by Irish coastal and marine ecosystems

Ecosystem type	Total Carbon Absorption (000's tCO2)	Carbon Absorption value (€ millions)
Saltmarsh	26.9	0.5
Sand dunes	26.4	0.5
Estuaries	-1,702	
Coastal waters and bays	525.7	
Offshore waters	42,059	
Estimated totals	40,936	1

Although the saltmarsh is the best carbon sequestrating ecosystem on a per hectare basis (and releases relatively little methane compared to freshwater marsh) the offshore waters are the largest contributor to the climate regulating service due to their large size. Also the high negative values associated with estuaries are due to carbon rich material in the rivers being converted into CO_2 by the highly productive ecosystems. As these values are based on values found in some of the larger European rivers entering the North East Atlantic region they may be over estimating the amount of CO_2 released from estuarine environments in Ireland. Also again it is noted that much of the carbon measured here is being absorbed and moved between ecosystems and there is currently insufficient evidence to estimate sequestered amounts for all bar the sand dunes and saltwater marsh.

5.6. Ireland’s Cultural Marine Ecosystem Services

5.6.1. *Recreational services*

Coastal and marine recreation is another important service provided by coastal and marine ecosystems. The value that recreationalists attach to the marine environment for direct use can be substantial although it may not be reflected by market prices. Taking these values into account is an important consideration in terms of the management, conservation and planning options for marine and coastal ecosystems.

5.6.1.1. Data source

Secondary sources of information were used to estimate the quantity (in terms of visitation rates) and value of marine and coastal recreation. The estimated number of trips for all coastal and marine recreational pursuits came from a nationwide household survey carried out by RedC Survey Company on behalf of SEMRU in 2012. A total of 812 people, aged 18 and over, were surveyed. Participants were sampled based on gender, age and working status giving a representative sample comparable to the Irish population. Respondents were asked several questions related to visits to the Irish coastline during the previous year. Further details on the survey are detailed in Chapter 3.

The estimates of the value of angling from shore and angling from a boat on the sea came from a recent study by Hynes et al. (2017). The estimates used for the value of sea kayaking came from Hynes (2006). The estimates of the value of swimming, wind surfing, diving, sailing, snorkelling, bird watching, walking along coast/sea/beach, other boating, surfing, kite surfing, whale/dolphin watching, family seaside visits, sunbathing, picnics, gathering seaweed, shellfish, etc. came from an extensive literature review that generated a database of 112 previous marine and coastal valuation studies for use in the development of a meta-analysis.

5.6.1.2. Methodology

As mentioned previously an alternative to the use of primary valuation methods is Value Transfer. Value transfer is a process of valuing a service benefit of a policy site by using values estimated for similar service benefits at another study site and applying these values to the policy site.

A unit value transfer method was used to estimate the total value for sea angling and sea kayaking. This involved a direct transfer of a value estimate from an existing study or studies to the policy site adjusting perhaps for inflation, and if transferring internationally adjusting also for exchange rates and purchasing power parity. In the cases of sea angling and sea kayaking the individual per trip values estimated from the previous studies of these pursuits in Ireland were multiplied by the total estimated number of trips taken in the population. This generated a total value estimate for these pursuits per annum.

A functional value transfer method was used to estimate the total value for swimming, wind surfing, diving, sailing, snorkelling, bird watching, walking along coast/sea/beach, other boating, surfing, kite surfing, whale/dolphin watching, family seaside visits, sunbathing, picnics, gathering seaweed, shellfish, etc. The chosen functional transfer method was what is referred to as a meta-analysis. Meta-analysis involves the statistical analysis of a large collection of results from individual studies for the purpose of integrating the findings and prediction of out of sample estimates. The meta-analysis developed here examined the study characteristics of 112 previous coastal and marine recreation valuation studies and the ability of those characteristics to explain the variation in value estimates using a log-linear regression model. By systematically analysing the variation in estimated values from the different studies, we identified the extent to which methods, design, ecosystem type, recreation pursuit and other site characteristics affect reported coastal and marine recreation values.

The estimated regression model for the meta-analysis was specified as follows:

$$\ln(y_i) = \propto + b_v X_{vi} + b_s X_{si} + b_c X_{ci} + u_i$$

where $\ln(y_i)$ is the natural logarithm of the value estimates from the previous studies measured in 2015 €/year; the subscript i is an index for the value observations; $\propto$ is a constant term; b_V, b_S and b_C are vectors containing the coefficients of the explanatory variables X_V (valuation study characteristics), X_S (site characteristics) and X_C (country level characteristics); and u is the error term. The resulting model was then used to estimate a per trip value for each of the activities listed above[16].

5.6.1.3. 4.1.3 Results

Based on the 2012 survey results the total number of trip taken by the population (aged 18+) for the range of marine recreation activities were estimated and are listed in the first two columns of table 5-31. Using the value estimates from the literature and calculations from the coastal and marine recreation value meta-analysis the aggregate recreational value obtained by Irish society from Ireland's marine resources were calculated (Hynes et al, 2017). Our coastal and marine environment provides us with an estimated €1.7 billion in recreation service value.

Table 5-31. Marine recreation activities by Irish residents

Activity	Mean number of trips per person per year	Estimated total number of trips per annum	Estimated Total Value (€) per year
Fishing from shore	0.424	1,450,985	351,138,395
Fishing from Sea	0.400	1,370,844	331,744,176
Swimming	3.142	10,760,068	113,411,119
Wind surfing	0.126	430,234	4,534,667
Diving	0.011	37,962	701,533
Sea Kayaking	0.054	185,591	15,404,053
Sailing	0.096	329,002	3,467,686
Snorkelling	0.075	257,297	4,754,843
Bird watching	0.761	2,606,713	27,474,752
Walking along coast/sea/beach	19.517	66,846,559	704,562,735
Other boating	0.151	518,812	5,468,275
Surfing	0.307	1,050,277	11,069,921
Kite Surfing	0.007	25,308	266,745
Whale/Dolphin watching	0.075	257,297	9,005,385
Family seaside visits, sunbathing, picnics, gathering seaweed, shellfish, etc.	3.159	10,819,120	114,033,529
Total		96,946,069	1,697,037,814

Note: Estimated trips refer only to those undertaken by Irish residents so will underestimate the total number of trips taken for marine recreation pursuits in the country.

[16] For further detail on the meta-analysis the interested reader is directed to Hynes et al. (2017).

5.6.2. *Aesthetic services*

The value of this ecosystem service lies in the beauty of the landscape generated by the ecosystem for those viewing it. Examples of the added value of a beautiful view is found in hotel rooms with a sea view which often command a premium or the additional price one pays for a house due to the scenic view it commands of an estuary or the sea. The hedonic pricing method can be employed to estimate the additional value of residential property located beside or near the coast relative to those properties inland.

5.6.2.1. Data source

A proxy for the aesthetic ecosystem service was based on estimating the portion of house values attributable to being located near the coast. Therefore, the data sources reflect the proxy for this ecosystem service. It is noted that this measure of the aesthetic of a sea view is very much a proxy and that it should be clear to respondents that it is understood by the author that many of these houses will not have a sea view. However, given the lack of information at the time of writing it is the best approach given the available data[17].

For house prices, Daft.ie prices (Daft, 2012) which detail house price by urban and rural markets and by number of bedrooms in a house were used for the year 2012 (See table 5.32) and to assign the value attributable to being located near the coast, percentages were taken from the paper by Lyons (2011) shown in table 5.33. To aggregate the values, housing density per bedroom type by small area (SA) was used from the Census 2011 data (CSO, 2015). To convert the stock value of the housing to a flow value, the stock was modelled as a perpetuity and a discount rate base on the average retail interest rate for loans for house purchases for 2012 (Central Bank, 2016) For further details see the methodology (Section 5.6.2.2.)

[17] More recently, work is being undertaken by a PhD student at NUI, Galway (Tom Gillespie) in conjunction with Ronan Lyons of Daft.ie on applying a more data intensive spatial approach to measure sea-views and value them. Future interested readers should be cognisance of this on-going work.

Table 5-32. House price value by number of bedrooms (000's)

House price value by number of bedrooms (000's)					
	1bed	2bed	3bed	4bed	5bed
Urban Areas					
Dublin City Centre	€123	€182	€203	€273	€350
Dublin North City	€105	€152	€215	€317	€465
Dublin South City	€116	€193	€229	€424	€578
Cork City	€80	€130	€180	€268	€383
Galway City	€78	€133	€164	€220	€309
Limerick City	€83	€105	€148	€220	€281
Waterford City	€52	€66	€115	€198	€271
Rural Areas					
Dublin North County	€116	€159	€207	€336	€509
Dublin South County	€162	€228	€320	€548	€694
West County	€93	€123	€167	€260	€434
Meath	€62	€114	€147	€238	€328
Kildare	€59	€115	€169	€259	€361
Wicklow	€100	€163	€194	€312	€409
Longford	*	€88	€93	€141	€226
Offaly	€67	€86	€124	€191	€275
Westmeath	€62	€104	€119	€169	€240
Laois	€55	€72	€105	€166	€308
Louth	€55	€91	€128	€209	€251
Carlow	*	€85	€125	€203	€302
Kilkenny	€74	€94	€140	€201	€338
Wexford	€83	€80	€123	€194	€248
Co. Waterford	€45	€75	€157	€239	€257
Kerry	€80	€131	€154	€213	€252
Co. Cork	€87	€120	€151	€248	€290
Clare	€81	€94	€124	€186	€261
Co. Limerick	€70	€92	€142	€239	€243
Tipperary	€59	€107	€130	€205	€252
Co. Galway	€54	€99	€135	€180	€228
Mayo	61	€87	€119	€169	€237
Roscommon	€35	€65	€99	€146	€197
Sligo	€46	€68	€125	€197	€271
Leitrim	€53	€80	€114	€141	€165
Donegal	€67	€79	€118	€187	€229
Cavan	€59	€69	€94	€166	€185
Monaghan	*	€58	€113	€172	€185

5.6.2.2. Methodology

Lyons (2011) estimated a logarithm-linear hedonic pricing model for Irish house sales between 2006 and 2010, which included dummies for sales at various distances from the coast. Lyons (2011) had two distance dummies related to the coast, those “at the coast” which was houses from 0-250m from the coast and those “near the coast” 250m to 1600m. Lyons (2011) showed a significant negative relationship between distance to the coast with houses at and near the coast showing higher relative prices compared to those further inland except for rural houses in the 250m-1600m zone which had a lower price relative to the base case of inland houses although the difference was quite small (-1.2%). There was no explanation given for this result. The method suggested by Kennedy (1981) was used to convert the dummy coefficients into percentage differences in price. The price differential for houses “at the coast” and “near to the coast” for both urban and rural areas is shown in table 5.33.

Table 5-33. Percentage increase in house prices at and near to coast

Distance to Coast	Location of house	Percentage increase in house price (%)
0-250m	Urban	14.2
	Rural	4.9
250-1600m	Urban	7.4
	Rural	-1.2

Using QGIS with the 2011 census data at the Small Area (SA) level (sub Electoral Division) the numbers of houses within 0-250m and 250-1600m of the coast by the number of bedrooms was estimated by overlaying a buffer area related to these (see figure 5.9. for an example) and multiplying these by the density of the houses in each SA which gave the numbers of houses within those distances. Price data for 2012 was taken from the Daft report (Daft, 2012) on house prices for county and cities around Ireland (see table 5.32.). This allowed a capital stock value for house values within each zone to be estimated. Then the coefficients from Lyons (2011) were applied to estimate the additional aesthetic value of having house at or near the coast.

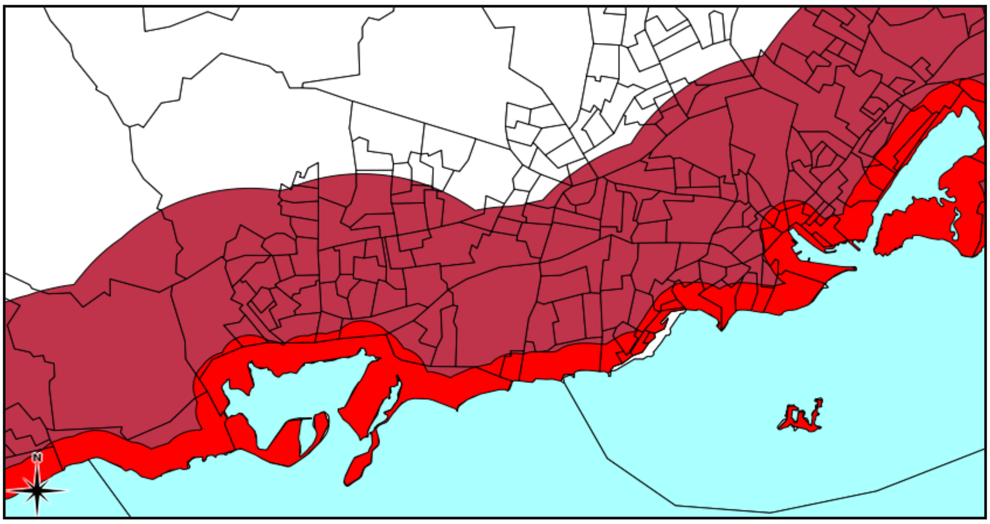

Figure 5-9. Coastal Buffers. Note: Overlay of 0-250m buffer shown in red and 250-1600m buffer shown in purple on Census SA's in Galway City

This stock value was then converted to a flow value to be comparable with other values estimated in this report. The 'stock value' was modelled as the present value of perpetuity with the flow of aesthetic ecosystem service modelled as a series of periodic payments using equation shown below.

$$PV \times r = A$$

Where: PV is present value of perpetuity

r is the rate of interest or discount rate

A is Amount of the periodic payment

A discount rate of 2.95% was selected based on the average retail interest rate for loans for house purchases for 2012.

5.6.2.3. Results

The values by county are shown in table 5.34 below and both the total estimated stock values and flow values are shown in table 5.35 below[18]. This represents a proxy of the value of the aesthetic view but does not include the total economic value of aesthetics as it measures only the value of living near the coast and doesn't take into account the economic value of an aesthetic view by visitors to the coast.

Table 5-34. Estimated aesthetic value by county

County	0m-250m	250m-1600m	0m-1600m
Clare County	€22,403,000	-€14,844,000	€7,559,000
Cork County	€113,848,000	-€68,493,000	€45,355,000
Donegal County	€47,660,000	-€34,023,000	€13,637,000
Dublin City	€425,060,000	€1,412,407,000	€1,837,467,000
Dún Laoghaire-Rathdown	€88,988,000	-€125,873,000	-€36,885,000
Fingal	€138,249,000	-€97,319,000	€40,930,000
Galway City	€80,411,000	€260,575,000	€340,985,000
Galway County	€26,010,000	-€13,000,000	€13,010,000
Kerry County	€31,936,000	-€20,486,000	€11,450,000
Leitrim County	€192,000	-€198,000	-€6,000
Limerick County	€9,027,000	-€2,254,000	€6,773,000
Louth County	€42,242,000	-€39,486,000	€2,755,000
Mayo County	€23,880,000	-€14,389,000	€9,491,000
Meath County	€9,959,000	-€10,704,000	-€745,000
Sligo County	€19,842,000	-€15,671,000	€4,170,000
Waterford County	€29,543,000	-€19,005,000	€10,538,000
Wexford County	€21,454,000	-€18,289,000	€3,165,000
Wicklow County	€35,436,000	-€52,168,000	-€16,732,000
Totals	€1,166,140,000	€1,126,779,000	€2,292,920,000

[18] Flows of ecosystem services are provided over a defined time interval by a stock of natural resources. Stocks are analogous to the stock value of a capital asset (e.g. savings, house value, shares of a company) and the flow is analogous to the interest that the stock provides (interest, rent, dividend). Stock values can be thought of as the net present value sum of all future flow values that could be derived from an ecosystem.

Table 5-35. Increased value of houses at or near the coast (proxy for aesthetic ecosystem service)

	Value "at the coast" 0-250m	Value "near the coast" 250-1600m	Total Aesthetic Value 0-1600m
Stock value	€1,166.14 million	€1,126,77 million	€2,292.92 million
Flow value	€34,401,130	€33,239,981	€67,641,140

5.7. Conclusions

This chapter demonstrated the data sources and methods that can be used to estimate the value of a number of coastal and marine ecosystem service benefit values. In particular the study estimated the value of waste assimilation services, coastal defence services, carbon absorption services, recreational services, the contribution proximity to the coast can make to the value of residential property, offshore and inshore capture fisheries, aquaculture and seaweed harvesting. A major issue facing coastal and marine managers and planners is how to ensure that the marine environment's capacity to continue providing ecosystem benefits is not diminished in the face of widespread pressures. As recognised by the integrated marine plan for Ireland 'Harnessing our ocean wealth' the maritime sector can play an important role in growing Ireland's economy but the innovation required to maximise opportunities from the marine environment is likely to put further pressure on coastal and marine ecosystems and the services they deliver. As The Economics of Ecosystems and Biodiversity report (TEEB, 2010) points out, ignoring the value of these ecosystem services and persisting with conventional approaches to wealth creation and development is a risky strategy if it means losing the benefits that coastal and marine ecosystems provide.

Placing a monetary value on a good or service may imply that full information is available but for non-market goods this is not always the case. The level of certainty associated with the quantities of the ecosystem services and their economic values are given in table 5.36 and are dependent on the assumptions and caveats associated with each.

The certainty scores are based on 3 point scale (low, medium, high) and are therefore a subjective measure dependent on the authors' best judgement. Those areas where there is lower certainty show where there is a need for more research or investigation, either in the information related to quantity of the ecosystem service provided or the valuation methodology used.`

Table 5-36. Certainty associated with generated values.

Ecosystem Service	CICES Classification	Quantity Estimate Certainty	Value Estimate Certainty
Provisioning ecosystem service			
Off shore capture fisheries	*Wild Animals*	High	High
Inshore capture fisheries	*Wild Animals*	Medium	Medium
Aquaculture	*Animals - Aquaculture*	High	High
Algae/ Seaweed harvesting	*Wild Plants & Algae/ Plants & Algae from Aquaculture*	Medium	Medium
Water for non-drinking purposes	*Surface water for non-drinking purposes*	High	-
Regulating and maintenance ecosystem services			
Waste services	*Mediation of waste, toxics and other nuisances*	High	Medium
Coastal defence	*Mediation of flows*	Medium	Low
Lifecycle and habitat services	*Lifecycle maintenance, habitat and gene pool protection*	High	-
Climate regulation	*Atmospheric composition and climate regulation*	Low	Low
Cultural services			
Recreational services	*Physical and experiential interactions*	Medium	Medium
Aesthetic services	*Aesthetic*	Medium	Medium
Non-use values	*Existence & bequest values*	High	Medium

The low certainty associated with several of the estimates produced indicate that knowledge gaps still exist for many ecosystem services, both in measuring the quantity of the ecosystem service in physical terms and in the lack of information and understanding needed to apply an economic value to certain ecosystem services.

This chapter offers an initial snapshot of the ecosystem services generated by the coastal, marine and estuarine ecosystems in Ireland. This approach is the current state of play in many studies (Beaumont et al., 2010, Olander et al., 2017, Picanço et al., 2017) However, it has many limitations, the first is the lack of data or lack of access to suitable data. One example of how this is improving is the recent release of fisheries data by the CSO (2018) where up to date (on a yearly basis) figures are available for fish prices. As with any snapshot, it only looks at a single time period. More work is needed to examine the change in both ecosystem services generated and the change in their value. Where market prices are available this may be easier, but for many of non-market goods, more primary research is required.

Additionally, work on producing time series of ecosystem services generated will allow the assessment of the health of the underlying ecosystem (i.e. the natural capital) to ascertain if the flow of ecosystem services generated are sustainable. The results of this chapter do not provide enough evidence to give an answer to this question. Another limitation of this work is the use of different valuation techniques which measuring different aspects of value. Market prices are measuring exchange value whereas the travel cost meta-analysis used is measuring consumer surplus.

However, there is hope that in the future better estimates on the value and health of our natural capital in the marine, coastal and estuarine zones will become available. The introduction of the SEEA (UN et al., 2014) is leading to more research in this area and with EU projects such the Copernicus Program, which provides free satellite data, means that the ecosystem services research community is moving from a data-poor to a data richer environment. Also work linking the impacts of society to the basic processes and functions of ecosystems to ecosystem services and the valuation of their flows provides a sounder basis for integrating ecosystem services into decision making process throughout our society. Recently, Bateman et al., (2013) demonstrated this for the UK, examining through spatially explicit models with valuation methods, the effects of climate change on a number of ecosystem services; including agricultural production, greenhouse gases emissions and sequestration, recreational visits, urban green space, and biodiversity. They examined a number of different scenarios to estimate comparable economic values for these services while taking account of possible climate change impacts. This work showed the state of the art that can be achieved with rich detailed time series datasets that are spatially linked to prediction models that can take into account the different variables associated with changes due to climate change. This paper offers a glimpse of the future of ecosystem services and how it can be used to inform policy and decisions at a variety of scales both spatially and temporally (Guerry et al., 2015, Chaplin-Kramer et al., 2017).

This initial assessment of Ireland's coastal and marine ecosystem services and their value is an important first step in incorporating ecosystem services into policy and decision making related to Ireland's marine and coastal environment. An avenue for future research is the mapping of the marine and coastal ecosystems and linking them to estimates of the associated ecosystem service value flows. Such research would assist decision makers with responsibility for marine spatial planning and the implementation of the EU Maritime Spatial Planning Directive as they attempt to manage coastal and marine developments in a manner that maximizes the delivery of value to society while minimizing forgone market opportunities.

Chapter 6

Estimating the Benefits of the MSFD in Atlantic Member States: A Spatial Value Transfer Approach

6.1. Introduction

In their communication on 'An Integrated Maritime Policy for the European Union' (EU Commission, 2007), the EU Commission noted that Europe is at a crossroads in their relationship with the oceans. One route will continue the status quo; that of extracting ever more resources from the sea and continued development along the coast, in turn causing further deterioration of Europe's marine environment. The alternative road proposed by the EU is sustainable economic and jobs growth in the maritime sector underpinned by a healthy and productive marine environment (EU Commission, 2007). This goal known as "blue growth" in the EU, is shared by other nations across the globe and is known alternatively as the "blue economy" or "blue wealth" (Visbeck et al., 2014).

The Integrated Maritime Policy (IMP) is the EU's plan for achievement of "blue growth" within the EU (EU Commission, 2007). The IMP's environmental pillar is enacted within the EU Marine Strategy Framework Directive (MSFD). The MSFD aims to achieve and maintain good environmental status (GES) of EU marine waters by 2020 (Long, 2011). A healthy and productive marine environment provides a variety of ecosystem goods and services that in turn generate benefits for society. Valuing these ecosystem services will provide policymakers with information on how society makes trade-offs between the societal benefits the marine environment provides against the possible degradation of the marine environment that may occur as the demand for marine ecosystem services increase (Börger et al, 2014).

The MSFD requires member states (MSs) to achieve GES by 2020 in their marine waters by enacting a marine strategy. This marine strategy will be composed of a programme of measures that will improve different aspects of the state of the marine waters as measured by 11 descriptors. Bertram and Rehdanz (2012) note that the MSFD requires that these measures should be cost-effective. MSs will have to assess the social and economic impacts of new measures which should include conducting cost-benefit analyses. MSs may delay or not achieve GES, if the cost of the measures needed are disproportionate. Additionally, the MSFD calls for a social and economic analysis as part of the initial assessment and consideration of social and economic impacts when setting environmental targets. While costs are thought to be easier to estimate for measures, many of the benefits generated by the MSFD will be non-market goods and services (Bertram and Rehdanz, 2012).

It is expected that non-use values arising from the introduction of the MSFD will form a considerable portion of its benefits (Bertram and Rehdanz, 2012). Non-use values attached to changes in the marine environment have been previously found to constitute a significant proportion of the total economic value of the benefits produced by changes to marine and coastal environments (Luisetti et al., 2010, McVittie and Moran, 2010). The contingent valuation method (CVM) has been widely used in the valuation of environmental goods and services or for changes to the environment (Darling 1973, Carson & Mitchell, 1989, Hanemann et al. 1991, Alberini et al. 2005, Bateman et al., 2006, Abdullah & Jeanty, 2011). The method was first used by Davis (1963), and has increased in popularity since a blue ribbon panel in the United States validated its use (Arrow et al. 1993). The CVM estimates values of a non-market good or service by presenting respondents with a hypothetical situation in a survey format. The name derives from the values being ‘contingent’ on the respondent’s willingness to pay (WTP) or willingness to accept (WTA) a change to the good or service being valued.

However, using primary valuation methods such as CVM and choice experiment (CE), as described above can be costly and time-consuming and for CE can be relatively complex to design and model. An alternative approach is value transfer (VT) also known as benefit transfer (BT) (Brouwer, 2000, Navrud and Ready, 2007, Johnston et al., 2015). A value transfer occurs when an estimated value, based on original studies (study sites), is transferred to a new application (policy site) (Boyle et al., 2010). This secondary valuation technique negates some of the problems with primary valuation as identified above; namely cost, time and complexity (Rosenberger and Loomis, 2003) but has the disadvantage of the VT practitioner not knowing how close to the actual value they have estimated, the difference known as the transfer error. As well as being time and cost efficient, VT's other advantage is that it can be applied on a scale that would be practicably unfeasible for primary research studies in terms of valuing large numbers of services across multiple ecosystems (Troy and Wilson, 2006, Brenner et al, 2010, Plummer, 2009, Hynes et al. 2013). This has been enabled by the recent combination of the VT method with GIS (Geographical Information Systems). The use of GIS in VT had been advocated by some (Lovett et al., 1997, Bateman et al., 2002, Boutwell, and Westra, 2013) as a way of improving VT and lowering transfer errors by including more socio-economic characteristics, allowing for spatial differences in preferences or allowing for substitute sites.

This chapter explores two issues arising from using spatial methods with VT that can affect the resulting value estimates; the functional form of distance decay measure and the modifiable area unit problem (MAUP). Distance decay is a well-known concept within non-market valuation literature (Sutherland and Walsh, 1985, Pate and Loomis, 1997, Loomis, 2000, Hanley et al., 2003, Bateman et al., 2005, Bateman et al. 2006, Kniivilä, 2006, Moore et al., 2011, Schaafsma et al., 2013, Jørgensen et al., 2013) and occurs where values tend to decline as one moves further from the site being valued. However, some studies also note that the spatial pattern may not be a monotonic continuous function where values may be distributed heterogeneously (Campbell et al. 2009, Johnston and Ramachandran, 2014). How the spatial distribution of values is modelled and applied in VT can offer solutions to issues like market extent (Bateman et al., 2006) but if incorrectly applied in VT can have a significant effect on the transfer error (Johnston et al., 2015).

The MAUP is long known to geography (Openshaw, and Taylor, 1979 Goodchild et al., 1993, Dark and Bram, 2007), in political science (Darmofal and Strickler, 2016) and to a lesser extent in the economics literature (Doll et al., 2006, Briant et al., 2010, Arbia and Petrarca, 2011). This is the first study to examine its impact on VT. It occurs through two effects;(1) the *scale effect* when aggregation of high resolution (i.e. a large number of small areas) data to a lower resolution (i.e. a smaller number of larger areas) and (2) the *zoning effect* where spatial units to which the higher-resolution data are aggregated are arbitrarily created by some decision-making process and represent only one of an almost infinite number of possible partitionings (Reynolds, 1999). This latter issue creates the gerrymandering problem in political science (Wong, 2009) but it is the former, the scale effect, which is examined in this chapter.

