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VALUING IRELAND'S BLUE ECOSYSTEM SERVICES

semru
Socio-Economic Marine Research Unit

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SEMRU

The Socio-Economic Marine Research Unit (SEMRU) within the Whitaker Institute of NUI Galway was established through the Beaufort Award in 2008 and since then has developed into the foremost marine economic analysis centre in Ireland. SEMRU was established with the objective of expanding marine socio-economic research capability in Ireland, centred around a research cluster in Galway led by NUI Galway and linking with Teagasc and the Marine Institute. The main research focus of the unit involves examining the economic utility of the marine environment (e.g. transportation, recreation) and the ecological value (e.g. fisheries, aquaculture) derived from the productivity of associated ecosystems.

MFRC

The Marine and Freshwater Research Centre (MFRC) within the Galway-Mayo Institute of Technology is focused on enabling the sustainability of marine and freshwater ecosystems and improving their management through research, working with industry and linking with partner organisations including the Marine Institute, Bord Iascaigh Mhara and NUI Galway. The MFRC also hosts the co-ordination offices of Ireland's Strategic Marine Alliance and Training (SMART).

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Executive Summary

From an economics perspective, Harnessing our Ocean Wealth (HOOW) – the integrated marine plan for Ireland (2012), is all about maximising the net benefits to society from the use of our substantial marine resources. Previous reports by the Socio-Economic Marine Research Unit (SEMRU) of the Whitaker Institute in NUI Galway have provided an in-depth analysis of the economic importance of the Irish ocean economy. The direct economic value of Ireland's ocean economy was estimated to be worth €1.8 billion or approximately 0.9% of GDP in 2016. The maritime sectors were also estimated to provide employment for approximately 30,000 individuals. These bi-annual ocean economy reports provide a first order understanding of the economic importance of our seas around us but the economic contribution of the oceans is still undervalued if the many other marine ecosystem services from which we benefit are not considered. For example, the oceans are known to produce half of the oxygen in the atmosphere and absorb 30% of all CO_2 emissions; they are a key source of food and play key roles in the mediation of waste and in the provision of recreational opportunities.

This report therefore is focused on the ecosystem service benefits that society receives from Ireland's marine environment, complementing previous work on the Irish ocean economy. Marine ecosystem services are provided by the processes, functions and structure of the marine environment that directly or indirectly contribute to societal welfare, health and economic activities. These services are vital to ensuring blue growth in the ocean economy. Blue growth is about fostering development of marine economic activities in such a manner that the long term ability of the marine environment to continue to provide ecosystem service benefits is not compromised. Knowing what those benefits are and understanding how marine ecosystems' ability to continue to deliver services is impacted by changes in the economic activities taking place in our waters is vital for deciding on the best use of our marine resources and to support blue growth.

Until recently, very little information was available in relation to the value of the many services provided by the marine environment; services such as carbon sequestration, waste assimilation, coastal defence, aesthetic services and recreational opportunities. These services have also by and large been invisible in the decisions that have been made around the management and use of our marine resources. HOOW highlighted as a key action the need for further research into generating "economic values of marine biodiversity and ecosystem services to ensure best practice planning and management of the ocean resource". This report is a first step at filling this research gap. In particular it aims to:

- Provide a profile of the marine ecosystem services derived from Ireland's coastal, marine and estuarine natural resources.
- Provide estimates of the value to society of these marine ecosystem services.
- Provide data that assists in the delivery of management and planning decisions relating to human activities in the marine environment.
- Provide information on the relative importance and potential economic trade-offs of existing marine uses as reflected in their social and economic values. This information should feed into assessments that are required under the EU Marine Strategy Framework Directive and Maritime Spatial Planning Directive.
- Identify knowledge gaps that continue to exist in the valuation of marine ecosystem services.

The report indicates the significant contribution that provisioning, regulation and maintenance, and cultural marine ecosystem services make to our welfare, health and to economic activity. On an annual basis, recreational services provided by Irish marine ecosystems are estimated to have an economic value of €1.6 billion. Fisheries and aquaculture are estimated to be worth €664 million in terms of output value from Irish waters, carbon absorption services are valued at €819 million, waste assimilation services €317 million, scientific and educational services €11.5 million, coastal defence services of €11.5 million, seaweed harvesting €4 million and the added value per annum to housing stock of being close to the shore (aesthetic services) is valued at €68 million. Even though not all of the ecosystem services provided by the marine environment can be monetized, this report indicates that the value of those that can is substantial.

Table 1. Values of Irish Coastal and Marine Ecosystem Service Benefits[1]

Ecosystem Service (ES)	CICES Classification	Estimate of the Quantity of ES per annum	Estimate of the Value of ES per annum
Provisioning ecosystem service			
Off shore capture fisheries	Wild Animals	469,735 tonnes	€472,542,000
Inshore capture fisheries	Wild Animals	14,421 tonnes	€42,113,000
Aquaculture	Animals - Aquaculture	39,725 tonnes	€148,769,000
Algae/ Seaweed harvesting	Wild Plants & Algae/ Plants & Algae from Aquaculture	29,500 tonnes	€3,914,000
Genetic materials	Genetic materials from biota	Not quantified	See section 5.5
Water for non-drinking purposes	Surface water for non-drinking purposes	1,189,493,326 m^3 of seawater used for cooling in power plants	Not valued, see section 5.6 for further details
Regulating and maintenance ecosystem services			
Waste services	Mediation of waste, toxics and other nuisances	9,350,642 kg organic waste 6,834,783 kg nitrogen 1,118,739 kg phosphorous	€316,767,000
Coastal defence	Mediation of flows	179 km of coastline protected by saltmarsh	€11,500,000
Lifecycle and habitat services	Lifecycle maintenance, habitat and gene pool protection	773,333 ha protected through SAC's	Not valued
Pest and disease control	Pest and disease control	Not quantified	See section 6.4
Climate regulation	Atmospheric composition and climate regulation	42,647,000 tonnes CO_2 absorbed	€818,700,000
Cultural services			
Recreational services	Physical and experiential interactions	96 million marine recreation trips per year	€1,683,590,000
Scientific and educational services	Scientific & educational	Marine education and training fees	€11,500,000
Marine heritage, culture and entertainment	Heritage, cultural and entertainment	Not quantified	See section 7.3
Aesthetic services	Aesthetic	Flow value of coastal location of housing	€68,000,000
Spiritual and emblematic values	Spiritual and/or emblematic	Not quantified	See section 7.5
Non-use values	Existence & bequest values	Not quantified	See section 7.6

1 The flow of ecosystem service values should not be added up as they represent only a certain portion of the total economic value (TEV). Aggregating the figures in an effort to give a single figure for the value of marine ecosystem services in Ireland is an overly simplistic approach which would misrepresent the TEV. Also, the values represented for each service uses different measures. For example, in some cases such as for fisheries, aquaculture and education the value is a measured as revenue while others such as recreation are measured as net economic contribution, while the value of waste treatment and coastal defence is measured using a cost based approach.

Harnessing Our Ocean Wealth is aimed at achieving blue growth in Ireland, which means developing our ocean resources in such a manner that we do not jeopardise the ability of our marine resources to continue to deliver marine ecosystem services. The figures presented in this report provide policymakers with information about the value of market and non-market marine ecosystem services, and the potential costs if these services are lost. This information is needed to underpin the evidence-based policies that will safeguard Ireland's marine ecosystems and support blue growth far into the future.

1. Introduction

The marine and coastal ecosystems around Ireland provide many valuable benefits to Irish society. These benefits, generated by nature, are known as 'Ecosystem Services'. One of the most commonly used definitions for ecosystem services is that they are "the benefits humans derive from nature"[2]. For the purpose of this report we define marine ecosystem services as those services that are provided by the processes, functions and structure of the marine environment that directly or indirectly contribute to societal welfare, health and economic activities. The value of such services can often be quantified in monetary terms using economic techniques.

"Marine ecosystem services are provided by the processes, functions and structure of the marine environment that directly or indirectly contribute to societal welfare, health and economic activities".

2 MEA (Millennium Ecosystem Assessment), 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Harnessing Our Ocean Wealth[3] – An Integrated Marine Plan (IMP) for Ireland laid out a 'roadmap' for adopting an integrated approach to marine governance in Ireland and for achieving the Government's ambitious targets for maritime sectors including: exceeding €6.4 billion turnover annually by 2020 and doubling the contribution of the ocean economy to GDP to 2.4% by 2030.

As part of this roadmap Harnessing Our Ocean Wealth highlighted the need for further research into generating "economic values of marine biodiversity and ecosystem services to ensure best practice planning and management of the ocean resource" as a key action. This report aims to contribute to filling this research gap.

Box 1. Key Concepts

Marine ecosystem services are provided by the processes, functions and structure of the marine environment that directly or indirectly contribute to societal welfare, health and economic activities.

The value of marine ecosystem service benefits can often be quantified in monetary terms using economic techniques.

The **ocean economy** includes any economic activity that directly or indirectly uses the sea as an input or produces an output for use in a sea-specific activity.

The **blue economy** results when ocean economic activity is in balance with the long-term capacity of marine ecosystems to deliver their services.

- This implies the ecosystems remain resilient and healthy.

To achieve a blue economy, marine industries need to account for the fact that they are dependent on, and have an impact on marine ecosystem services. If the delivery of these services is being hampered, then this is a cost on society (social costs) and should be factored in to the production decision along with the other private costs of the firm as well as being factored into policy, planning and management decisions.

Marine ecosystem services can be classified as provisioning, regulation and maintenance, cultural or supporting services:

- Provisioning services – These ecosystem services are tangible goods and there is often a direct connection between the ecosystem and the provision of these ecosystem services. Examples of the provisioning ecosystem services generated by Irish marine and coastal ecosystems are the fish and seaweed that are harvested and also the aquaculture production around our coasts.
- Regulation and maintenance services – These ecosystem services regulate the world around us and often are consumed indirectly. Examples of these ecosystem services include carbon sequestration[4] which helps to mitigate climate change, treatment of wastewater and its return to the hydrological cycle and flood and storm protection by sand dunes and saltmarsh which lessens the damage from winter storms.
- Cultural services – The cultural ecosystem services refer to the psychical, 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, etc. and also the added value that having a sea view from your house has on your well-being.
- Supporting ecosystem services uphold and enable the maintenance and delivery of the other ecosystem service categories. To avoid double counting, supporting services tend not to be included in ecosystem value assessments as only final impacts on well-being are counted as economic benefits. For example, the effects of changes in nutrient cycling in marine systems will be reflected in the final welfare impact on provisioning services such as commercial fish catches or in the cultural service of recreational fishing.

3 GoI (Government of Ireland), 2012. Harnessing Our Ocean Wealth – An Integrated Marine Plan (IMP) for Ireland. Government of Ireland Strategy document, Inter-Departmental Marine Coordination Group (MCG), Dublin. [Available online: www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf]

4 Carbon sequestration refers to the long-term storage of carbon dioxide or other forms of carbon which slows down the atmospheric accumulation of greenhouse gases.

Valuation involves the measurement of the benefits that an individual or society obtains from a good or service. In terms of ecosystem services, economic valuation attempts to quantify the benefits to society and express these values in monetary units that can be compared with other sources of value. While the value of some of these goods such as fish and aquaculture produce are somewhat easier to measure as they have established market prices, many other benefits such as carbon absorption, waste treatment and recreation are not generally traded in markets and therefore do not generally command a price. However, without incorporating these values into the decision making processes these benefits may be ignored and changes within the coastal and marine environment may incur a net loss to Irish society. Furthermore, there may also be opportunities to enhance natural capital value which the industry / firm might be willing to / interested in exploring, particularly where this may help with corporate social accounting or help with stakeholder relations and/or shareholder value.

This being an evolving area of research there are a number of different methods used for classifying ecosystem services, of which The Millennium Ecosystem Assessment (MEA)[5] and The Economics of Biodiversity and Ecosystems (TEEB)[6] are just two examples. This report uses the classification system called the UN Common International Classification of Ecosystem Services (CICES) . It has been endorsed as a tool for classification of ecosystem services by the United Nations and the European Commission. However, there are some interactions with the environment that CICES[7] does not classify as ecosystem services that earlier reports have.

While there is an accompanying classification of abiotic (non-living) outputs from natural systems, CICES mainly focuses on biotic (living) elements rather than abiotic elements of nature. Therefore the use of water as a medium for transportation of goods, as in the case of shipping, is not classed as an ecosystem service. Another example is oil and gas; although of biological origin as the accumulated remains of marine organisms oil and gas have through time and geological processes become abiotic mineral resources. Both shipping and oil and gas are valuable marine services with the most recent Ocean Economy Report[8] finding that in 2016 shipping and maritime transport in Ireland had a turnover of €2.12 billion and a direct gross valued added (GVA) of €533 million. For oil and gas marine services the values were €199 million in turnover and €24 million in GVA in 2014 and with the coming on stream of the Corrib gas field these figures have increased to €597 million and €72 million respectively for 2016. While these services are not included within a CICES based ecosystem services assessment, these other abiotic services should still be considered in policy and decision making processes.

There have been a small number of previous efforts at valuing marine ecosystem services in Ireland. These have tended to only focus on a small number of services[9] or were at a localised spatial scale[10]. This report goes beyond this previous research by identifying the significant ecosystem services generated by the whole of Ireland's coastal, marine and estuarine (CME) ecosystems and estimating their values.

5 MEA (Millennium Ecosystem Assessment), 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

6 Kumar, P., 2010. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. UNEP/Earthprint, London.

7 Haines-Young, R.H. and Potschin, M., 2010. Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for Integrated Environmental and Economic Accounting. European Environment Agency, Copenhagen.

8 Vega, A., and Hynes, S., 2017. Ireland's Ocean Economy, SEMRU, NUI Galway. [Available online: http://www.nuigalway.ie/semru/documents/semru__irelands_ocean_economy_2017_online.pdf]

9 Bullock, C., Kretsch, C. and Candon, E., 2008. The Social and Economic Value of Biodiversity. Published by NPWS on behalf of the Government of Ireland, Dublin. [Available online: https://www.npws.ie/sites/default/files/publications/pdf/Bullock_et_al_2008_Economic_%26_Social_Benefits_of_Biodiversity.pdf]

10 Hynes, S., Norton, D. and Hanley, N., 2013. Adjusting for cultural differences in international benefit transfer. Environmental and Resource Economics 56(4):499–519.

2. Ecosystems and biodiversity

'Nature' or 'the environment' are terms often used to describe the physical world around us that was not created by human beings. More recently, the terms 'ecosystems' and 'biodiversity' are used in environmental policy circles but what do these terms mean and how do they fit into our concepts of nature and the environment?

For most people 'nature' is thought of as a collection of animals and plants within a landscape. Each of these plants and animals can be classed as a certain 'species', groups of genetically aligned individuals with the potential to interbreed with each other and produce offspring in nature. This ability to interbreed is dictated by the similarity of their genetic makeup otherwise known as their 'genes'. The environment where these different species interact with each other, with other species and with the abiotic elements of the landscape is known as an 'ecosystem'. More formally an 'ecosystem' is defined as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit"[11,12]. Ecosystems are varied in both size and complexity, often vary temporally and spatially and may be nested within each other[13]. Ecosystems can occur over varying spatial scales (for example, an individual rock pool, beach or the Celtic Sea) and are interconnected[14]. The dynamic part of an ecosystem arises from the fact that organisms interact with each other and with the abiotic part of the environment. These dynamic interactions and relationships are known as 'ecosystem processes' and these combine to form 'ecosystem functions'. Table 2 shows some examples of ecosystem functions and related ecosystem processes.

Another term that is commonly found in the ecosystems literature is 'biodiversity'. Biodiversity or biological diversity is the rich variety of life on earth at all levels; more formally defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"[15]. Note that biodiversity is not only the array of species within a habitat but is also the different types of genes (diversity within species) and different types of ecosystems (diversity of ecosystems).