This chapter adds to the marine valuation literature by using the CV methodology to estimate the value of the non-market ecosystem service benefits associated with the achievement of GES as specified in the EU MSFD and it is the first to highlight the MAUP in VT. A 'value function transfer approach' based on the CVM results of achieving GES is employed to transfer values to five EU Atlantic MSs. The chapter also explores the differences arising from how distance decay is specified in the VT function.

In what follows, section 6.2 provides a brief review of marine valuation studies, the description of the MSFD and its requirement for economic valuation and VT. Section 6.3

outlines the spatial issues addressed in this chapter. Section 6.4 describes the CVM that is used to estimate the value of achieving GES in Irish marine waters and the VT methodology. Section 6.5 details the results and finally the discussion and conclusions are presented in Section 6.6.

6.2. The MSFD and marine environmental valuation

The MSFD (2008/EC/56) requires that EU MSs achieve GES by 2020 in their coastal and marine waters. GES is measured using 11 descriptors. When all 11 descriptors are at good status then the marine region/ sub-region will have achieved GES. Achieving GES will be met by protecting, maintaining and preventing deterioration of the marine ecosystems and also by preventing polluting inputs being introduced into the marine environment. These targets are to be achieved by developing and implementing measures that will manage human activities to ensure a balance between sustainable use of the waters and conservation of marine biodiversity (Long, 2011).

The MSFD builds on previous EU legalisation in the environmental area such as the Water Framework Directive (WFD) (2000/60/EC). The MSFD complements the efforts of the WFD within coastal water bodies where the two Directives overlap by allowing for interaction of management plans. MSFD does not apply to transitional waters which are solely covered by the WFD. This process may not be seamless. Borja et al (2010) have identified some potential conflicts between the two directives due to issues of spatial application.

Several commentators, including the EU Commission, have found deficiencies in the manner MSs developed marine strategies and the lack of co-ordination between MSs leading to lack of coherence in what GES is, even within the same regions/sub-regions and noting the lack of ambition in the programme of measures announced to-date (EC, 2014; Hanley et al., 2015; Oinonen et al., 2016a).. The deficiencies could be considered a fulfilment of the concerns highlighted by some (Long, 2011, Van Leeuwen, 2012) of the willingness of MS to implement the MSFD and improve the status of their marine waters. Most recently this has led to a revision in how GES is measured (EC, 2017)

Four main requirements have been identified within the MSFD by Bertram and Rehdanz (2012) that require valuation of the benefits generated by the MSFD. These are:

- An initial assessment of a Member States' marine waters, including economic and social analysis (ESA) of the use of those waters, and of the cost of degradation of the marine environment (Art.8.1(c) MSFD).
- Establishment of environmental targets and associated descriptors describing GES, including due consideration of social and economic concerns (Art.10.1 in connection with Annex IV, No. 9 MSFD).
- Identification and analysis of measures needed to be taken to achieve or maintain GES, ensuring cost-effectiveness of measures and assessing the social and economic impacts including cost-benefit analysis (Art.13.3 MSFD).
- Justification of exceptions to implement measures to reach GES based on disproportionate costs of measures taking account of the risks to the marine environment (Art.14.4 MSFD).

Estimating the value of coastal and marine ecosystem services is even more difficult than estimating the value of their terrestrial counterparts as the majority of coastal ecosystem services are not traded in established markets where they command a price (fish consumption and established marine energy sources being obvious exceptions) (Beaumont et al. 2007, McVittie & Moran, 2010). Also, for changes to the marine environment as envisaged by the MSFD, the impact on non-use values is expected to be much larger relative to use values (McVittie and Moran, 2010, Bertram and Rehdanz, 2012). This is due to a combination of a lower number of direct users for the ecosystem services and the smaller area over which these users operate (i.e. mainly restricted to the coastal zone). The CVM employed in this chapter allows us to pick up both the use and non-use values associated with achieving good environmental status as described in the MSFD.

In a review of valuation of coastal and marine environments in the Black Sea and Mediterranean, two of the regions designated by the MSFD, Remoundou et al. (2009) found that CVM was the most common valuation methodology used, being used in six of the thirteen studies reviewed. CVM has been also used by others to values changes in coastal and marine environments. Nunes and van den Bergh, (2004) used a joint travel cost (TC) - CVM survey to estimate the value in preventing harmful algae blooms (HAB) for the Dutch coastline. The programme valued the treatment of ballast water for ships to prevent establishment of invasive algae species. The TC method was used to estimate the value of recreational users while the CV was targeted at valuing indirect and non-use values. Using the TC method the authors estimated an annual gross recreation benefit per individual of €55. The CVM using a double-bounded dichotomous choice question estimated the WTP for preventing HABs was €76 per respondent. Carson et al. (2003) used CVM to estimate the non-use value or passive value of an oil spill in Alaska and estimated a mean WTP of $79.20 based on a modified Weibull distribution.

Elsewhere, Ressurreição et al. (2012) undertook a CVM with 1502 respondents in three sites (Azores islands (Portugal), the Isles of Scilly (UK) and in the Gulf of Gdansk region (Poland)) to estimate WTP for biodiversity. They found that mean values for subsets within their study varied from a WTP of US$101 for both mammals and fish by visitors in the Azores to a WTP of US$14 for both invertebrates and algae by visitors in Gdansk. For a more detailed discussion of non-market valuation of coastal and marine environments the interested reader is directed to Torres and Hanley (2016) who undertook a comprehensive review of 196 papers on the subject. Aggregating a large number of studies they note is useful for those using value transfer (VT) in response to a growing political demand.

Value transfer (VT) is the second methodology used in this chapter and is an alternative to the primary non-market valuation methods such as revealed (e.g. travel cost and hedonic valuation methods) and stated (e.g. CVM and CE) preference approaches. When analyzed carefully, information from past studies published in the literature can form a meaningful basis for coastal zone management policy (Rosenberger and Loomis, 2000, Brouwer, 2000, Ledoux and Turner, 2002). As with CVM, the VT method has been widely applied in the environmental literature (Luken et al, 1992, Bateman et al., 1995, Brander et al. 2012 Johnston et al., 2015) and also to value marine and coastal environments or elements within these environments.

Brenner et al (2010) estimated the value of the non-market ecosystem services of the Catalan coastal area of Spain using GIS with VT. Fifteen different ecosystem types were valued, four of which were coastal ecosystem types (coastal shelf, seagrass beds, beaches, saltwater marshes) covering 22.2% of the total study area. In the UK, Beaumont et al. (2008) used a mixture of market prices and VT to estimate values for 8 of 13 ecosystem services supported by marine biodiversity. Hynes et al (2013) used an international value transfer with a cultural adjustment to value the marine and coastal ecosystems of Galway Bay, a coastal inlet on the western coast of Ireland. The cultural adjustment only lowered the VT error in two of the four cases tested. Elsewhere, Ghermandi and Nunes, (2013) undertook VT using a GIS based meta-analysis to generate a global map of coastal recreation values. Brander et al. (2007) also undertook a meta-analysis of marine related recreation but only at coral reef sites.

There are various methods of transferring values between sites (Colombo & Hanley, 2008). The simplest and most commonly used is to use the unadjusted WTP estimates from one or more study sites and apply their average value to the policy site. This method is referred to as 'unit value transfer'. An extension to the unit value transfer method is where the WTP values are adjusted for one or more factors (e.g. adjustments for differences in income between study and policy sites and for differences in price levels over time or between sites) before the values are transferred between the sites. The next step in complexity of value transfer is to use a value 'function transfer' method (Loomis, 1992). This is the approach adopted in this chapter. This involves using the parameters from the original demand function from the study site (WTPS) and using environmental and population characteristics from the policy site to generate the WTP for the policy site (WTPP). In effect it is assumed that;

$$predicted\,WTP\;(\beta^S, X^P)\;=\;WTP^P \qquad (6.1)$$

Meta-analytic value function transfer is a more complex form of value function transfer that uses a value function estimated from multiple study results together with information on parameter values for the policy site, to estimate policy site values (Brander et al., 2012). The use of spatial micro-simulation techniques for VT is another form of value function transfer that has been suggested and used by Hynes et al. (2010).

However, VT has some disadvantages, the most significant being that the value transferred may not be similar to the actual value (which is unrevealed to the VT practitioner) at the study site. This difference between the transferred value and the actual real value is known as the 'VT error' (Kaul et al, 2013). Where this error has been calculated in some studies it has been found to be highly significant with values of up to 7496% being reported

(Kaul et al, 2013). Transfer errors and the applicability of transferring certain values are of the greatest concern in the transfer valuation literature as these issues are the most important for providing confidence in the final valuation of the policy site (Colombo and Hanley, 2008). The subject of VT is a maturing area, and with more studies and more understanding of the valuation of ecosystems, more confidence will be attained in the methodology. It has been acknowledged that the general view within the literature is that function transfers generally outperform unit transfers (Johnston and Rosenberger, 2010) although this is not always found to be true. Brouwer (2000) found that the unit-VT method had a lower range of transfer errors in half of the VT studies he reviewed. However, Kaul et al. (2013) undertook a meta-analysis with 1071 transfer errors finding a median transfer error of 39%, that benefit function transfer outperforms unit value transfer, that CVM performs no worse than other valuation methods and combining data from multiple studies tends to reduce transfer errors. Bateman et al. (2011) suggested that unit VT is more accurate for similar study and policy sites but that value function transfer is more accurate for dissimilar study and policy sites. The inclusion of environmental attitudes which is often an unobserved preference may also help to increase the accuracy of benefit transfers (Brouwer and Spaninks 1999). Brouwer et al. (2015) noted that for international VT transferring multi-country values can also reduce VT errors.

Transfer errors are typically presented as the percentage difference between the value estimated for the policy site and the 'actual' value at the policy site. Following Bateman et al. (2000), the transfer error is calculated as:

$$Transfer\ Error = \left(\frac{Transferred\ Estimate - Policy\ Site\ Esimate}{Policy\ Site\ Esimate}\right) \times 100 \qquad (6.2)$$

An alternative method (equation 6.3) has been proposed by Chattopadhyay (2003) which would give the same answer no matter which site was the policy site and which site was the study site.

$$Transfer\ Error = \left(\frac{\frac{Transferred\ Estimate - Policy\ Site\ Esimate}{Transferred\ Estimate + Policy\ Site\ Esimate}}{2}\right) \times 100 \qquad (6.3)$$

While the reason for undertaking a VT exercise is that the 'Policy Site Estimate' is unknown, many studies have estimated the policy site value using primary valuation techniques and then undertaken VT and tested the difference between the two. Brouwer (2000) reviewed several VT exercises that reported transfer errors and found transfer errors varied between 1% and 475% but noted that most of them were in the range of 20%-50% which includes the median error reported by Kaul et al. (2013). Kaul et al. (2013) also noted the large variability in transfer errors finding transfer errors between 0 and 7496% with a median of 39% and a mean of 172% indicating some large outliers had skewed the distribution.

6.3. Spatial issues with value transfer – Distance decay and MAUP

One suggested method for reducing transfer errors is through the use of geographic information systems (GIS). Eade & Moran (1996) were one of the early adopters of GIS for VT and noted that it had great scope to take account of the spatial variation of respondent's characteristics in VT. Lovett et al. (1997) used GIS to improve a travel cost demand function for forest recreation by incorporating spatial variation in socio-economic characteristics and allowing for substitute sites. They noted that using GIS in improving VT is dependent on the amount of data available and the spatial scale that data is available. Bateman et al. (2002) also noted that using GIS with VT can allow easier communication of results to policymakers and the general public.

Another important issue in using GIS with VT is defining the extent of the market at the policy site. Bateman et al. (2006) argued that the use of GIS coupled with the concept of distance decay may be a method of determining market size for public goods, especially for non-use values, coining the term "economic jurisdiction". Loomis (2000) and Bateman et al. (2006) argue that the extent of the market may be more important in determining aggregate values than any changes related to the precision of the estimates of per-person values. Norton et al. (2012) also highlight the importance of the choice of the relevant population and the extent of the market in the aggregation process.

Distance decay is one concept that has been used to determine the extent of the market for non-market goods (Bateman et al., 2006). Often this is based on the concept that users will pay and Bateman noted that where both users and non-users are surveyed (as in this study) that distance decay will arise due to a lowering in the number of users (that should have a higher value for a resource relative to non-users) relative to non-users. Bateman et al. (2006) also noted that some in the literature had found a distance decay element for 'pure' non-use values but stated that there was no theoretical basis for this. However, if one considers the composition of the different elements of non-use value, there are valid reasons for non-use values incorporating distance decay. The first is the altruistic element where respondents value a site for the reason of knowing that someone else might use it. Often people may have a higher WTP value if the site is near to themselves, their family and friends. This could be considered an application of Tobler's First law of geography – "*All things are related, but near things are more related than far things*" (Tobler, 1970). The same logic can be applied to the bequest element of non-use value in passing down an environment in good condition to the next generation which traditionally live close to their parents although this may be changing (Compton and Pollak, 2015). The final element of non-use value is option value where the person may opt to use the ecosystem service or good in the future and geography dictates that location may be a factor in this as discussed by Jørgensen et al. (2013).

Schaafsma (2010) found in a review that nearly 85% of studies that include a spatial element, found significant distance effects but noted that these were a very small proportion of stated preference studies in the sample. However, often these studies assume spatial homogeneity where spatial variation is not accounted for or model it as a single monotonic continuous function (Johnston et al., 2011) which may not be the case. The same author (Schaafsma, 2011) noted that users' preferences measuring in a CE are less responsive to distance decay compared to non-users, and that the non-users WTP declines at faster rate with the distance to the site relative to user's WTP. Johnston and Ramachandran (2014) examined more complex spatial patterns in stated WTP using local indicators of spatial association (LISA) to identify WTP hotspots. The same paper also found population density, measured at zip code level in the USA (local scale), was found to affect WTP. Higher population density was associated with a higher probability of hot spots for some attributes and a lower probability of cold spots for other attributes. Other studies have also studied heterogeneous spatial patterns related to stated WTP (Campbell et al. 2008, 2009, Johnston et al., 2015). Jørgensen et al. (2013) tested several different functional forms for distance decay in a CVM study for restoring Odense River in Denmark. In their study they the functional forms they tested include squared, exponential, logarithmic, and a range of different power functions but they found that a linear distance decay function performed the best. The same paper also found allowing for substitutes had an effect on distance decay with the further distance to substitutes increasing the WTP of respondents keeping distance constant, *ceteris paribus*.

The other spatial issue that has not been previously discussed in detail in the VT literature is the modifiable areal unit problem (MAUP). The MAUP, as identified by Openshaw and Taylor (1979), arises from the use of modifiable area units in quantitative analysis. These area units can take a variety of shapes or sizes. This causes complications with statistical analysis related to both scale and the method used to create the area units. It occurs through two effects, namely the scale effect when aggregation of high resolution (i.e. a large number of small areas) data to a lower resolution (i.e. a smaller number of larger areas) and the zoning effect spatial units to which the higher-resolution data are aggregated are arbitrarily created by some decision-making process (Reynolds, 1999). The scale issue is the complication in this chapter and arises due to the inclusion of population density as an explanatory variable. Goodchild et al. (1993) identified this as a particular problem for using population density as a socio-economic variable.

While population density is not commonly included within demand functions for public goods (maybe as a result of MAUP), a binary form of population density in the form of a rural/urban split has been used by some in various fields. The EU uses the OECD methodology (OECD, 2009) and classifies LAU2 with a population density below 150 inhabitants per km² as rural, it is often not clear how the decision was made to divide locations into urban and rural[19]. Several papers in economic valuation have noted that there does seem to be differences in WTP between areas of differing population density (Bergmann et al., 2008, Hensher et al., 2009). Ericsson et al., (2007) included human density in their WTP study on wolverine (*Gulo gulo*) conservation finding that the more urban the location, the higher the WTP. Population density has been also been used in meta-analysis VT and

[19] The EU has several spatial levels that demographic and socioeconomic data is reported at. These are termed Nomenclature of Units for Territorial Statistics (NUTS). Different types of data are reported at various levels. The highest level with the coarsest level of spatial detail is the NUTS1 regions that often have the greatest level of socio-economic data. These are either large areas of MSs or the entire MS itself for smaller EU members. The levels then go down to NUTS2, NUTS3, LAU1 and LAU2. As the spatial scale of the NUTS region increases the amount of socio-economic data available for that area decreases. Therefore, there is a trade-off in what level is acceptable in terms of spatial detail and socio-economic or demographic detail.

found to be positively related to WTP (Ghermandi & Nunes, 2013, Wright and Eppink, 2016).

Population density is calculated by dividing the population within an area by that area. It is assumed that the population is distributed evenly throughout the area. The population density effect is likely to only apply at a smaller spatial level e.g. LAU1 or LAU2. In this study, population density for each respondent is calculated based on their LAU2. However, most of the variables used for the VT exercise were only available at the higher NUTS3 level. This leads to the MAUP as identified by Goodchild et al. (1993[20]).

To further demonstrate this issue, the following is an example of a hypothetical value function transfer. Imagine a value function (function 6.4) where only three factors affect WTP for a marine ecosystem service; namely income (modelled as a log function), distance to the sea (based on distance from centroid of region to sea) and population density (modelled as a log function).

$$WTP = -70 + 27\ln(income) - 0.25 distance + 1.5\ln(population\ density) \qquad (6.4)$$

Now the region that the function is being transferred to is shown in figure 6.1 and comprises of rectangular region (10 x 3 km) beside the sea and home to 45 residents of varying income. As shown in scenario A, the function value transfer could treat the region as a whole, or in scenario B be divided into two parts or three in case of scenario C. The varying mean WTP results (Table 6.1) of applying the same function value transfer to the same population in the same region only differing in how the region is split up shows how the scale MAUP arises and is another issue practitioners of VT should be careful of.

[20] Imagine picking random people from a NUTS3 region and calculating the population density in their area. If the area is NUTS3, they all people from the same NUTS3 will have the same population density. However, imagine again picking random people from a NUTS3 region but this time their population density variable is based on the LAU2 region they are in. Then the odds of picking a person from a higher density area is higher due to its larger population. Therefore, the mean population density for a NUTS3 region based on LAU2 region as weighted by population will be higher. This spatial mismatch between data zones is the MAUP as the population density was calculated for Irish LAU2 in the survey data but the spatial unit for the VT exercise is the NUTS3 level.

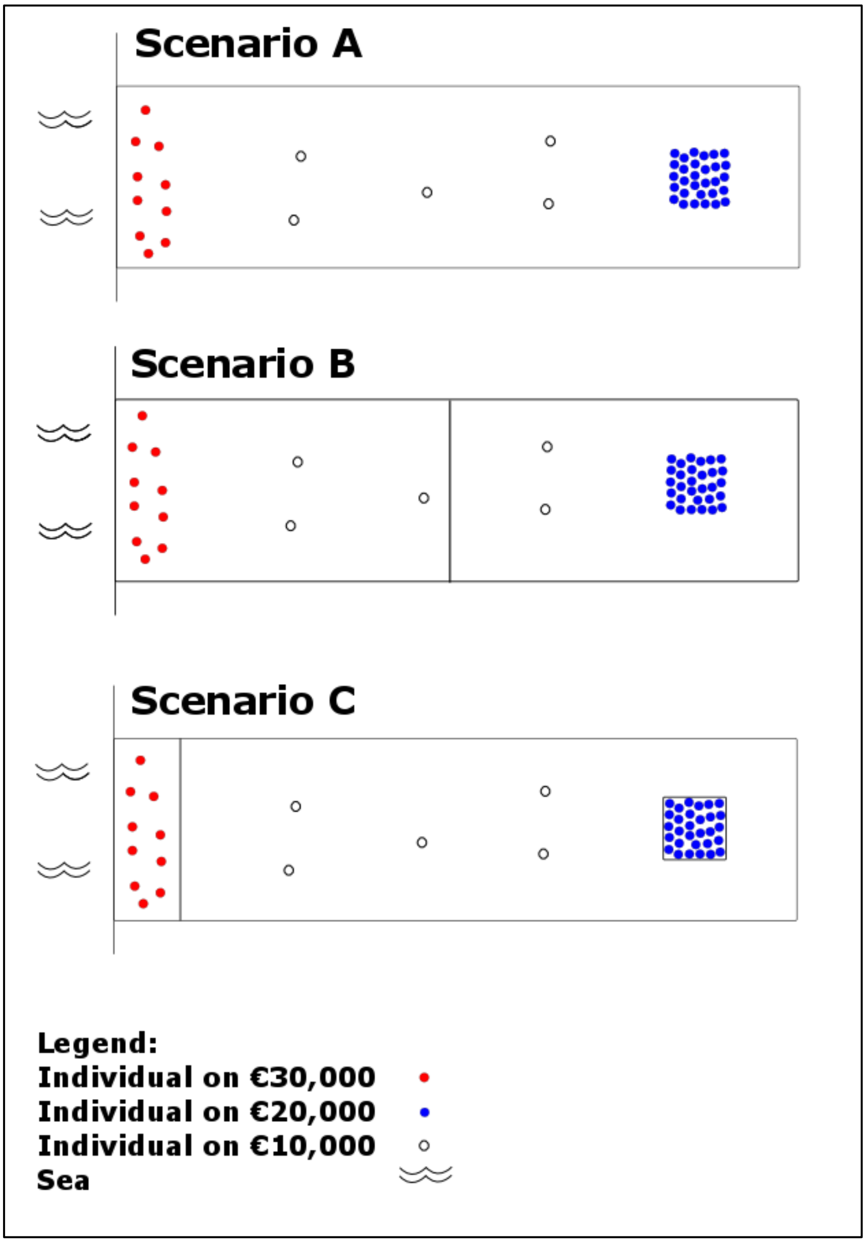

Figure 6-1. MAUP arising from hypothetical scenarios for VT to a hypothetical coastal NUTS 3 region

Table 6-1. Population weighted variables for scenarios in Figure 5.1.

Scenario	Population Weighted Variables			
	Income (€ ,000s)	Distance (km)	Population Density (persons km^{-2})	Mean WTP (€ $person^{-1}$)
A	21.1	5	1.5	11.69
B	21.1	6.05	1.76	11.37
C	21.1	7.04	20.76	13.00

6.4. Methodology

A survey was undertaken with 812 respondents throughout the Republic of Ireland. The details of this survey are detailed in chapter 3 of this thesis. This chapter covers the results of a CVM exercise. Further details on the CVM are detailed in section 1.3 of this thesis. The payment card (shown in figure 6.2) was presented to respondents and they were asked maximum WTP for GES after they had undertaken a CE to that is detailed in the next chapter (Chapter 7) of this thesis. The question was stated as follows *"Based on all the information you have heard so far and again remembering your income and budget, what would be the most that you would be willing to contribute as an annual cost towards achieving good environmental status in the seas around Ireland?"*

Nothing/€0		€25		€100	
€1		€30		€120	
€3		€35		€150	
€5		€40		€200	
€8		€45		More than €200	
€10		€50			
€12		€55			
€15		€60			
€18		€70			
€20		€80			

Figure 6-2. Payment card for the CVM exercise

The fact the respondent is asked to choose their maximum willingness to pay from the card the data generated through this method is treated as interval data. This means that although it is highly possible that the amount chosen by the respondent correspond directly to the amount on the payment card, (it was noted there were higher frequencies at euro note denominations) it is also possible that the amount chosen could also be between that amount and the next figure on the payment card. Additionally it is noted that there were several respondents that chose the '€200 or more' option meaning that these amounts are right censored. While the analysist could still employ OLS, using the midpoints of the intervals, Cameron and Hubbert (1989) suggest that interval regression model is a more appropriate model for this type of data as using OLS may lead to biased parameter estimates. For further detail the interested reader should consult Cameron and Hubert (1989). This model has previously been used to estimate WTP for reducing air and noise pollution (O'Garra & Mourato, 2007), offsetting carbon emissions from passenger flights (Brouwer et al., 2008) and for biodiversity conservation (Hynes et al., 2010).

The interval regression used 558 of the 812 available survey observations. Some 254 respondents gave zero values for their WTP that were classed as protest responses if they choose one of the following options, "I object to paying taxes; The Government/ County Council/EU or other body should pay; I don't believe the improvements will actually take place; Those who pollute the seas and ocean should pay; I didn't know which option was best, so I stayed with the "No Change" option; Don't know". A total of 184 zero bids were retained as legitimate responses. Two models were estimated that differ only in terms of the definition of distance to the coast. In model 1 the distance is modelled linearly. In model 2 the distance decay is measured using a log function that assumes that the WTP values decay exponentially.

Following the estimation of the two CVM WTP models, a VT exercise was undertaken where data based on the spatial unit of NUTS3 regions (See Table 6.2) was used. While the CV valuation exercise was restricted to Ireland, it was decided that VT would be used to estimate values for achieving GES across the Atlantic EU MSs.

It was decided that the NUTS3 level would be used as the spatial unit for the VT exercise due to the availability of the geographic variables of distance and population density to allow for heterogeneity within MSs; this was the finest scale that most data was readily available. Data was available from Eurostat or from its agglomeration of Census 2011 results from all MSs, CensusHub2 (ESS, 2016), or from individual MSs central statistics agencies (France -

INSEE, Spain - INE, Portugal - INE, Republic of Ireland - CSO, England and Wales - ONS, Scotland - NRS, Northern Ireland - NISRA). All data used was based on the year 2011 as this was the census year that most of the data was available. Income was adjusted using purchasing power parity (PPP) figures from the Penn World Table (Feenstra et al., 2015). The income data was only available at the NUTS2 level, and the attitudinal variables from the KNOWSEAS Project (Potts et al., 2011) were only available at the MS level. Table 6.2 details the source of each variable used in the VT exercise. Table 6.3 outlines the descriptive statistics for the NUTS3 variables. A graphical summary of the methodology is shown in Figure 6.3.

Table 6-2. Sources of data for the VT exercise

Variable	Geo. Level	Source
PPP Adjusted Income (€'000)	NUTS2	Eurostat (2011)
Married	NUTS3	CSO, INE (ES), INE (PT), INSEE, ONS (2011)
Children in the household	NUTS3	CSO, INE (ES), INE (PT), INSEE, ONS (2011)
Has third level education	NUTS2	Eurostat (2011)
Male	NUTS3	Eurostat (2011)
Age (years)	NUTS3	Eurostat (2011)
Distance from the coast	NUTS3	QGIS - Own calcs.
Rated ocean health as important or very important	Member State	Knowseas (2010-2011)
Log of population denisty (LAU2 level)	NUTS3	Eurostat (2011)
Agreed or strongly agreed with Marine Protected Areas	Member State	Knowseas (2010-2011)
How competent is the government to manage and protect the marine waters	Member State	Knowseas (2010-2011)

Table 6-3. Descriptive statistics for all NUTS3 regions (5 MSs) used in the VT exercise.

VT Exercise NUTS3 Variables (n=332)	Mean	Standard Deviation
Income (€'000)	25.43	6.82
% Married	0.49	0.05
% people living with children in the house hold	0.32	0.07
% with third level education	0.25	0.07
% Male	0.49	0.01
Mean Age (>17years)	48.02	2.59
Distance from the NUTS3 centroid to the coast (km)	84.01	94.36
Population density (NUTS3 level) (persons km^{-2})	768	1838
% that rated ocean health as important or very important	0.47	0.13
% that agreed or strongly agreed with marine protected areas (MPAs)	0.75	0.07

To investigate the MAUP scale effect in relation to population density, two different scales were used to measure population density, the first was the NUTS 3 population density and the second was population weighted LAU2 population densities aggregated for each NUTS3 region. For both, population density was calculated at the NUTS3 level then log transformed. In the regression models 1 and 2, the log transformed population density was calculated based on NUTS3 regions. Models 3 and 4 use the same coefficients as models 1 and 2 respectively but population weighted LAU2 population densities aggregated for each NUTS3 region were used instead. Table 6.4 compares the different population density measures and their values for Irish NUTS3 regions for the interval regression and the VT exercises. The MAUP issue seems to be a bigger issue for rural areas compared to the large urban agglomeration of the Dublin NUTS3 region.

Table 6-4. Population weighted natural log of population density for Irish NUTS3 regions based on this survey, NUTS3 data and LAU2 data.

NUTS 3	Survey (n=812)	NUTS3 (Ireland) (n=8)	LAU 2 (Ireland) (n=3409)
Dublin	8.38	7.23	8.35
Mid-West	6.41	3.87	6.59
Mid-East	6.13	4.48	6.38
Border	6.34	3.76	6.01
South-East (IE)	7.02	3.98	6.47
South-West (IE)	7.05	4.00	6.92
West	5.66	3.48	6.20
Midland	6.23	3.78	5.92

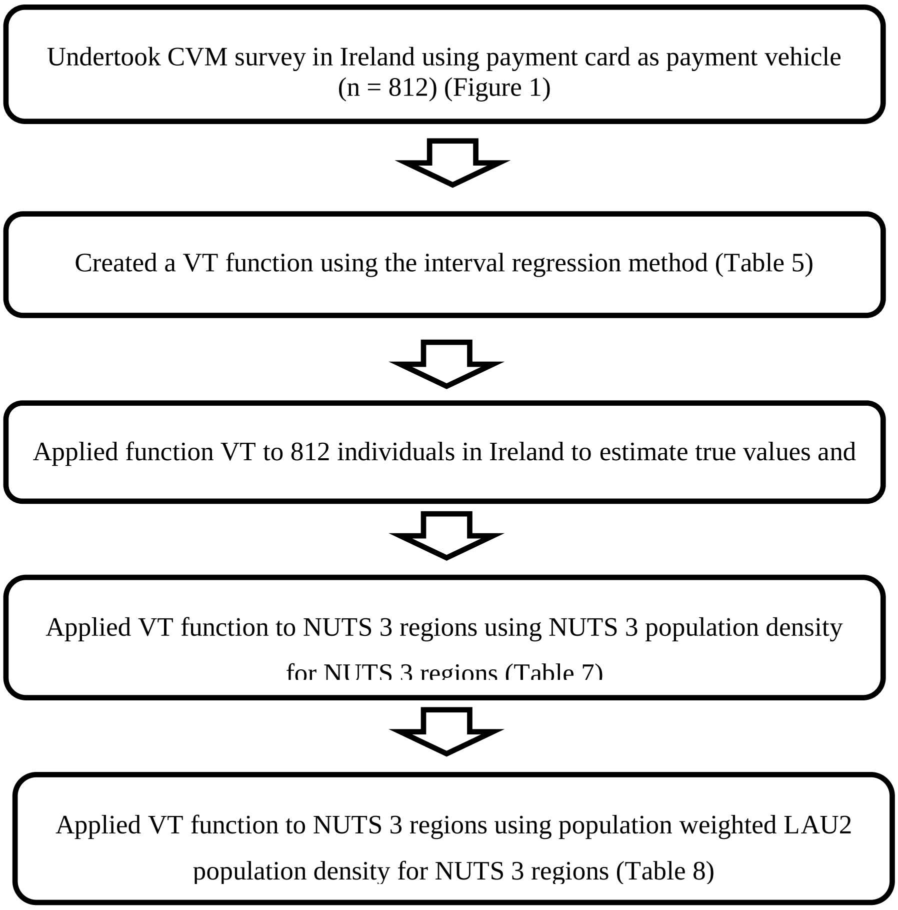

Figure 6-3. Flowchart of the steps undertaken during the valuation process.

6.5. Results

Table 6.5 presents the results of the interval regression models. WTP to achieve GES per annum over ten years is used as the dependent variable. Two models were estimated that differ only in terms of how distance to the coast was specified. In model 1 the distance is modelled linearly. In model 2 the distance is measured using a log function. Figure 6.4 shows how the values decline over distance between the models, *ceteris paribus*.

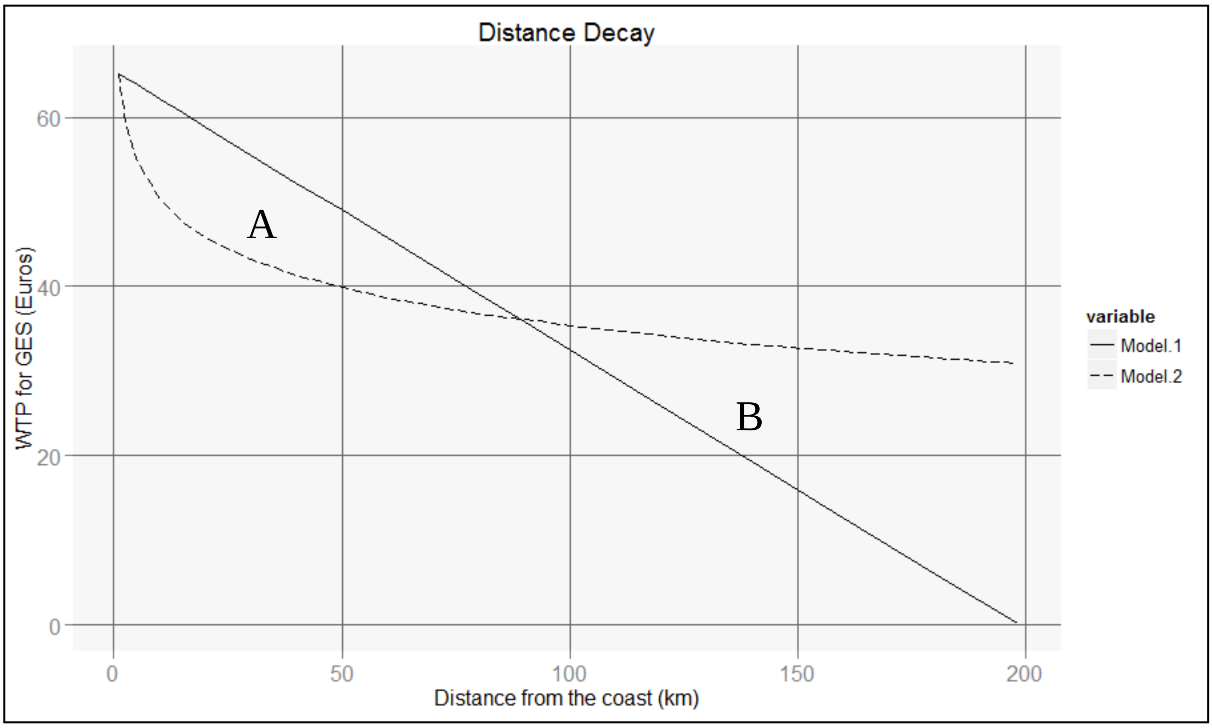

Figure 6-4. Distance Decay for Model 1 and Model 2

Most of the parameters are of the expected sign and the coefficients are very similar in both models (apart from the distance decay variable)[21]. WTP for GES increases with income interacted with log natural of population density and is significant. The log natural of population density interacted with age is also positive and significant.

Having children in the household increases the WTP in both models (Model 1 - €5.46, Model 2 - €5.55); this is thought to represent part of the bequest element of non-use value,

[21] The coefficient results from the interval regression model can be interpreted in the same manner as an OLS model (Mahieu et al., 2012).

households with children may consider the state of the environment that their children will inherit. However, it is noted that this variable is insignificant. Males also tend to have a higher WTP and respondents who are married have high negative WTP that is also highly statistically significant. Age was modelled as a quadratic function and the linear element is significant and negative but as previously noted age is interacted with the natural log of population density and is positive.

Table 6-5. Interval regression models for WTP for GES in Irish marine waters.

	Model 1- Linear Distance Decay	Model 2- Exponential Distance Decay
Ln of Income (€1,000's)	-2.95 (10.60)	-5.61 (10.60)
Ln of Income x ln pop. density	4.88 (1.56) ***	5.07 (1.57) ***
Married	-8.73 (3.89)**	-8.43 (3.91)**
Children in the house hold	5.46 (3.43)	5.55 (3.45)
Has third level education	-5.90 (7.02)	-5.28 (7.05)
Third level education x ocean health	19.46 (7.60)***	19.83 (7.64)***
Male	7.15 (2.89) ***	6.95 (2.90)***
Age (years)	-1.18 (0.63)**	-1.14 (0.59)**
Age^2 (years)	0.01 (0.01)	0.01 (0.01)
Distance from the coast (km)	-0.25 (0.07) ***	
Ln of distance from the coast (ln (km))		-3.73 (1.38)***
Ln of population density (LAU2 level)	-18.89 (5.31)***	-19.43 (5.34)***
Ln of pop density x age	0.11 (0.04)***	0.11 (0.04)***
Rated ocean health as important or very important	6.93 (4.13)*	7.16 (4.16)*
Agreed or strongly agreed with Marine Protected Areas	6.17 (3.01)**	5.06 (2.99)*
Constant	57.96 (36.78)	68.74 (17.90)
Log Likelihood	-2117.02	-2120.04
AIC	4266.03	4272.07
BIC	4335.22	4341.26
n	558	558

Standard errors in brackets; * indicates significant at 10%, ** indicates significant at 5%, *** indicates significant at 1%.

Examining the two spatial variables, distance decay and population density, it can be seen that in both models they are highly statistically significant. The distance decay variable in both models is negative as expected. The linear model suggests that WTP decreases by

€0.25 per km. The log of population density is shown to have a positive effect when interacted with age and incomes, indicating that older, higher income residents living in higher density areas have a higher WTP.

Examining the attitudinal variables, the highest marginal impact on WTP was found for third level education interacted with rating ocean health as important or very important (based on a five point Likert scale) (model 1 - €19.46, model 2 - €19.83). Those who rated ocean health as important or very important without a third level degree also have a positive WTP. Those who agreed or strongly agreed with marine protected areas also have a positive marginal WTP which is statistically significant in both models.

In terms of which model performs better, model 1 (the linear distance decay) was found to have a smaller AIC and BIC and a larger log-likelihood. However, model fit should not determine which model is best for VT. Bateman (2009) noted the phenomenon whereby unit VTs often outperform function VTs as measured by transfer errors could be due to researchers typically transferring statistical best fit functions, a problem that could be mitigated through the use of functions that were derived solely from theoretical principles.

Table 6-6. Mean WTP per person predictions for each NUTS3 region in Ireland

NUTS3	n	Model 1	Model 2	Difference
Ireland	812	€29.83 (0.63)	€29.92 (0.62)	-0.31%
Dublin	231	€38.31 (1.29)	€37.91 (1.29)	1.06%
Mid-East	72	€26.55 (2.01)	€25.62 (2.03)	3.65%
Midlands	64	€22.28 (1.76)	€28.70 (1.74)	-22.35%
South-East	112	€28.13(1.58)	€27.59 (1.55)	1.96%
South-West	96	€30.81 (1.70)	€28.82 (1.68)	6.88%
Mid-West	69	€21.50 (1.48)	€22.67 (1.42)	-5.19%
West	80	€27.34 (1.97)	€27.75 (1.88)	-1.49%
Border	88	€25.64 (1.76)	€25.19 (1.76)	1.76%

Standard error in brackets.

The estimated value for the average Irish individual's WTP to achieve GES was €29.83 in model 1 and €29.92 in model 2; a difference of 0.3%. It varied from a high of €38.31 for the Dublin NUTS3 region (model 1) to a low of €21.50 (model 1) for the Mid-

West NUTS3 region. The models predicted the same values for all NUTS3 regions at the 95% confidence level except for the Midlands NUTS3. A t-test shows significant difference at the 95% level (p= 0.0035).

Examining the results from the VT exercise it is noted that where the VT exercise generated negative values, the WTP was set at zero. Table 6.7 presents the results from the VT exercise. It shows the population weighted mean value for the five Atlantic MSs and the aggregated values for each MS. Both Ireland and Portugal have the highest individual WTP's in both models and this is followed by UK in model 1. However, model 2 shows that French individuals have a higher WTP compared to the average UK resident. Model 2 produces higher WTP estimates than model 1for three MSs; Ireland and Portugal being the exceptions.

Table 6-7. Mean WTP per person and in aggregate from VT exercise for each MS

Member State	Mean (Pop. Wt.)	Mean (Pop. Wt.)	Total (millions)	Total (millions)
(NUTS 3 n)	Model 1	Model 2	Model 1	Model 2
Ireland (8)	€25.50	€24.62	€87	€84
UK (139)	€19.88	€20.22	€989	€1,006
France (96)	€12.27	€22.37	€604	€1,101
Spain (59)	€12.36	€16.85	€475	€648
Portugal (30)	€24.78	€24.14	€214	€209
			€2,371	€3,048

At the aggregate level, model 2 produced higher estimates for achieving GES than model 1. Model 1 estimates that the aggregated annual WTP for achieving GES in Atlantic MSs is €2.4 billion compared to over €3 billion for model 2. However, there is nothing to say which functional form of distance decay is more accurate.

Examining the results for the VT exercise across the five MSs whilst adjusting for the MAUP increases the overall value of GES across the five North-East Atlantic MSs to €2.78 billion using model 3 and to €3.64 billion using model 4, an increase of 12.7% and 14.1% respectively over the standard models 1 and 2. Table 6.9 shows the percentage differences for the alternative distance decay specifications and the MAUP. The difference between linear and logarithm distance decay specification was mixed ranging from -3% to 82%. Interestingly, while most MSs had similar results between the MAUP and non-MAUP, for

Spain using the population weighted LAU2 population densities increased the differences due to the distance decay function specification. The MAUP adjustment caused an increase of between 13% (Portugal, Model 3) and 25% (France, both models) in the estimated WTP values with a mean increase in WTP of 17%. Portugal had the lowest level of adjustment and that is thought to relate to the high number of NUTS3 regions relative to its population (352,072 persons per NUTS3 region) which is less than 45% that of Spain (793,490 persons per NUTS3 region). However, there may be other factors, such as the heterogeneity of population density, affecting the adjustment rate as this relationship does not hold for all MSs. Figure 6.6 shows the relationship between predicted WTP per person (based on Model 4) and population density showing somewhat of a positive trend between the two.

Table 6-8. Mean WTP per person and in aggregate from VT exercise for each MS with MAUP adjustment

Member State	Mean per person (Pop. Wt.)	Mean per person (Pop. Wt.)	Total (millions)	Total (millions)
	Model 3	Model 4	Model 3	Model 4
Ireland	€29.14	€28.48	€100	€98
UK	€22.68	€23.17	€1,128	€1,152
France	€15.29	€27.88	€752	€1,372
Spain	€14.58	€20.34	€560	€782
Portugal	€27.99	€27.66	€235	€239
			€2,783	€3,644

Table 6-9. Percentage differences between estimates for different distance decay and MAUP specifications

Member State	Difference between linear and logarithm distance decay specification			Difference between NUTS 3 and LAU 2 population density measures		
	Model 1 vs Model 2	Model 3 vs Model 4	Mean difference	Model 1 vs Model 3	Model 2 vs Model 4	Mean difference
France	82%	82%	82%	25%	25%	25%
Ireland	-3%	-2%	-3%	14%	16%	15%
UK	2%	2%	2%	14%	15%	14%
Spain	36%	40%	38%	18%	21%	19%
Portugal	-3%	-1%	-2%	13%	15%	14%
Absolute means			25%			17%

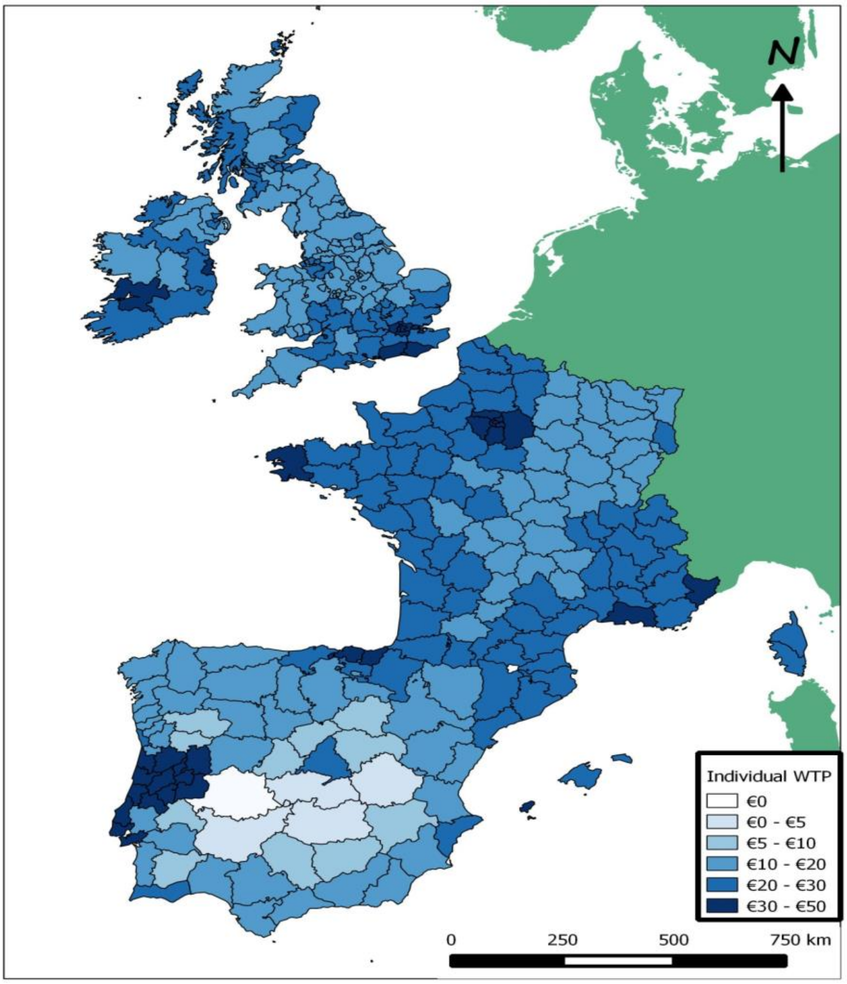

Figure 6-5. Map of estimated individual's WTP to achieve GES in their nation's marine waters using model 4. (Created using QGIS).

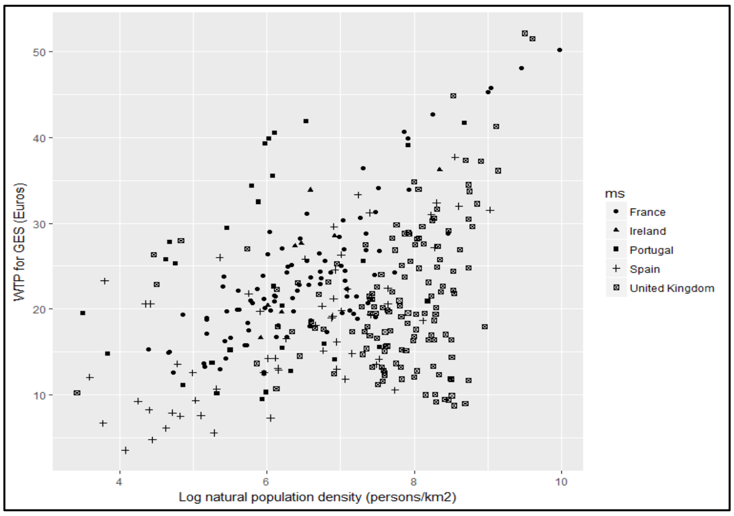

Figure 6-6. Change in predicted WTP for GES (Model 4) of NUTS3 regions along the population density gradient.

6.6. Discussion and conclusion

This chapter presented the results of a CVM exercise undertaken in Ireland on the WTP of the Irish public to achieve GES as described in the MSFD. The results provide estimates of the non-market benefits generated by the implementation of the MSFD for possible use in CBA required under article 13 of the MSFD. The results could also be used to determine if there is evidence of disproportionate costs of measures as required under article 14 of the MSFD. The model results show that respondent's income, education, age and attitudes are important factors in determining WTP as well as the spatial factors of distance to the sea and their region's population density.

There was no clear choice of the functional form of distance decay to use based on the comparison in Table 6.5 and Table 6.9. Based on the model fit it would appear that model 1 (linear distance decay) was the better choice, but model 2 (exponential distance decay) performed nearly as well. Population density has the biggest negative effect but is also included in two interaction terms, income and age, which are both positive. It is likely that urban areas, which usually have higher incomes and higher population densities, will have the highest values of WTP. Overall as shown in figure 6.6, there is positive relationship WTP for GES and population density. It is difficult to suggest a reason for this relationship but it is worth further investigation. Salka (2001) and Rodden (2010) suggest that environmental concerns have become a social and political issue in the rural/urban divide but there is not enough evidence in our survey to support this hypothesis.

The mean WTP generated by both models 1 and 2 are similar (Model 1 - €29.83, Model 2 - €29.92). These are at the lower range of the biodiversity values reported by Ressurreição et al. (2012) and by Carson et al. (2003). They are significantly higher than the values estimated by Solomon et al. (2004) for the protection of the Florida manatee and of a similar range to that reported by Machado and Mourato (2002) for clean bathing water. Comparing the CVM values estimated in this chapter to the costs of implementing GES is difficult as many countries are currently fully implementing older EU environmental directives first before applying any new measures. It is uncertain to see if this changes under the new Commission Decision based on a risk based approach to measuring GES (EC, 2017) which supersedes the previous commission decision on GES (EC, 2010). There is also a data gap with respect to costs involved in implementing the MSFD (Bertram et al., 2014).A study by Börger et al. (2016) estimated that the cost of the Finnish programme of measures to achieve GES based on work by Oinonen et al. (2016b) would be €136.2m compared to the estimated benefits of reaching GES yielding benefits to the Finnish population of €300–894 m (Mean WTP per person – €54.7 – 163).

Primary valuation studies on marine ecosystem service benefits resulting from implementation of the MSFD are important for use by decision makers working to achieve GES. Although it was hoped that there would be an increase in the number of studies related to the directive similar to those carried out after the introduction of the WFD (see for example Moran & Dann, 2008, Martin-Ortega and Berbel, 2010, Doherty et al, 2014, Brouwer et al., 2015),this has yet to happen. This is disappointing as introduction of the WFD saw the number of related valuation studies increase and a greater potential to use VT as a cost-effective tool (Bateman et al, 2011, Norton et al. 2012).

Looking at the VT exercise in this study, the main reason for Ireland and Portugal having such high WTP values to achieve GES is due to the high Likert scale rating that both MS respondents gave for ocean health in the EU Knowseas project. The high income in the Irish case and the high population density in the coastal area of Portugal, coupled with the closeness of the all NUTS3 regions in both countries to the coast also feed into the higher WTP estimates in each case. The biggest difference between models is for France (82%). This is thought to relate to the fact that most NUTS3 regions across Europe fall into area A in figure 6.4 but the French NUTS3 regions (especially around the Paris region) fall into area B. The reason is thought to relate to the high incomes and high population density around Paris resulting in higher WTP estimates compared to the lower value NUTS3 regions closer to the coast. A similar but less extreme story can be used to explain the differences between models for Spain (36%).

The spatial variables show different effects on the predicted WTP with large variations in values (-1% to 82%) produced particularly for the distance decay effect which had a mixture of positive and negative effects depending on the functional specification used. The latter value exceeds the transfer range of 20%-50% suggested by Brouwer (2000) and is over double the median of 39% found by Kaul et al. (2013). The MAUP adjustment showed a smaller adjustment, an increase by an average of 17% using the population weighted LAU2 population densities and is most likely an improvement as seen from the estimates generated for Ireland but still the MAUP may be an insolvable one (Sheppard and McMaster, 2004). The results highlight that while GIS may add more data and address some issues, used incorrectly in VT, may lead to poor estimates. Practitioners of VT should be cognisant of the

MAUP when using density variables at different scales and with respect to distance measurement if there is any reason to suspect that socio-political units being used have been gerrymandered as shown here, it can have a significant effect on aggregated results.

However, the use of GIS should not be dismissed. Tompkins and Southward (1999) noted that one of the benefits of GIS is its ease in presenting large volumes of data in spatial manner to policymakers and other stakeholders as well as allowing for linkages between research, policy and practice. An example of this is a map of estimated individual's WTP to achieve GES in their nation's marine waters using model 4 is shown in figure 6.5. This map clearly shows the distance decay effect, especially for France and Spain, indicating that large swathes of both nations may have lower WTP values for the marine environment.

Another issue that arose surrounds obtaining socio-demographic data. While, much of the data was standardised and available either at Eurostat (EC, 2016) or through CensusHub2 (ESS, 2016), some MSs still have not made all their data available on these platforms. Future initiatives by such projects as the EU MARNET project (Foley et al., 2014) which collates and makes available a variety of comparable demographic and socio-economic data at a regional scale across the Atlantic member states (and in particular in the marine and coastal areas) may be alternative source of data for those undertaking similar functional VT exercises in marine related areas.

Additionally, there may be strong reservations about the robustness of using the values generated in a single stated preference study as the basis for a value transfer exercise, particularly when these have been collected in one country but are applied internationally. We also note that since this study there has been a limited amount of work on non-market valuation exercises related to the MSFD. The EU Commission in its review of implementation of the MSFD (EC, 2014) found inadequacies in Member States' first assessments submitted to the Commission. In particular they commented on the many data gaps and that in many cases the environmental targets set out by the MSs were not sufficient to achieve good environmental status. We note that the results of this study should not be interpreted as a definitive estimate of the benefits of achieving GES in EU Atlantic MSs but instead spur on further study on the value of achieving the targets set out in the MSFD and fill in these data gaps.

This valuation exercise using VT shows that there are significant values attached to achieving GES in MSs' waters. We estimate the value of achieving GES for Atlantic MSs is between €2.3 billion and €3.6 billion per annum for marine areas within these MSs but again note that there is a high level of uncertainty associated with these values. As this chapter demonstrates, there are still issues with the approach in terms of how much variability the VT function capture, the specification of the model, the spatial level at which data is obtained and the level at which it is applied. Those caveats aside, decisions that could affect the quality of coastal and marine ecosystems and the ecosystem services they generate are routinely made without taking into account any of the non-market benefits that would be foregone if the environmental quality of these ecosystems deteriorated. Better decision making could be achieved if both the level and accuracy of information on the non-market benefits of maintaining or achieving high environmental quality were improved for use in VT exercises such as that carried out in this study.