Table 2. Examples of biological and physical processes and interactions that combine to produce ecosystem functions

Ecosystem function	Ecosystem processes
Primary production:	Photosynthesis
	Plant nutrient uptake
Decomposition:	Microbial respiration
	Soil and sediment food web dynamics
Nitrogen cycling:	Nitrification
	Denitrification
	Nitrogen fixation
Hydrologic cycle:	Plant transpiration
	Root activity
Biological control:	Predator-prey interactions

Adapted from Virginia and Wall (2000)[16]

11 The Convention on Biological Diversity of 5 June 1992 (1760 U.N.T.S. 69). [Available online: https://www.cbd.int/doc/legal/cbd-en.pdf]

12 MEA (Millennium Ecosystem Assessment), 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

13 Kumar, P., 2010. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. UNEP/Earthprint, London.

14 Dernie, K.M, Ramsay, K., Jones, R.E, Wyn, G.C., Hill, A.S., and Hamer, J.P., 2006. Implementing the Ecosystem Approach in Wales: Current status of the maritime environment and recommendations for management. CCW Policy Research Report No. 06/9 [Available online: http://ecosystemsknowledge.net/sites/default/files/wp-content/uploads/2012/05/CCW-Policy-Research-Report.pdf]

15 The Convention on Biological Diversity of 5 June 1992 (1760 U.N.T.S. 69). [Available online: https://www.cbd.int/doc/legal/cbd-en.pdf]

16 Virginia, R. A. and Wall, D. H. 2000. Ecosystem functioning. Encyclopaedia of Biodiversity, Vol 2. (Ed. by S. Levin), pp 494-499.

Biodiversity is not an ecosystem service in itself but it does contribute towards various types of ecosystem services. Having high genetic variety within a species can be a resource for gene based medicines, confer populations with resistance to certain diseases or give certain breeds within a species characteristics that affect the type of the ecosystem service they provide (e.g. all cows are of the same species but some breeds are more suitable for producing meat and some breeds are more suited to producing milk; this affects the provisioning ecosystem service of food/nutrition). Additionally high levels of heterogeneity at the species and ecosystem level can contribute to resilience and productivity of these environments.

Box 2. Resilience and the precautionary approach in ecosystem management

"Ecosystems have an intrinsic ability to cope with a certain amount of change or stress. The ability of an ecosystem to maintain its structural and functional integrity when subject to stress is typically described as its resilience. In practical terms an ecosystem will continue to function under increasing pressure whilst resilience deteriorates. At some point resilience will be reduced to such a level that significant, and possibly irreversible, change occurs to the system. Management based on the Ecosystem Approach seeks to avoid such change. The Ecosystem Approach has been defined as 'a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way'. Ecosystem services can play an important part of an Ecosystem Approach to management of our natural environment. However the possibility of significant or irreversible damages to ecosystems and resulting effects on ecosystem service provision means that where there is a significant degree of uncertainty then the precautionary approach should be adopted. The precautionary principle state that where the consequences of an activity are unknown, but are judged to have potential for major negative environmental consequences, then the activity should be avoided until a better understanding is established."

(Dernie et al., 2006)[17]

Ireland is located in the North-Eastern Atlantic; an island off Britain and mainland Europe. Irish waters are home to some of the most diverse and productive marine ecosystems on the planet[18]. This is as a result of Ireland being at the edge of a shallow continental shelf that slopes rapidly to the abyssal plain of the Atlantic Ocean. The edge of the continental shelf is subject to upwelling bringing nutrients from the deep which combined with sunlight penetrating the shallower seas on the continental shelf results in some of the most biologically productive waters in the world.

Overall the state's marine territory covers 880,000 km^2 which is 10 times our terrestrial territory. Approximately 450,000 km^2 of this area falls within 200 nautical miles from the State's baseline, an area known as the Exclusive Economic Zone (EEZ). Within this zone, the Irish state has exclusive exploitation rights over all natural resources. For this reason it was the boundary used for this project. However, it should be noted that fishing rights in this area are shared with other EU member states and are regulated under the EU Common Fisheries Policy (CFP)[19]. The continental shelf is the extension of a State's territorial waters where the natural land extends under the sea to the outer edge of the continental margin beyond 200 nautical miles. The Irish state has the exclusive right to harvest mineral and non-living material in the subsoil of its continental shelf but not creatures living in the water column. Closer to shore, the area out to 12 nautical miles from the coast (or baseline[20]) is known as the "territorial waters" where the Irish state is free to set laws, regulate use, and use any resource. This area can be considered the "inshore area" while the area beyond 12 nautical miles can be considered the "offshore area". Figure 1 shows the boundaries of the 'territorial waters', the EEZ and the 'continental shelf'.

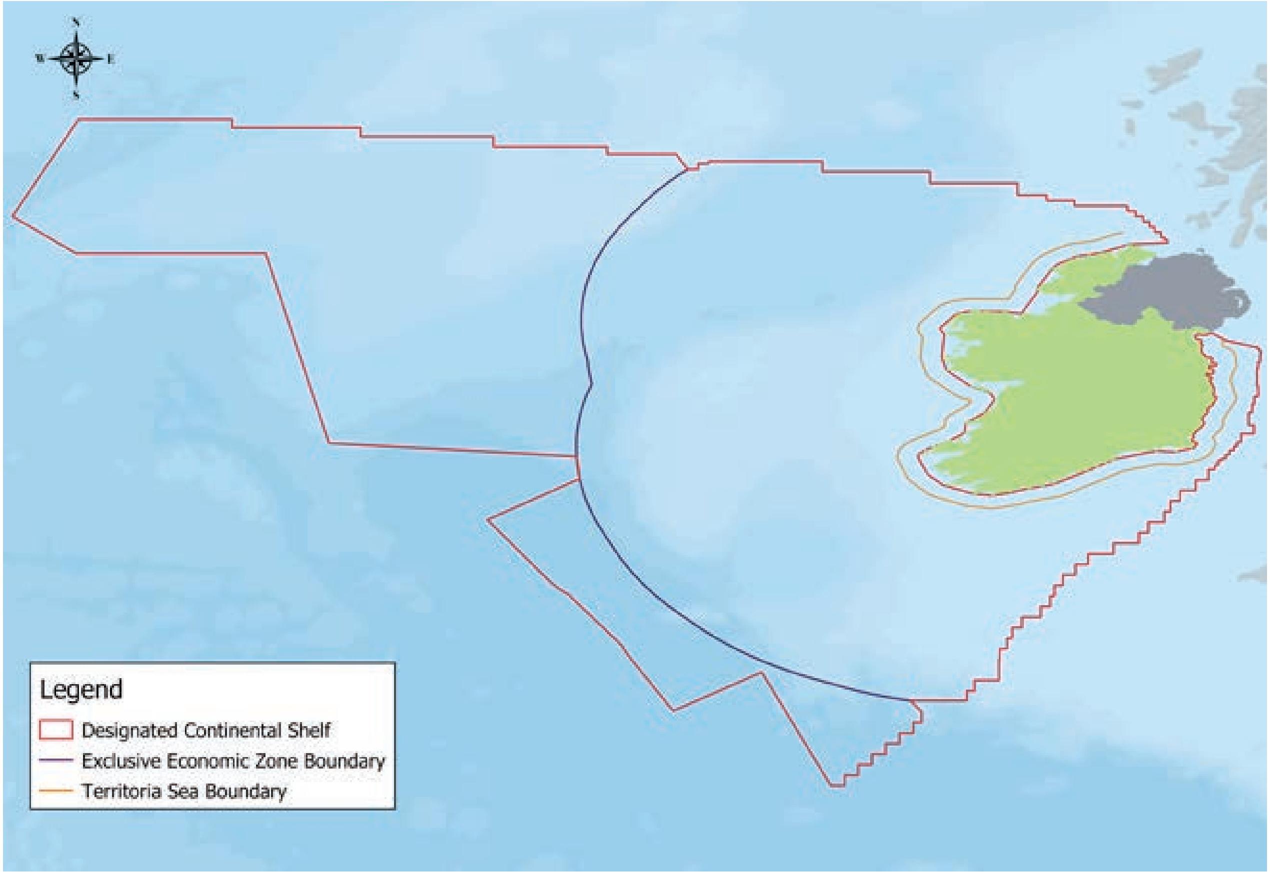
17 Dernie, K.M, Ramsay, K., Jones, R.E, Wyn, G.C., Hill, A.S., and Hamer, J.P., 2006. Implementing the Ecosystem Approach in Wales: Current status of the maritime environment and recommendations for management. CCW Policy Research Report No. 06/9 [Available online: http://ecosystemsknowledge.net/sites/default/files/wp-content/uploads/2012/05/CCW-Policy-Research-Report.pdf]

18 GoI (Government of Ireland), 2012. Harnessing Our Ocean Wealth – An Integrated Marine Plan (IMP) for Ireland. Government of Ireland Strategy document, Inter-Departmental Marine Coordination Group (MCG), Dublin. [Available online: www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf]

19 The Common Fisheries Policy (CFP) [Available online: https://ec.europa.eu/fisheries/cfp_en]

20 Waters inside the baseline are known as internal waters.

Figure 1. Ireland's Marine Areas



Based on data from the Maritime Limits theme accessed through Ireland's Marine Atlas at http://atlas.marine.ie/, [10/08/2017]

A report[21] conducted as part of Ireland's initial assessment for the Marine Strategy Framework Directive (MSFD) rated Ireland's marine and coastal environment as generally good but noted that there were significant knowledge gaps in some areas. Gaps identified included certain pressures acting on the marine environment and the status of many marine habitats and species.

21 Marine Institute and the Department of Environment, Community and Local Government, 2013. Ireland's Marine Strategy Framework Directive Article 19 Report - Initial Assessment, GES and Targets and Indicators [Available online: http://www.environ.ie/sites/default/files/migrated-files/en/Publications/Environment/Water/FileDownLoad%2C34365%2Cen.pdf]

Box 3. Deep sea marine ecosystems and their value

Deep sea ecosystems cover 65 percent of the world's surface; they are an extreme environment and little studied in comparison to terrestrial and coastal ecosystems. Danovaro et al. (2008)[22] found that deep sea ecosystem functioning is highly dependent on biodiversity. In Ireland's deep sea, reefs made up of cold water corals provide habitat for a wide variety of species including some commercial fish species such as the orange roughy. However, as was found with the orange roughy which is no longer fished intensively[23], deep sea species tend to be slow growing and highly sensitive to human impacts. Thurber et al. (2014)[24] explored many of the ecosystem services that the deep provides, some of the most important being climate regulation and waste treatment. They note that the vast area and size of deep-sea environments means that even relatively rapid processes on small spatial scales can create significant services, although in most cases the processes are far removed from their resultant services. This remoteness may cause the resulting services to be undervalued. Despite this there have been some efforts to value the ecosystem services of the deep-sea. Jobstvogt et al. (2014)[25] used a choice experiment to estimate the public's willingness to pay (WTP) for certain deep sea ecosystem services. They estimated a WTP per person of UK £35.95 to protect deep sea habitats in order to preserve the possibility of potential discovery of new medicinal products from deep-sea organisms and a WTP per person of UK £36.38 was estimated for an increase in the number of deep-sea species under protection from 1000 to 1600.

An EU Horizon 2020 funded project involving 23 partner institutes, including NUI Galway, continues to investigate the ecosystem values associated the deep sea. The ATLAS (A Trans-AtLantic Assessment and deep-water ecosystem-based Spatial management plan for Europe) project aims to improve our understanding of deep Atlantic marine ecosystems and populations by collecting and integrating high resolution measurements of ocean circulation with functioning, biological diversity, genetic connectivity and ecosystem service values. Within the project, valuation methods are being used to create a comprehensive understanding of the provisioning, regulation and maintenance, cultural ecosystem service values and the Blue Growth potential at the sea basin and regional management scales (www.eu-atlas.org/).

22 Danovaro, R., Gambi, C., Dell'Anno, A., Corinaldesi, C., Fraschetti, S., Vanreusel, A., Vincx, M. and Gooday, A.J., 2008. Exponential decline of deep-sea ecosystem functioning linked to benthic biodiversity loss. Current Biology, 18(1), pp.1-8.

23 Foley, N.S., van Rensburg, T.M. and Armstrong, C.W., 2011. The rise and fall of the Irish orange roughy fishery: An economic analysis. Marine Policy, 35(6), pp.756-763.

24 Thurber, A.R., Sweetman, A.K., Narayanaswamy, B.E., Jones, D.O.B., Ingels, J. and Hansman, R.L., 2014. Ecosystem function and services provided by the deep sea. Biogeosciences, 11(14), pp.3941-3963.

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

3. What are Ecosystem Services?

The ecosystem services framework offers a way of understanding the effects of changes in the natural environment on human welfare. An early definition offered by the Millennium Ecosystem Assessment defined ecosystem services as "the benefits humans derive from nature". The UK NEA[26] defines ecosystem services as "the benefits provided by ecosystems that contribute to making human life both possible and worth living". The term 'services' here is usually understood to encompass both the physical goods and the more intangible service benefits that humans obtain from ecosystems. As highlighted in the introduction we define marine ecosystem services as the services provided by the processes, functions and structure of the marine environment that directly or indirectly contribute to societal welfare, health and economic activities. Figure 2 displays the main ecosystem services provided by the marine environment.

Ecosystem functioning is always happening in nature but when humans interact with this ecosystem functioning then ecosystem services (and sometimes disservices) are produced. Identifying these ecosystem services, quantifying them and finally valuing the benefits to society from the services enables decision makers to take them into account when assessing policies or projects which may affect the natural environment.

The Millennium Ecosystem Assessment (MEA, 2005) was initiated in 2001 following a call by the United Nations Secretary-General Kofi Annan for an assessment of the effects of ecosystem change on human well-being. The MEA aimed to provide evidence for action needed to protect ecosystems and their ecosystem services. The MEA took place from 2001 to 2005. As well as data on the linkages between biodiversity, conservation and ecosystem services and their linkages to social welfare, it also provided a classification system separating the ecosystem services into four groupings.

The first three, provisioning services, regulation and maintenance services and cultural services, were all underpinned by the fourth, supporting services. The interconnectedness of ecosystems through which different ecosystems provide unique habitats for various species (including migratory species at different periods of their lifecycles) and the fact that certain ecosystems display significantly high levels of species and genetic diversity means that some ecosystems may be more critical in maintaining biodiversity than others. This means that such ecosystems help to "support" services and the benefits derived in other ecosystems as well as their own. An understanding of ecosystem functioning and how these functions provide benefits is needed in order to generate value indicators for the different ecosystem services. In turn, these indicators can be used in conjunction with the value that the population places on these ecosystem services to estimate the benefit values that they produce. A number of studies have emphasised the need to differentiate between different elements of the ecosystem service cascade (processes - functions – services - benefits - values) in order that different elements are not confused[27, 28]. They point out that one service can deliver multiple benefits and confusing services and benefits could lead to double counting. This is why a classification system is needed for the assessment of ecosystem values in addition to the need to classify ecosystem services and identify gaps in knowledge.

The framework adopted in this report is presented in Figure 3. It is assumed that changes in marine policy and management of the marine environment affect the functioning of the marine ecosystem which in turn has impacts on the ability of the marine environment to deliver both functions and ecosystem services. These changes in the marine ecosystem services in turn produce benefits and costs to society that can be estimated using the economic toolkit shown in the white box of Figure 3. The results of the valuation process and the information on the behavioural response resulting from the change in the ecosystem service benefits can then be incorporated into marine policy analysis and management. As Hanley et al. (2015)[29] point out the ideal management situation would be that this process can lead to a further change in management through a feedback loop to optimise the system.