Chapter 7

Valuing the non-market benefits arising from the implementation of the EU Marine Strategy Framework Directive

7.1. Introduction

The European Union (EU) adopted the Marine Strategy Framework Directive (MSFD) (EC, 2008) in February 2008. The Directive is aimed at achieving, or maintaining, good environmental status (GES) of Europe's marine and coastal waters, as measured by 11 descriptors, by the year 2020. Article 8.1 (c) of the Directive calls for 'an economic and social analysis of the use of those waters and of the cost of degradation of the marine environment'. This element of the directive will therefore require member states to estimate the value associated with changes in the environmental state of their marine waters that come about as a result of the implementation of the MSFD. As pointed out by Turner et al. (2010), the MSFD is 'informed' by the Ecosystem Management Approach, with GES interpreted in terms of ecosystem functioning and services provision. It is considered to be the first attempt to undertake an ecosystem management approach to protect and maintain the marine environment while ensuring that marine based activities are sustainable (Long, 2011). This ecosystem approach can also be considered a more holistic approach toward water body management compared to what has been perceived as a more prescriptive approach taken by previous water body related directives such as the EU Water Framework Directive (WFD), (EC, 2000) Bathing Water Directive (CEC, 1976) and the Urban Waste Water Directive (CEC, 1991) (Borja et al. 2010).

Marine and coastal waters provide a variety of benefits to society generated through ecosystem goods and services (Ledoux and Turner, 2002). Some of these goods are valued by the market (such as fishing and aquaculture) but others, which are still valuable to society, are not captured by the market. These non-market goods and services are valued for the regulating functions they provide such as carbon sequestration, waste treatment and storm and flood protection in addition to cultural values such as recreation, aesthetic values and spiritual values (TEEB, 2010). These non-use values attached to the marine environment are considered to be a significant proportion of the total economic value of the benefits arising from the introduction of the MSFD (Bertram and Rehdanz, 2012) and substantial non-use values have been noted for changes to a broad range of environmental goods (Stevens et al, 1991, Bateman and Langford, 1997). TEEB (2010) also identifies non-use values that are not captured by the market and instead can only be estimated through the use of stated preference techniques such as contingent valuation (CV) and choice experiment (CE) methodologies.

Through the use of such stated preference techniques, estimates can be made of the additional non-market ecosystem service benefits that implementing the MSFD may provide[22]. Different economic valuation methodologies can be used to value non-market benefits accruing from the implementation of a marine environmental policy by assessing the public's willingness to pay for the outputs from such a policy as a whole or by modelling the preferences of society for the change in the component ecosystem services that result from the implementation of the policy. CE, for example, deal more explicitly with how society values relate to individual marine ecosystem related attributes, and combinations of attributes, while the CV method takes a more holistic approach by focusing on the value of (inter alia) moving from the status quo policy situation to an alternative where the marine environment is enhanced under a marine environmental policy. While both CV and CE can be used to estimate the value of improving the status of the marine environment, the CE approach has the advantage of being capable of measuring the marginal value of a change in the individual marine ecosystem services that are impacted by the policy (e.g. separate marginal values of improvement to benthic health, of enhanced recreation opportunities and of sustainable fish stocks) while a CV can usually only be used to value of the final specified change (e.g. value of achieving GES in marine waters) in the marine environment.

It should be noted that primary non-market valuation studies have previously been undertaken in connection with several EU policies concerned with coastal and marine ecosystem services. Georgiou et al. (2004) undertook a CV exercise examining the benefits of coastal water bodies meeting the EC Directive on Bathing Water (CEC, 1976) and the ecosystem service values resulting from changes to the same Directive were examined using a choice experiment by Hynes et al. (2013b). Östberg et al. (2012) also undertook a CV study examining coastal water quality, boat noise and litter in coastal waters. These studies show that stated preference techniques using primary valuation methodologies can play a crucial role in helping policymakers to implement EU directives within the aquatic environment (i.e. revised Bathing Water Directive (EC 2006), the WFD and the MFSD).

[22] Hynes et al. (2013a) and Brenner et al. (2010) used value transfer to estimate the value of various marine and coastal ecosystem goods and services within Galway Bay on the West coast of Ireland and the Catalan Coast respectively. These studies demonstrated that coastal and marine ecosystems generate large benefits but such secondary techniques are dependent upon a constant flow of primary estimates for these values, which in the case of marine ecosystem services are relatively scarce.

Further offshore, Armstrong et al. (2012) present a categorisation and synthesis of deep-sea ecosystem goods and services, and review the current state of human knowledge about these services, the possible methods of their valuation, and possible steps forward in its implementation.

Elsewhere, Eggert and Olsson (2009) used a CE with the attributes of coastal cod stock levels, bathing water quality levels, and biodiversity levels to estimate the values of changes in these aspects of a coastal marine ecosystem. Examining the offshore ocean, Jobstvogt et al. (2014) used CE to estimate the values attached to additional marine protected areas in the Scottish deep-sea which included attributes for deep-sea biodiversity and the potential of new medicinal products. McVittie and Moran (2010) also used a CE to estimate the non-use values associated with the introduction of marine conservation areas within the UK. The attributes in that study included biodiversity, environmental benefits (such as CO_2 sequestration, water treatment and recreation) and restrictions to fishing and marine extractive industries. The authors argued that non-use values compose a large segment of the values associated with changes to marine environment due to their spatial remoteness relative to other ecosystems.

Several studies have also attempted to analyse the diversity within the marine and coastal ecosystem service valuation literature. Remoundou et al. (2009) for example undertook a review of valuation studies related to coastal and marine goods within the Black Sea and Mediterranean regions; finding thirteen relevant studies. Most of the studies were undertaken using the CV method (n=6) while two valuations used the CE method. They noted that further valuations are needed both for use and non-use marine and coastal goods and the potential for valuations to assist with policy and governance related to these resources. In another paper, Ghermandi and Nunes (2013) examined the welfare impact of the recreational services provided by coastal ecosystems. The authors constructed a global database of primary valuation studies that focus on recreational benefits of coastal ecosystems and then build a meta-analytical framework using a Geographic Information System that allowed for the exploration of the spatial dimension of the valued ecosystems, including the role of spatial heterogeneity of the selected meta-regression variables.

Valuation studies have also been carried out that examines the non-market benefits associated with the implementation of the WFD. Bateman et al. (2009) for example used CV across five northern European countries to estimate the increased welfare associated with improvements in river water quality. Elsewhere, Brouwer et al. (2010) used a CE to value improvements in water quality in Spain while Hanley et al. (2006) and Stithou et al. (2012) used a CE to estimate values associated with improved river ecology in catchments in the UK and Ireland respectively.

In this chapter, we add to the above literature by using the CE methodology to estimate the value of the non-market ecosystem service benefits associated with the achievement of good (marine) environmental status (GES) as specified in the EU Marine Strategy Framework Directive (MSFD). A novel feature of this research is that that the measures of meeting the MSFD, namely the 11 GES descriptors outlined within the Directive, were used to generate the attributes used in this CE. As such, this chapter presents the results of the first study to attempt to value the 'Cost of Degradation' of the marine environment as set out in the MSFD. In what follows section 7.2 provides a description of the MSFD and briefly reviews the requirements for the valuation of marine ecosystem services within the directive. Section 7.3 then describes the CE methodology that is used to estimate the value of achieving GES in Irish marine waters. Section 67.4 discusses the generation of the choice attributes and levels used in the application of the CE and other details related to the survey instrument. Section 7.5 presents the results and some discussion and conclusions are presented in Section 7.6.

7.2. The Marine Strategy Framework Directive

In trying to balance the demands on the marine environment with ensuring the sustainability of marine resources for future generations, the EU has put in place the Marine Strategy Framework Directive (MSFD) (2008/EC/56). The directive establishes a legally binding framework within which Member States shall take the necessary measures to achieve or maintain good environmental status in the marine environment by the 2020 at the latest. It is similar in scope and objectives to the Water Framework Directive (WFD) (2000/60/EC) and provides a framework model for achieving its aims rather than following a prescriptive approach. The MSFD allows for the interaction of plans with the WFD where there is coastal zone water bodies covered by both directives (but not transitional waters). The MSFD therefore complements the efforts of the WFD within the coastal zone.

The MSFD requires that EU member states (MSs) achieve GES in their waters by protecting, maintaining and preventing deterioration of the marine ecosystems and by preventing polluting inputs being introduced into the marine environment (Art. 1). This is to be achieved by developing and implementing strategies (Art. 5.1) that employ an ecosystem-based approach to the management of human activities in marine waters. GES is defined in the directive using 11 descriptors. A brief description of each descriptor is shown in Table 7.1. These descriptors have been further defined by Commission Decision (2010/477/EU). A marine water body is said to be at GES when all descriptors are at favourable levels. However, a recent report from the commission (EC, 2014) regarding the first phase of implementation of the MSFD found that the "*quality of reporting varies widely from country to country, and within individual Member States, from one descriptor to another*".

Table 7-1. MSFD Descriptors of GES

1.	Biological diversity is maintained, including sufficient quality and quantity of habitats and species.
2.	Marine food webs occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of each species.
3.	Healthy stocks of all commercially exploited fish and shellfish which are within safe biological limits.
4.	Contaminants in fish and other seafood for human consumption do not exceed unhealthy levels.
5.	Concentrations of contaminants are at levels not giving rise to pollution effects.
6.	Human-induced eutrophication is minimised.
7.	Marine litter does not cause harm to the coastal and marine environment.
8.	Non-indigenous species introduced by human activities have minimal affect on native ecosystems.
9.	Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded.
10.	Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.
11.	Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

Additionally, knowledge gaps were found across many countries in relation to data relevant to the 11 GES descriptors and a lack of data which could provide a baseline in which to measure change towards GES was also highlighted. Amongst its recommendations, the EU commission report indicated a need to review and improve the current Commission Decision Document 2010/477/EU by 2015 to produce a clearer, more coherent and comparable set of GES criteria that could also include the impact of climate change on GES.

The need to estimate the value of the benefits from achieving GES is driven by several elements required under the MSFD. The MSFD refers to the “costs of degradation”, which has been taken to mean the benefits foregone if the MSFD is not implemented. Bertram and Rehdanz (2012) identified the four main requirements for the valuation of ecosystem service benefits within the MSFD. These are:

- Initial assessment of a Member States' marine waters, including economic and social analysis (ESA) of the use of those waters, and of the cost of degradation of the marine environment (Art.8.1(c) MSFD).
- Establishment of environmental targets and associated descriptors describing GES, including due consideration of social and economic concerns (Art.10.1 in connection with Annex IV, No. 9 MSFD).
- Identification and analysis of measures needed to be taken to achieve or maintain GES, ensuring cost-effectiveness of measures and assessing the social and economic impacts including cost-benefit analysis (Art.13.3 MSFD).
- Justification of exceptions to implement measures to reach GES based on disproportionate costs of measures taking account of the risks to the marine environment (Art.14.4 MSFD).

Also, it has been shown throughout the literature that non-use values can form a significant portion of the total economic value of the marine environment to society (McVittie and Moran, 2010, Bertram and Rehdanz, 2012). It should also be noted that while any costs associated with implementing elements of the MFSD may be relatively easy to determine (e.g. through foregone revenues or costs of monitoring rules), the estimation of benefits may be more difficult and costly to determine. As is evident from the brief review of the literature in section 7.1, the CE approach is a suitable methodology to estimate the non-use value of improvements to the marine environment as required under the MFSD and has been used previously both to estimate the values associated with changes to the marine environment and other EU directives. The presentation of the 11 descriptors in the Directive is laid out in a manner that also them suitable attributes to be considered for inclusion in the CE.

7.3. The Choice Experiment (CE) Method

Stated preference techniques are the only methodologies that can be used for estimating both the use and the non-use value of a change in the environment. As mentioned previously, it is expected that a significant portion of the benefits arising from the implementation of the MSFD will be associated with the non-use values of protecting the marine environment due to the large spatial area covered by the directive and the low number of users of marine ecosystems relative to many users of terrestrial ecosystems. The use of stated preference techniques such as CE or the CV method will therefore be required to estimate the welfare impacts resulting from the environmental improvements that are expected under the directive.

The CV method derives values of a non-market good or service by presenting people with a hypothetical situation in the form of a questionnaire. The values are ‘contingent’ on the respondent’s willingness to pay or willingness to accept a change to the good or service being valued (Ryan and Watson, 2008). This methodology is widely used to value stated preferences for environmental goods (Bjornstad & Kahn, 1996). An alternative to the CV method, and the tool used in this chapter, is the CE approach where instead of a change in one attribute, the good is broken down into several attributes, each with their own levels (Haab and McConnell, 2002)[23]. Respondents are then asked to choose between different sets of these attribute levels. By including a price attribute within the choice sets, the value of a change between different levels of an attribute can be estimated[24].

Both CV and CE have an advantage over revealed preference methods of valuation (such as the travel cost and hedonic price methods) in that they can handle both use and non-

[23] The CE method offers more flexibility compared to the CV method as it allows the environmental change to be broken down into several attributes and the different levels that they could take. Including a monetary amount at various price levels can allow a willingness to pay (WTP) for marginal changes to each of the attributes to be measured. Scenarios related to changes in the environment can be constructed and WTP for each of these can then be compared. A disadvantage compared to the CV method is that the CE method requires more of the respondents, both in terms of time and cognitive ability in answering the survey and is more complex and time consuming to analyse.

[24] For a further in-depth examination of the CE methodology and its application to policy the interested reader is directed towards Birol & Koundouri (2008).

use values and also the different types of non-use values. Non-use values can be decomposed into several types; an existence value where the person holds a value for the maintenance of the marine waters in a healthy state regardless of their use, a bequest value where the value arises from being able to pass on the marine waters in a healthy state to future generations and an altruistic value where the value is generated from knowing that other people (including one's family and friends) may benefit from the use of a healthy marine ecosystem. However, respondents to stated preference surveys may also be motivated by other factors including potential or current use of the marine environment.

Stated preference techniques can handle all of these categories of use and non-use and, as previously discussed, have been employed for a variety of valuation exercises within the environmental economics field (Atkinson et al., 2012, Hanley and Barbier, 2009). Their use for decision making within policy has also been generally accepted (Arrow and Solow, 1993) and the results from stated preference methodologies are often used in conjunction with other data to guide the environmental decision making process. This section follows on from section 1.3 of this thesis.

The use of the CE methodology originated within the spheres of marketing and transport research (Louviere and Woodworth, 1983; Louviere, 1988) but has spread to other policy areas including environmental economics (Hanley et al., 1998). The CE methodology is based upon the concept known as "the characteristics theory of value" (Lancaster, 1966) where a good may be thought of as being composed of several characteristics or attributes, which the respondent values independently, rather than valuing the good as a whole. The theoretical framework behind the analysis of CE data is random utility maximization (McFadden, 1974). The random utility maximization (RUM) expression of the utility *U* associated with choice alternatives *(0,1...J)* for individual *i* can be written as:

$$U_{i1} = \beta_0 X_{i0} + \varepsilon_{i0} \qquad (7.1)$$

$$U_{i1} = \beta_1 X_{i1} + \varepsilon_{i1}$$

....

$$U_{iJ} = \beta_J X_{iJ} + \varepsilon_{iJ}$$

The observed outcome is then denoted as

yi = choice j if Ui(alternative j) > Ui(alternative q) $\forall\ q \neq j$. (7.2)

where X_J is a vector of explanatory choice attributes of the alternatives weighted by the unknown parameter vector β and ε is the random error term, which represents the unobserved variations in taste that influence choice.

The RUM model can be specified in different ways depending on the distribution of the error term. If the error terms are independently and identically drawn from an extreme value distribution, the RUM model is specified as multinomial (conditional) logit (McFadden, 1974). This can be expressed as:

$$\text{Prob(choice } j) = \text{Prob}(\mathrm{U}j > \mathrm{U}q),\ \forall\ q \neq j \qquad (7.3)$$

$$= \frac{\exp(\beta_j x_{ij})}{\sum_{q=0}^{J} \exp(\beta_q x_{iq})}\ ,j = 0,\ldots,J \qquad (7.4)$$

A conditional logit (CL), as described above, was used initially on the dataset of valid choices. This is the basic model in the stable of CE models and it allows an initial exploration into the preferences of the respondents. However, the CL is based on several restrictive assumptions including independently and identically distributed error terms (IID) and independence of irrelevant alternatives (IIA). McFadden and Train (2000) showed that mixed logit models provide a more flexible and computationally practical econometric method for estimating a discrete choice model derived from the random utility maximization framework that can overcome these limitations. Additionally with the use of a mixed logit model it is possible to account for dependence across repeated choices made by the same respondent by specifying a panel version of the model. The random parameters logit (RPL) is one type of mixed model and was used in this case as it allows these assumptions to be relaxed. The use of RPL also allows for random taste variation, unrestricted substitution patterns and correlation in observed factors (Train, 2003).

In the random parameters logit (RPL) (Train, 1998), the unconditional choice probability is the integral of logit formulas over all possible variables such that:

$$P_{ni} = \int \left[\frac{e^{\beta_n' x_{nit}}}{\sum_j e^{\beta_n' x_{njt}}} \right] f(\beta) d(\beta) \tag{7.5}$$

However unlike the CL model, the integral in equation (7.5) does not have a closed form for integration. Therefore simulation is needed to obtain a solution and calculate the probabilities. Train (1998) has developed a method that is suitable for simulating (7.5). His simulator is smooth, strictly positive and unbiased (Brownstone and Train 1998), and can be easily modified to allow for non-negative/positive random parameters. Simulating (7.5) is carried out simply by drawing a β_{nr}, calculating the bracketed part of the equation and repeating the procedure many times. Although Train's simulator is unbiased for just one draw of β_{nr}, its accuracy is increased with the number of draws. Using R draws of β_{nr} from $f(\beta)$, the simulated probability of (7.5) is:

$$P_{ni} = \frac{1}{R} \sum_{r=1}^{R} \left[\frac{e^{\beta_{nr}' x_{nit}}}{\sum_j e^{\beta_{nr}' x_{njt}}} \right] \tag{7.6}$$

The subscript *nr* on β indicates that the probability is calculated for each respondent using R different sets of β vectors. For the RPL the modeller must decide which β coefficients are to be estimated as random and how they are to be distributed $f(\beta)$. Allowing all β coefficients to be random would result in a virtually identified specification (Ruud, 1996) so in this thesis we keep the price fixed as is common practice in the literature (Martin-Ortega et al., 2012; Birol et al.,2006). When employing the RPL model the modeller must also decide on the parameterization of the covariance matrix. In this thesis, we also allow preference parameters to be correlated. The correlations across the random parameters are shown in Appendices G and H. To estimate the model a simulated maximum likelihood estimator with Halton draws was used. In the final estimation of the model 300 Halton draws were employed.

An alternative model that accounts for heterogeneity is the latent class logit model (Greene and Hensher, 2003). Instead of parameter heterogeneity being modelled according to a predefined distribution, a latent class approach models parameter heterogeneity across individuals with a discrete distribution, or set of 'classes', (Q), the number which is defined by the modeller. The individual resides in a 'latent' class which is not revealed to the analyst. To test what number of 'classes', the modeller should use; Roeder et al. (1999) suggest using the Bayesian information criterion.

Again using y_{it} to denote the specific choice made, so that the model provides

$$P_{it|q}(j) = Prob(y_{it} = j|class = q) \qquad (7.7)$$

which is simplified to $P_{it|q}$. Within each class, parameters do not vary with choice probabilities and are assumed to be generated by the conditional logit model (Equation 7.4). For the given class assignment, the contribution of individual i to the likelihood would be the joint probability of the sequence $y_i = [y_{i1}, y_{i2}, . , y_{iT}]$. This is

$$P_{i|q} = \prod_{t=1}^{T_i} P_{it|q} \qquad (7.8)$$

Class probabilities are specified by the multinomial logit form. Let H_{iq} denote the prior probability for class q for individual i

$$H_{iq} = \frac{\exp(z'_i\theta_q)}{\sum_{q=1}^{Q} exp(z'_i\theta_q)}, \quad q = 1, \ldots, Q, \ \theta_Q = 0, \qquad (7.9)$$

where z_i denotes an optional set of observable characteristics which enter the model for class membership. The Qth parameter vector is normalized to zero to secure identification of the model. The model does not impose the IIA property on the observed probabilities (Greene and Hensher, 2003). The likelihood for individual i is the expectation of the class-specific contributions

$$P_i = \sum_{q=1}^{Q} H_{iq} P_{i|q} \qquad (7.10)$$

and the log-likelihood for the sample is

$$lnL = \sum_{i=1}^{N} \ln P_i = \sum_{i=1}^{N} ln\left[\sum_{q=1}^{Q} H_{iq}\left(\prod_{t=1}^{T_i} P_{it|q}\right)\right] \quad (7.11)$$

For each model, in order to estimate a marginal value for each of the marine environment attributes in the choice experiment, a price attribute was included. This allows the monetary welfare impact to be calculated of moving from the current marine environment today (i.e. the status quo) to an alternative marine environment with attribute levels set to be representative of what could result if the MSFD was or was not implemented (i.e. the cost of marine environment degradation). The marginal willingness to pay for the different marine environmental attributes (often referred to in the literature as the implicit prices) and the welfare impact from a move from x^0 to x^1 and conditional on individual taste β_n being logit can then be derived using the standard compensating variation (SCV) log-sum formula (Hanemann, 1984):

$$SCV = -1/\beta_m \left[\ln\left[\sum \exp(\beta' x_n^1)\right] - \ln\left[\sum \exp(\beta' x_n^0)\right]\right]. \qquad (7.12)$$

With the use of a RPL model, the welfare measure needs integration over the taste distribution in the population so that:

$$SCV = \int \left\{-1/\beta_m \left[\ln\left[\sum \exp(\beta' x_n^1)\right] - \ln\left[\sum \exp(\beta' x_n^0)\right]\right]\right\} f(\beta) d(\beta). \qquad (7.13)$$

This integral is also approximated by simulation from draws of the estimated distributions for the random parameters in our chosen model (Hynes et al., 2008). Using the above formula (7.13), the welfare impact of a change in the marine environmental attributes from the status quo scenario to various possible future scenarios may be calculated.

A CE was undertaken with 812 members of the Irish general public aged 18 and over to estimate their WTP to achieve GES in Irish marine waters. The details of the design, development and deployment of the survey instrument including the design of the choice cards is detailed in Chapter 3 of this thesis. The next section now details the results from this CE.

7.4. Results

The choice data was first examined for trends in choices across individuals. Examining the choices of those who opted for change indicated that there was only one respondent who chose all option A and one who chose all option B on all 12 choice occasions. This indicates that the majority of those who opted for change avoided adopting simplistic choice heuristics. Fifty percent of the respondents always chose option C (the “status quo”), which had zero payment attached. This represents a high proportion of the sample. A follow up question to those respondents that always chose option C was included in the survey. This allowed those respondents to outline their reasons for always choosing option C (Table 7.2).

Table 7-2. Reasons for always choosing status quo option C

	All reasons % (n=411)	One reason only % (n=244)
I cannot afford to pay	52.55	47.54
I object to paying taxes	17.76	8.2
The improvements are not important to me	4.62	0.82
The 'No Change' option is satisfactory	3.65	2.46
The Government/ County Council/EU or other body should pay	29.68	13.93
I don't believe the improvements will actually take place	18.98	9.43
Those who pollute the seas and ocean should pay	19.22	7.79
I didn't know which option was best, so I stayed with the 'No Change' option	4.38	3.28
I don't use the sea or marine environment	3.65	1.23
Don't know	1.46	2.46
Other	9.49	2.87

It can be seen from Table 7.2 that the most common reason for always choosing the status quo option was that the respondent could not afford to pay. The high proportion stating they cannot afford to pay may reflect the impact of the downturn in the Irish economy since 2007. The other most frequent reasons for picking option C was that others should pay (the Government/ EU or those who pollute) and concerns that the measures described would not be introduced. The only responses that were considered genuine zero-value responses and that were included within the sample for analysis were those that stated "I cannot afford to pay” ,”The improvements were not important to me" or "The 'No Change' option is satisfactory" or "I don't use the sea or marine environment". The sample size employed for the choice analysis was therefore 558 respondents.

Initially a conditional logit model was run but the results (Table 7.3.) showed poor fit and the model does not account for correlation, assumes choices are independent of each other and that preferences are homogenous (Train, 2003). Results are shown here for comparison with other models. Two models which do allow for heterogeneity are the random parameters logit (or mixed logit model) and latent class models. The results for these models (Table 7.3 for random parameters logit, Table 7.4 for latent class logit) show that only for the alternative specific constant (ASC) was there any significance for the interaction variables. In both models, those who visited the coast in the previous year, those with third level education and older people (>45 years) were more likely to choose an alternative rather than the status quo. The latent class model suggests that a 70:30 split between respondents in preference for choosing an alternative to status quo versus the status quo.

Both models (random parameters logit - log likelihood: -3128.80, pseudo p^2: 0.575; latent class logit - log likelihood: -3507.04, pseudo p^2: 0.523) show better fit than the conditional logit model (log likelihood: -6306.26, pseudo p^2: 0.143). To estimate the general public's preferences for the various attributes it was decided to omit the interactions to simplify the model and a random parameters model was chosen. The results generated are similar to the random parameters ASC interaction model and the latent class model and are shown in Table 7.5.

The results from the RPL are shown in Table 7.5. Both the mean attribute level coefficients and their standard deviations (modelled as normally distributed) are presented. The mean coefficients of most of the attribute levels have positive signs and are significant at the 95% level except for the following; *no change in biodiversity* is insignificant[25] and both *increase in biodiversity* and *no change in invasive species* have negative signs and are significant at the 95% level. This indicates that on average, respondent's utility would increase by moving towards GES in Irish marine waters. However, all the standard deviations are significant and some of them are quite large relative to the means indicating that there is sizable heterogeneity in people's preferences for changes to the marine environment.

[25] For each attribute the levels associated with status quo are taken as the base case and coefficients are therefore only presented for the alternative levels in each case.