26 Watson, R., Albon, S., Aspinall, R., Austen, M., Bardgett, B., Bateman, I., Berry, P., Bird, W., Bradbury, R., Brown, C. and Bullock, J., 2011. UK National Ecosystem Assessment: understanding nature's value to society. Synthesis of key findings.[Available online: http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx]

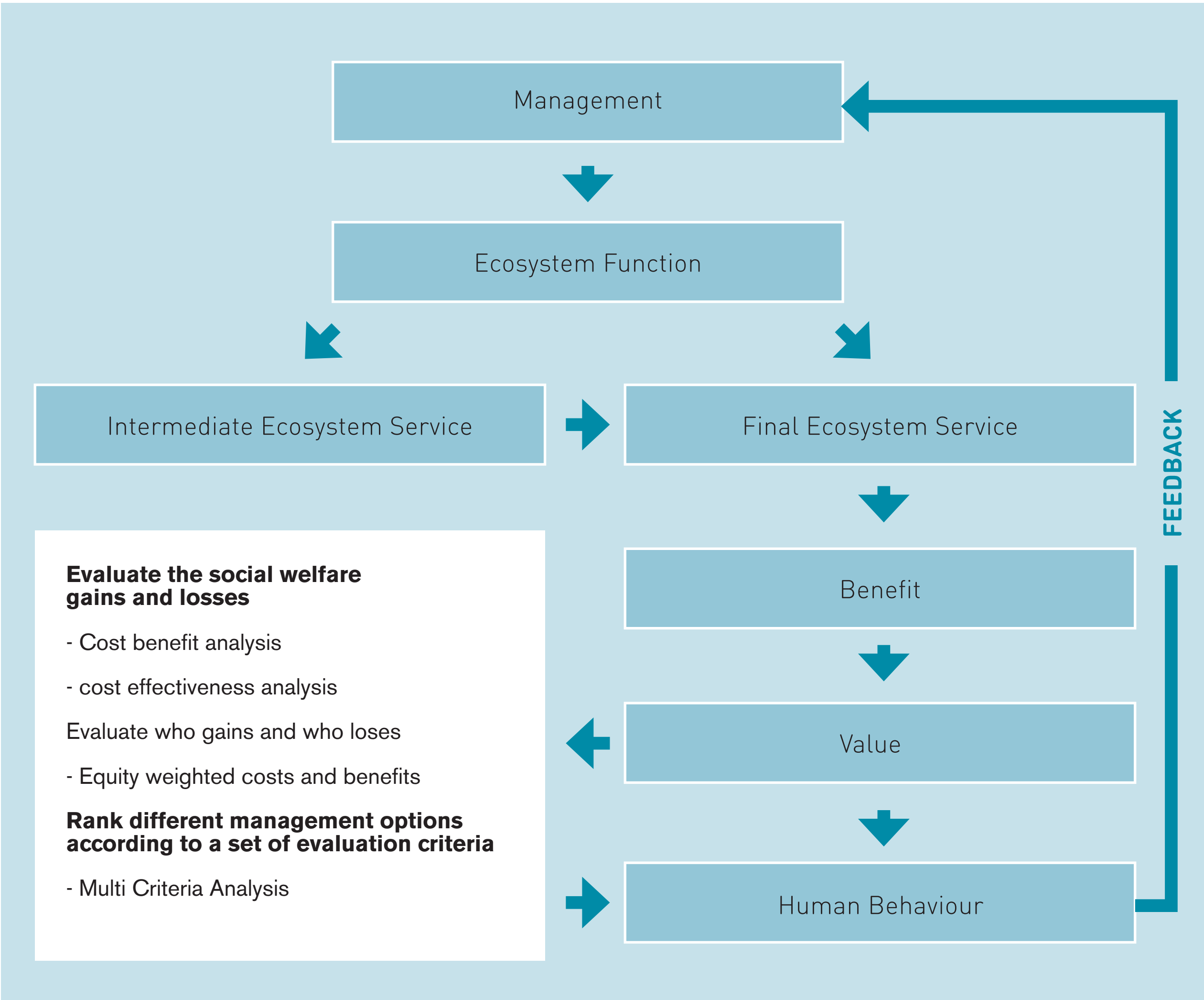
27 Bohnke-Henrichs, A., Baulcomb, C., Koss, R., Hussain, S. S., and de Groot, R. S., 2013. Typology and indicators of ecosystem services for marine spatial planning and management. Journal of environmental management, 130, 135-145.

28 Fisher, B., Turner, R. K., and Morling, P. (2009). Defining and classifying ecosystem services for decision making. Ecological economics, 68(3), 643-653

29 Hanley N, Hynes S, Patterson D, Jobstvogt N. Economic Valuation of Marine and Coastal Ecosystems: Is it currently fit for purpose? Journal of Ocean and Coastal Economics. 2015;2 (1):1.

Figure 2.
Ecosystem Services
from the Sea

Figure 3. Ecosystem service conceptual framework



(Adapted from Hanley et al., 2015[30]*)*

In many cases each new study develops its own concepts and classifications or develops a variation on a previously used ES framework or classification system. However, the UN and others have advocated that there would be a move towards a standard environmental-economic assessment classification system especially for integrating environmental accounts with national accounts[31]. This has lead in recent years to a proposed new international classification system, CICES[32].

30 Hanley N, Hynes S, Patterson D, Jobstvogt N. Economic Valuation of Marine and Coastal Ecosystems: Is it currently fit for purpose? Journal of Ocean and Coastal Economics. 2015;2 (1):1.

31 United Nations (UN), the European Commission, the Food and Agriculture Organization of the United Nations, the Organisation for Economic Co-operation and Development, and the World Bank Group, 2014. System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting, [Available online http://unstats.un.org/unsd/envaccounting/seeaRev/eea_final_en.pdf]

32 Haines-Young, R.H. and Potschin, M., 2010. Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for Integrated Environmental and Economic Accounting. European Environment Agency, Copenhagen.

3.1. The CICES Ecosystem Services Classification System

The CICES ecosystem service classification system was originally proposed by Haines-Young and Potschin (2010)[33]. 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 ecosystem services types, (provisioning, regulation and maintenance, cultural) makes it an ideal classification system for assessment of ecosystem services[34]. Since the original report it has been updated as part of the revision of the System of Environmental-Economic Accounting (SEEA) by the UN Statistical Commission[35]. 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 and if ecosystem services are benefits or contribute to benefits. In regards to the latter point some ecosystem services (mostly regulating services) provide direct benefits to society whereas others – and particularly provisioning services – need human input before the benefits can be realised, e.g. crops need to be planted and harvested, etc. This report uses CICES 4.3 of the CICES classification system to classify the ecosystem services valued in this report.

3.2. Valuing ecosystem services

Providing an economic quantification of the benefits derived from marine ecosystem services is one approach that may assist in the delivery of responsible environmental management decisions. The change in economic value 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 (willingness to pay (WTP)) or the amount of compensation they 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 estimated economic value of a good is therefore the WTP or where there is a market price, it is the market price plus the CS[36].

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 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 4.

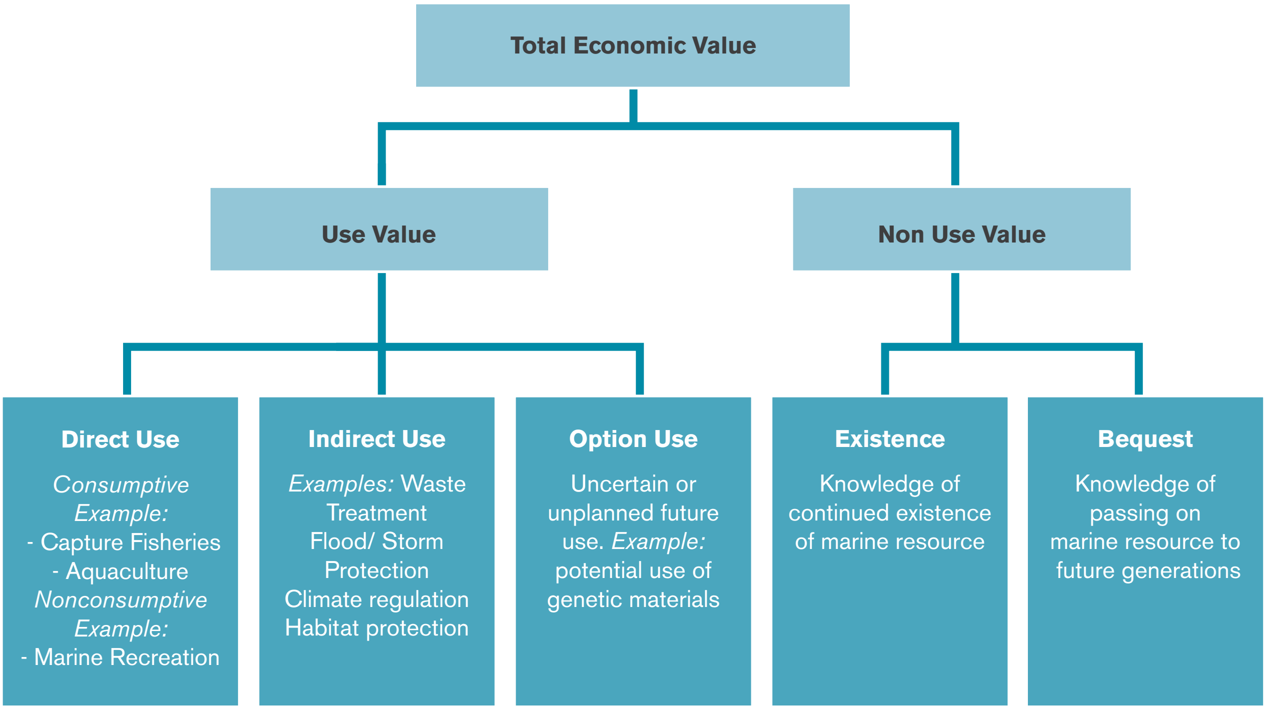
33 Haines-Young, R.H. and Potschin, M., 2010. Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for Integrated Environmental and Economic Accounting. European Environment Agency, Copenhagen.

34 Maes J, Teller A, Erhard M, et al., 2013. Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union, Luxembourg. [Available online http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf]

35 United Nations (UN), the European Commission, the Food and Agriculture Organization of the United Nations, the Organisation for Economic Co-operation and Development, and the World Bank Group, 2014. System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting, [Available online http://unstats.un.org/unsd/envaccounting/seeaRev/eea_final_en.pdf]

36 For an in-depth discussion of the theory behind environmental valuation and the methods used the interested reader is directed to "Hanley, N. and Barbier, E., 2009. Pricing nature: cost-benefit analysis and environmental policy. Edward Elgar Publishing" as a good introductory text.

Figure 4. Total Economic Value Framework (TEV)



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. There are two primary valuation typologies, revealed preference (RP), and stated preference (SP) techniques (see Table 3).

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 3. 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. In 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 is to be estimated). While the transferred values can be adjusted for differences between the sites (income differences, temporal differences, differences in affected population, etc.) there is still the possibility of over or under estimation of the transferred values compared to the value derived using a primary study at the policy site. However the method can still provide a broad estimate of the value of the benefits delivered by ecosystem services[37].

37 Johnston, R. J. and Rosenberger R.S., 2010. Methods, Trends and Controversies in Contemporary Benefit Transfer" Journal of Economic Surveys, 24(3):479–510

Table 3. Main methodologies for estimating marine ecosystem service values

Type and methods	Notes	Where used in report
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
Production functions	Production functions are statistical models which relate how changes in some ecosystem function affect production of a marketed good or service.	
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
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 value of access to the site.	Recreational services
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
Stated preference methods	Methods based on surveys in which respondents give valuation responses in hypothetical situations	
Contingent valuation	Contingent valuation is a 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
Choice experiments	Choice experiments estimate values from the choices respondents make between options with different specified attributes of an environmental good.	Non-use values
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.	
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.	Waste services, climate regulation, aesthetic services, recreational services

(Adapted from UNEP-WCMC, 2011[38])

38 UNEP-WCMC, 2011. Marine and coastal ecosystem services: Valuation methods and their application. UNEP-WCMC Biodiversity Series No. 33. 46 pp [Available online: http://www.unep.org/dewa/Portals/67/pdf/Marine_and_Coastal_Ecosystem.pdf]

4. Why should we value ecosystem services?

The valuation of marine ecosystem service benefits can help to promote sustainable development by providing policymakers with information about the estimated 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.

Marine ecosystem service values can also be used by marine policymakers to assess the costs and benefits of any new activity that is taking place in the marine environment or resulting from a change in marine policy.

Valuation can also play a role in developing markets for ecosystem services. Payment for Ecosystem Services (PES) is based on the idea that if people benefit from a service then they should be willing to pay for it. For example society may be willing to pay a price premium for a more sustainably farmed salmon or be willing to pay an access fee to a marine or coastal conservation area. PES works by creating a market for these services to internalize benefits or costs in the decision-making of the owner/manager of the ecosystem[39].

Another application of marine ecosystem valuation is to determine a level of compensation in environmental litigation and in particular in the case of damage to marine ecosystems.

Borger et al. (2014)[40] have also highlighted the potential for marine ecosystem service valuation to support marine spatial planning which is all the more relevant given the need for the development of integrated marine spatial plans across coastal member states under the EU Directive on Maritime Spatial Planning. The authors point out that ecosystem service values can be used in every step of the planning process from motivating financial support for planning efforts by defining the benefits from better planning, to providing information on the relative importance of existing uses as reflected in their estimated social and economic values and improving the understanding of potential economic trade-offs. The authors also recommend that ecosystem benefits and costs be highlighted even if they cannot be valued or else they may be otherwise overlooked in the planning procedure. Finally they note that ecosystem service valuation should be considered in the monitoring of the success of a maritime plan.

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 UN Convention on Biological Diversity (CBD). The outcome of this Strategic Plan was 20 targets (Aichi Targets)[41]. These targets were in addition to previous targets[42] to protect and conserve global biodiversity and protection of ecosystem services was incorporated into three of the targets (Target 11, Target 14, Target 15).

At a European level the EU aims to protect, value and, where necessary, to restore nature both for biodiversity's intrinsic value and for its contribution to human wellbeing and economic prosperity through ecosystem services[43]. This commitment has led to the EU 2020 Biodiversity Strategy. The strategy aims to halt the loss of biodiversity and ecosystem services in the EU member states by 2020. Target 2 of the strategy 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 allow spatially explicit prioritisation and identification of

39 Gomez-Baggethun, E., De Groot, R., Lomas, P.L. and Montes, C., 2010. The history of ecosystem services in economic theory and practice: from early notions to markets and payment schemes. Ecological economics, 69(6), pp.1209-1218.

40 Borger, T., Beaumont, N.J., Pendleton, L., Boyle, K.J., Cooper, P., Fletcher, S., Haab, T., Hanemann, M., Hooper, T.L., Hussain, S.S. and Portela, R., 2014. Incorporating ecosystem services in marine planning: The role of valuation. Marine Policy, 46, pp.161-170.

41 Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., and Naeem, S., 2012. Biodiversity loss and its impact on humanity. Nature, 486 (7401), 59-67.

42 Balmford, A., Bennun, L., Ten Brink, B., Cooper, D., Cote, I. M., Crane, P. and Walther, B. A., 2005. The convention on biological diversity's 2010 target. Science, 307(5707): 212–213

43 EC (European Commission), 2011. Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions "Our life in insurance, our natural capital: an EU biodiversity strategy to 2020". COM (2011) 0244 final.[Available online: http://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/EP_resolution_april2012.pdf]

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 [39,44]. 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 its resources in the future through the MSFD[45]. 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 4) by 2020. It is considered to be the first attempt by an EU directive to undertake an ecosystem approach to protect and maintain marine ecosystems[46]. As can be seen in Table 4 many of the descriptors relate to services provided by marine ecosystems such as provision of food (descriptors 3 and 4), regulating services it provides 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 4. 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.

Many of the aims of the MSFD overlap the EU 2020 Biodiversity Strategy and with Ireland currently implementing MSFD the output of this project may contribute to helping policy makers in their assessment of the measures needed to achieve good environmental status required by the MSFD while ensuring the sustainable use of marine goods and services by present and future generations. At a national level the Irish government launched an integrated marine plan for Ireland, "Harnessing Our Ocean Wealth" (HOOW)[47] in 2012. The plan's primary goal is to develop and grow Ireland's ocean economy; it aims to do this in a sustainable manner to ensure that Ireland's marine biodiversity and ecosystems are protected.

44 Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, L., Berry, P., Egoh, B., Puydarrieux, P., Fiorina, C., Santos, F., Paracchini, M.L., Keune, H., Wittmer, H., Hauck, J., Fiala, I., Verburg, P.H., Condé, S., Schägner, J.P., San Miguel, J., Estreguil, C., Ostermann, O., Barredo, J.I., Pereira, H.M., Stott, A., Laporte, V., Meiner, A., Olah, B., Royo Gelabert, E., Spyropoulou, R., Petersen, J.E., Maguire, C., Zal, N., Achilleos, E., Rubin, A., Ledoux, L., Brown, C., Raes, C., Jacobs, S., Vandewalle, M., Connor, D. and Bidoglio, G., 2013. Mapping and Assessment of Ecosystems and their Services. An Analytical Framework for Ecosystem Assessments under Action 5 of the EU Biodiversity Strategy to 2020. Publications office of the European Union, Luxembourg. [Available online: http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf]

45 EC (European Commission), 2008. Council Directive 2008/56/EC of the European Parliament of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). OJ L 164, 25.6.2008, p. 19–40.

46 Long, R., 2011. The Marine Strategy Framework Directive: A new European approach to the regulation of the marine environment, marine natural resources and marine ecological services. Journal of Energy and Natural Resources Law 29(1) pp. 1-44

47 Government of Ireland, 2012. Harnessing Our Ocean Wealth – An Integrated Marine Plan (IMP) for Ireland. Government of Ireland Strategy document, Inter-Departmental Marine Coordination Group (MCG), Dublin. [www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf]

5. Ireland's Provisioning Marine Ecosystem Services

Coastal, marine and estuarine ecosystems have historically provided a wide variety of biotic goods that were used for a variety of purposes. In Irish waters, the harvesting of whales or basking sharks for their oil or the extraction of maërl (a free living calcareous algae) for use as fertiliser have ceased (although still permitted under licence) whilst other ecosystem services have grown both in scale and value. The most significant of these ecosystem services in terms of value are capture fisheries and aquaculture services. Values have also been estimated for harvesting of plants and algae (e.g. seaweeds). Although water is an abiotic material it is classed under CICES as an ecosystem service. Therefore details on its use for cooling power stations are included although there was insufficient information available to value this service. Table 5 shows an outline of the provisioning ecosystem services valued for Ireland's coastal, marine and estuarine ecosystems.