Table 7-3. CL and RPL Model Results with ASC Interactions

		Conditional Logit – AI			Random Paramters Logit – AI	
		C.E.	z-ratio		C.E.	z-ratio
No change in biodiversity	μ	**-0.034**	(-0.73)	μ	**0.136**	.90
	σ			σ	2.157	(13.45)***
Increase in biodiversity	μ	**-0.124**	(-1.88)*	μ	**-0.560**	(-3.16)***
	σ			σ	2.278	(9.96)***
No change in invasive species	μ	**-0.164**	(-2.92)***	μ	**-0.203**	(-1.57)
	σ			σ	0.855	(5.27)***
No invasive species	μ	**-0.042**	(-0.81)	μ	**0.341**	(2.97)***
	σ			σ	1.036	(7.29)***
Non sustainable fisheries	μ	**-.00859**	(-0.12)	μ	**0.674**	(4.07)***
	σ			σ	1.936	(9.46)***
Healthy & sustainable fisheries	μ	**0.513**	(6.81)***	μ	**1.879**	(9.04)***
	σ			σ	3.060	(11.18)***
No change in pollution	μ	**0.504**	(8.71)***	μ	**1.116**	(8.04)***
	σ			σ	1.572	(8.45)***
Decrease in pollution	μ	**0.692**	(11.16)***	μ	**1.543**	(8.34)***
	σ			σ	2.589	(11.15)***
Moderate physical impact	μ	**0.294**	(5.70)***	μ	**0.799**	(6.46)***
	σ			σ	1.420	(8.37)***
Limited physical impact	μ	**0 .666**	(12.48)***	μ	**1.431**	(9.90)***
	σ			σ	2.243	(12.28)***
ASC (Status Quo)	μ	**1.931**	(15.69)***	μ	**2.292**	(4.55)***
	σ			σ	13.942	(38.25)***
Cost		**-0.015**	(-13.78)***		**-0.023**	(-8.32)***
ASC Interactions						
Age greater than 45 years		**-0.454**	(-6.36)***		**-1.084**	(-2.27)**
Visited the coast in past year		**-1.145**	(-18.08)***		**-8.537**	(-10.16)***
Female		**0.072**	(1.25)		**1.187**	(2.47)**
Children in household		**0.042**	(0.58)		**2.311**	(3.97)***
Married		**-0.165**	(-2.64)***		**-0.671**	(-1.38)
Third level education		**-1.320**	(-19.66)***		**-4.057**	(-7.32)***
LL		-6306.26			-3128.80	
AIC		12648.53			6425.60	
BIC		12771.09			6997.58	
n		558			558	
Pseudo p^2		0.143			0.575	

Table 7-4. Two-class latent class model results

	LCM Class 1		Class 2	
Attributes	C.E.	z-ratio	C.E.	z-ratio
No change in biodiversity	0.073	(1.32)	-0.144	(-0.50)
Increase in biodiversity	-0.018	(-0.21)	-0.441	(-0.86)
No change in invasive species	-0.139	(-1.88)*	0.099	(0.27)
No invasive species	0.108	(1.76)*	-0.208	(-0.59)
Non sustainable fisheries	0.387	(4.66)***	0.100	(0.26)
Healthy & sustainable fisheries	1.051	(10.82)***	0.035	(0.09)
No change in pollution	0.589	(8.24)***	-0.017	(-0.05)
Decrease in pollution	0.989	(12.80)***	-0.398	(-0.97)
Moderate physical impact	0.474	(7.91)***	0.011	(0.03)
Limited physical impact	1.011	(16.05)***	-0.430	(-1.11)
ASC (Status Quo)	-1.465	(-10.44)***	2.541***	(5.43)
Cost	-0.0097	(-7.95)***	-0.0698***	(-5.01)
Average Class Probabilities	0.683		0.317	
Class membership characteristics				
Constant	-0.661**	-2.4	Fixed parameter	
Age greater than 45 years	0.518**	2.04	Fixed parameter	
Visited the coast in past year	1.137***	4.89	Fixed parameter	
Female	-0.070	-0.34	Fixed parameter	
Children in household	-0.010	-0.04	Fixed parameter	
Married	0.083	0.37	Fixed parameter	
Third level education	1.375***	5.43	Fixed parameter	
LL	-3507.04			
AIC	7076.1			
BIC	7287.2			
n	558			
Pseudo p^2	0.523			
k	31			

Table 7-5. RPL Model Results

		Random Paramters Logit – AI C.E.	z-ratio	Implicit Prices[26]
No change in biodiversity	μ	**0.098**	(0.71)	€3.75 {-€6.62, €14.87}
	σ	2.122	(13.02)***	
Increase in biodiversity	μ	**-0.650**	(-3.59)***	-€25.65 {-€41.15, -€12.22}
	σ	2.347	(9.87)***	
No change in invasive species	μ	**-0.218**	(-1.76)*	-€8.72 {-€18.86, €0.48}
	σ	0.767	(3.67)***	
No invasive species	μ	**0.237**	(1.95)*	€9.77 {€0.54, €21.47}
	σ	1.048	(6.26)***	
Non sustainable fisheries	μ	**0.677**	(3.78)***	€27.21 {€11.96, €45.05}
	σ	1.890	(8.44)***	
Healthy & sustainable fisheries	μ	**1.856**	(8.22)***	€74.65 {€11.96, €109.07}
	σ	3.022	(10.64)***	
No change in pollution	μ	**0.801**	(5.22)***	€31.96 {€19.77, €46.28}
	σ	1.881	(9.72)***	
Decrease in pollution	μ	**1.118**	(6.00)***	€44.44 {€30.88, €62.55}
	σ	2.699	(12.65)***	
Moderate physical impact	μ	**0.733**	(4.81)***	€29.44 {€17.82, €45.74}
	σ	1.275	(7.42)***	
Limited physical impact	μ	**1.063**	(5.96)***	€42.62 {€28.42, €59.90}
	σ	2.332	(10.24)***	
ASC (Status Quo)	μ	**-1.568**	(-3.66)***	
	σ	14.153	(14.00)***	
Cost		**-.0250**	(-8.44)***	
LL		-3146.28		
AIC		6448.56		
BIC		6979.69		
n		558		
Pseudo p^2		0.572		

Notes: Figures in parenthesis indicate z-ratios and ***, **, * indicate significance at 1%, 5%, 10% level, respectively.

[26] Implicit prices are based on medians and confidence intervals generated using Krinsky and Robb (1986) procedure.

The largest change in utility levels was found to be associated with the change from *unhealthy fish stocks* to *healthy & sustainable fisheries* (1.856). Changing from *unsustainable and unhealthy fisheries* to *sustainable and healthy fisheries* would result in a marginal benefit (implicit price) of €74.65. The next largest change in utility is the change from the status quo (as demonstrated by the magnitude of the ASC dummy) indicating that respondents in general are in favour a change to a different marine environmental scenario. This has been previous demonstrated using the latent class model (table 7.4). The next largest changes in utility is associated with a *decrease in pollution* (1.118) followed by *limited physical impact* (1.063). Changing from an *increase in pollution* to a *decrease in pollution* will result in a marginal benefit per person per year of €44.44 and changing from *wide-scale physical impact* to *limited physical impact* would result in a marginal benefit of €42.62. The large changes in utility levels for pollution and fisheries make sense as both of these attributes affect people either directly if they visit the coast (beach litter, wastewater, pollution in the water) or if they eat fish or shellfish.

The attributes related to biodiversity and invasive species were not as clear to interpret as the previously discussed attributes. *Decreased biodiversity* is preferred to the *increased biodiversity* levels (-0.650) while for *no change in biodiversity* there is no significant difference seen in utility levels. However it can be seen that there is large and significant standard deviation for this latter level. However the larger standard deviation associated with both biodiversity attributes shows that there are stronger preferences in both directions and this may be supported by the latent class model where both attributes are insignificant. This unexpected result may be because of difficulty in understanding the biodiversity concept; Bullock et al (2008) stated that *"that most people have a very limited understanding of biodiversity even where they do value its outcomes"*, respondents may have ignored this attribute and an approach considering non-attendance may be needed or people may have strong views (indicated by the large standard deviation) supporting the human activities that affect marine biodiversity (fishing, marine construction). These were activities mentioned in the description of the attributes to respondents as shown in Box 3.1.

The invasive species level coefficients for the *no invasive species* attribute is of the expected sign, but his compares to the loss of utility associated with the change from new invasive species to existing invasive species (-0.218). Similar to the biodiversity levels, the seemly inverted level was associated with a large standard deviation. Trying to interpret this, it may be that respondents found this attribute difficult to understand, may have ignored it or maybe a certain proportion of respondents have a positive preference associated with the introduction of new marine species.

As well as being able to examine the changes in utility associated with respondents' preferences, the inclusion of a monetary amount in the form of a tax allows the estimation of respondents willing to pay for or willingness to accept changes to the marine environment. Using formula (7.13) given above, the welfare impact of a change in the marine environmental attributes from the status quo scenario to 3 possible future scenarios representing a low level of degradation to the marine environment, a medium level of degradation to the marine environment and a high level of degradation to the marine environment are also calculated. These are 3 possible future scenarios that might come to pass should the MSFD not be implemented in full. Results of the scenarios are shown below and are based on the results of the random parameter logit choice model presented in table 7.5. It is assumed that if the MSFD is implemented in full GES will be achieved. Therefore the alternative degradation scenarios are compared against the attribute levels associated with the achievement of GES as shown in the final column of table 7.6. The scenarios consist of a best guess of how the ecosystems will evolve should the MSFD not be implemented in full but this may change based on further information arising from the MFSD assessment that is ongoing in Ireland now.

The results from Table 7.6 show that the non-use cost of degradation resulting from not implementing the MFSD in Ireland, as measured in terms of the welfare impact on society, could be large. The estimated compensating surplus per person varies between €62.52 for the medium degradation scenario and €145.16 for the change from high level of degradation scenario to GES. The Irish adult population (aged over 17) stood at 3,439,565 individuals according to the last Census in 2011. Aggregating these estimates up to the relevant population shows that compensating surplus would range between €215 million for the medium degradation scenario to €500 million for the meeting GES scenario per year. Confidence intervals were generated using the simulation method proposed by Krinsky and Robb (1986).

Table 7-6. Attribute levels and compensating surplus value estimates for 3 alternative levels of degradation (€ per person per year)

Attribute	**Status Quo: High level of degradation**	**Scenario 1: Medium level of degradation**	**Scenario 2: Low level of degradation**	**Scenario 3: Marine waters at GES**
Biodiversity and Healthy Marine Ecosystem	Biodiversity decreases	Biodiversity decreases	Biodiversity maintained at current levels	Biodiversity increases
Sustainable fisheries	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*
Pollution levels in sea	Pollution increases	No change in pollution	Pollution decreases	Pollution decreases
Non-native species	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	Irish waters are virtually free of non-native species*(Ecosystem unaltered)*
Physical Impacts to the Sea	Wide scale damage	Wide scale damage	Wide scale damage	Limited damage
Compensating Surplus (€/ person/year)*	-	62.52 (57.64, 71.22)	118.61 (107.09, 130.13)	145.16 (131.50, 158.81)
Total Population Compensating Surplus (€m/year)*	-	215 (198, 245)	408 (368, 448)	500 (452, 546)

*95% confidence interval in brackets)

7.5. Discussion and Conclusions

This chapter presented the results of the first study to attempt to value the 'Cost of Degradation' of the marine environment as set out in the MSFD using the choice experiment approach. As such, it demonstrated the usefulness of the methodology in assessing the welfare impact of changes in a range of marine ecosystem services that align with the 11 marine environmental descriptors outlined in the Directive. The use of the CE approach is also in line with the EU Commissions expectations that Member States carry out "*an economic and social analysis of the use of [their] waters and of the cost of degradation of the marine environment*" as an integral part of their initial ecosystem based assessments as it enables the researcher to consider the welfare impacts of changes in the marine environment across a range of ecosystems.

It is envisaged that implementation of the MSFD will lead to significant changes within the EU in relation to how the marine environment is managed. The results presented demonstrate that the Irish people attach a high value to the changes that may occur under future marine policy scenarios. The aggregated values show that the mean values range from €215 million up to €500 million. The use of CE also allows scenarios different to those modelled here to be estimated and these models can be changed if needed, based on the results of the initial scientific assessment being completed now by the Irish Department of the Environment (and by all member states), as required by the MSFD.

However, as with all outputs from econometric modelling, care must be taken in how estimates are aggregated to population level. Loomis (2000) and Bateman et al., (2006) argued that the extent of the market may be more important in determining aggregate values than any changes related to the precision of the estimates of per-person values while Bateman et al. (2006) further argued that the use of GIS coupled with the concept of distance decay may be a method of determining market size for public goods, especially for non-use values, coining the term "economic jurisdiction". In this chapter, since the population surveyed was the general public in the Republic of Ireland, the mean estimates from the RPL model with no-interactions were used in the scenario analysis to estimate the mean welfare change and then multiplied by the total population of the Republic of Ireland age 18 and over. It may be argued that given the significant heterogeneity in the models, (e.g. for some attributes the preferences vary widely around the means, significant interactions with the ASC and the fact that 50% said that wouldn't pay anything), aggregation to population level in this chapter should be treated with some caution[27].

The non-use value associated with the achievement of GES, arising from the MSFD, will need to be assessed in conjunction with how the MFSD will affect the provision of ecosystem goods and services before policymakers can make any marine planning decisions aimed at achieving the Directive's objectives. However, if as it has been suggested by others (Bertram and Rehdanz, 2012, McVittie and Moran, 2010), non-use values compose a significant portion of the total economic value of GES in marine waters then derogations from meeting the requirements of the MFSD may be low.

The EC-DGE (2010) report examines several different approaches to valuing the "costs of degradation". The use of CE for valuing non-use values would fit within the Ecosystem Service Approach to valuation put forward by the European Commission in the report. The Ecosystem Services Approach breaks down the changes in the marine environment by the different ecosystem services that are impacted, such as provisioning services (e.g. fish and aquaculture), regulating services (e.g. waste treatment and carbon sequestration) and cultural services (e.g. recreation and aesthetic values). The two alternatives to the Ecosystem Based Approach put forward by the European Commission in the EC-DGE (2010) are the Cost-Based Approach and the Water Accounts Approach. The Cost Based Approach considers only the costs of meeting the GES targets and could be considered a cost effectiveness approach rather than the cost-benefit analysis (CBA), which the MFSD requires. The Water Accounts Approach uses currently reported national economic data from sectors that would be impacted by the changes arising from achieving GES in the marine waters. The benefits of both the Cost-Based and the Water Accounts approaches are that both the costs and national accounts data are more readily available compared to measuring both the benefits and costs under the ecosystem based approach. However, given that the MSFD is framed in the context of the Ecosystem Approach, with Good Environmental Status being interpreted in terms of ecosystem functioning and services provision it seems more appropriate to follow the same approach when attempting to

[27] The previous chapter (Chapter 6) dealt with many other issues related to aggregation including specification issues with modelling distance decay which is how Bateman et al., (2006) defines economic jurisdiction and the MAUP.

estimate, as was done in this chapter, the costs of degradation to the marine environment should the MSFD not be implemented in full.

From a policy perspective, the results of our analysis indicate that marine programs that will have a high impact upon the welfare of the Irish public are those that target pollution and ensure that fisheries are both sustainable and safe to eat. The next highest change in welfare would be from policies aimed at reducing physical impacts to the marine waters including those from marine construction and drilling. Interestingly, the change from sustainable and safe-to-eat seafood from unsustainable but safe-to-eat seafood is associated with a higher change in utility than those related to biodiversity and prevention of new invasive species.

There are some limitations that need to be kept in mind in terms of the analysis presented in this chapter. For many of the attributes, the worst case levels have significant and large standard deviation parameter values indicating that preferences may vary widely from the means. Further investigation is needed to try and explain why such a wide range of preferences exist and how these preferences are distributed. This could be accompanied by examining the effect of attitudes (collected in this survey) on choice decisions and seeing if they suggest reasons for heterogeneity within preferences. Additionally, the construction of the attributes from the MSFD GES descriptors for use in the CE assumes that there is no correlation between them. While this was controlled for to some extend in the modelling process through the specifications of the Cholesky matrix, which facilitates a degree of correlation in taste attribute variation, the implications for valuing the benefits of programmes of measures that affect more than one descriptor require further consideration. Additionally, respondents may have been adopted a heuristic to ignore some attributes to reduce cognitive burden (Lunn et al. 2016) and further modelling to account for this may provide better model fit and may account for some unexpected results for the biodiversity and invasive attributes.

Finally, it should be noted that the assessment of the impact of human activity on the marine environment should be carried out at the regional seas level. Many of ecosystem loss and degradation problems such as eutrophication of coastal waters have to be viewed at the regional sea/catchment scale. As Turner et al. (2010) point out, the drivers and pressures acting on the marine environment, e.g. agricultural intensification/expansion etc., are located in physical catchments or political designations, which extend well beyond a countries own coastal zone. As such, it may be more appropriate for a CE such as that presented here to be conducted across member states sharing a coastline at a regional sea level[28]. This would be an interesting avenue for future work where cross country differences in cultures and attitudes to the environment would have to be controlled for.

Despite the above limitations, this chapter is timely. The requirement for EU Member States to carry out "an economic and social analysis of the use of [their] waters and of the cost of degradation of the marine environment" as an integral part of their initial assessments (Article 8(1c) MSFD) means that methodologies such as that employed in this chapter will be necessary. Indeed, CE has already been shown to be useful for estimating the value of benefits both for changes to the marine environment and other EU Directives related to the environment. EC-DGE (2010) noted that while value transfer was used for undertaking economic studies needed for the WFD the use of value transfer for MSFD benefit analysis may be limited as there is not a sizeable enough literature related to the marine ecosystem service valuation exercises available relative to that which was available to the WFD. However, with this study and more like it, a sufficient number of primary valuations may lead to more use of value transfer within the marine environment using perhaps the meta-analysis methodology employed previously for analysing coastal recreation service benefits by Ghermandi and Nunes (2013).

This study therefore contributes both to the expanding marine valuation literature and to the implementation of the MFSD since it demonstrates how member states might approach the required estimation of 'the cost of degradation', using a method that is in line with the concept ecosystem based marine management. It is hoped that further valuation studies akin to this study will be undertaken once the initial MSFD assessment has been completed by all EU member states. This would greatly aid the comparison of the costs and benefits of regional sea level marine policies across EU Member States. Finally, while future uncertainty will always remain in relation to the future state of any ecosystem, the CE approach presented in this chapter and the accompanying scenario analysis is a means of dealing with that uncertainty and can provide relevant marine policy makers with useful

[28] In the first stage of the MSFD assessment process all member states have analysed the drivers, pressures and impacts arising within their own borders and acting on their own adjacent marine waters. It is envisaged by these authors that the necessary regional sea level perspective will become more evident in subsequent follow up assessments that are required under the specifications of the MSFD.

information on costs associated with a range of possible future states of the marine environment.

Chapter 8

Conclusions

8.1. Introduction

Section 8.2 of this chapter summarises the thesis and highlights key findings from each of the four central chapters. In section 8.3 the limitations of the research are discussed and possible future research avenues arising out of this work are explored in Section 8.4. Finally, in section 8.5, this chapter concludes with policy recommendations based on the results from the thesis related to the estimated values of the benefits of the MSFD.

8.2. Summary of thesis and key findings

The main objective of this thesis was to provide an estimate of the value of the benefits of the marine environment to societies in the Northeast Atlantic, particularly in Ireland. This is needed to provide value estimates for the initial socio-economic analysis assessment required under the MSFD. The thesis also facilitated the estimation of the estimation of the "cost of degradation", the value lost by not achieving GES under the MSFD which is a second economic element within the MSFD. Several different approaches were undertaken to try and estimate the welfare values and these are briefly summarized below.

Before carrying out the valuation exercises Chapter 2 provided a brief overview of the background of the MSFD and how it functions in creating a marine strategy to achieve or maintain GES by 2020 in EU waters. It also assessed the economic elements which require either CEA or CBA, the latter of which requires estimating the value of the benefits associated with the achievement of GES. A brief overview of the economic approaches that may be employed to estimate the non-market benefit values of achieving GES was given and Ireland's progress in achieving GES was also reviewed.

Chapter 3 gives an overview of the design, development and application of the survey. The survey tested knowledge of the marine environment, attitudes towards the state of the marine environment and threats against it, activities in the marine environment and stated preference questions (choice experiment and contingent valuation question). The chapter lays out the conception and design of the survey, giving overview of the survey testing and results from the pilot and final sample before some concluding discussion on lessons learnt.

Chapter 4 presented the results of a nationwide survey in Ireland that explored the values, concerns and preferences of individuals regarding the Irish marine environment. Many of the questions asked on the marine environment of the Irish sample were also asked in a similar survey in other maritime countries in the EU by Potts et al. (2011). The results of both of these surveys would suggest similar attitudes toward the marine environment across Ireland, the UK, Spain, Portugal, Poland, Italy, Germany and France, although the Irish respondents tended to give a higher ranking on many of the questions asked. Previous to this survey being carried out, the views of the Irish public towards the seas and oceans around the Irish coast were relatively unknown. Additionally, the inclusion of these questions helped in carrying out the value transfer in Chapter 6.

The results of the Irish survey demonstrate a reasonable level of knowledge of the main threats facing Ireland's marine environment and of the importance of the non-market as well as market ecosystem services that the seas around the Irish coast provide. The results also suggested that the Irish public are sceptical of the ability of government and private industry to manage the Irish marine economy but instead place a large amount of trust in the competency of scientists. This would imply that a greater, more transparent role for scientists in marine policy formation and the decision making process would result in marine policy measures receiving greater support from the public than measures that are perceived to be mainly driven through government departments. Indeed this increased role for scientists (including social scientists) is already becoming more evident in policies such as the EU Marine Strategy Framework Directive with its integrated assessment approaches which incorporates the viewpoints of many stakeholders and the current reforms of the Common Fisheries Policy which is attempting to boost participatory decision making and co-management.

However, the Irish public's response to marine special planning and designation of MPA's by the government was less enthusiastic than their European counterparts. This may be related to the perceived competency of the government by the Irish general public in relation to the management of the marine environment. With the establishment of MPAs and the use of marine spatial planning likely to increase in the coming years the relevant Irish authorities will need to find a way to communicate the importance of such marine planning and protection approaches to the Irish public and to educate them on the flow of benefits that could flow from any further MPA designations in Irish waters; benefits from both an economic and social as well as a conservation perspective. The differences between the public and scientific perception of the main threats to the marine environment also suggests that better communication between the relevant authorities and the public on marine issues and policies is needed. Finally, the perception of whether or not they consider where they live as being a coastal area would also suggest that the Irish public hold a much more narrow view of what constitutes a coastal area than that held by statistical agencies such as Eurostat.

Chapter 5 provided an assessment of Ireland's marine ecosystem services and their value. Using the CICES framework as a guide, estimates for the quantity and value of provisioning, regulating and cultural ecosystem services were generated. For some ecosystem services, there was insufficient data to estimate either the quantity of the ecosystem service or the value. Therefore this chapter should be viewed as an initial overview of the ecosystem services data available to decision-makers and the economic methods that may be used to value their contribution to the Irish blue economy. Those with responsibility for the implementation of EU policies such as the MSFD and MSPD which rely on an ecosystem approach, the EU 2020 Biodiversity Strategy which requires an assessment of ecosystems (terrestrial and marine based) and the ecosystem services they generate and the Harnessing Our Ocean Wealth Strategy should also benefit from the information generated in this chapter.

While noting that due to the different methods used, value estimates may not be directly comparable; certain ecosystem services stand out as particularly important at a national level. Recreational services interacting with coastal, marine and estuarine ecosystems result in approximately 96 million marine recreation trips per year by Irish residents with an estimated value of €1.7 billion. The sea is also an important source of nutrition for society and Irish marine waters (within its EEZ) produce over 500,000 tonnes of seafood valued at €578 million. Regulating and maintenance ecosystem services occur in the background for many people and may sometimes be overlooked by society. However this chapter demonstrated that the value of these ecosystem services can be significant, valuing carbon absorption at €855 million per year and wastewater treatment at €311 million per year.

This initial assessment of Ireland's marine ecosystem services and their value is an important first step in incorporating ecosystem services into policy and decision making related to Ireland's marine and coastal zones. It demonstrates the use of the CICES framework which was initially developed for green accounting. The inclusion of marine ecosystem services values into the national accounts may help to ensure a sustainable "blue economy" for Ireland by making sure that growth in the ocean economy does not exceed the carrying capacity of the marine environment. The application of an ecosystem service assessment at a smaller spatial scale could also help to improve knowledge in the planning process whether it be a local area plan or a one off development. The planning process requires that the impact on humans in addition to the environment be examined. While valuation of ecosystem service values should not be the sole determinant of a decision, their inclusion in impact assessments should contribute to a more explicit and transparent decision making process. This also applies to policy at other various spatial scales.

Chapter 6 presented the results of a CVM exercise undertaken in Ireland on the WTP of the Irish public to achieve GES as described in the MSFD. The results provide estimates of the non-market benefits generated by the implementation of the MSFD for possible use in CBA required under article 13 of the MSFD. The results could also be used to determine if there is evidence of disproportionate costs of measures as required under article 14 of the MSFD. The model results indicated that respondent's income, education, age and attitudes are important factors in determining WTP as well as the spatial factors of distance to the sea and their region's population density. There was no clear choice of the functional form of distance decay to use and population density variable also with the distance variable demonstrated how the MAUP can affect values using value transfer. Overall there is a positive relationship between WTP for GES and population density although by itself in the regression model it was found to have the biggest negative effect. It is likely that urban areas, which usually have higher incomes and higher population densities, will have the highest values of WTP. It is difficult to suggest a reason for this relationship but it is worth further investigation. Salka (2001) and Rodden (2010) suggest that environmental concerns have become a social and political issue in the rural/urban divide but there is not enough evidence in our survey to support this hypothesis.

However, the use of GIS should not be dismissed. Tompkins and Southward (1999) noted that one of the benefits of GIS is its ease in presenting large volumes of data in a spatial manner to policymakers and other stakeholders as well as allowing for linkages between research, policy and practice. An example of this is a map of estimated individual's WTP to achieve GES as was shown in figure 6.5. This map clearly shows the distance decay effect, especially for France and Spain, indicating that large swathes of both nations may have lower WTP values for the marine environment.

The valuation exercise using VT shows that there are significant values attached to achieving GES in MS's waters. The estimated value of achieving GES for Atlantic MSs is between €2.3 billion and €3.6 billion per annum for marine areas within these MSs but again there is a high level of uncertainty associated with these values. However, it is noted that the estimates generated are of a similar magnitude to those produced for Spain, the Netherlands and France that showed that the cost of degradation is €1.5-2 billion annually using the cost approach (Oinonen et al. (2016a).

Chapter 7 then presented the results of the first study to attempt to value the 'Cost of Degradation' of the marine environment as set out in the MSFD using the choice experiment approach. As such, it demonstrated the usefulness of the methodology in assessing the welfare impact of changes in a range of marine ecosystem services that align with the 11 marine environmental descriptors outlined in the Directive. The use of the CE approach is also in line with the EU Commissions expectations that Member States carry out "*an economic and social analysis of the use of [their] waters and of the cost of degradation of the marine environment*" as an integral part of their initial ecosystem based assessments. The use of CE enables the researcher to consider the welfare impacts of changes in the marine environment across a range of ecosystems.

It is envisaged that implementation of the MSFD will lead to significant changes within the EU in relation to how the marine environment is managed. The results presented demonstrate that the Irish people attach a high value to the changes that may occur under future marine policy scenarios. The aggregated values show that the mean values range from €215 million up to €500 million. The use of CE also allows scenarios different to those modelled in chapter 6 to be estimated. The non-use value associated with the achievement of GES, arising from the MSFD, will need to be assessed in conjunction with how the MFSD will affect the provision of ecosystem goods and services before policymakers can make any marine planning decisions aimed at achieving the Directive's objectives. However, if as it has been suggested by others (Bertram and Rehdanz, 2012, McVittie and Moran, 2010), non-use values compose a significant portion of the total economic value of GES in marine waters then derogations from meeting the requirements of the MFSD may be low.

This thesis is also timely. The requirement for EU Member States to carry out "an economic and social analysis of the use of [their] waters and of the cost of degradation of the marine environment" in time for the second assessment (Article 8(1c) MSFD) means that methodologies such as that employed in this thesis will be necessary. Indeed, CE has already been shown to be useful for estimating the value of benefits both for changes to the marine environment and other EU Directives related to the environment. EC-DGE (2010) noted that while value transfer was used for undertaking economic studies needed for the WFD the use of value transfer for MSFD benefit analysis may be limited as there is not a sizeable enough literature related to marine ecosystem service valuation exercises available relative to that which was available to the WFD. However, with this study and more like it, a sufficient number of primary valuations may lead to more use of value transfer.