Table 5. Provisioning Ecosystem Services

Provisioning Ecosystem Service	CICES Classification	Estimate of Quantity of ES per annum	Estimate of Value of ES per annum
Off shore capture fisheries	Wild Animals	469,735 tonnes	€472,541,917
Inshore capture fisheries	Wild Animals	14,421 tonnes	€42,113,000
Aquaculture	Animals - Aquaculture	39,725 tonnes	€148,769,000
Algae/ Seaweed harvesting	Wild Plants & Algae/ Plants & Algae from Aquaculture	29,500 tonnes	€3,914,000
Genetic materials	Genetic materials from biota	Not quantified	See section 5.5
Water for non-drinking purposes	Surface water for cooling in power stations	1,189,493,326 m^3 of seawater used for cooling in power plants	Not valued, see section 5.6 for further details

5.1. Offshore capture fisheries

Ireland is located in UN Food and Agriculture Organization (FAO) major fishing area 27 (Atlantic, Northeast). Area 27 covers 4% of the world's ocean surface area and accounts for 10% of the world's capture fisheries; thus making it the second most productive area in the world[48]. The capture fisheries ecosystem service is measured in tonnes of fish capture and valued using market price data. Production, measured as tonnes for Area 27 of fish landed, was at its highest in 1976 at approximately 13 million tonnes decreasing to 8.1 million tonnes in 2012[49]. The main data source for the capture fisheries is from the Scientific, Technical and Economic Committee for Fisheries (STECF)[50] which is the advisory body for the EU Commission on fisheries management.

Table 6 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 for the year 2014. 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.

48 OSPAR Commission, 2009. Assessment of the Environmental Impact of Fishing. [Available online: qsr2010.ospar.org/media/assessments/p00465_JAMP_QSR_fisheries_assessment.pdf]

49 FAO (Food and Agriculture Organization of the United Nations), 2014. Fishery and Aquaculture Statistics: Capture Production. FAO Yearbook, 2012. [Available online: http://www.fao.org/fishery/docs/CDrom/CD_yearbook_2012/navigation/index_content_capture_e.htm]

50 STECF Data Dissemination [Available online: https://stecf.jrc.ec.europa.eu/dd/effort/graphs-quarter]


JEANIE JOHNSTON

Table 6. Estimated landings and value for capture fisheries within the Irish EEZ for vessels greater than 15m (2014)

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**

Source: Landings are calculated based on STECF[51] and ICES[52] data. Prices are based on species prices from Gerritsen and Lordan (2014)[53] and The Stock Book 2015[54]

51 STECF Data Dissemination [Available online: https://stecf.jrc.ec.europa.eu/dd/effort/graphs-quarter]

52 ICES. Catch statistics: Official Nominal Catches. [Available online: http://www.ices.dk/marine-data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx]

53 Gerritsen, H.D. and Lordan, C., 2014. Atlas of Commercial Fisheries Around Ireland. Marine Institute. [Available online: http://hdl.handle.net/10793/958]

54 MI (Marine Institute), 2015. The Stock Book 2015: Annual Review of Fish Stocks in 2015 with Management Advice for 2016. Marine Institute, Oranmore, Galway

Figure 5. The total capture value per ICES rectangle in millions of euro (2014).

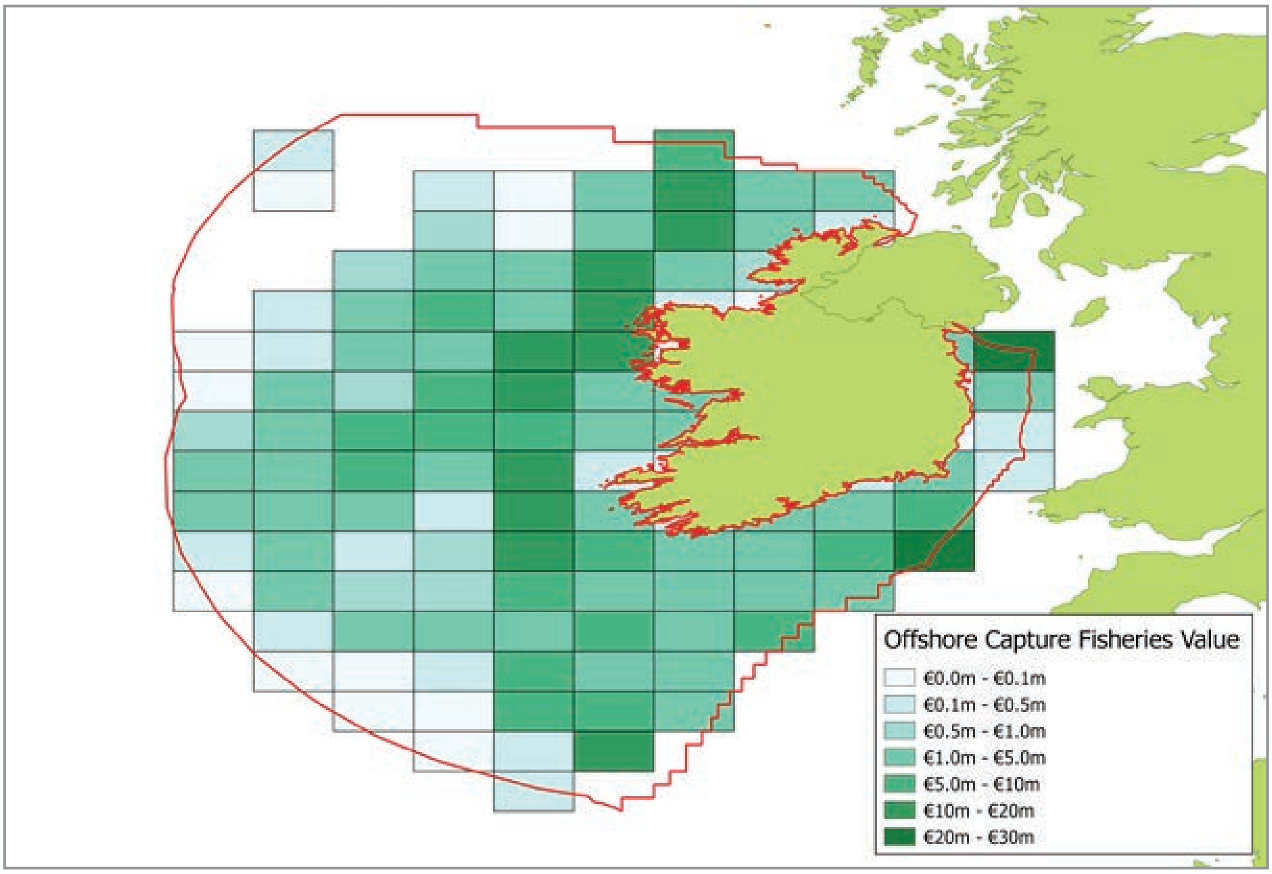


Figure 5 shows the spatial distribution of the value of catch by the offshore fleet. As shown in Table 6 there is significant heterogeneity in the value each species contributes. Looking at ICES rectangle value maps of some of the key species by value (Figure 6) patterns can be distinguished for certain 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[55]. Nephrops are also very region specific with major resources to the west of the Aran Island, the South East and East while albacore tuna is mostly caught far off the south-western shores of Ireland. Table 7 shows the main beneficiaries from this provisioning service in terms of member state share in the resource by value and landings.

55 Note that only blue whiting caught by EU nations is mapped. For further details refer to Appendix.

Figure 6. Value maps for megrim value map (top left), blue whiting value map (top right), nephrops Value Map (bottom left) and, albacore tuna Value Map (bottom right).

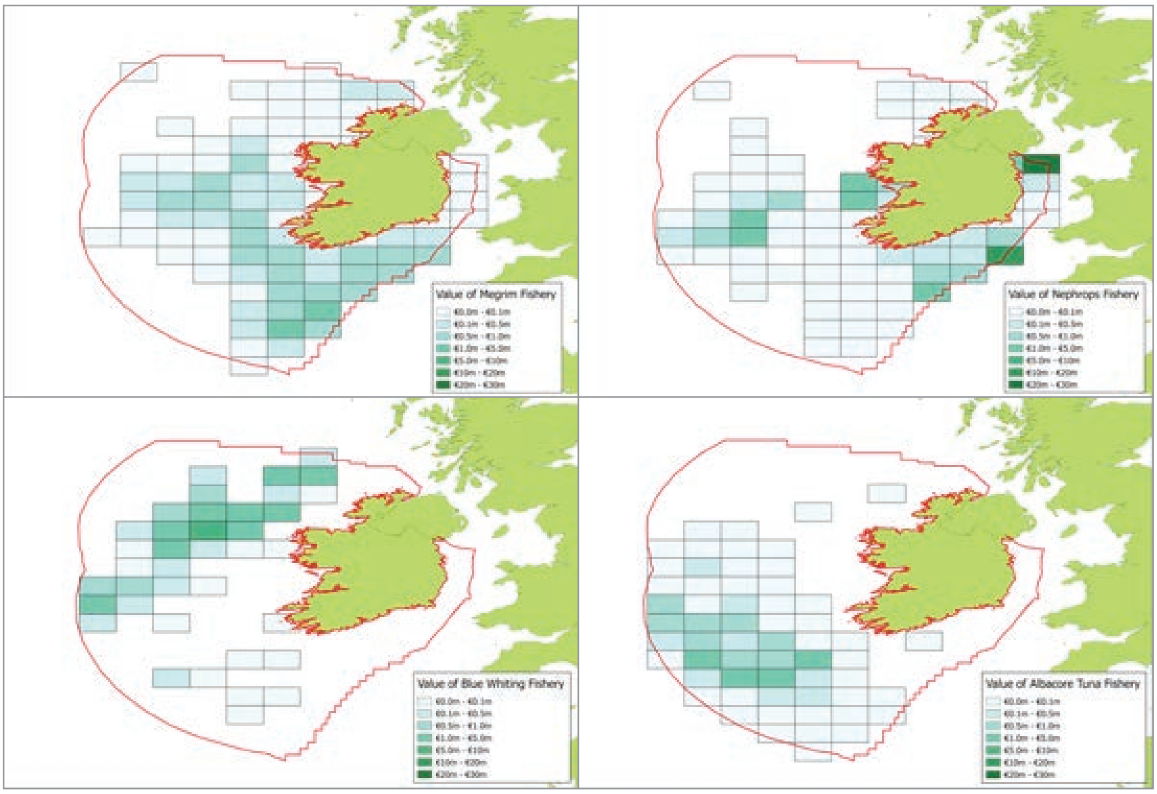


Table 7. Off-shore landings and value by Member State fishing in Irish EEZ, 2014

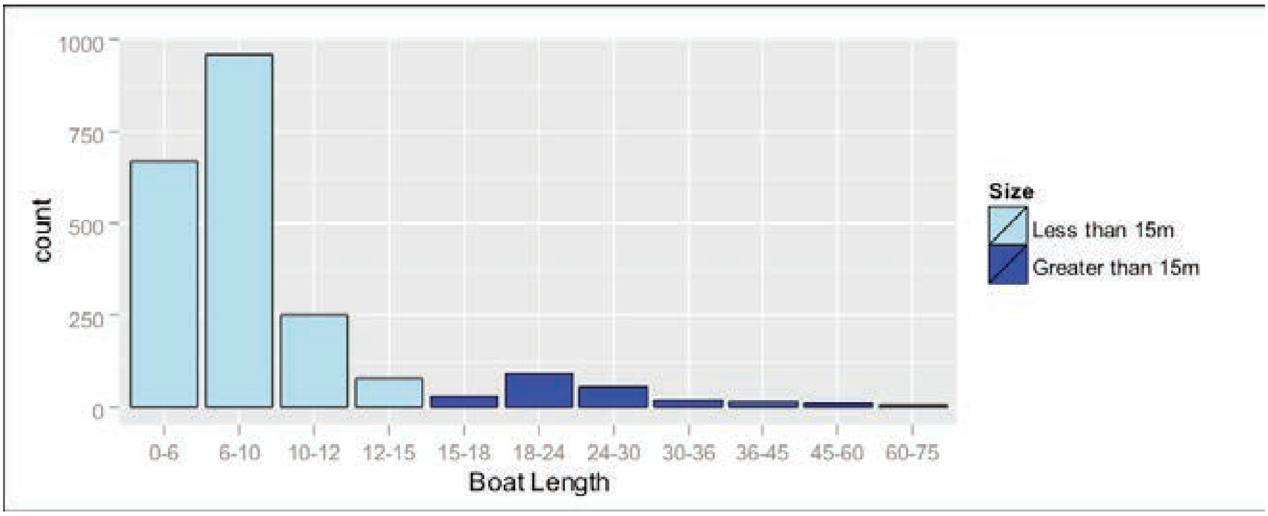
	Estimated Landings (tones)	**Estimate Value of Landings**	**% of total value**	**% of total landings**
Ireland	156,735	€155,879,060	33	33.4
France	41,704	€86,720,080	18.4	8.9
Spain	23,239	€55,057,710	11.7	4.9
Scotland	58,543	€44,017,690	9.3	12.5
England	16,523	€24,183,039	5.1	3.5
Netherlands	34,453	€20,774,560	4.4	7.3
Germany	27,981	€18,551,512	3.9	6
Northern Ireland	7,765	€14,014,175	3	1.7
Denmark	22,375	€12,758,888	2.7	4.8
Belgium	417	€1,546,003	0.3	0.1
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**

Note: Figures are calculated based on STECF and ICES data. Prices are the species prices from Gerritsen and Lordan (2014) and The Stock Book 2015. Value estimates account for 99% of off-shore landings and are only for boats over 15m in length and is therefore an underestimate of total value. Non-EU fisheries figures are based solely on blue whiting catches by Norway.

5.2. Inshore capture fisheries

The inshore capture fisheries are based in the territorial waters that extend out to 12 nautical miles from the coast and are mainly composed of boats less than 15m in length. The EU Fishing Fleet Register[56] indicates that the majority (89%) of the boats in the Irish fleet are less than 15m in length (Figure 7). The vast majority of these target shellfish stocks[57]. There are some boats less than 15m targeting finfish within the inshore fishery but due to lack of data the inshore finfish fishery was not examined in this report.

Figure 7. Composition of the Irish fleet



Source: EU Fishing Fleet Register. Most of the Irish fleet is composed of boats less than 15m and work in the inshore area (<12nm)

The data for the shellfish and crustacean fishery are based on the Shellfish Stocks and Fisheries Review 2014[58], with figures for the year 2013. These reports focus 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 15m.

56 Community Fishing Fleet Register (CFFR). 2015 Fleet Register for Ireland Dataset. [Available online: http://ec.europa.eu/fisheries/fleet/index.cfm?method=Download.Menuandcountry=IRL]

57 MI and BIM (Marine Institute and Bord Iascaigh Mhara), 2015. Shellfish Stocks and Fisheries Review 2014: An Assessment of Selected Stocks. Marine Institute and Bord Iascaigh Mhara. [Available online: http://hdl.handle.net/10793/1063]

58 MI and BIM (Marine Institute and Bord Iascaigh Mhara), 2015. Shellfish Stocks and Fisheries Review 2014: An Assessment of Selected Stocks. Marine Institute and Bord Iascaigh Mhara. [Available online: http://hdl.handle.net/10793/1063]

Table 8. 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). 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.

5.3. Aquaculture

Aquaculture is an important sector particularly in rural areas along the Irish western seaboard. Most of the aquaculture output produced relates to salmon, oyster and mussel farming and is mainly based along the western coast of Ireland. Salmon farming is generally carried out using cages floating in the water. Oysters are grown using bottom production methods while mussels are predominantly grown on suspended rope systems.

The main data source for the aquaculture production is the Bord Iascaigh Mhara (BIM) Annual Aquaculture Survey 2016[59]; it also has market price for aquaculture species in Ireland. The Atlantic salmon is the most valuable farmed marine species in Ireland while the pacific oyster is the most valuable farmed shellfish species even though the quantity of blue mussels farmed is approximately double that of pacific oysters (Table 9).