8.3. Limitations of the research

Two main limitations were encountered when undertaking this work; firstly the lack of ecosystem data, particularly related to the marine environment around Ireland. This has been highlighted within many assessment reports related to the MSFD and this thesis similarly had this issue. The second major limitation is the many issues that accompany undertaking stated preference studies and in particular the issue of non-attendance of attributes in the CE task.

The data issue was a particular problem for both Chapter 5 and 6 and was a hindrance in the development of choice scenarios and background information in Chapter 7. Placing a monetary value on a good or service may imply that full information is available but for non-market goods this is not always the case. The uncertainty associated with the estimates produced in this thesis indicate that knowledge gaps still exist for many ecosystem services, both in measuring the quantity of the ecosystem service in physical terms and a lack of information to apply an economic value to certain ecosystem services. This thesis attempts to estimate values for a flow of ecosystem services but does not look at trends over time which may indicate if the health or long-term ability of marine ecosystems to deliver ecosystem services is being degraded. This is particularly true for climate regulation ecosystem services which are likely to see further demands on it in the future. Additionally, more research is needed to determine how climate change and ocean acidification will affect other ecosystem services.

For many of the regulating services in Chapter 5 (such as coastal defence and waste treatment) more studies are needed to answer questions such as how do Irish CME ecosystems provide these services and does Irish society value these services to the same degree as other nations where some of the values used in the VT exercise were sourced. For the cultural ecosystem services, information about use of the CME ecosystems is not captured routinely and is dependent on one off reports which use different methods. Additionally, the area of cultural ecosystem services valuation is a relatively new research area compared to the valuation of provisioning and regulating ecosystem services. Where valuation methodologies within this area are not sufficiently developed (e.g. marine heritage, culture and entertainment) or where valuation may be inappropriate (spiritual values), more research may be needed to demonstrate how to incorporate these values into decision making.

Another issue that arose, particularly in Chapter 6, surrounds obtaining socio-demographic data. While, much of the data was standardised and available either at Eurostat (EC, 2016) or through CensusHub2 (ESS, 2016), some MSs still have not made all their data available on these platforms. Future initiatives by such projects as the EU MARNET project (Foley et al., 2014) which collates and makes available a variety of comparable demographic and socio-economic data at a regional scale across the Atlantic member states (and in particular in the marine and coastal areas) may be an alternative source of data for those undertaking similar functional VT exercises in marine related areas.

Additionally, there may be strong reservations about the robustness of using the values generated in a single stated preference study as the basis for a value transfer exercise, particularly when these have been collected in one country but are applied internationally. We also note that since this study there has been a limited amount of work on non-market valuation exercises related to the MSFD. The EU Commission in its review of implementation of the MSFD (EC, 2014) found inadequacies in Member States' first assessments submitted to the Commission. In particular they commented on the many data gaps and that in many cases the environmental targets set out by the MSs were not sufficient to achieve good environmental status. We note that the results of this study should not be interpreted as a definitive estimate of the benefits of achieving GES in EU Atlantic MSs but instead spur on further study on the value of achieving the targets set out in the MSFD.

For both Chapter 6 and 7 which are stated preference studies there are a slew of methodologic issues in the literature which this study encountered and did its best to overcome. These include the fact that respondents are valuing hypothetical scenarios for what may be unfamiliar goods. In addition the CE models assume full attribute attendance which may not be the case. Additionally, there are some limitations that need to be kept in mind in terms of the analysis presented in the chapter 7. For many of the attributes, the worst case levels have significant and large standard deviation parameter values indicating that preferences may vary widely from the means. Further investigation is needed to try and explain why such a wide range of preferences exist and how these preferences are distributed. This could be accompanied by examining the effect of attitudes (collected in this survey) on choice decisions and seeing if they suggest reasons for heterogeneity within preferences. Additionally, the construction of the attributes from the MSFD GES descriptors for use in the CE assumes that there is no correlation between them. While this was controlled for to some extend in the modelling process through the specifications of the Cholesky matrix, which facilitates a degree of correlation in taste attribute variation, the implications for valuing the benefits of programmes of measures that affect more than one descriptor require further consideration. Additionally, respondents may have been adopting a heuristic strategy, ignoring some attributes in the presented choice cards to reduce cognitive burden (Lunn et al. 2016) and further modelling to account for this may provide better model fit and may account for some unexpected results for the biodiversity and invasive attributes. Recently, a guidance paper for conducting stated preference studies (Johnston et al., 2017) has been published and the vast majority of the recommendations were followed in undertaking this work which should limit the criticisms of the validity of the value estimates generated.

8.4. Future research

There are several ways that the research in this thesis could be extended. The most obvious would be to look at the questions on the survey that have not been examined within this thesis. One of the aspects of the survey that was not examined in this thesis was the split sample approach with Q.21 (See Appendix A) where respondents were required to reflect and recall the choice card attributes. Recently there has been a concern about attribute non-attendance (A-NA) in the choice experiment literature (Scarpa et al, 2009, Campbell et al., 2011, Hensher et al., 2012) This is caused by individual decision-makers not using all information on the choice cards describing the choices they face and they instead ignore certain attributes and use heuristics to make their choices (Hess et al., 2018) Not accounting for this non-attendance may lead to violations of utility maximisation in the RUMs underlying the econometrics used to estimate coefficients or generate WTP estimates. This may be linked to the issue of choice complexity, especially in the context of stated choice surveys (Rose et al., 2008) especially for new or exotic goods. While this concept of bounded rationality is not new (Simon, 1955), Lunn et al.,(2016) tested respondents cognitive ability using increasing number of attributes (increaing from 1 to 2 to 3 to 4) to value a virtual egg noting that *"precision with which surpluses could be identified was limited by cognitive constraints relating to the number of attributes that had to be simultaneously processed"*.

In the survey for this PhD, I was also interested in testing cognitive effects on valuation of the marine environmental, which may be a novel good in many people's eyes. Therefore, to test this, I included a split sample question (Q21) in the survey. Half the sample were given the question and half were not. This did not affect which block of cross choice cards the respondent was given. The question was placed after the respondents had the different attributes of the marine environment described to them. Half the sample were then asked a recall question *"Take a moment to reflect on the 6 attributes, I just described. Can you remember what they are and say them back?"* The interviewer then noted which attributes the respondent could remember. Unfortunately due to miscommunication with the survey company, cost was the one attribute that was not collected.

Looking towards a paper examining the effect of inclusion of this question, the first hypothesis to test is whether the inclusion of this question affected choices either in terms of coefficients or standard errors. If it is shown that asking this question and/or giving respondents time to reflect on the attributes produced more consistent estimators then it may be a simple and effective tool for inducing this effect. Another approach is to test if recall is related in the survey to education levels or level of learning (tested using the changes in levels from Q1 to Q19 & Q20) in conjunction with A-NA. If found to be related to both then education could be used as a proxy in other choice experiment results reported and used to adjust for non-attendance. The survey also has a question on non-attendance post choices (Q23) which states *"When making your decision, did you consider all of the different attributes when making your choices or did you ignore any?"* Both the recall question results and the post-choice A-NA question could be used to test different A-NA models and also to test against the inferred models for A-NA prosed by Scarpa et al.,(2009) by constraining coefficients to zero in a latent class framework.

It is noted that the same paper found that in certain models that cost was the least attended attribute and that not allowing for this Cost-NA means that WTP estimates may be highly biased. As mentioned before Cost attribute recall was not collected and is therefore an issue in any paper looking at recall in identifying A-NA using data from this survey. However, an alternative may be examined using the differences between the CVM payment card data and the CE choices to see if there any irrational choices (i.e. where a person picked a higher value during the CE compared to the CVM task). This also could be explored in the same paper as a measure of Cost-NA. This work will be done and will hopefully add to the literature in this area of non-attendance and choice complexity.

Another aspects which have not been examined in this study is Q29 in the survey (Appendix A) which showed respondents a map (Showcard 6, Appendix E) and asked them if they would like to focus their monetary contribution to one area, all over or let policymakers dictate. A spatial regression model examining how their location in addition to other characteristics affects how respondents direct their payments would be an interesting extension of this work. The following question, Question 30 of the survey (Appendix A), that gave respondents a choice to work some hours related to marine environment protection in lieu of the WTP they had being willing to give up would also be an interesting topic to pursue further.

Finally, it should be noted that the assessment of the impact of human activity on the marine environment should be carried out at the regional seas level. Many of ecosystem loss and degradation problems such as eutrophication of coastal waters have to be viewed at the regional sea/catchment scale. As Turner et al. (2010) point out, the drivers and pressures acting on the marine environment, e.g. agricultural intensification/expansion etc., are located in physical catchments or political designations, which extend well beyond a countries own coastal zone. As such, it may be more appropriate for a CE such as that presented here to be conducted across member states sharing a coastline at a regional sea level. This would be an interesting avenue for future work where cross country differences in cultures and attitudes to the environment would have to be controlled for mirroring similar work done on the WFD by Bateman et al. (2011).

8.5. Concluding remarks and recommendations

On the 14th February, 1990 the Voyager 1 space probe at a distance of 6 billion kilometres faced back towards Earth and took one of the furthest pictures of the Earth ever taken. Against a vast blackness, Earth appeared as tiny pale blue dot. The 'Blue Planet' is aptly named, as in all photos taken of the Earth from space, the dominating colour is blue. The reason of course for this is that the surface of Earth is covered by over 70% water, our oceans and seas. Failing as a society or a people to properly value and protect the shared resources and space that the seas of our planet provide could mean a bleak future for all of us.

This study contributes both to the expanding marine valuation literature and to the implementation of the MFSD since it demonstrates how member states might approach the required estimation of values for the economic and social analysis and for measuring 'the cost of degradation', using one or more of the methods demonstrated above that is in line with the concept of ecosystem based marine management. It is hoped that further valuation studies akin to this study will be undertaken under the next round of MSFD assessments by EU coastal member states. This would greatly aid the comparison of the costs and benefits of regional sea level marine policies across EU Member States. Finally, the approaches presented in this thesis offer a variety of means of dealing with that uncertainty and can provide relevant marine policy makers with useful information on the costs and benefits associated with a range of possible future states of the marine environment.

Looking at Ireland, it is also noted here that in S.I. No. 249/2011, there is only a call for cost benefit analysis to be used in drawing up new measures. To date, most of work on the MSFD in Ireland has been to address knowledge gaps including creating sufficient monitoring frameworks for each of the descriptors. As targets for some parts of some descriptors have not yet been set, it is unlikely that there will be any requirements for cost-benefits analysis to be undertaken any time soon. It is hoped that the ecosystem services assessment carried out in Chapter 4 will contribute to future assessments and that attitudes of the Irish public recorded in Chapter 3 will provide impetus for change in the attitude to the speed at which Ireland attains GES in its marine waters. However, with the changes to defining GES and other changes made by Commission Decision 2017 (2017/848) and changes to Annex III in the MSFD as amended by the Directive 2017 (2017/845) and implementation of the recommendations by Oinonen et al. (2016a) there is hope that GES can be achieved and that a new positive welfare will accrue to society. Additionally as noted by Oinonen et al. (2016a), environmental economic analyses are interdisciplinary, and such analyses cannot be produced by economists working in isolation.

From a policy perspective, the results of our analysis in Chapter 5 and Chapter 6 indicate that marine programs that will have a high impact upon the welfare of the Irish public are those that target pollution and ensure that fisheries are both sustainable and safe to eat. The next highest change in welfare would be from policies aimed at reducing physical impacts to the marine waters including those from marine construction and drilling. Interestingly, the change from sustainable and safe-to-eat seafood from unsustainable but safe-to-eat seafood is associated with a higher change in utility than those related to biodiversity and prevention of new invasive species.

The European Union introduced the Marine Strategy Framework Directive (MSFD) to ensure that Europe's seas are healthy, clean and productive. To meet these goals, decisions will have to be made and cost and benefits balanced against each other implicitly or explicitly. The use of the approaches undertaken here make this decision process more transparent and explicit. The ecosystem services approach through the use of CICES offers a checklist that makes sure that all aspects of a decision are taken into account and the valuation methodologies used give a starting value for the debate on what each aspect of the marine is worth to each member of society. Away from the coast the majority of the sea area is used only by a few so of all the ecosystems on this planet, the sea has the probably the greatest non-use to use ratio. This means that failure to take non-use values for our marine environment into account would vastly underestimate the value of the seas. The inclusion of non-market values into our decision making offers one way to a sustainable and blue future.

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Appendix A. Survey

Marine Environment Survey
Questionnaire

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Col 1-5

(Block Capitals)	MR/MRS/MS	
FULL ADDRESS **(Block Capitals)**	....	**(6) (7) (8) (9)**
	....	
	....	
PHONE NUMBER	....	**CARD ONE** **Col 10/11/(01)**

Puncher Skip Col 12		**Puncher Skip Col 20**	
SEX	(13)	**Nationality**	(21)
Male	1	Irish	1
Female	2	UK	2
MARITAL STATUS	(14)	Rest of Western Europe	3
Married	1	Rest of Eastern Europe	4
Living with partner	2	Rest of World	5
Single	3	**Education Level to date**	(22)
Separated/Divorced/Widowed	4	Primary Level or equivalent	1
WORKING STATUS	(15)	Secondary Level or equivalent	2
Working full-time (30+ hours per week)	1	Third Level or equivalent	3
Working part-time (18-29 hours per week)	2	Other (specify):____________	4
Working part-time (17 or less hours/week)	3	**Stage**	(23)
Student	4	Pilot	1
Housewife	5	Main	2
Retired	6	**Choice Card Set**	(24)
Unemployed	7	Block 1	1
Unable to work (sickness/disability)	8	Block 2	2
Other (specify):____________	9	**Questionnaire version**	
OCCUPATION OF CHIEF INCOME EARNER		Version 1	1
Record and code below:____________		Version 2	2
SOCIAL CLASS	(16)		
A	1		
B	2		
C1	3		
C2	4		
D	5		
E	6		
F 50+	7		
F 50-	8		
AGE (write in and then code below):	(17-18)		
	(19)		
18-24	1		
25-34	2		
35-44	3		
45-54	4	**EDIT CHECK INITIALS**	
55-64	5	INTERVIEWER	
65+	6	SUPERVISOR	

	DAY		MONTH	
DATE OF INTERVIEW Use two digit coding system (e.g. 2nd June = 02 06)				
	(25)	(26)	(27)	(28)

ASSIGNMENT NUMBER	(29)	(30)	(31)	(32)	(33)

Good morning/afternoon/evening. I am ____________ from RED C Research & Marketing, an independent market research agency. We're conducting a survey in this area, on behalf of the National University of Ireland, Galway, relating to the marine environment (seas and oceans) of Ireland.

Your reply is very important, because you are part of only a small group of people that was randomly selected to represent the Irish population. We would like to ask you a few questions – it will take about 30 to 35 minutes. The answers you give will be completely confidential; your answers will be amalgamated with those of others. Would you mind answering a few questions?

The Irish government is interested in introducing new protection for the seas and oceans around Ireland. The seas around Ireland provide Irish people with many goods such as fish and energy (e.g. gas and off-shore wind) and are also valued by people for recreational purposes. Some people might even just value having clean and healthy seas. However, due to increased exploitation of the marine environment and increased risk of pollution combined with the increased influence of land based activities on the sea, the marine environment (e.g. fish, whales, seaweeds, etc) is at risk of being degraded. Therefore there is a trade off between using the seas versus maintaining or restoring the marine environment to healthy and clean status.

We are interested in your opinion regarding how much protection should be afforded to the seas around Ireland. While you may not have thought much about this issue, this survey may help to guide policy makers in the marine area; therefore we need to get a wide range of opinions on this subject, including yours.

Q.1 How much of what I just told you about the seas and oceans around Ireland did you know beforehand? **SINGLE CODE, READ OUT**

	(34)
I knew none of what I have been told	1
I knew very little	2
I knew half of it	3
I knew most of it	4
I knew everything	5

Q.2 How important, if at all, do you think each of the following issues are?
SHOWCARD 1, READ OUT, CHOOSE RANDOM STARTING POINT, ONE ANSWER PER ISSUE

	Not at all important	A little important	Somewhat important	Important	Very important	Don't Know	
The economy	1	2	3	4	5	V	(35)
Cost of living	1	2	3	4	5	V	(36)
Health	1	2	3	4	5	V	(37)
Education	1	2	3	4	5	V	(38)
Terrorism	1	2	3	4	5	V	(39)
Species loss	1	2	3	4	5	V	(40)
Pollution	1	2	3	4	5	V	(41)
Affordable energy	1	2	3	4	5	V	(42)
Poverty	1	2	3	4	5	V	(43)
Ocean health	1	2	3	4	5	V	(44)
Climate change	1	2	3	4	5	V	(45)
Safe available food	1	2	3	4	5	V	(46)

Q.3 Do you consider where you live as being in a coastal area?

	(47)
Yes	1
No	2

Q.4 Do you think that changes to the marine environment affect you, personally?
READ OUT, SINGLE CODE

	(48)
No affect on me	1
Some affect on me	2
Major affect on me	3

Q.5 Approximately how far do you live from the coast?

CAN ANSWER IN <u>EITHER KILOMETRES OR MILES BUT NOT BOTH</u>. IF LESS THAN 1 ENTER AS 0.

USE LEADING ZEROS E.G. 24 = 024

Kilometres [ ][ ][ ] (49-51) **OR** Miles [ ][ ][ ] (52-54)

Q.6 Approximately how often during the last year did you visit the seaside or coast anywhere on the island of Ireland? This can include daily walks on a local beach or coast (including promenades) plus any other trips. Please also include visits to coastal areas in Northern Ireland but not visits to other nations.
SINGLE CODE, PROBE TO PRECODES.

	(55)	
Everyday	1	**CONTINUE**
5 days a week	2	**CONTINUE**
Twice a week	3	**CONTINUE**
Once a week	4	**CONTINUE**
Once a month	5	**CONTINUE**
6-10 times in the year	6	**CONTINUE**
2-5 times in the year	7	**CONTINUE**
Once	8	**CONTINUE**
Not in the past year	9	**Go to Q.9**

ASK ALL WHO HAVE VISITED SEASIDE OR COAST AT LEAST ONCE IN THE PAST YEAR (CODE 1-8 IN Q.6)
Q.7a Have you been to a beach anywhere in Ireland or Northern Ireland in the past 12 months?

	(56)	
Yes	1	**CONTINUE**
No/can't recall	2	**Go to Q.8**

ASK ALL WHO VISITED A BEACH IN THE PAST 12 MONTHS (CODE 1 IN Q.7a)
Q.7b Can you tell me the location of the beach you visit most often? If you don't often go to the beach, where was the last beach you visited?
INTERVIEWER: MAKE SURE TO WRITE NAME OF BEACH IN A READABLE FORMAT USING CAPITAL LETTERS.

Name of Beach:

IF NAME OF BEACH <u>NOT KNOWN</u> ASK:
Q.7c What is the name of the nearest town or village to the beach you are thinking of?
INTERVIEWER: MAKE SURE TO WRITE NAME OF TOWN IN A READABLE FORMAT USING CAPITAL LETTERS.

Name of Town:

Col 57-80 blank
PUNCHER RE-PUNCH COL 1-9
CARD TWO COL 10-11/(02)

ASK ALL WHO HAVE VISITED SEASIDE OR COAST AT LEAST ONCE IN THE PAST YEAR (CODE 1-8 IN Q.6)

Q.8 Approximately, how many trips have you undertaken for the following marine or coastal based activities in the past year in Ireland? This can include trips where you personally or someone you were with did this activity.

READ OUT AND ROTATE ORDER.

ALL ACTIVITIES MUST BE ANSWERED - IF RESPONDENT HAS NOT DONE THIS ACTIVITY IN IRELAND DURING THE LAST YEAR, WRITE IN 000.

IF RESPONDENT IS NOT SURE, ASK FOR BEST ESTIMATE/GUESS.

USE LEADING ZEROS E.G. 24 = 024

ROTATE ORDER	No. Trips			
Fishing from seashore				(12-14)
Fishing at sea				(15-17)
Swimming				(18-20)
Wind surfing				(21-23)
Diving				(24-26)
Sea Kayaking				(27-29)
Sailing				(30-32)
Snorkelling				(33-35)
Bird Watching at coast or sea				(36-38)
Walking along Coast				(39-41)
Other Boating				(42-44)
Surfing				(45-47)
Kite Surfing				(48-50)
Whale/ Dolphin Watching				(51-53)
Sunbathing				(54-56)
Picnicking				(57-59)
Family Day Trip				(60-62)
Gathering Seaweed				(63-65)
Gathering Shellfish				(66-68)
Other(Please specify)______________				(69-71)

ASK ALL

Q.9a Have you ever worked in any of the following industries?

Q.9b Has anyone else in your household ever worked in any of the following industries?

READ OUT LIST.

	Q.9a Self	**Q.9b Other household member**
	(57)	(58)
Fisheries	1	1
Aquaculture	2	2
Marine Transport	3	3
Marine-based Oil or Gas Exploration	4	4
None of these	X	X

Q.10a Are you a member of any environmental organisation?

Q.10b Is anyone else in your household a member of any environmental organisation?

	Q.10a Self	**Q.10b Other household member**
	(59)	(60)
Yes	1	1
No	2	2

Q.11 How often do you eat fish or shellfish?

SINGLE CODE, PROMPT TO PRECODES

	(61)
Never	1
Less often than once a month	2
Once a month	3
Weekly	4
Daily	5

Q.12 Thinking about coastal waters and beaches in Ireland, how would you rate their condition? Would you say they are...

SHOWCARD 2. SINGLE CODE.

	(62)
Very poor	1
Fairly poor	2
Neither good nor poor	3
Fairly good	4
Very good	5
Don't know	V

Q.13 Thinking about deep oceans away from the coast (out of sight of land), how would you rate their condition? Would you say they are...
SHOWCARD 2. SINGLE CODE.

	(63)
Very poor	1
Fairly poor	2
Neither good nor poor	3
Fairly good	4
Very good	5
Don't know	V

Q.14 Thinking about the importance of the ocean to you personally, how important is the ocean, in each of the following ways?
SHOWCARD 1, READ OUT, CHOOSE RANDOM STARTING POINT, ONE ANSWER PER ISSUE

	Not at all important	**A little important**	**Somewhat important**	**Important**	**Very important**	**Don't Know**	
Recreation and tourism	1	2	3	4	5	V	(64)
Trade and shipping	1	2	3	4	5	V	(65)
Weather and climate	1	2	3	4	5	V	(66)
Source of food	1	2	3	4	5	V	(67)
For its scenery	1	2	3	4	5	V	(68)
Producer of energy	1	2	3	4	5	V	(69)
Culture and identity	1	2	3	4	5	V	(70)
Employment	1	2	3	4	5	V	(71)
For creativity	1	2	3	4	5	V	(72)
Education and science	1	2	3	4	5	V	(73)

Col 74-80 blank
PUNCHER RE-PUNCH COL 1-9
CARD THREE COL 10-11/(03)

Q.15 When it comes to managing and protecting the ocean environment, how competent do you think each of the following are?
SHOWCARD 3, READ OUT, CHOOSE RANDOM STARTING POINT

	Not at all competent	**A little competent**	**Somewhat competent**	**Competent**	**Highly competent**	**Don't Know**	
Environment groups	1	2	3	4	5	V	(12)
Scientists	1	2	3	4	5	V	(13)
European Union	1	2	3	4	5	V	(14)
Community groups	1	2	3	4	5	V	(15)
Irish government	1	2	3	4	5	V	(16)
Individuals	1	2	3	4	5	V	(17)
County councils	1	2	3	4	5	V	(18)
Private industry	1	2	3	4	5	V	(19)

Q.16 In your opinion, to what extent do each of the following pose a threat to the marine environment?

SHOWCARD 4, READ OUT, CHOOSE RANDOM STARTING POINT

	Does not pose any threat	**Poses little threat**	**Poses somewhat of a threat**	**Poses a threat**	**Poses a severe threat**	Don't know	
Climate change	1	2	3	4	5	V	(20)
Non native species	1	2	3	4	5	V	(21)
Farming	1	2	3	4	5	V	(22)
Aquaculture excluding fishing (i.e. underwater agriculture – growing of aquatic animals or plants of any kind)	1	2	3	4	5	V	(23)
Marine renewables	1	2	3	4	5	V	(24)
Industry pollution	1	2	3	4	5	V	(25)
Litter	1	2	3	4	5	V	(26)
Oil and gas extraction	1	2	3	4	5	V	(27)
Ocean acidification	1	2	3	4	5	V	(28)
Shipping	1	2	3	4	5	V	(29)
Fisheries	1	2	3	4	5	V	(30)

Q. 17 It has been suggested that governments should make plans that specify the different activities that can happen and where they can happen in the sea. To what extent do you agree or disagree with this idea?

SHOWCARD 5, SINGLE CODE

	(31)
Strongly disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly agree	5

Q.18 Some people have suggested that governments should designate parts of the ocean as protected areas, in the same way that they do with national parks on land, while others have said this is not a good idea. To what extent do you agree or disagree with this suggestion?

SHOWCARD 5, SINGLE CODE

	(32)
Strongly disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly agree	5

ASK ALL – READ OUT THE FOLLOWING TEXT AND MAKE SURE RESPONDENT UNDERSTAND

We would now appreciate your opinion on the marine environment of Ireland – this involves the use of choice cards.

INTERVIEWER: USE THE EXAMPLE CHOICE CARD (PAGE 2 IN THE CHOICE CARD SET) TO EXPLAIN WHAT IS REQUIRED:

The health of the marine environment is measured using a number of attributes. We have combined these attributes into different scenarios. We ask you to look at a number of choice cards, where you will have 3 choices. For each choice card, please choose one option. Within each choice card there will always be a choice (Choice C) reflecting the status quo in which you will pay nothing. If you choose an alternative, there will be an amount that you as an individual will have to pay annually for 10 years to help protect the marine environment under this alternative. Payment is expected to be made through a ring fenced tax dedicated to protecting the marine environment either through your income tax or VAT. Please consider how much money is available in your budget considering all your other expenses before making your decision.

Before you make your choices please let us describe the different attributes that measure the health of the marine environment and the levels associated with them.

a) Marine Biodiversity and Healthy Ecosystem

High levels of biodiversity are often a sign of a healthy well-functioning ecosystem. An area has high biodiversity if there are high numbers of different species (especially high level predators), high numbers of those species and the areas in which they live are protected from damage. Biodiversity and healthy ecosystems in Irish waters are known to be under threat from a variety of human activities (i.e. fishing, pollution, marine construction, etc). Currently, most of the seas and oceans around Ireland are rated as at good status with some areas of moderate and poor status; without protection, it is expected that biodiversity will decrease (less species) and there will be a reduction in the area and number of healthy ecosystems.

b) Sustainable and healthy fisheries

The sea provides a variety of fish species which are both nutritious and tasty. In Irish seas while some fisheries are currently have stable populations (e.g. it is sustainable to harvest them) and are safe to eat, other fisheries have been overfished and no longer produce the same yield as in previous years (e.g. it is unsustainable to harvest them). Providing sustainable fisheries may mean closing some fisheries in the short term to allow fish stock to replenish so that they are available both for us in the longer term and for future generations. Management may also be required to ensure fish are healthy and safe to eat.

c) Pollution levels in sea

A variety of polluting substances and litter are known to be entering the seas around Ireland. These pollutants can cause damage to marine environment (e.g. oil slicks), can affect humans by being absorbed through eating fish and can cause harmful algae blooms (e.g. red tides) which can close bathing areas and cause shellfish poisoning. Marine litter can look unsightly and cause damage to marine life. Preventive measures will be needed to reduce the levels of pollution and litter in Irish seas.

d) Non-native species

Marine non-native species are animals and plants that humans transport to Ireland either on purpose or accidently (attached to ships or in ballast water of ships).There are small numbers of marine non-native species in Irish marine waters currently. Non-native species are known to cause damage to oyster beds and disrupt ecosystems. Without preventative measures, these species could spread and new non-native species could travel to Irish waters.

e) Physical impacts on the sea

Physical altering the seabed and changing flows can cause damage to habitats on which various marine species depend and also may cause pollution by stirring up pollutants which were buried in the seabed. Different human activities in the sea and on the coast can change the sea bed and the flows of tides and currents. Underwater noise caused by sonar, ships propellers and construction within the marine environments can also cause disturbance to fish populations and induce stress in marine mammals that use sonar like whales and dolphins. It is expected that some of these activities will increase in the future which is expected to cause more changes to the sea bed and flows. Management of these activities will be needed to prevent significant damage to the marine environment.