Table 9. Estimated Irish Aquaculture Production and Value 2015

Common Name	Estimated Production (tonnes)	Estimated 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 8 shows the distribution of salmon, oyster and mussel aquaculture by county around the coast of Ireland (BIM, 2016)[60]. These figures are presented in Table 10 and demonstrate the importance of this provisioning service to counties on the west coast in particular.

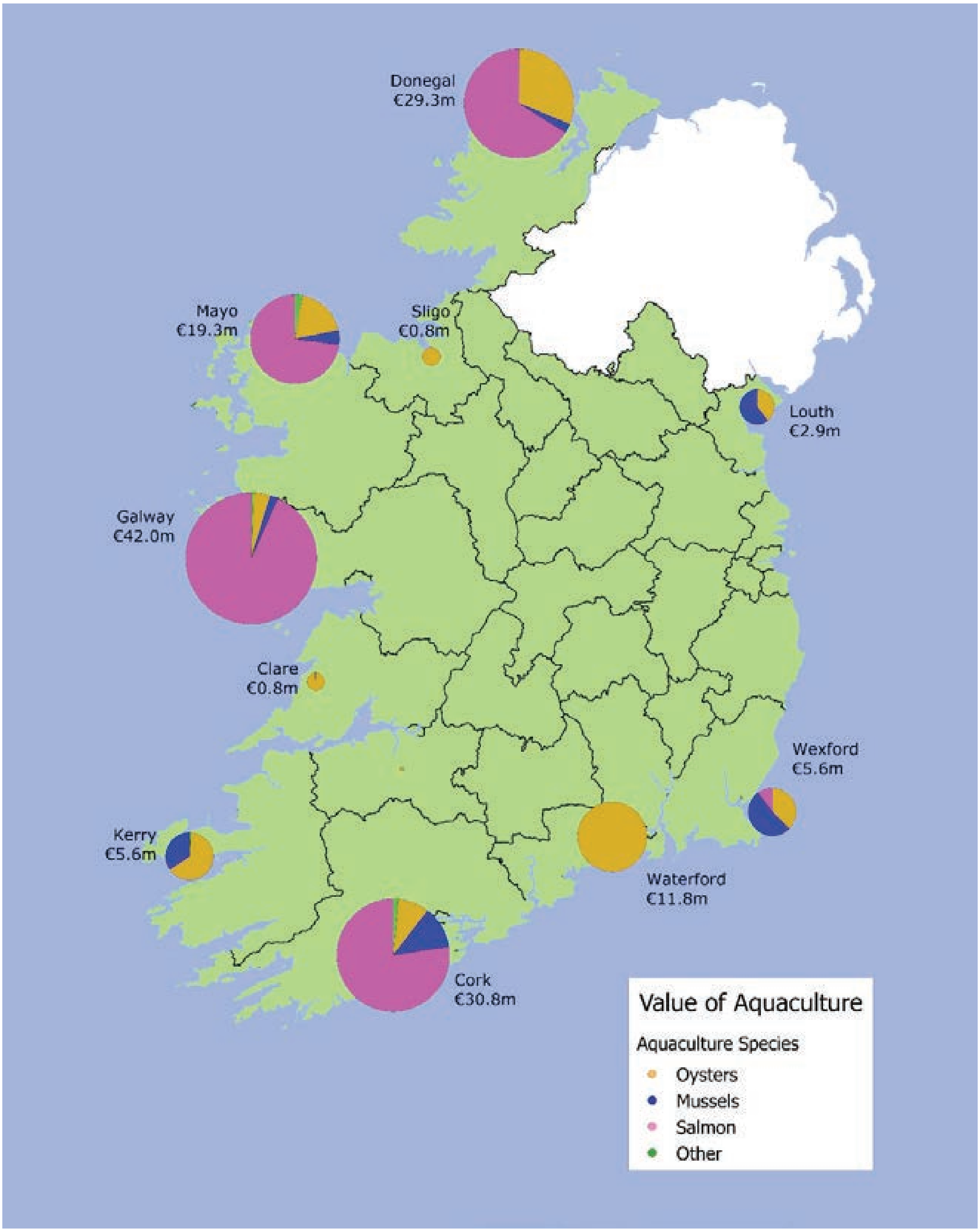
Table 10. Aquaculture by type and county

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

59,60 BIM (Bord Iascaigh Mhara), 2016. BIM Annual Aquaculture Survey 2016. [Available online: http://www.bim.ie/media/bim/content/publications/BIM,Annual,Aquaculture,Survey,2016.pdf]

Figure 8. Value of Irish aquaculture activity by county 2015



5.4. Algae/seaweed Harvesting

The main type of provisioning services under the Wild Plants and Algae and Plants and Algae from Aquaculture categories in Ireland is seaweed harvesting. Seaweeds, also known as macro-algae, are plant-like marine species 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, on the shores of Donegal, Sligo, Mayo, Galway, Clare and Cork. It is estimated that there is annual harvesting of approximately 30,000 tonnes of seaweed in Ireland[61,62] but it could be as high as 36,000-40,000 tonnes[63,64]. Seaweed is mainly harvested from wild stocks by hand but there is a small but growing aquaculture sector (estimated at less than 100 tonnes in 2015) that focuses on low-volume, high-value species such as *Palmaria palmata* and *Laminaria digitata*[65]. There are many uses of the seaweed harvested in Ireland; 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[66].

Ascophyllum nodosum (brown algae) is the main species harvested 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[67]. The other species that are harvested are Fucus serratus (brown algae), Laminaria digitata (brown algae), Chondrus crispus (red algae) and Palmaria palmata (red algae). The estimated harvest for 2012 for the main types of seaweed is based on the Food and Agriculture Organization of the United Nations (FAO)[68] and the value estimated for 2012 is based on the figures from O'Toole & Hynes (2014)[69].

Table 11. 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**

61 FAO (Food and Agriculture Organization of the United Nations), 2014. Fishery and Aquaculture Statistics: Capture Production. FAO Yearbook, 2012. [Available online: http://www.fao.org/fishery/docs/CDrom/CD_yearbook_2012/navigation/index_content_capture_e.htm]

62 O'Toole, E. and Hynes, S., 2014. An Economic Analysis of the Seaweed Industry in Ireland. SEMRU Working Paper 14-WP-SEMRU-09. [Available online: http://www.nuigalway.ie/semru/documents/14_wp_semru_09.pdf]

63 Morrissey, K., O'Donoghue, C. and Hynes, S., 2011. Quantifying the value of multisectoral marine commercial activity in Ireland. Marine Policy 35(5): 721–727.

64 JCECG (Joint Committee on Environment, Culture and the Gaeltacht), 2015. Report of The Committee on Developing the Seaweed Industry in Ireland. 31st Dail Eireann/24th Seanad Eireann, 2015. JCECG. [Available online: https://www.oireachtas.ie/parliament/media/seaweed-report-15.docx]

65 JCECG (Joint Committee on Environment, Culture and the Gaeltacht), 2015. Report of The Committee on Developing the Seaweed Industry in Ireland. 31st Dail Eireann/24th Seanad Eireann, 2015. JCECG. [Available online: https://www.oireachtas.ie/parliament/media/seaweed-report-15.docx]

66 O'Toole, E. and Hynes, S., 2014. An Economic Analysis of the Seaweed Industry in Ireland. SEMRU Working Paper 14-WP-SEMRU-09. [Available online: http://www.nuigalway.ie/semru/documents/14_wp_semru_09.pdf]

67 O'Toole, E. and Hynes, S., 2014. An Economic Analysis of the Seaweed Industry in Ireland. SEMRU Working Paper 14-WP-SEMRU-09. [Available online: http://www.nuigalway.ie/semru/documents/14_wp_semru_09.pdf]

68 FAO (Food and Agriculture Organization of the United Nations), 2014. Fishery and Aquaculture Statistics: Capture Production. FAO Yearbook, 2012. [Available online: http://www.fao.org/fishery/docs/CDrom/CD_yearbook_2012/navigation/index_content_capture_e.htm]

69 O'Toole, E. and Hynes, S., 2014. An Economic Analysis of the Seaweed Industry in Ireland. SEMRU Working Paper 14-WP-SEMRU-09. [Available online: http://www.nuigalway.ie/semru/documents/14_wp_semru_09.pdf]

5.5. Genetic materials

The rich biodiversity within the marine and coastal zones provide a rich hunting ground for genetic material. This genetic material has a variety of uses. These include the exploitation of genes related to certain traits to genetically modify organisms that can facilitate the improvement of farmed species through breeding for improved yield, increased resistance to disease and adaptation to change in environmental conditions.

Genetic resources also lead to the generation of pharmaceutical products from species based within marine and coastal ecosystems. Marine species such as the sponge Cryptotheca crypta which produce anti-cancer and anti-viral compounds and the cone snail Conus magus which produces a drug used in the treatment of chronic pain are examples of marine medicinal resources[70].

Jobstvogt et al. (2014)[71] used a choice experiment to estimate the public's values for certain deep sea ecosystem services. They estimated a WTP of £37.85 per person for protecting deep-sea ecosystems that provide society with the option of potential future discovery of new medicinal products derived from deep-sea species. In Ireland, Rae et al. (2013)[72] processed over 130 marine specimens from Irish waters as part of the Beaufort Marine Biodiscovery Research Programme in an effort to identify potential biodiversity and bioactivity "hotspots" within the Irish EEZ.

While the world's pharmaceutical value is measured in hundreds of billions of Euro, there is insufficient information to generate a reliable estimate of the potential value of medicinal resources extracted from Irish marine ecosystems.

70 Vierros, M., Hamon, G., Leary, D., Arico, S. and Monagle, C., 2007. An Update on Marine Genetic Resources: Scientific Research, Commercial Uses and a Database on Marine Bioprospecting, United Nations Informal Consultative Process on Oceans and the Law of the Sea Eight Meeting, United Nations, New York, 25-29 June 2007 [Available online: http://www.ias.unu.edu/resource_centre/Marine%20Genetic%20Resources%20UNU-IAS%20Report.pdf]

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

72 Rae, M., Folch, H., Moniz, M.B., Wolff, C.W., McCormack, G.P., Rindi, F. and Johnson, M.P., 2013. Marine bioactivity in Irish waters. Phytochemistry reviews, 12(3), pp.555-565.

5.6. Water for non-drinking purposes

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

For Poolbeg Generating Station and Dublin Bay Power Plant, the volumes of cooling water used was based on licence files and annual environmental reports (AERs) submitted to the Environmental Protection Agency (EPA) in 2015[73]. Estimates of the volume of cooling water used for Aghada Generating Station were based on its 2012 AER. The volume for Moneypoint was estimated on hours of energy generation reported for 2015 from their AER to the EPA and a figure of 83,160 m^3 hr^{-1} cooling water used when Moneypoint was in operation based on a report by Connolly and Rooney (1997)[74]. The volume used for Great Island was based on figures for the cooling water used per hour in the environmental impact statement[75] for the plant multiplied by the hours reported in the 2015 AER. Not enough information was available to estimate volume used in Tarbert.

As shown in Table 12, the total amount of water used for cooling in electricity generating stations was estimated at nearly 1,200 million cubic metres.

Table 12. 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**

73 EPA. Search for an application, licence or Annual Environmental Report [Available online: http://www.epa.ie/terminalfour/ippc/index.jsp]

74 Connolly D. and Rooney, S., 1997. Externe National Implementation, Ireland. A Study of the Environmental Impacts of the Generation of Electricity in Ireland at Europeat 1 and Moneypoint Power Stations. UCD Environmental Institute. [Available online: http://alphawind.dk/download/Energy_Balance_and_ExternE/ExternE%20National%20Implementation.pdf]

75 Great Island EIS, 2010. EIS - Section 4 to 14 [Available online: http://www.epa.ie/licences/lic_eDMS/090151b28035fbfd.pdf]

6. Ireland's Regulating and Maintenance Marine Ecosystem Services

Regulating services provide benefits to humankind through the use of natural systems which regulate the environment in which we live. This type of benefit is often known as indirect use value as many of these regulating services tend to happen in the background (i.e. climate regulation and waste treatment) or infrequently (i.e. disturbance prevention) and are not perceived by the majority of the population which benefits. The other main regulating services provided by our coastal, marine and estuarine ecosystems are reviewed in Table 13 and in the following sub-sections.

Table 13. Ireland's Coastal, Marine and Estuarine Regulating Services

Regulating and maintenance ecosystem services	CICES Classification	Estimated Quantity of ES per annum	Estimated Value of ES per anum
Waste services	Mediation of waste, toxics and other nuisances	9,350,642 kg organic waste 6,834,783 kg nitrogen 1,118,739 kg phosphorous	€316,767,000
Coastal defence	Mediation of flows	179 km of coastline protected by saltmarsh	€11,500,000
Lifecycle and habitat services	Lifecycle maintenance, habitat and gene pool protection	773,333 ha protected through SACs	Not valued
Pest and disease control	Pest and disease control	Not quantified	See section 6.4
Climate regulation	Atmospheric composition and climate regulation	40,936,000 tonnes CO_2 absorbed	€818,700,000

6.1. Waste services

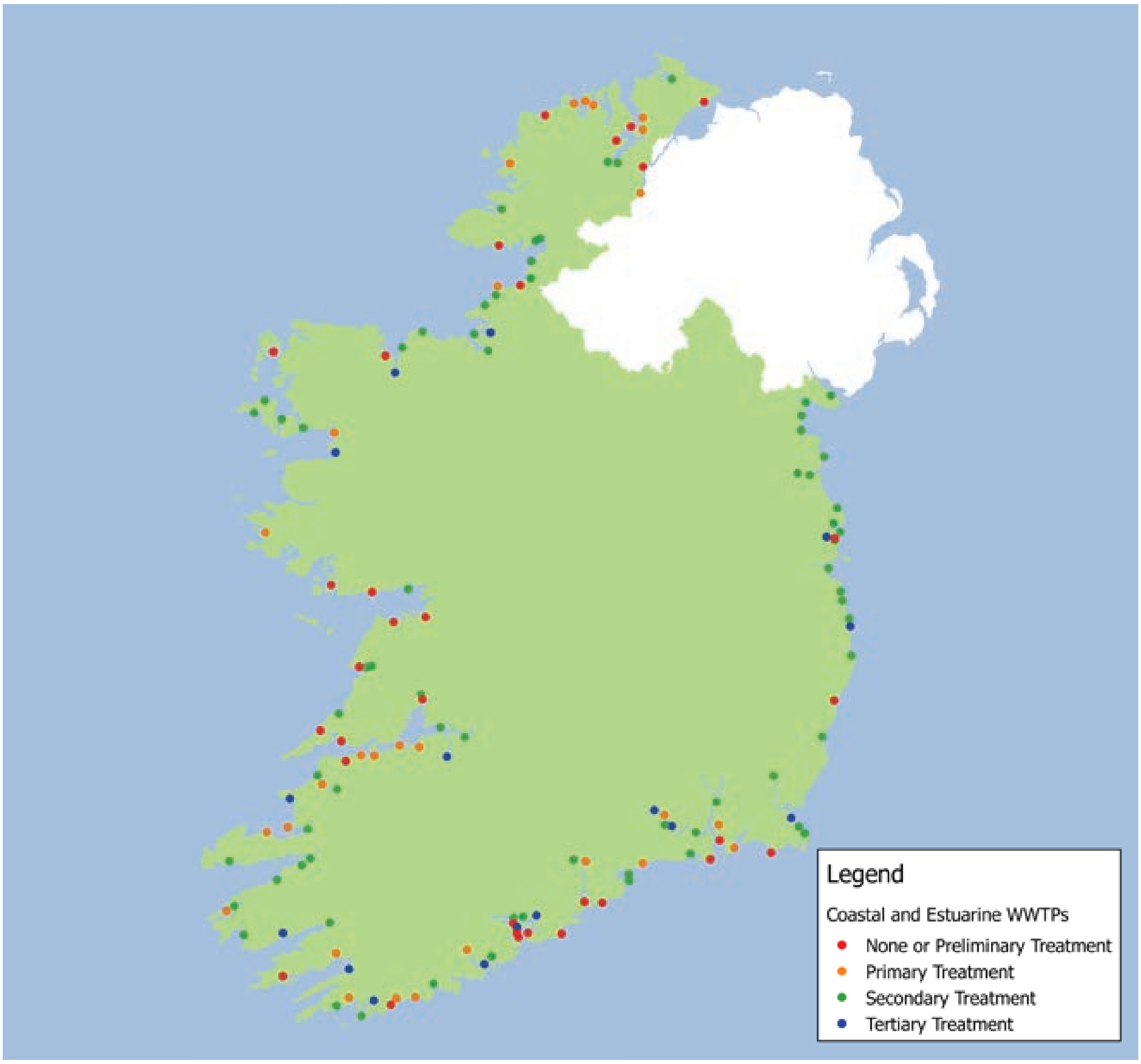
The use of natural ecosystems as a sink for waste products has been common practice for most of history. The oceans with their vastness have often been seen as having unlimited absorption capacity in terms of waste assimilation although it is now known not to be the case. However, storage is not always an ecosystems response to waste material entering it. In some cases, provided the ecosystem is not overloaded, it can process the waste material through either physical or biochemical means and the output is much less harmful and indeed may be a beneficial product.