ASK ALL

Q.19 How much of what I just told you about the marine environment around Ireland did you know beforehand?

SINGLE CODE, READ OUT.

	(33)
I knew none of what I have been told	1
I knew very little	2
I knew half of it	3
I knew most of it	4
I knew everything	5

Q.20 How well do you think you understand this issue now?

SINGLE CODE. READ OUT.

	(34)
I do not understand it at all	1
I understand very little	2
I understand half of it	3
I understand most of it	4
I understand everything	5

<u>**REMOVE EXAMPLE CHOICE CARD**</u>

Q.21 Take a moment to reflect on the 6 attributes, I just described. Can you remember what they are and say them back?

<u>**DO NOT PROMPT/READ OUT.**</u> **CODE ALL THAT APPLY.**

	(35)
Biodiversity and Healthy Marine Ecosystem	1
Non-native species	2
Sustainable fisheries	3
Pollution levels in sea	4
Physical Impacts to the Sea	5
None	V

INTERVIEWER: SHOW <u>EXAMPLE CHOICE CARD</u> (PAGE 2 IN THE CHOICE CARD SET) AGAIN:

These are the six attributes affecting that measure the health of the marine environment:

- Biodiversity and Healthy Marine Ecosystem
- Non-native species
- Sustainable fisheries
- Pollution levels in sea
- Physical Impacts to the Sea

The final row represents:

- An annual increase in income tax
- To be paid for next 10 years
- The money raised will be ring fenced to fund improvements <u>in Irish marine and coastal waters</u>

EXPLANATION OF HOW THE CHOICE CARDS WORK:
Each choice card has three options shown in three columns: Option A, Option B and Option C

- Each option differs in at least one way and each has a price.
- Option C is always the status quo option with no required payment.
- For each choice card I show you, could you please choose the column that you prefer most out of all three options on the card.

INTERVIEWER INSTRUCTION: PLEASE SHOW THE <u>EXAMPLE CHOICE CARD</u> TO THE RESPONDENT (PAGE 2 IN CHOICE CARD SET) AND GIVE THE RESPONDENT TIME TO EXAMINE IT.

ASK THE RESPONDENTS THE FOLLOWING QUESTION AND RECORD THE ANSWER IN THE GRID ON THE BOTTOM OF THE CHOICE CARD PAGE:

Which of the three options do you prefer?

INTERVIEWER, MAKE SURE THE PARTICIPANTS UNDERSTAND THE CHOICE CARD EXERCISE BEFORE CONTINUING TO THE NEXT 12 CHOICE CARDS (PAGE 3-14). GO THROUGH THE EXERCISE AGAIN IF NECESSARY.

You will now be presented with a series of similar choice cards and on each choice card you will see three options like the example show cards. I would like you to tell me for each page in the choice card set which of the three options you would choose.
EACH PAGE IN THE CHOICE CARD MUST HAVE A RESPONSE IN THE GRID WHERE IT ASKS 'REGISTER CHOICE'.
CIRCLE <u>ONE</u> CODE ONLY IN EACH GRID ON EVERY PAGE IN THE CHOICE CARD SET. REMIND RESPONDENTS TO TREAT EACH PAGE IN THE CHOICE CARD SET INDEPENDENTLY. AN INTERVIEW WILL NOT BE VALID UNLESS EVERY PAGE ON THE CHOICE CARD HAS A RESPONSE IN THE GRID.

SHOW RESPONDENT THE 12 REMAINING CHOICE CARDS ONE BY ONE AND ASK HER/HIM TO CHOOSE ONE OF THE OPTIONS PROVIDED ON EACH PAGE.

PLEASE NOTE THE CHOICE CARDS MUST BE SHOWN ONE BY ONE AND THE RESPONDENT IS NOT ALLOWED TO LOOK BACK ON PREVIOUS CHOICE CARDS. MAKE SURE TO REGISTER CHOICE ON EACH CHOICE CARD BEFORE PROCEDING

MAKE SURE TO ATTACH CHOICE CARD WITH REGISTERED ANSWERS TO QUESTIONNAIRE AND DOUBLE-CHECK THAT EACH PAGE HAS A RESPONSE BEFORE FINISHING INTERVIEW.

PLEASE TRANSFER THE RESPONDENT ID FROM THE QUESTIONNAIRE TO THE CHOICE CARD SET TO ENSURE WE ARE CLEAR IN THE OFFICE WHICH CHOICE CARD SET BELONGS TO WHICH QUESTIONNAIRE.

ASK ALL

Q.22 Thinking back over the choice cards you've just gone through, how confident are you about the choices you made?
SHOWCARD 7

	(36)
Not very confident	1
Somewhat confident	2
Fairly confident	3
Confident	4
Very confident	5

Q.23 When making your decision, did you consider all of the different attributes when making your choices or did you ignore any? More specifically, did you… **READ OUT**

	Yes	No
	(37)	(38)
….ignore the non-native species attribute	1	1
….ignore the biodiversity & healthy ecosystems attribute	2	2
….ignore the sustainable and healthy fisheries attribute	3	3
….ignore pollution levels in sea attribute	4	4
….ignore the physical impacts attribute	5	5
….ignore the cost attribute	6	6
….consider all attributes when picking an option	7	7

ASK THOSE WHO ANSWERED OPTION C (NO CHANGE) FOR <u>ALL</u> TWELVE CHOICE CARDS

Q.24 You have chosen Option C (status quo) throughout, could you tell us why?
Prompt fully: Any other reasons? What other reasons?
DO NOT READ OUT, CODE ALL THAT APPLY

	(39)
I cannot afford to pay	1
I object to paying taxes	2
The improvements are not important to me	3
The "No Change" option is satisfactory	4
The Government/ County Council/EU or other body should pay	5
I don't believe the improvements will actually take place	6
Those who pollute the seas and ocean should pay	7
I didn't know which option was best, so I stayed with the "No Change" option	8
I don't use the sea or marine environment	9
Don't know	0
Other (please specify)____________________	X

ASK ALL

Q.25 Do you think that good environmental status in Irish seas should be aimed for?

	(40)
Yes	1
No	2
Don't know	X

Q.26 Based on all the information you have heard so far and again remembering your income and budget, what would be the <u>most</u> that you would be willing to contribute as an annual cost towards achieving good environmental status in the seas around Ireland?

SHOWCARD 8

	(41)		(42)		(43)
Nothing/€0	1	€25	1	€100	1
€1	2	€30	2	€120	2
€3	3	€35	3	€150	3
€5	4	€40	4	€200	4
€8	5	€45	5	More than €200	5
€10	6	€50	6		
€12	7	€55	7		
€15	8	€60	8		
€18	9	€70	9		
€20	0	€80	0		

INTERVIEWER: RESPONDENT MUST ANSWER THIS QUESTION!

ASK ALL

Q.27 Do you think on average other people in Ireland would be willing to pay towards achieving good environmental status in Irish waters?

	(44)	
Yes	1	**CONTINUE**
No	2	**GO TO Q.29**

ASK IF YES AT Q.27 (CODE 1 IN Q.27)

Q.28 How much do you think on average each person would be willing to contribute as an annual cost?
SHOWCARD 9

	(45)		(46)		(47)
[redacted]		€25	1	€100	1
€1	2	€30	2	€120	2
€3	3	€35	3	€150	3
€5	4	€40	4	€200	4
€8	5	€45	5	More than €200	5
€10	6	€50	6		
€12	7	€55	7		
€15	8	€60	8		
€18	9	€70	9		
€20	0	€80	0		

ASK ALL WHO SAY THEY WOULD BE WILLING TO PAY €1 OR MORE AT Q.26.

ALL OTHERS GO TO Q.30

Q.29a Would you prefer to pay more towards certain areas or let policymakers decide how to target the funds?

USE SHOWCARD 6 (map)

The map below shows the Irish territorial waters outlined in black. We want to know whether you would prefer your contribution to be targeted at a particular marine area or all Irish seas. The different choices of marine areas are the Irish Sea, Celtic Sea, Atlantic Ocean or all Irish Seas.

All Irish waters are outline in the thick black line. Irish Sea is to the east (right) of the island of Ireland shaded dark grey. The Celtic Sea is to the south of the island of Ireland shaded light grey. The Atlantic Ocean is to the west (left) of the island of Ireland and is shaded mid grey.

	(48)	
Direct 100% of your payment to all of seas around Ireland (policymakers will decide how to target funds)	1	**Go to Q.30**
Direct a percentage towards a certain sea/ ocean	2	**CONTINUE**

ASK ALL WHO PREFER TO DIRECT A PERCENTATGE TOWARDS A CETAIN SEA/OCEAN (CODE 2 AT Q.29a)

Q.29b What percentage would you like to direct towards each sea/ocean?

USE SHOWCARD 6 (map)

READ OUT. TOTAL MUST ADD TO 100%

USE LEADING ZEROS E.G. 24 = 024

Irish Sea				% (49-51)
Celtic Sea				% (52-54)
Atlantic Ocean				% (55-57)
	1	**0**	**0**	**%**

ASK ALL

Q.30 We would also like to give you the option of contributing some of your time towards helping towards achieving good environmental status in Ireland's seas (perhaps by volunteering for beach clean up duties, educating school children on the importance of our marine environment, coastal erosion prevention works, marine wildlife conservation, etc).

Approximately how many hours a year would you be willing to help out?

	Number of hours per year			
USE LEADING ZEROS E.G. 24 = 024				(58-60)

Q.31. If given the choice, would you prefer to contribute some of your time or would you prefer to pay any of the tax amount mentioned earlier?

	(61)
Would prefer to contribute time	1
Would prefer to pay	2

FINALLY, I WOULD LIKE TO ASK A FEW QUESTIONS ABOUT YOUR HOUSEHOLD.

Q.13 Including you, how many people are there in your household in the following age groups:
USE LEADING ZEROS, E.G. 04 FOR 04 PEOPLE

	NO. OF PEOPLE		
a) Below 5 years old			(62-63)
b) Between 5-15 years old			(64-65)
c) Between 16-60 years old			(66-67)
d) Over 60 years old			(68-69)

Q.15 Could you please indicate the letter that best describes your total <u>personal income</u> per year (whether from employment, pensions, state benefits, investments or any other sources) before deduction of tax.
IF RESPONDENTS DO NOT WANT TO DISCLOSE THEIR INCOME REMIND THEM THAT IT WILL BE KEPT CONFIDENTIAL.

	(70)
A) Less than €10,000	1
B) €10,001 – €20,000	2
C) €20,001 – €30,000	3
D) €30,001 – €40,000	4
E) €40,001 – €50,000	5
F) €50,001 - €60,000	6
G) €60,001 - €70,000	7
H) €70,001 - €80,000	8
I) €80,001-€90,000	9
J) €90,001 - €99,999	0
K) €100,000+	X
L) Refused	V

THANKS AND CLOSE

Appendix B. Block 1 Choice Cards

Choice Card 1

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	**Biodiversity increases**	**Biodiversity maintained at current levels**	**Biodiversity decreases**
Sustainable fisheries	**Healthy fish stock** *(stocks sustainable, no contaminant in fish and other seafood)*	**Healthy to eat but Non-sustainable fish stock** *(stock is over-fished but no contaminants present in fish and other seafood)*	**Unhealthy fish stock** *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	**Pollution decreases**	**Pollution increases**	**Pollution increases**
Non-native species	**No new non-native species but existing non-native species remain** *(Ecosystem altered by 5%)*	**Irish waters are virtually free of non-native species***(Ecosystem unaltered)*	**New non-native species invade Irish waters in addition to existing non-native species** *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	**Limited damage**	**No damage**	**Wide scale damage**
Amount you have to pay	**€30**	**€10**	**€0**
Please indicate your choice by checking box	☐	☐	☐

Choice Card 2

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity maintained at current levels	Biodiversity decreases	Biodiversity decreases
Sustainable fisheries	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution increases	No change in pollution	Pollution increases
Non-native species	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	Irish waters are virtually free of non-native species *(Ecosystem unaltered)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Wide scale damage	Limited damage	Wide scale damage
Amount you have to pay	€5	€70	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 3

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity maintained at current levels	Biodiversity decreases	Biodiversity decreases
Sustainable fisheries	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	No change in pollution	No change in pollution	Pollution increases
Non-native species	Irish waters are virtually free of non-native species *(Ecosystem unaltered)*	Irish waters are virtually free of non-native species *(Ecosystem unaltered)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Limited damage	Wide scale damage	Wide scale damage
Amount you have to pay	€5	€70	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 4

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity maintained at current levels	Biodiversity increases	Biodiversity decreases
Sustainable fisheries	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	No change in pollution	No change in pollution	Pollution increases
Non-native species	Irish waters are virtually free of non-native species*(Ecosystem unaltered)*	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Wide scale damage	No damage	Wide scale damage
Amount you have to pay	€70	€10	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 5

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity increases	Biodiversity maintained at current levels	Biodiversity decreases
Sustainable fisheries	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution decreases	No change in pollution	Pollution increases
Non-native species	Irish waters are virtually free of non-native species*(Ecosystem unaltered)*	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	No damage	Limited damage	Wide scale damage
Amount you have to pay	€10	€5	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 6

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity increases	Biodiversity increases	Biodiversity decreases
Sustainable fisheries	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	No change in pollution	No change in pollution	Pollution increases
Non-native species	Irish waters are virtually free of non-native species *(Ecosystem unaltered)*	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	No damage	Limited damage	Wide scale damage
Amount you have to pay	€30	€30	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 7

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity decreases	Biodiversity maintained at current levels	Biodiversity decreases
Sustainable fisheries	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution increases	Pollution increases	Pollution increases
Non-native species	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Wide scale damage	Limited damage	Wide scale damage
Amount you have to pay	€70	€5	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 8

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity increases	Biodiversity decreases	Biodiversity decreases
Sustainable fisheries	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	No change in pollution	Pollution increases	Pollution increases
Non-native species	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Limited damage	Limited damage	Wide scale damage
Amount you have to pay	€20	€45	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 9

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity decreases	Biodiversity maintained at current levels	Biodiversity decreases
Sustainable fisheries	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	No change in pollution	Pollution decreases	Pollution increases
Non-native species	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	Irish waters are virtually free of non-native species*(Ecosystem unaltered)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Limited damage	Wide scale damage	Wide scale damage
Amount you have to pay	€45	€20	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 10

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	**Biodiversity maintained at current levels**	**Biodiversity maintained at current levels**	**Biodiversity decreases**
Sustainable fisheries	**Healthy fish stock** *(stocks sustainable, no contaminant in fish and other seafood)*	**Healthy to eat but Non-sustainable fish stock** *(stock is over-fished but no contaminants present in fish and other seafood)*	**Unhealthy fish stock** *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	**Pollution increases**	**No change in pollution**	**Pollution increases**
Non-native species	**Irish waters are virtually free of non-native species***(Ecosystem unaltered)*	**New non-native species invade Irish waters in addition to existing non-native species** *(Ecosystem altered by 20%)*	**New non-native species invade Irish waters in addition to existing non-native species** *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	**Wide scale damage**	**No damage**	**Wide scale damage**
Amount you have to pay	**€20**	**€45**	**€0**
Please indicate your choice by checking box	☐	☐	☐

Choice Card 11

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity maintained at current levels	Biodiversity increases	Biodiversity decreases
Sustainable fisheries	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution decreases	Pollution decreases	Pollution increases
Non-native species	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Limited damage	No damage	Wide scale damage
Amount you have to pay	€45	€30	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 12

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity maintained at current levels	Biodiversity decreases	Biodiversity decreases
Sustainable fisheries	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution decreases	No change in pollution	Pollution increases
Non-native species	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	No damage	Wide scale damage	Wide scale damage
Amount you have to pay	€20	€20	€0
Please indicate your choice by checking box	☐	☐	☐

Appendix C Block 2 Choice Cards

Choice Card 1

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity decreases	Biodiversity maintained at current levels	Biodiversity decreases
Sustainable fisheries	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	No change in pollution	No change in pollution	Pollution increases
Non-native species	Irish waters are virtually free of non-native species*(Ecosystem unaltered)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	No damage	Limited damage	Wide scale damage
Amount you have to pay	€10	€70	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 2

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity maintained at current levels	Biodiversity decreases	Biodiversity decreases
Sustainable fisheries	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	No change in pollution	Pollution increases	Pollution increases
Non-native species	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Wide scale damage	Limited damage	Wide scale damage
Amount you have to pay	€70	€5	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 3

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity increases	Biodiversity increases	Biodiversity decreases
Sustainable fisheries	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution decreases	No change in pollution	Pollution increases
Non-native species	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	Irish waters are virtually free of non-native species *(Ecosystem unaltered)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	No damage	Limited damage	Wide scale damage
Amount you have to pay	€30	€30	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 4

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity maintained at current levels	Biodiversity maintained at current levels	Biodiversity decreases
Sustainable fisheries	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	No change in pollution	Pollution decreases	Pollution increases
Non-native species	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Limited damage	Wide scale damage	Wide scale damage
Amount you have to pay	€70	€10	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 5

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity maintained at current levels	Biodiversity increases	Biodiversity decreases
Sustainable fisheries	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution increases	Pollution decreases	Pollution increases
Non-native species	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	Irish waters are virtually free of non-native species *(Ecosystem unaltered)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	No damage	Limited damage	Wide scale damage
Amount you have to pay	€45	€20	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 6

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity decreases	Biodiversity maintained at current levels	Biodiversity decreases
Sustainable fisheries	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	No change in pollution	Pollution increases	Pollution increases
Non-native species	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Wide scale damage	Wide scale damage	Wide scale damage
Amount you have to pay	€5	€70	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 7

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity decreases	Biodiversity maintained at current levels	Biodiversity decreases
Sustainable fisheries	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution increases	No change in pollution	Pollution increases
Non-native species	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	Irish waters are virtually free of non-native species*(Ecosystem unaltered)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	No damage	Wide scale damage	Wide scale damage
Amount you have to pay	€10	€45	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 8

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity increases	Biodiversity decreases	Biodiversity decreases
Sustainable fisheries	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	No change in pollution	Pollution decreases	Pollution increases
Non-native species	Irish waters are virtually free of non-native species*(Ecosystem unaltered)*	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Limited damage	No damage	Wide scale damage
Amount you have to pay	€30	€20	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 9

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity increases	Biodiversity decreases	Biodiversity decreases
Sustainable fisheries	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution decreases	Pollution increases	Pollution increases
Non-native species	Irish waters are virtually free of non-native species*(Ecosystem unaltered)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Limited damage	No damage	Wide scale damage
Amount you have to pay	€20	€45	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 10

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity decreases	Biodiversity maintained at current levels	Biodiversity decreases
Sustainable fisheries	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution increases	Pollution decreases	Pollution increases
Non-native species	Irish waters are virtually free of non-native species*(Ecosystem unaltered)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Wide scale damage	No damage	Wide scale damage
Amount you have to pay	€5	€10	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 11

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity maintained at current levels	Biodiversity decreases	Biodiversity decreases
Sustainable fisheries	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	No change in pollution	No change in pollution	Pollution increases
Non-native species	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Wide scale damage	Limited damage	Wide scale damage
Amount you have to pay	€45	€5	€0
Please indicate your choice by checking box	☐	☐	☐

Choice Card 12

Attribute	Choice A	Choice B	Choice C
Biodiversity and Healthy Marine Ecosystem	Biodiversity decreases	Biodiversity increases	Biodiversity decreases
Sustainable fisheries	Healthy to eat but Non-sustainable fish stock *(stock is over-fished but no contaminants present in fish and other seafood)*	Healthy fish stock *(stocks sustainable, no contaminant in fish and other seafood)*	Unhealthy fish stock *(stock over-fished and unsafe levels of contaminants present in fish and other seafood)*
Pollution levels in sea	Pollution decreases	No change in pollution	Pollution increases
Non-native species	No new non-native species but existing non-native species remain *(Ecosystem altered by 5%)*	Irish waters are virtually free of non-native species*(Ecosystem unaltered)*	New non-native species invade Irish waters in addition to existing non-native species *(Ecosystem altered by 20%)*
Physical Impacts to the Sea	Limited damage	No damage	Wide scale damage
Amount you have to pay	€10	€30	€0
Please indicate your choice by checking box	☐	☐	☐

Appendix D. Appendix III of the Commission Directive 2017

'ANNEX III'

Indicative lists of ecosystem elements, anthropogenic pressures and human activities relevant to the marine waters

(referred to in Articles 8(1), 9(1), 9(3), 10(1), 11(1) and 24)

Table 1

Structure, functions and processes of marine ecosystems

with particular relevance for point (a) of Article 8(1), and Articles 9 and 11

Theme	Ecosystem elements	Possible parameters and characteristics (Note 1)	Relevant qualitative descriptors laid down in Annex I (Notes 2 and 3)
Species	Species groups (Note 4) of marine birds, mammals, reptiles, fish and cephalopods of the marine region or subregion	Spatial and temporal variation per species or population: —distribution, abundance and/or biomass — size, age and sex structure —fecundity, survival and mortality/injury rates — behaviour including movement and migration —habitat for the species	(1); (3)

		(extent, suitability) Species composition of the group	
Habitats	Broad habitat types of the water column (pelagic) and seabed (benthic) (Note 5), or other habitat types, including their associated biological communities throughout the marine region or subregion	Per habitat type: — habitat distribution and extent (and volume, if appropriate) — species composition, abundance and/ or biomass (spatial and temporal variation) — size and age structure of species (if appropriate) — physical, hydrological and chemical characteristics Additionally for pelagic habitats: — chlorophyll a concentration —plankton bloom frequencies and spatial extent	(1); (6)
Ecosystems, including food webs	Ecosystem structure, functions and processes, comprising: — physical	Spatial and temporal variation in:	(1); (4)

	and hydrological characteristics — chemical characteristics — biological characteristics — functions and processes	— temperature and ice —hydrology (wave and current regimes; upwelling, mixing, residence time, freshwater input; sea level) — bathymetry —turbidity (silt/sediment loads), transparency, sound — seabed substrate and morphology —salinity, nutrients (N, P), organic carbon, dissolved gases (pCO2, O2) and pH — links between habitats and species of marine birds, mammals, reptiles, fish and cephalopods — pelagic-benthic community structure — productivity

Notes related to Table 1

Note 1: An indicative list of relevant parameters and characteristics for species, habitats and ecosystems is given, reflecting parameters affected by the pressures of Table 2 of this Annex and of relevance to criteria laid down in accordance with Article 9(3). The particular parameters and characteristics to be used for monitoring and assessment should be determined in accordance with the requirements of this Directive, including those of its Articles 8 to 11.

Note 2: The numbers in this column refer to the respective numbered points in Annex I.

Note 3: Only the state-based qualitative descriptors (1), (3), (4) and (6) which have criteria laid down in accordance with Article 9(3) are listed in Table 1. All other, pressure-based, qualitative descriptors under Annex I may be relevant for each theme.

Note 4: These species groups are further specified in Part II of the Annex to Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU (see page 43 of this Official Journal).

Note 5: These broad habitat types are further specified in Part II of the Annex to Decision (EU) 2017/848.