For Irish coastal and marine ecosystem services the main waste treatment service provided is for wastewater emitted from human sources. The main pollutants found in wastewater are nitrogen (N) and phosphorous (P) and substances that cause or result in an oxygen demand known as biochemical oxygen demand (BOD). For urban agglomerations discharging into the coastal and estuarine waters of Ireland the amount of BOD, N and P was estimated[76] from the annual environment reports (AER) produced by each County Council for the EPA as part of their discharge licences[77]. Where an AER was not available the wastewater licence application was examined and the amounts were taken from these or estimated based on stated volumes or the population equivalent (PE) served by the wastewater treatment plant. Figure 9 shows the locations of the agglomerations and the type of wastewater treatment at each.

76 Further details on the discharges from urban wastewater treatment plants over 500 population equivalent into Irish coastal and estuarine waters are available in the accompanying EPA technical report No. 239. [Available online: http://www.epa.ie/pubs/reports/research/water/Research_Report_239.pdf]

77 EPA. Search for a Waste Water Discharge Application, Authorisation or Annual Environmental Report, Database [Available online: http://www.epa.ie/terminalfour/wwda/index.jsp]

Figure 9. Location and level of treatment for each coastal agglomeration discharging wastewater.



WWTP – Waste water treatment plants

The method of valuing this ecosystem service is based on the cost avoided if society had to provide the same water treatment services, such as the removal of pollutants [biochemical oxygen demand (BOD (a measure of organic waste), nitrogen and phosphorus) from the wastewater. Hernandez-Sancho et al. (2010)[78] 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 are shown in Table 14.

78 Hernandez-Sancho, F., Molinos-Senante, M. and Sala-Garrido, R., 2010. Economic valuation of environmental benefits from wastewater treatment processes: an empirical approach for Spain. Science of the Total Environment 408(4): 953–957.

Table 14. Shadow prices of removing a kilogram kg of each pollutant (values from 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

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. Note these values are based on operating costs and do not include capital expenditure. By multiplying the shadow prices represented in Table 14 above by the total amount of wastewater pollutants discharged the value of the ecosystem service of waste water treatment in Irish waters is estimated as shown in Table 15.

Table 15. The value of the waste treatment ecosystem service for each pollutant

Pollutant removed	Estimated total amount discharged (kg) per annum	Estimated value of ecosystem service (€) per annum
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 15 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.

Box 4. Interaction between Different Ecosystem Services

While not examined here, wastewater from some aquaculture (finfish) is treated by the ecosystems surrounding the facility whereas for other aquaculture activity involving filter feeders, such as mussels, the removal of pollutants from the water in the surrounding area may be accelerated. Additionally, in the section on climate regulation it is noted that estuaries have a negative benefit (i.e. a cost) as they emit carbon dioxide due to organic material (some of it waste material) being consumed (or treated). Any study examining changes to an ecosystem and its consequent effects on ecosystem services should examine the interactions between ecosystem services in addition to examining each class type individually.

6.2. Coastal defence

The ecosystem service of coastal defence (also known as mediation of flows under CICES) is the preventative or moderating effect that 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 dampen or reduce the energy hitting the terrestrial portion of the seashore. Such ecosystems include reefs, seagrasses, kelp beds/forests, dunes and saltmarshes.

Following the approach taken by Beaumont et al. (2010)[79] 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. This 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, 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)[80] 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 associated maintenance costs by €8,000 per hectare per year (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 per metre and maintenance costs of €64 per metre length per year.

Based on Coordination of Information on the Environment (CORINE) data[81] saltmarsh area was available for saltmarshes larger than 25 ha[82]. Using QGIS software, the land-use of the land bordering each of these 64 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 sea. This left 59 sites.

Based on these 59 sites, with a total area of 4,744 ha, the total length of protected land was estimated at 201,830m with an average length of protected area of 3,420m. Table 16 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.

79 Beaumont, N., Hattam, C. Mangi, S., Moran, D., van Soest, D., Jones, L. and Tobermann, M., 2010. National Ecosystem Assessment (NEA): Economic Analysis Coastal Margin and Marine Habitats, Final Report. UK NEA Report. Available online: http://uknea.unep-wcmc.org/LinkClick.aspx?fileticket=O%2B8tTp%2F5ZPg%3Dandtabid=82]

80 King, S.E. and Lester, J.N., 1995. The value of salt marsh as a sea defence. Marine Pollution Bulletin 30: 180–189.

81 EPA, Corine Land Cover Mapping. [http://www.epa.ie/soilandbiodiversity/soils/land/corine/]

82 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 data either in area (because of the linear nature of saltmarsh creation) or in width may still provide valuable coastal defence ecosystem services in certain areas. This is highlighted as a limitation to the methodology used here and is an area for future research.

Table 16. Land cover type protected by saltmarsh in Ireland

Land-use type protected (based on CORINE level 2 codes)	CORINE level 1 code	Estimated length of coast protected (m)	Percentage of total land-use type protected
Pastures	Agricultural areas	134957	67%
Non-irrigated arable land	Agricultural areas	14601	7%
Beaches, dunes, sands	Forest and semi-natural areas	10630	5%
Discontinuous urban fabric	Artificial surfaces	8938	4%
Land principally occupied by agriculture, with significant areas of natural vegetation	Agricultural areas	8645	4%
Sport and leisure facilities	Artificial surfaces	7517	4%
Transitional woodland-shrub	Forest and semi-natural areas	3646	2%
Peat bogs	Forest and semi-natural areas	2691	1%
Mixed forest	Forest and semi-natural areas	2455	1%
Natural grasslands	Forest and semi-natural areas	2158	1%
Road and rail networks and associated land	Artificial surfaces	1839	1%
Complex cultivation patterns	Agricultural areas	1657	1%
Industrial or commercial units	Artificial surfaces	1085	1%
Broad-leaved forest	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 (protected length of 19,379m) and the second is the CORINE level 1 'agricultural areas' (protected length of 159,860m). Combined this indicates a total protected length of 179,239m.

Multiplying the total protected length bordered by saltmarsh by the values generated for the capital costs gives a total 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.

6.3. Lifecycle and habitat services

Lifecycle and habitat services add to the value of commercial stocks as well as adding to the conservation value to society of all marine life. Usage of certain habitats is 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 for 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. Within the Irish context there are numerous examples of areas being set aside for the protection of lifecycle maintenance but valuation studies related to these are sparse, especially in a marine or coastal context.

The Biologically Sensitive Area (BSA) located off the southern Irish coast is a limited Marine Protected Area which aims to protect the nursery and spawning grounds of a number of commercial fish species, particularly hake, but also cod, haddock and herring. This protection is provided by restricting fishing effort within the BSA (Marine Institute, 2006)[83]. Another example is the EU Birds Directive (2009/147/EC), which designates 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 SPAs form part of the Natura 2000 protected sites and these can overlap with Special Areas of Conservation (SACs) which provide protection to habitats and species under the EU Habitats Directive (92/43/EEC). In Ireland, 60 habitats and 25 species are protected under the Directive and there are 423 protected sites covering 1,355,624 ha. An examination of designations 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).

It is difficult to provide an estimate of the value of these protected sites although it may be considerable. In the UK, McVittae and Moran (2010)[84] examined the benefits of marine conservation zones (MCZ) using a choice experiment methodology. The total aggregate value for a policy that halts UK marine biodiversity loss through the introduction of a UK MCZ network was estimated to be £1.7 billion per annum.

Box 5. Valuing the lifecycle maintenance ecosystem services

Outside of Ireland there has been some work valuing lifecycle maintenance ecosystem services. Foley et al. (2010)[85], 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 1 km^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.

83 Marine Institute, 2006. "Biologically Sensitive Area", A Deeper Understanding. [Available online: http://hdl.handle.net/10793/601]

84 McVittie, A. and Moran, D., 2010. Valuing the non-use benefits of marine conservation zones: an application to the UK Marine Bill. Ecological Economics 70(2):413–424.

85 Foley, N. S., Kahui, V., Armstrong, C. W., and Van Rensburg, T. M., 2010. Estimating linkages between redfish and cold water coral on the Norwegian coast. Marine Resource Economics, 25(1), 105-120.

6.4. Pest and disease control

Pests, diseases and invasive species cause economic loss through damage to crops, health and biodiversity. Predators and parasitoids can provide control of these invasives and maintain a balance in the ecosystem; this is the biological control service.

This ecosystem service is expected to come under increased pressure due to invasive species and changes in ecosystems related to climate change. Stokes et al. (2006)[86] examined the impact of invasive species in Ireland and noted that invasive species may bring both benefits and costs. Benefits are wide-ranging and may include new crop or pasture species, new aquaculture opportunities, ornamental plants and fish and novel biological control agents for economic pests. The costs may include damage to existing economic interests, harm to native species and habitats and the cost associated with removal of invasive species or preventing their introduction.

Two coastal species highlight the trade-offs faced when invasive species are introduced. Brown seaweed (Sargassum muticum) is able to inhabit previously unproductive waters sparsely inhabited by native seaweeds, providing increased biological productivity. Additionally, its strands may provide shelter to young fish and crustaceans and there is some evidence that this relates to higher catches of eels, mullet, bass and prawns in seaweed stands[87]. However, on the cost side it competes with native plant species, is known to clog intake pipes, foul marinas and aquaculture structures and dense growth may hinder shellfish growth and harvesting on commercial shellfish beds.

Similarly, common cordgrass (Spartina anglica), a saltmarsh plant that was initially introduced to help protect the Irish coastline from erosion through increased sediment accretion has other negative effects. These include converting mudflat habitat into a less diverse, monospecific sward which subsequently reduces the intertidal feeding ground available to waders and other birds. Additionally, as it alters the physical shape of coastal areas it may contribute to flooding in estuaries, particularly near river mouths[88].

Another introduced species, the protistan parasite (Bonamia ostrea), first detected in Irish waters in 1987 can infect the flat oyster (Ostrea edulis) and is known to have caused up to 90% mortality in the stocks causing economic losses[89]. Its spread throughout Europe caused a decrease in cultured flat oysters from 29,600 tonnes in 1961 to 5,900 tonnes in 2000, with a shift towards rearing of the Pacific oyster (Crassostrea gigas) occurring concurrently. Over €2.5 million worth of flat oyster (O. edulis) (See Table 9) were produced in Ireland in 2015, mainly in Kerry, Donegal and Galway. Culloty & Mulcahy (2007)[90] note that the only two parasite free oyster growing regions in the country are Tralee Bay, Co. Kerry and Kilkieran Bay, Co. Galway.

Kelly et al. (2013)[91] attempted to estimate the economic impact of invasive species in Ireland by projecting values estimated for Great Britain by Williams et al. (2010)[92] on a per capita basis. This method was used due to a lack of data in the Irish case and it produced a figure of €202 million for the estimated annual cost of invasive species in the Republic of Ireland and €57 million for Northern Ireland. The report attempted to break the costs down by sector, the two most relevant for the marine and coastal ecosystems being aquaculture, and tourism and recreation. For the aquaculture sector an annual cost of €570,000 was estimated for the Republic of Ireland and €220,000 for Northern Ireland while for tourism and recreation (total tourism and recreation rather than just marine) the estimated costs were €7.8 million and €3 million for the Republic of Ireland and Northern Ireland respectively. The figures for hull fouling of recreational boats was €2.1 million for Republic of Ireland and €850,000 for Northern

86 Stokes, K., O'Neill, K. and McDonald, R.A., 2006. Invasive species in Ireland. Report to Environment and Heritage Service and National Parks and Wildlife Service by Quercus, Queens University. Environment and Heritage Service, Belfast and National Parks and Wildlife Service, Dublin [Available online: http://invasivespeciesireland.com/wp-content/uploads/2010/11/Invasive_Species_in_Ireland_Report.pdf]

87 Davison, D.M., 1996. Sargassum muticum in Strangford Lough, 1995-1998. A review of the introduction and colonization of Strangford Lough MNR and cSAC by the invasive brown algae Sargassum muticum. Report to the Environment and Heritage Service, D.O.E. (N.I.).

88 Stokes, K., O'Neill, K. and McDonald, R.A., 2006. Invasive species in Ireland. Report to Environment and Heritage Service and National Parks and Wildlife Service by Quercus, Queens University. Environment and Heritage Service, Belfast and National Parks and Wildlife Service, Dublin [Available online: http://invasivespeciesireland.com/wp-content/uploads/2010/11/Invasive_Species_in_Ireland_Report.pdf]

89 Culloty S.C. and Mulcahy M. F., 2000. Bonamia ostrea in the native oyster Ostrea edulis: A review Marine Environment and Health Series, No. 29

90 Culloty S.C. and Mulcahy M. F., 2000. Bonamia ostrea in the native oyster Ostrea edulis: A review Marine Environment and Health Series, No. 29

91 Kelly, J., Tosh, D., Dale, K., and Jackson, A., 2013. The economic cost of invasive and non-native species in Ireland and Northern Ireland. A report prepared for the Northern Ireland Environment Agency and National Parks and Wildlife Service as part of Invasive Species Ireland.

92 Williams, F., Eschen, R., Harris, A., et al., 2010. The Economic Cost of Invasive Non-Native Species on Great Britain, Wallingford: CABI for The Scottish Government, Department for Environment Food and Rural Affairs UK Government, and Department for Economy and Transport Welsh Assembly Government

Ireland but only a portion of these costs related to invasive species in coastal and marine ecosystems. However, the report also noted large gaps in Irish data and the projection of values based on a per capita or area basis may provide very inaccurate figures, particularly for coastal and marine ecosystems. Further research is therefore needed in this regard.

6.5. Climate regulation

The most important greenhouse gases are water vapour, carbon dioxide, methane and nitrous oxide. In this valuation we only examine the benefit value of marine and coastal ecosystems absorbing carbon dioxide. As in the case of Canu et al. (2015)[93], the air-sea CO_2 exchanges are regarded in this study as "additional, spatially distributed, sources (or sinks) of the ecosystem service which translate into a cost (or benefit) for society by building up (or reducing) the concentration of greenhouse gases in the atmosphere that are responsible for climate change"[94]. By removing greenhouse gases from the atmosphere, marine ecosystems can help to slow down or mitigate the effects of climate change. The value of the carbon dioxide removed is based on the Irish carbon tax of €20 per tonne of CO_2 equivalent[95]. The valuing of this carbon sequestration service uses the avoided damage method of valuation 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).

Five ecosystems were examined with respect to carbon sequestration. The carbon absorbed per unit area (per hectare) for each ecosystem is based on studies done elsewhere. Table 17 shows the ecosystem types, their associated areas in Ireland (in hectares), the amount of carbon absorbed (tonnes carbon (tC) per ha) and the references for the amount of carbon absorbed.

For the saltmarsh and sand dunes, the areas are based on CORINE data[96]. Note that the minimum area associated with the CORINE data is 25ha and due to the linear nature of many coastal ecosystems, this most likely underestimates the area of saltmarsh and sand dune. The area of estuaries is based on that reported for the Water Framework Directive[97] and likewise for the coastal waters and bays. The area of offshore waters used in the calculation is based on the Irish EEZ and the coastal waters and bays have been subtracted from this.

93 Canu, D. M. Andrea Ghermandi, A., Nunes, P., Lazzari, P., Cossarini, G. and Solidoro, C. 2015. Estimating the value of carbon sequestration ecosystem services in the Mediterranean Sea: An ecological economics approach. Global Environmental Change 32, 87–95.

94 The reason for use of absorption in this report is that CO_2 transfer across the water/air boundary for some ecosystems was used to measure the removal of CO_2 from the atmosphere. This CO_2 is not locked away from the ecological system but instead can contribute to ocean acidification, which itself is an ecosystem disservice or cost. Also we are focused on the flow of the service in just one year which is reflected to some extent by the net flux (air-sea gas exchange) over the period. The contribution of physical (abiotic) processes to carbon sequestration could be either positive or negative in any given period and is only one element in the carbon cycle. The locking of the carbon away in true sequestration will take place through a more complex process over a much longer time horizon. As such the estimates presented here will be an underestimate of the total carbon sequestration value of the marine environment.

95 Department of Finance, 2011. Budget 2012 [Available online: http://www.budget.gov.ie/budgets/2012/2012.aspx]

96 EPA. Corine Land Cover Mapping. [Available online: http://www.epa.ie/soilandbiodiversity/soils/land/corine/]

97 EPA. Epa Geoportal Site. [Available online: http://gis.epa.ie/GetData/Download]

Table 17. Irish coastal and marine ecosystem areas and estimated carbon absorption amounts

Ecosystem	Irish area (ha)	Estimated Carbon absorption (tCO_2 ha^{-1} yr^{-1})[1]	References
Saltmarsh	5,179	5.2 (2.4, 8.0)	Cantell et al. (1999)[98]
Sand dunes	12,013	2.1 (0.25, 4)	Jones et al. (2008)[99]
Estuaries	80,680	-21.1 (-33.4 - -1.0)	Chen and Borges (2009)[100]
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)[101]

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

Table 18. Estimated total amount of carbon absorbed and value by Irish coastal and marine ecosystems per annum

Ecosystem type	Estimated Total Carbon Absorption (000's tCO_2)	Estimated Carbon Absorption value (€ millions)
Saltmarsh	26.9	0.5
Sand dunes	26.4	0.5
Estuaries	-1,702	-34.0
Coastal waters and bays	525.7	10.5
Offshore waters	42,059	841.2
Estimated totals	**40,936**	**818.7**

Although saltmarsh is the best carbon sequestrating ecosystem on a per hectare basis (additionally so as relatively little methane is released compared to freshwater marsh) the offshore waters are the largest contributor to the climate regulating service due to their large size. 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.

Box 6. Climate Change & Ocean Acidification

In the CICES classification system it is assumed that removing greenhouse gases from the atmosphere is an ecosystem service and it is valued as such here. However, the absorption of greenhouse gases is also having an impact on our oceans and seas. Although the oceans are moderating the impact of climate change by adsorption of greenhouse gases, this is changing the pH of the ocean and seas making them more acidic in a process called ocean acidification. This change in ocean chemistry could have future negative impacts on marine and coastal ecosystems including commercial fish and shellfish. Many of these species rely on specific pH regimes to develop from larval to adult forms and in conditions that are too acidic these species may fail to reproduce. This is not taken into account in this report[102].

98 Cannell, M.G., Milne, R., Hargreaves, K.J., Brown, T.A., Cruickshank, M.M., Bradley, R.I., Spencer, T., Hope, D., Billett, M.F., Adger, W.N. and Subak S., 1999. National Inventories of Terrestrial Carbon Sources and Sinks: The UK Experience. Climate Change, 42(3) 505–530

99 Jones, M.L.M., Sowerby, A., Williams, D.L. and Jones, R.E. (2008) Factors controlling soil development in sand dunes: evidence from a coastal dune soil chronosequence. Plant and Soil, 307(1–2), 219–234.

100 Chen, C. T. A., and Borges, A. V., 2009. Reconciling opposing views on carbon cycling in the coastal ocean: continental shelves as sinks and near shore ecosystems as sources of atmospheric CO_2, Deep Sea Res., Part II, 56(8–10), 578–590

101 NOAA (National Ocean and Atmospheric Association), 2016. Ocean viewer. [Available online: http://cwcgom.aoml.noaa.gov/cgom/OceanViewer/]

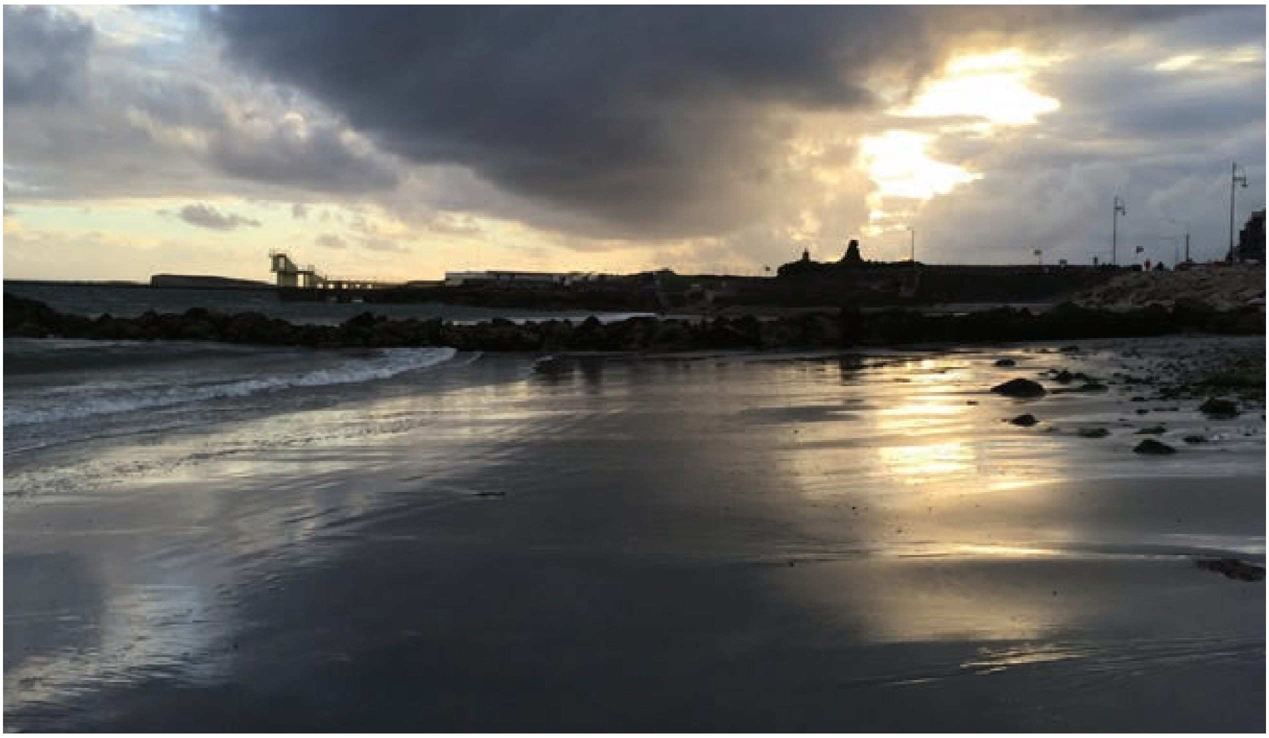
102 Nolan, G., Gillooly, M. and Whelan, K., 2010. Irish Ocean Climate and Ecosystem Status Report 2009. Marine Institute, Oranmore, Galway

7. Ireland's Cultural Marine Ecosystem Services

Cultural services refer to the benefits that people obtain from the natural world beyond just staying alive and healthy. It encompasses the aesthetic, spiritual, psychological and other such immaterial benefits that are obtained from contact with ecosystems (and in some cases without contact where the knowledge of either the benefits such ecosystems produce for others or simply knowing that the species which they support exist can provide value to individuals).

Table 19. Ireland's CME cultural ecosystem services and values

Cultural services	CICES Classification	Estimated Quantity of ES per annum	Estimated Value of ES per annum
Recreational services	Physical and experiential interactions	96 million marine recreation trips per year	€1,683,590,000
Scientific and educational services	Scientific & educational	Marine education and training fees	€11,500,000
Marine heritage, culture and entertainment	Heritage, cultural & entertainment	Not quantified	See section 7.3
Aesthetic services	Aesthetic	Flow value of coastal location of housing	€68,000,000
Spiritual and emblematic values	Spiritual and/or emblematic	Not quantified	See section 7.5
Non-use values	Existence & bequest values	Not quantified	See section 7.6



7.1. Recreational Services

Recreation is one of the more visible cultural ecosystem services provided by the marine and coastal environment. People enjoy undertaking a variety of leisure activities both on the shoreline and in the sea. Tourism initiatives such as Fáilte Ireland's Wild Atlantic Way are exposing more and more tourists and residents alike to the many opportunities that Ireland's marine environment offers. Previous research by the ERSI (2004)[103] focused on water-based (both marine and freshwater) recreational activities and found that approximately 1,475,000 people participated in water-based recreational activities. The majority of these activities were marine water based activities. The two most popular activities took place in two coastal and marine ecosystems, the beach and the sea. The most popular activity was trips to the seaside/beach (1,134,000 participants) followed by swimming in the sea (353,000 participants).

A more recent survey by SEMRU of the Irish population's coastal and marine based recreational activities was carried out in October and November, 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 a number of questions related to visits to the Irish coastline during the previous year.

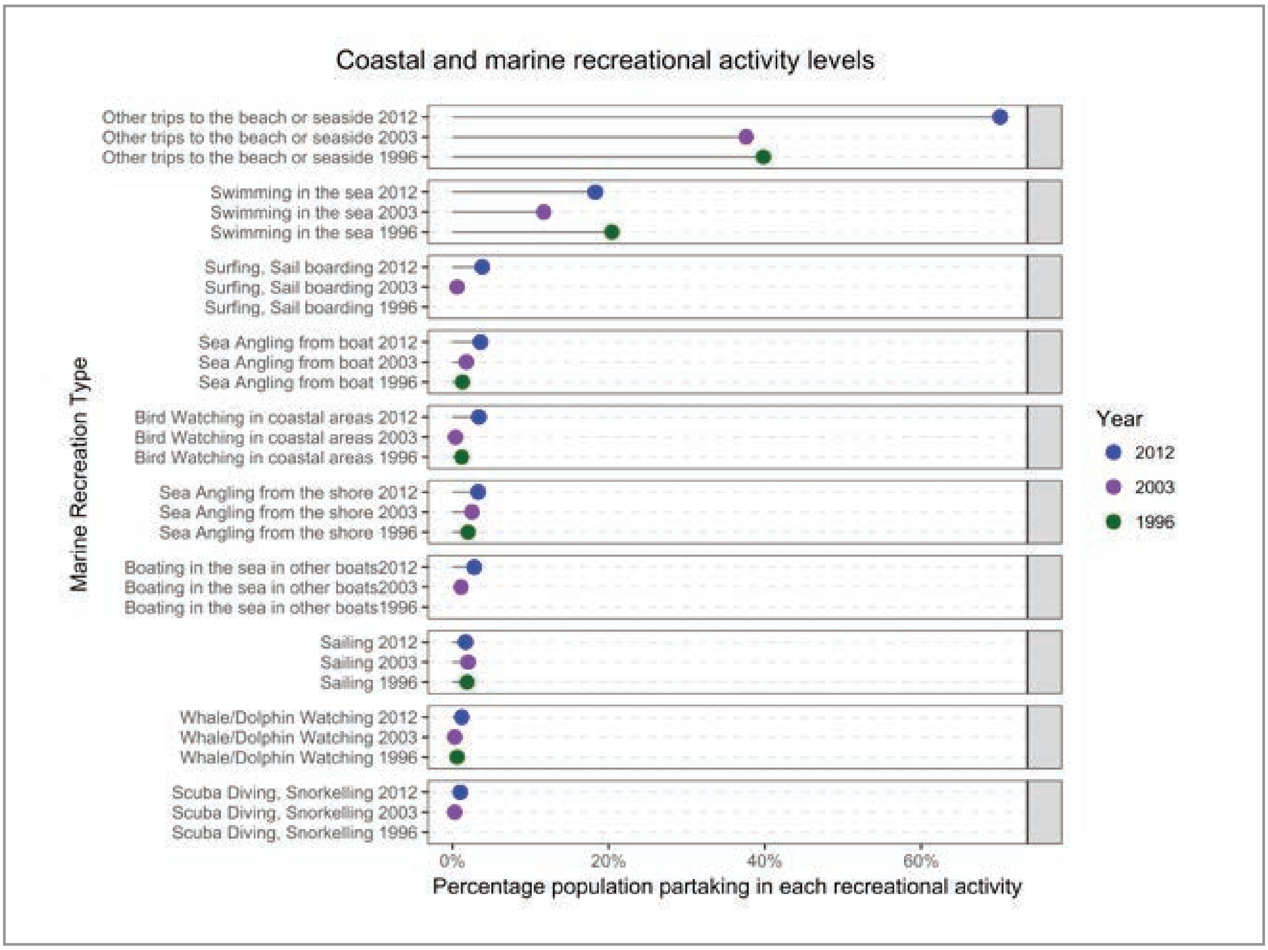
The survey found that during the previous 12 months, 73% of respondents visited the coastline at least once and 38% visited the coastline more than ten times. As shown in Table 20, for those who had visited the coastline at least once, beaches were the most visited type of coastal site.

103 ESRI, 2004. A National Survey of Water Based Leisure Activities in Ireland in 2003. ESRI Report, Dublin.[Available online: https://www.esri.ie/pubs/BKMNEXT62.pdf]

Table 20. Type of coastal sites visited for recreation in 2012 by Irish population

Type of Coastal Site Visited	% of total visits
Beach	78.97
Promenade & Beach	12.66
Pier or Quay	5.35
Cliff or Headland	2.85
Promenade Only	0.18

Respondents were also asked what activities they undertook during their visits and the results (Figure 10) are compared with previous research on marine activity participation rates carried out by the ERSI in 1996[104] and 2003[105].



104 Whelan, B., 1997. A National Survey of Water-Based Leisure Activities: Report carried out by the Economic and Social Research Institute on behalf of the Marine Institute

105 Williams, J. and Ryan, B., 2004. A National Survey of Water-Based Leisure Activities in Ireland 2003, Marine Institute [Available online: http://hdl.handle.net/10793/551]

Figure 10. Participation rates in marine recreation in Ireland from 3 studies

While the participation rates for the majority of marine related recreation activities are comparable across all three years there was a significant increase in the number of the population participating in the general category of "other trips to the seaside or beach" which may be due to the observed reduction in gym membership and increase in numbers of people undertaking 'free' outdoor recreation following the onset of the recession in late 2007[106].

Table 21. Marine recreation activities

Activity	Mean number of trips per person	Estimated total number of trips per annum	Estimated Total Value per annum
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**

Various sources – see appendix 1. 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.

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 Table 21. Using per trip welfare estimates from the literature and calculations from a marine recreation value meta-analysis[107], the aggregate recreational value obtained by Irish society from Ireland's marine resources was calculated[108]. Our coastal and marine environment provides us with an estimated €1.7 billion in recreation service value each year.

106 The methodology used in the 2012 survey had a smaller sample than the 1996 and 2003 surveys and was on a face to face basis rather than by telephone.

107 A meta-analysis involves collecting studies applicable to the ecosystem service that the researcher wishes to value, coding information from them, and analysing the coded data using appropriate statistical techniques. For full report on the meta analysis - see Hynes, S., Ghermandi, A., Norton, D. and Williams, H. (2017). Marine Recreational Ecosystem Service Value Estimation: A Meta-Analysis with Cultural Considerations. Ecosystem Services. https://doi.org/10.1016/j.ecoser.2018.02.001

108 See the technical report prepared for the EPA for further breakdown on literature estimate sources and explanation of techniques used. http://www.epa.ie/pubs/reports/research/water/research239.html

7.2. Scientific and educational services

Marine scientific research and education in Ireland is reflected in the many marine research laboratories and dedicated building facilities available across state agencies such as the Marine Institute and Bord Iascaigh Mhara (BIM) and across Irish third level institutions. The State also has purpose-built research vessels; the RV Celtic Explorer which is a 65.5m multi-purpose research vessel suitable for fisheries acoustic research, oceanographic, hydrographic and geological research and the smaller RV Celtic Voyager which is 31.4m in length and also outfitted with state-of-the-art scientific instrumentation. Ireland's role in marine research is also seen in projects such as SmartBay and INFOMAR. SmartBay is a marine test facility for the development and trial of novel marine sensors, prototype equipment and the collection and dissemination of marine data. The Integrated Mapping for the Sustainable Development of Ireland's Marine Resource (INFOMAR) programme is a joint venture between the Marine Institute (MI) and Geological Survey of Ireland (GSI) that is aimed at mapping the remaining unsurveyed coastal and continental shelf areas in Ireland's EEZ. Since 1999, Ireland's EEZ has been subject to one of the most extensive seabed mapping exercises in the world.

In terms of education, Ireland's third level education institutions offer a range of marine and marine-related undergraduate and postgraduate courses. At an undergraduate level, Vega and Corless (2016)[109] identified 6 fully marine undergraduate courses, 2 partial marine based undergraduate courses (at least two marine based modules, partial marine course) and 16 marine related undergraduate courses (contains a marine based module). At a postgraduate level, the authors identified 4 fully marine postgraduate courses, 2 partial marine based postgraduate courses and 14 marine related postgraduate courses. Combined, these courses account for approximately 1650 students on average per annum.