Table 2

Anthropogenic pressures, uses and human activities in or affecting the marine environment

2a. Anthropogenic pressures on the marine environment

with particular relevance for points (a) and (b) of Article 8(1), and Articles 9, 10 and 11

Theme	Pressure (Note 1)	Possible parameters	Relevant qualitative descriptors laid down in Annex I (Notes 2 and 3)

Biological	Input or spread of non-indigenous species Input of microbial pathogens Input of genetically modified species and translocation of native species Loss of, or change to, natural biological communities due to cultivation of animal or plant species Disturbance of species (e.g. where they breed, rest and feed) due to human presence Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)	Intensity of, and spatial and temporal variation in, the pressure in the marine environment and, where relevant, at source For assessment of environmental impacts of the pressure, select relevant ecosystem elements and parameters from Table 1	(2) (3)
Physical	Physical disturbance to seabed (temporary or reversible) Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate) Changes to hydrological		(6); (7)

	conditions		
Substances, litter and energy	Input of nutrients — diffuse sources, point sources, atmospheric deposition		(5)
	Input of organic matter — diffuse sources and point sources		
	Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) — diffuse sources, point sources, atmospheric deposition, acute events		(8);(9)
	Input of litter (solid waste matter, including micro-sized litter)		(10)
	Input of anthropogenic sound (impulsive, continuous)		(11)
	Input of other forms of energy (including electromagnetic fields, light and heat)		
	Input of water — point sources (e.g. brine)		

2b. Uses and human activities in or affecting the marine environment

with particular relevance for points (b) and (c) of Article 8(1) (only activities marked * are relevant for point (c) of Article 8(1)), and Articles 10 and 13	
Theme	Activity
Physical restructuring of rivers, coastline or seabed (water management)	Land claim
	Canalisation and other watercourse modifications
	Coastal defence and flood protection*
	Offshore structures (other than for oil/gas/renewables)*
	Restructuring of seabed morphology, including dredging and depositing of materials*
Extraction of non-living resources	Extraction of minerals (rock, metal ores, gravel, sand, shell)*
	Extraction of oil and gas, including infrastructure*
	Extraction of salt*
	Extraction of water*
Production of energy	Renewable energy generation (wind, wave and tidal power), including infrastructure*
	Non-renewable energy generation
	Transmission of electricity and communications (cables)*

Extraction of living resources	Fish and shellfish harvesting (professional, recreational)*
	Fish and shellfish processing*
	Marine plant harvesting*
	Hunting and collecting for other purposes*
Cultivation of living resources	Aquaculture — marine, including infrastructure*
	Aquaculture — freshwater
	Agriculture
	Forestry
Transport	Transport infrastructure*
	Transport — shipping*
	Transport — air
	Transport — land
Urban and industrial uses	Urban uses
	Industrial uses
	Waste treatment and disposal*
Tourism and leisure	Tourism and leisure infrastructure*

	Tourism and leisure activities*
Security/defence	Military operations (subject to Article 2(2))
Education and research	Research, survey and educational activities*

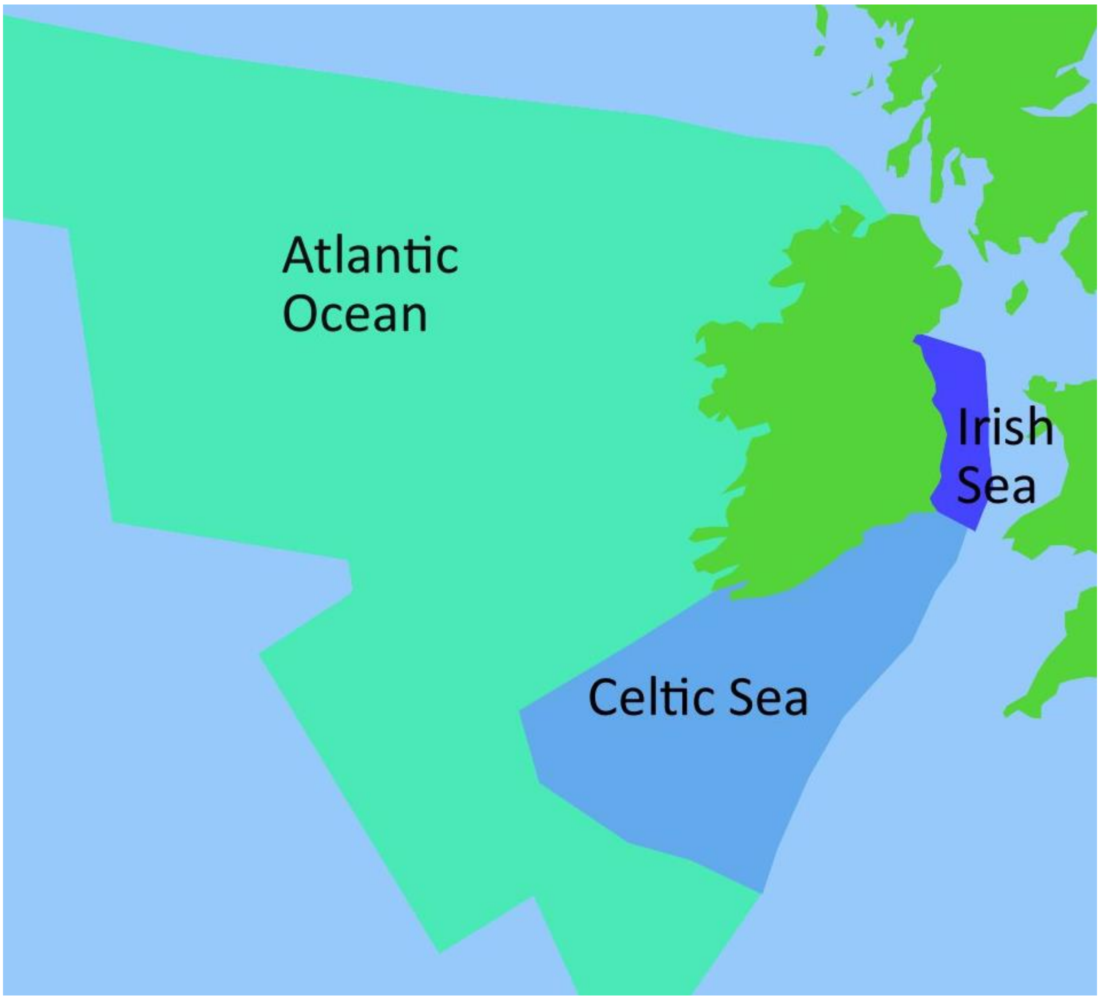
Notes related to Table 2

Note 1: Assessments of pressures should address their levels in the marine environment and, if appropriate, the rates of input (from land-based or atmospheric sources) to the marine environment.

Note 2: The numbers in this column refer to the respective numbered points in Annex I.

Note 3: Only pressure-based qualitative descriptors (2), (3), (5), (6), (7), (8), (9), (10) and (11), which have criteria laid down in accordance with Article 9(3), are listed in Table 2a. All other, state-based, qualitative descriptors under Annex I may be relevant for each theme.'

Appendix E. Showcard 6 (Map of Irish Marine Areas)



Appendix F. Details of the pollutants discharged from coastal and estuarine licensed urban wastewater treatment plants.

Reg CD	Name	BOD/cBOD(kg/yr)	TN(kg/yr)	TP(kg/yr)	Source	Source_Link	Primary_Discharge_Waterbody	WFD_WB_Type	Notes
D0034	Ringsend	3,880,506	3,205,575	613,235	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c5e5.pdf	Liffey Estuary Lower	Transitional	
D0013	Limerick	152,681	185,770	40,155	2014 AER	http://www.epa.ie/licences/lic_eDMS/090151b280526114.pdf	Limerick Dock	Transitional	
D0033	Cork City	496,875	816,784	88,514	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c452.pdf	Lough Mahon	Transitional	
D0050	Galway	45,125	309,991	19,893	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c458.pdf	Inner Galway Bay North	Coastal	
D0057	Ringaskiddy	1,505,351	294,664	61,095	2014 AER	http://www.epa.ie/licences/lic_eDMS/090151b280528adc.pdf	Cork Harbour	Coastal	
D0038	Shanganagh	74,876	407,023	41,028	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c5e8.pdf	Southwestern Irish Sea - Killiney Bay (HA10)	Coastal	
D0022	Waterford city	77,385	177,730	22,813	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30ad.pdf	Lower Suir Estuary (Little Island - Cheekpoint)	Transitional	
D0024	Swords	20,101	43,904	3,172	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30af.pdf	Broadmeadow Water	Transitional	
D0041	Drogheda	24,536	87,456	5,018	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059d4ae.pdf	Boyne Estuary	Transitional	
D0053	Dundalk	15,249	96,393	9,690	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059bebb.pdf	Castletown Estuary	Transitional	
D0010	Greystones	14,317	41,062	10,532	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30a9.pdf	Southwestern Irish Sea - Killiney Bay (HA10)	Coastal	
D0030	Wexford town	13,667	36,204	1,088	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30b1.pdf	Wexford Harbour	Coastal	
D0023	Balbriggan	8,467	26,022	9,728	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b31c6.pdf	Northwestern Irish Sea (HA 08)	Coastal	
D0009	Letterkenny	10,842	12,927	1,580	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f5a0.pdf	Swilly Estuary	Transitional	
D0051	Clonakilty and Environs	15,150	2,637	2,707	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f5a0.pdf	Clonakilty Harbour	Transitional	
D0014	Sligo	41,347	39,196	4,344	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c368.pdf	Garavoge Estuary	Transitional	
D00	Dungarvan	8,250	26,966	5,838	2015	http://www.epa.ie/licences/lic_eDMS/090151	Dungarvan Harbour	Coastal	

17					AER	b28059c44d.pdf			
D0114	Portrane-Donabate	6,765	24,403	6,254	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30cb.pdf	Northwestern Irish Sea (HA 08)	Coastal	
D0006	Arklow and Environs	*372,234*	*62,039*	*12,408*	Application Form	http://www.epa.ie/licences/lic_eDMS/090151b2804c29e7.pdf	Avoca Estuary	Transitional	Estimates based on PE taken from Application Form
D0021	Malahide	11,507	21,887	5,119	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30ab.pdf	Malahide Bay	Coastal	
D0055	Westport	3,684	9,837	1,981	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059d4af.pdf	Westport Bay	Trans	
D0012	Wicklow	8,388	21,797	5,657	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30aa.pdf	Southwestern Irish Sea - Killiney Bay (HA10)	Coastal	
D0045	Shannon Town	196,602	77,936	16,761	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c456.pdf	Upper Shannon Estuary	Transitional	
D0139	Youghal	*313,170*	*52,195*	*10,439*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b2805389d3.pdf	Lower Blackwater M Estuary / Youghal Harbour	Transitional	Estimates based on PE taken from EPA Inspectors Report
D0040	Tralee	20,670	40,801	5,528	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30c4.pdf	Lee K Estuary	Transitional	
D0056	Midleton	4,572	11,684	*675*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c45b.pdf	North Channel Great Island	Transitional	
D0044	Carrigtwohill and Environs	27,794	17,352	2,011	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c455.pdf	Lough Mahon (Harper's Island)	Transitional	
D0016	Ballina	3,955	42,700	4,711	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c369.pdf	Moy Estuary	Transitional	
D0036	New Ross	9,140	15,506	844	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30c3.pdf	New Ross Port	Transitional	
D0125	Buncrana	101,639	*32,650*	*6,530*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f5a6.pdf	Lough Swilly	Coastal	

D0015	Tramore	6,801	30,491	1,408	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c44c.pdf	Tramore Back Strand	Coastal	
D0046	Courtown-Gorey	4,828	18,510	2,332	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c457.pdf	Southwestern Irish Sea (HAs 11;12)	Coastal	
D0148	Carrick-on-Suir	1,978	4,160	174	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c476.pdf	Upper Suir Estuary	Transitional	
D0029	Enniscorthy	8,740	20,080	2,521	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30b0.pdf	Upper Slaney Estuary	Transitional	
D0179	Listowel WWTP	3,191	10,869	*1,040*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30e7.pdf	Upper Feale Estuary	Transitional	
D0185	Dingle	2,953	*7,901*	*986*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c618.pdf	Dingle Harbour	Coastal	
D0119	Rush	*137,817*	*22,969*	*4,594*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b28039f8e8.pdf	Northwestern Irish Sea (HA 08)	Coastal	Estimates based on PE taken from EPA Inspectors Report
D0011	Killybegs	246,078	37,451	11,274	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f5a1.pdf	Killybegs Harbour	Coastal	
D0132	Kinsale	3,662	5,823	1,101	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805a0171.pdf	Lower Bandon Estuary	Transitional	
D0078	Kilkee	*109,062*	*18,177*	*3,635*	AER 2015	http://www.epa.ie/licences/lic_eDMS/090151b28059c2ed.pdf	Shannon Plume (HAs 27;28)	Coastal	Estimates based on PE taken from 2015 AER
D0075	Kilrush	*101,616*	*16,936*	*3,387*	AER 2015	http://www.epa.ie/licences/lic_eDMS/090151b28059c371.pdf	Mouth of the Shannon (HAs 23;27)	Coastal	Estimates based on PE taken from 2015 AER

D01 35	Donegal Town	2,225	10,013	278	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151 b28059ec18.pdf	Donegal Bay (Erne)	Coastal	
D01 13	Carndonagh-Malin	1,715	6,464	791	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151 b28059e015.pdf	Trawbreaga Bay	Coastal	
D03 31	Milltown	1,070	*5,185*	*579*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151 b2805b3115.pdf	Castlemaine Harbour	Transitional	
D01 70	Dunmore East	*95,221*	*15,870*	*3,174*	AER 2015	http://www.epa.ie/licences/lic_eDMS/090151 b28059c613.pdf	Waterford Harbour	Coastal	Estimates based on PE taken from 2015 AER
D01 88	Blackrock	14,198	16,773	2,574	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151 b28059c47f.pdf	Inner Dundalk Bay	Transitional	
D01 72	Rosscarbery-Owenahincha	*62,102*	*13,308*	*2,662*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151 b28057af23.pdf	Rosscarbery Bay	Coastal	Estimates based on PE taken from EPA Inspectors Report
D01 82	Killorglin	2,960	*5,122*	*721*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151 b2805a0172.pdf	Castlemaine Harbour	Transitional	
D01 84	Kenmare	716	*4,377*	*474*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151 b28059c617.pdf	Inner Kenmare River	Transitional	
D00 72	Achill Island Central Waste Water Treatment Plant	927	6,887	375	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151 b28059c464.pdf	Western Atlantic Seaboard (HAs 32;33;34)	Coastal	
D01 30	Bundoran	64,415	10,429	1,728	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151 b2805a2c4d.pdf	Bundoran Bay	Coastal	
D00 87	Kilcoole	594	2,783	202	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151 b2805b30c8.pdf	Kilcoole Marsh	Transitional	
D01 68	Bantry	2,678	*6,576*	*144*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151 b28059c611.pdf	Inner Bantry Bay	Transitional	

D0107	Strandhill	17,715	8,917	1,452	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c379.pdf	Sligo Bay	Coastal	
D0166	Skibbereen	2,942	2,541	601	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c47c.pdf	Ilen Estuary	Transitional	
D0198	Clifden	20,243	11,980	1,064	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f5a8.pdf	Clifden Bay	Transitional	
D0102	Enniscrone	1,071	1,993	401	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c378.pdf	Killala Bay	Coastal	
D0212	Moville	*60,072*	*10,012*	*2,002*	Application Form	http://www.epa.ie/licences/lic_eDMS/090151b2802798ea.pdf	Lough Foyle	Coastal	Estimates based on PE taken from Application Form
D0183	Ballybunion	950	2,054	502	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30e8.pdf	Cashen	Transitional	
D0162	Ardmore	*57,378*	*9,563*	*1,913*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b28035fcab.pdf	Eastern Celtic Sea (HAs 13;17)	Coastal	Estimates based on PE taken from EPA Inspectors Report
D0199	Clareabbey	2,596	2,431	525	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c61c.pdf	Fergus Estuary	Transitional	
D0268	Carlingford Sewerage Scheme	2,725	3,426	559	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c498.pdf	Carlingford Lough	Coastal	
D0173	Rosslare Strand and Environs	1,437	7,496	1,396	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30e3.pdf	Southwestern Irish Sea (HAs 11;12)	Coastal	
D0211	Dunfanaghy-Portnablagh	6,796	*6,504*	*1,301*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f0dd.pdf	Sheephaven Bay	Coastal	
D0423	Whitegate-Aghada	*42,771*	*7,128*	*1,426*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b28055dce8.pdf	Cork Harbour	Coastal	Estimates based on PE

									taken from EPA Inspectors Report
D0345	Rathmullan	41,656	*6,169*	*1,234*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f5ad.pdf	Swilly Estuary	Transitional	
D0176	Lismore	808	3,871	410	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c614.pdf	Upper Blackwater M Estuary	Transitional	
D0352	Lifford	28,233	*5,972*	*1,194*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f5ae.pdf	Foyle and Faughan Estuaries	Transitional	
D0272	Cappoquin	31,026	5,392		2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c62a.pdf	Upper Blackwater M Estuary	Transitional	
D0128	Ballyshannon	1,528	5,129	709	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059ec16.pdf	Erne Estuary	Transitional	
D0350	Downings	45,020	5,509	832	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805a2c4e.pdf	Sheephaven Bay	Coastal	
D0276	Kinvara	30,683	7,945	1,233	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c382.pdf	Kinvarra Bay	Transitional	
D0274	Portlaw	6,559	4,852	864	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c62c.pdf		Transitional	
D0074	Belmullet	*36,989*	*6,165*	*1,233*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b28046f39c.pdf	Belmullet Bay	Coastal	Estimates based on PE taken from EPA Inspectors Report
D0208	Dungloe	8,391	2,289	290	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f5a9.pdf	Dungloe Bay	Coastal	
D0343	Falcarragh	10,172	*6,015*	*1,203*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059d4b0.pdf	Ballyness Bay	Coastal	
D0341	Ramelton	30,222	19,345	6,460	AER 2015	http://www.epa.ie/licences/lic_eDMS/090151b28059f0de.pdf	Swilly Estuary	Transitional	
D0232	Kilmore Quay Village and Environs	*35,215*	*5,869*	*1,174*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b2804b9038.pdf	Eastern Celtic Sea (HAs 13;17)	Coastal	Estimates based on PE

									taken from EPA Inspectors Report
D0067	Killala	*32,850*	*5,475*	*1,095*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c460.pdf	Killala Bay	Coastal	Estimates based on PE taken from 2015 AER
D0327	Ballyvaughan Wastewater Treatment Plant	*32,850*	*5,475*	*1,095*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c4a9.pdf	Ballyvaghan Bay	Coastal	Estimates based on PE taken from 2015 AER
D0224	Newport	*22,535*	*4,829*	*966*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b280579098.pdf	Newport Bay	Transitional	Estimates based on PE taken from EPA Inspectors Report
D0512	Ardara	642	2,368	249	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f5b0.pdf	Owenea Estuary	Coastal	
D0297	Castletownbere	*28,470*	*4,745*	*949*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c635.pdf	Berehaven	Coastal	Estimates based on PE taken from 2015 AER
D0080	Lahinch	3,675	2,850	718	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c5f4.pdf	Inagh Estuary	Transitional	

D0418	Ballyduff	32,570	*4,075*	*815*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b313a.pdf	Cashen	Transitional	
D0081	Ennistymon	5,410	2,167	411	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c5f5.pdf	Inagh Estuary	Transitional	
D0461	Castlegregory	13,533	*3,962*	*792*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c662.pdf	Outer Tralee Bay	Coastal	
D0186	Ballyheigue	1,264	*3,140*	*45*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30e9.pdf	Outer Tralee Bay	Coastal	
D0245	Duncannon	*25,667*	*4,278*	*856*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b2804ffac7.pdf	Barrow Suir Nore Estuary	Transitional	Estimates based on PE taken from EPA Inspectors Report
D0312	Adare	863	1,138	36	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c640.pdf	Maigue Estuary	Transitional	
D0181	Cahersiveen	691	*1,423*	*190*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c616.pdf	Ferta	Transitional	
D0095	Ballysadare	675	3,248	134	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c377.pdf	Ballysadare Estuary	Transitional	
D0145	Mooncoin	717	1,192	154	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c608.pdf	Middle Suir Estuary	Transitional	
D0295	Schull	619	*1,305*	532	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c4a2.pdf	Roaring Water Bay	Coastal	
D0322	Clarecastle	*21,900*	*3,650*	*730*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b2805122b9.pdf	Fergus Estuary	Transitional	Estimates based on PE taken from EPA Inspectors Report
D0140	North Cobh	527	1,080	227	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c606.pdf	Lough Mahon	Transitional	
D0285	Sneem	544	*1,059*	*117*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c62d.pdf	Sneem Harbour	Transitional	

D0265	Clogherhead	2,377	5,391	766	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c623.pdf	Louth Coast (HA 06)	Coastal	
D0538	St Johnston	*20,236*	*3,373*	*675*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b2805567f3.pdf	Foyle and Faughan Estuaries	Coastal	Estimates based on PE taken from EPA Inspectors Report
D0241	Fethard-on-Sea and Environs	4,569	*2,996*	*599*	2014 Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b28050ce3c.pdf	Eastern Celtic Sea (HAs 13;17)	Coastal	
D0266	Tullyallen Sewerage Scheme	376	1,700	159	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c497.pdf	Boyne Estuary	Transitional	
D0522	Mountcharles	4,928	*2,432*	*617*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f0e8.pdf	Donegal Bay (Erne)	Coastal	
D0165	Rosslare Harbour	1,049	3,438	865	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b30e1.pdf	Southwestern Irish Sea (HAs 11;12)	Coastal	
D0284	Fenit	10,336	3,501	417	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b3113.pdf	Outer Tralee Bay	Coastal	
D0358	Baile Na nGall	772	343	208	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c4b2.pdf	Dungarvan Harbour	Coastal	
D0535	Fahan	3,686	*2,480*	*496*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f0e8.pdf	Swilly Estuary	Transitional	
D0471	Glengarriff	*11,498*	*2,464*	*493*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b314d.pdf	Glengarriff Harbour	Transitional	Estimates based on PE taken from 2015 AER
D0516	Ballycotton	36,034	*2,657*	*531*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c670.pdf	Ballycotton Bay	Coastal	
D0523	Carrigart	13,050	2,172	444	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f5b2.pdf	Mulroy Bay Broadwater	Coastal	

D0469	Union Hall	*9,857*	*2,112*	*422*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b3143.pdf	Glandore Harbour	Transitional	Estimates based on PE taken from 2015 AER
D0430	Liscannor	13,928	*2,321*	*464*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c4c1.pdf	Liscannor Bay	Coastal	
D0353	Stradbally	2,957	*1,971*	*394*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c653.pdf	Eastern Celtic Sea (HAs 13;17)	Coastal	
D0269	Castlebellingham	4,291	3,018	285	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c625.pdf	Outer Dundalk Bay	Coastal	
D0519	Manorcunningham	1,024	*932*	*169*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059f0e4.pdf	Swilly Estuary	Transitional	
D0218	Mallaranny	78	543	120	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c48a.pdf	Clew Bay	Coastal	
D0283	Tarbert	3,518	*1,679*	*336*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b3112.pdf	Lower Shannon Estuary	Transitional	
D0467	Ballydehob	7,879	*1,643*	*329*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c663.pdf	Roaring Water Bay	Coastal	
D0429	Innishannon	29,833	9,973	951	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c4c0.pdf	Upper Bandon Estuary	Transitional	
D0296	Baltimore	272	237	140	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c634.pdf	Ilen Estuary	Transitional	
D0286	Glenbeigh	879	*790*	*144*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c62e.pdf	Cromane	Transitional	
D0315	Askeaton	9,070	1,875	327	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c643.pdf	Deel Estuary	Transitional	
D0239	Mullaghmore	2,979	1,094	177	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c37f.pdf	Donegal Bay (Erne)	Coastal	
D0381	Grange	3,581	1,874	182	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c388.pdf	Donegal Bay Southern	Coastal	
D0502	Foynes	9,690	4,821	455	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c66a.pdf	Foynes Harbour	Transitional	
D0324	Doonbeg	462	554	49	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c4a8.pdf	Doonbeg Bay	Coastal	
D05	Fiddown	7,255	3,090	315	2015	http://www.epa.ie/licences/lic_eDMS/090151	Middle Suir Estuary	Transitional	Based on

28					AER	b28059c674.pdf			effluent samples in AER report
D0287	Waterville	441	*542*	*86*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b3114.pdf	Ballinskelligs Bay	Coastal	
D0373	Easky	296	*477*	*69*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c387.pdf	Easky Estuary	Transitional	
D0539	Rossnowlagh	255	*442*	*62*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059ec1f.pdf	Donegal Bay (Erne)	Coastal	
D0504	Glin	6,455	1,939	216	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c4de.pdf	Lower Shannon Estuary	Transitional	
D0394	Cliffony	47	323	12	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c38d.pdf	Donegal Bay Southern	Coastal	
D0541	Belgooly	1,132	*622*	*148*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c676.pdf	Oysterhaven	Transitional	
D0511	Achill Sound	53	438	269	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c4e0.pdf	Blacksod Bay SW / Achill Sound	Coastal	
D0468	Castletownshend	*4,117*	*686*	*137*	Inspectors Report	http://www.epa.ie/licences/lic_eDMS/090151b28040c091.pdf	Rosscarbery Bay	Coastal	Estimates based on PE taken from EPA Inspectors Report
D0421	Knightstown	890	*506*	*101*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b313c.pdf	Valencia Harbour	Coastal	
D0459	Ballylongford	160	*180*	*30*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b2805b313f.pdf	Lower Shannon Estuary	Transitional	
D0409	Campile	7,659	2,103	342	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059c656.pdf	Barrow Suir Nore Estuary	Transitional	
D0388	Carraroe	1,664	*277*	*55*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059ec1b.pdf	Casla Bay	Coastal	
D0396	Spiddal	1,369	*230*	*46*	2015 AER	http://www.epa.ie/licences/lic_eDMS/090151b28059ec1c.pdf	Aran Islands, Galway Bay, Connemara (HAs 29;31)	Coastal	
D03	Doogort	49	271	44	2015	http://www.epa.ie/licences/lic_eDMS/090151	Blacksod Bay	Coastal	

67					AER	b28059c4b6.pdf			
D0054	Cobh						Cork Harbour	Coastal	Included in Ringaskiddy estimates
D0129	Passage-Monkstown						Cork Harbour	Coastal	Included in Ringaskiddy estimates
D0436	Ringaskiddy Village						Cork Harbour	Coastal	Included in Ringaskiddy estimates
D0005	Bray								Sent to Shanganagh WWTP
D0122	Lusk								Sent to Portrane-Donabate WWTP

Appendix G. Correlations for RPL with ASC Interactions

	No change in biodiversity	Increase in biodiversity	No change in invasive species	No invasive species	Non sustainable fisheries	Healthy & sustainable fisheries	No change in pollution	Decrease in pollution	Moderate physical impact	Limited physical impact	ASC (Status Quo)
No change in biodiversity	1.00	1.00	-0.03	-0.21	0.39	0.46	-0.21	-0.43	0.06	0.28	-0.28
Increase in biodiversity	1.00	1.00	-0.03	-0.19	0.42	0.48	-0.19	-0.41	0.09	0.30	-0.30
No change in invasive species	-0.03	-0.03	1.00	0.84	0.04	0.08	0.15	-0.13	0.02	0.18	0.16
No invasive species	-0.21	-0.19	0.84	1.00	0.23	0.29	0.37	0.22	0.32	0.37	0.04
Non sustainable fisheries	0.39	0.42	0.04	0.23	1.00	0.04	0.13	-0.01	0.60	0.76	-0.19
Healthy & sustainable fisheries	0.46	0.48	0.08	0.29	0.04	1.00	0.24	0.26	0.24	0.20	-0.41
No change in pollution	-0.21	-0.19	0.15	0.37	0.13	0.24	1.00	0.14	-0.19	-0.22	0.20
Decrease in pollution	-0.43	-0.41	-0.13	0.22	-0.01	0.26	0.14	1.00	0.41	0.28	-0.43
Moderate physical impact	0.06	0.09	0.02	0.32	0.60	0.24	-0.19	0.41	1.00	0.91	-0.49
Limited physical impact	0.28	0.30	0.18	0.37	0.76	0.20	-0.22	0.28	0.91	1.00	-0.51
ASC (Status Quo)	-0.28	-0.30	0.16	0.04	-0.19	-0.41	0.20	-0.43	-0.49	-0.51	1.00

Appendix H. Correlations for RPL

	No change in biodiversity	Increase in biodiversity	No change in invasive species	No invasive species	Non sustainable fisheries	Healthy & sustainable fisheries	No change in pollution	Decrease in pollution	Moderate physical impact	Limited physical impact	ASC (Status Quo)
No change in biodiversity	1.00	1.00	-0.01	-0.21	0.36	0.42	-0.09	-0.31	0.21	0.36	-0.19
Increase in biodiversity	1.00	1.00	-0.07	-0.25	0.40	0.46	-0.07	-0.27	0.23	0.37	-0.21
No change in invasive species	-0.01	-0.07	1.00	0.90	0.06	0.14	-0.04	-0.23	-0.09	-0.04	0.20
No invasive species	-0.21	-0.25	0.90	1.00	0.32	0.35	0.03	-0.04	-0.01	-0.07	0.24
Non sustainable fisheries	0.36	0.40	0.06	0.32	1.00	0.96	0.22	0.29	0.34	0.28	-0.10
Healthy & sustainable fisheries	0.42	0.46	0.14	0.35	0.96	1.00	0.24	0.29	0.37	0.28	-0.14
No change in pollution	-0.09	-0.07	-0.04	0.03	0.22	0.24	1.00	-0.19	-0.51	-0.63	0.30
Decrease in pollution	-0.31	-0.27	-0.23	-0.04	0.29	0.29	-0.19	1.00	0.49	0.46	-0.48
Moderate physical impact	0.21	0.23	-0.09	-0.01	0.34	0.37	-0.51	0.49	1.00	0.88	-0.33
Limited physical impact	0.36	0.37	-0.04	-0.07	0.28	0.28	-0.63	0.46	0.88	1.00	-0.39
ASC (Status Quo)	-0.19	-0.21	0.20	0.24	-0.10	-0.14	0.30	-0.48	-0.33	-0.39	1.00