Vega and Corless (2016)[110] also examined the provision of marine training. They point out that "Ireland provides a broad range of marine related courses across vocational and continuous professional development areas and sector-specific training e.g. seafood, merchant (seafarer) and ocean energy. These are provided by both the State and private operators." Course operators include the National Maritime College of Ireland (NMCI), a number of small and medium sized business providing STCW training courses, the Irish Sailing Association (ISA), BIM and the Institute of Chartered Shipbrokers (ICS). NMCI provided marine training courses to over 2000 trainees and students annually. Elsewhere BIM offered 36 courses to 1600 students in 2013 while the Strategic Marine Alliance for Research and Training (SMART) delivered 24 national and international sea-going training courses to 285 third-level students. Vega and Corless (2016) estimate the value of marine training to the Irish economy to be in the region of €6.2m. This figure includes turnover from training from both public and private operators such as BIM, NMCI, SMART, ISA and ICS and a number of small private operators. In total the authors estimate an aggregate total turnover of €11.5m for the marine education and training sector in Ireland in the 2014-2015 period.

109 Vega, A. and Corless, R. (2016). A Measurement of Third Level Marine Education and Training in Ireland. SEMRU Report Series [Available online: www.nuigalway.ie/semru/documents/semru_marineeducation_training_reportseries_june2016.pdf]

110 Vega, A. and Corless, R. (2016). A Measurement of Third Level Marine Education and Training in Ireland. SEMRU Report Series [Available online: www.nuigalway.ie/semru/documents/semru_marineeducation_training_reportseries_june2016.pdf]

7.3. Marine heritage, culture and entertainment

Inspiration for culture, art and design is a very difficult service to measure and value. It is an indirect service, a virtual experience of ecosystems conveyed through books, art, cinema and television. While these goods in themselves have values, some which may be significant, apportioning the value attributable to the ecosystem is very difficult and is thus still an ecosystem service which needs further research.

In an Irish context the marine and coastal ecosystems have provided the inspiration and/or backdrop to many cultural goods. An auction of Irish marine themed art at Bonhoms[111] sold a piece named "Island Men Returning" by Jack B Yeats for €87,697 while another piece, "The Currach" by Gerard Dillon was sold for €31,455. These pieces are inspired by people using the provisioning service of a capture fishery from the sea.

The act of fishing and the use of other coastal ecosystems also provide inspiration for one of the earliest films shot in Ireland, the Man of Aran (1934) and coastal and marine ecosystems still play a significant role in Irish film making. Examples include large parts of the film Calvary (2014) filmed on the north west coast with the climactic scene taking place on the beach or a large number of beach scenes within the Oscar nominated film Brooklyn (2015). More recently, the iconic Scellig Mhicil off the Kerry coast has been made famous as the spiritual home of the Jedi in the Star Wars movie, Star Wars: The Force Awakens (2017).

Within the realm of Irish literature inspiration provided by marine and coastal ecosystems can be seen often with many famous works having marine based locales from Peig (1936) to the award winning The Sea (2005) by John Banville.

The above works are indeed valued by society but more work is needed in this area to examine how value can be attributed to ecosystems related to the inspiration that it generates or indeed if such values should be estimated. It may be that this ecosystem service is interlinked with the spiritual experience ecosystem service and that non-monetary decision making tools may be a better policy instrument for ensuring that they are considered in management and development plans (consider their value implicitly rather than make them explicit).

7.4. 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 paid for a house because of 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 due to the fact that it is located beside or near the coast relative to those properties inland.

Lyons (2011)[112] estimated a log-linear hedonic pricing model for Irish house sales between 2006 and 2010 which included dummies for sales at various distances from the coast. He had two distance dummies related to the coast, those "at the coast", which were 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 with those further inland. The exception was 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)[113] 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 22.

111 This auction took place on 28th May 2014. [Available online: https://www.bonhams.com/auctions/21769/?category=results#/aa0=1andw0=resultsandm0=0]

112 Lyons, R., 2011. The real value of house prices: What the cost of accommodation can tell policymakers, Conference paper presented to the Statistical and Social Inquiry of Ireland 15th March 2012 at Royal Irish Academy [Available Online: http://www.ssisi.ie/RLyons_draft.pdf]

113 Kennedy, P., 1981. Estimation with correctly interpreted dummy variables in semilogarithmic equations [the interpretation of dummy variables in semilogarithmic equations]. American Economic Review, 71(4), p 801.

Table 22. Percentage increase in house prices at and near to the 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 software 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 was estimated by overlaying a buffer area related to these (see Figure 11) and multiplying 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[114] report on house prices for counties and cities around Ireland. This allowed a capital stock value for house values within each zone to be estimated as well as the additional aesthetic value of having a house at or near the coast. The relative price difference for being near the coast was then applied to estimate a stock value for this proxy of the aesthetic ecosystem service.

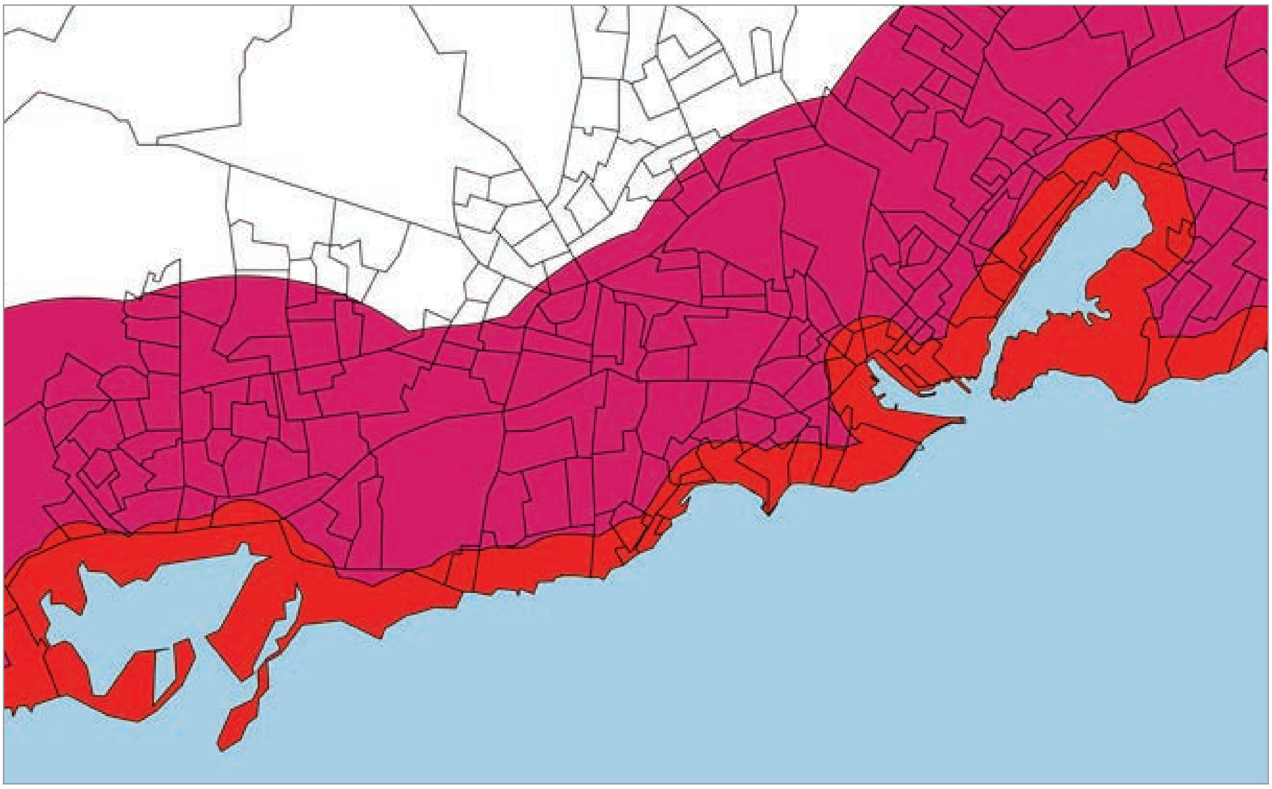


Figure 11. Coastal Buffers

An overlay of 0-250m buffer (red) and 250-1600m buffer (maroon) is shown for Census SAs in Galway City

This stock value was then converted to a flow value to be comparable to other values estimated in this report. The "stock value" was modelled as the present value of a perpetuity, with the flow of aesthetic ecosystem service modelled as a series

114 Daft, 2012. The Daft.ie House Price Report An analysis of recent trends in the Irish residential sales market 2012 Q2, Report by Daft.ie [Available online: http://www.daft.ie/report/Daft-House-Price-Report-Q2-2012.pdf]

of periodic payments. A discount rate of 2.95% was selected based on the average retail interest rate for loans for house purchases for 2012[115]. The values for both stocks and flows are shown in Table 23[116].

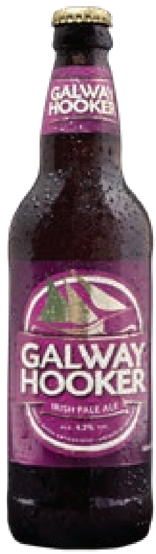
Table 23. Increased value of houses at or near the coast (proxy for aesthetic ecosystem service)

	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 per annum	€34,401,130	€33,239,981	€67,641,140

7.5. Spiritual and emblematic values

As in the case of maritime culture and entertainment values both market and non-market valuation tools are generally insufficient to place monetary values on spiritual and emblematic marine ecosystem service benefits. It may be possible that some element of the spiritual value people attribute to ecosystem services might be estimated using the revealed preference travel-cost method. However, no method is likely to succeed in picking up on the complete spiritual value that connection with marine ecosystems holds for individuals and society. Also while emblems connected with the sea and ships are used on county crests and as logos their contribution to the identity of a group in society or to the bottom line of a business is difficult to quantify. Indeed, an image such as the traditional gaff rigged Galway hooker is used as an emblem by a multitude of agencies and businesses in Galway city and county.

Cooper (2009)[117] refers to two main understandings of what might be involved with spiritual ecosystem service values. The first is the value held by indigenous people, the second is the values held by individuals and societies who seek inspiration from nature in their lives. The Millennium Ecosystem Assessment notes that "traditional societies all over the world have institutionalized sacred landscapes and ecosystems in a variety of ways, large and small, as part of their belief systems…". The marine environment holds a particularly powerful connection for an island nation such as Ireland and the spiritual connection of the Gaeltacht areas along the western seaboard is even more evident with many sea related terms in daily use through the Irish language and the traditional songs and poetry of these places.



"The mysterious magic of the sea grips the mind and imagination of the men who struggle with her and whose lot it is to knock a living out of her in one way or another. The spell of the sea is like an incurable disease and the man who has it in his blood does not easily find a medicine or remedy for it. This is something which the mountainy man or landlubber has trouble understanding, but if he were only to spend just a single evening gazing from the shore out across the ocean and listening to its voice, be it stormy or peaceful, then he might get a hint of the intoxicating spell I speak of…"

Translation of an Irish quote by a Gaeltacht fisherman at the fishing port of Teelin in Co. Donegal from Béaloideas XXXIII (1965) by Ó Cathain (1982[118]).

115 Central Bank of Ireland, 2016 [Available online: http://www.centralbank.ie/polstats/stats/cmab/Pages/Retail%20Interest%20Rate%20Statistics.aspx]

116 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.

117 Cooper, N., 2009. The spiritual value of ecosystem services: an initial Christian exploration, Anglia Ruskin University Working Paper [Available online: http://arro.anglia.ac.uk/288687/1/Spiritual_value_of_ecosystem_services%5B1%5D.pdf]

118 O Cathain, S., 1982. The Folklore of the Sea. In De Courcy Ireland, J and O hAnluain E. (eds.). Ireland and the Sea, Mount Salus Press, Dublin.

Non-monetary decision support tools may be a better policy instrument in dealing with these type of values. Deliberative methods such as discussion groups could be used to express these spiritual values in words rather than in numbers but it is still important that these values are recorded and considered in any marine ecosystem management approach.

7.6. Non-use values

As shown in Figure 4, non-use values are values that are not associated with actual use, or even the option to use a good or service. They include existence and bequest values. Existence values refer to the value associated with the knowledge or satisfaction that the resource exists or 'is there'. In this case, there are individuals who do not currently make use of the goods and services of an ecosystem but wish to see them preserved 'in their own right'. Bequest values arise when an individual gains utility from the knowledge that the ecosystem service remains available to other persons in the present and/or future. In this case the current generation places value on ensuring the availability of biodiversity and ecosystem functioning to future generations. An often used example of a non-use value is the willingness to pay expressed by individuals for the conservation of the blue whale even though it is unlikely that they will ever see or interact with this species themselves in the wild.

It can be argued that one of the reasons for our failure in the past to protect marine ecosystems is that we did not fully consider these non-use values[119,120]. A small number of studies in the Irish case have examined the Irish public's willingness to pay for the non-use values associated with Ireland's marine environment. Box 7 outlines a study by Doherty et al. (2014)[121] that explored the preferences of residents in the Republic of Ireland for a number of ecosystem services provided by Irish marine waters. Elsewhere, Norton and Hynes (2015)[122] used a Choice Experiment (CE) stated preference valuation technique to estimate the welfare impacts of achieving good environmental status (GES) in Irish marine waters as specified in the Marine Strategy Framework Directive (MSFD). This was an ecosystems service approach to valuing the 'cost of degradation' of the marine environment as set out in the MSFD. The welfare impact of a change in the marine environmental attributes from the status quo scenario of GES to a level of degradation scenario associated with low but negative levels of change in the attributes of: biodiversity in the Irish marine ecosystem, the sustainability of fisheries, the pollution levels in the sea, the presence of non-native species and physical impacts to the seabed, came to €343 million. This figure can be thought of as the costs avoided (in terms of lost benefits) of maintaining GES. Further research is needed however to tease out the marginal value of the many non-use values associated with our marine ecosystems.

Box 7. A discrete choice experiment to assess the non-market values associated with marine ecosystems

Doherty et al. (2014) 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. Of interest to this report 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. The DCE format allows marginal utility estimates for changes in the level of each attribute to be easily converted to willingness to pay (WTP) estimates. In their DCE, Doherty et al. (2014) found that the total value of a policy change that ensures the highest standards is reached for all attributes in marine water bodies, as shown in Table 24, 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.

Table 24. Attribute levels and welfare value estimates for policy change scenario (€ per person per year)

Attribute	Levels
Health of ecosystems (fish, insects, plants, wildlife on shoreline)	Good (100% of endangered aquatic species are present)
Water Clarity and Smell	Good (Good water clarity, no algae, no smell)
Access to recreational activities	All, including primary contact recreation: e.g. swimming and kayaking
Conditions of banks or shoreline	Low erosion and damage (extreme flooding event once every 20 years)
Welfare impact (€/ person/year)	€95

119 Ring, I., Hansjurgens, B., Elmqvist, T., Wittmer, H. and Sukhdev, P., 2010. Challenges in framing the economics of ecosystems and biodiversity: the TEEB initiative. Current Opinion in Environmental Sustainability, 2(1), pp.15-26.

120 World Bank, 2004. How much is an ecosystem worth? Assessing the economic value of conservation. Washington, DC: World Bank.[Available online: http://documents.worldbank.org/curated/en/2004/10/5491088/much-ecosystem-worth-assessing-economic-value-conservation]

121 Doherty, E., Murphy, G., Hynes, S., and Buckley, C., 2014. Valuing ecosystem services across water bodies: results from a discrete choice experiment. Ecosystem Services, 7, 89-97.

122 Norton, D., and Hynes, S., 2014. Valuing the non-market benefits arising from the implementation of the EU Marine Strategy Framework Directive. Ecosystem Services, 10, 84-96.

8. Conclusions

This report provided an assessment of Ireland's marine ecosystem services and their value. While the focus here has been on the biotic services the value of the many abiotic marine services such as shipping and marine renewable energy are reported on by SEMRU in its biannual ocean economy reports[123]. Using the CICES classification system as a guide, estimates for the quantity and value of provisioning, regulation and maintenance, 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 report 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 the 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 report.

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 annual value of €1.7 billion. The sea is also an important source of nutrition for society and Irish marine waters produce over 500,000 tonnes of seafood per annum 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 report shows that the value of these ecosystem services can be significant, valuing carbon absorption at €818 million per year and wastewater treatment at €317 million per year.

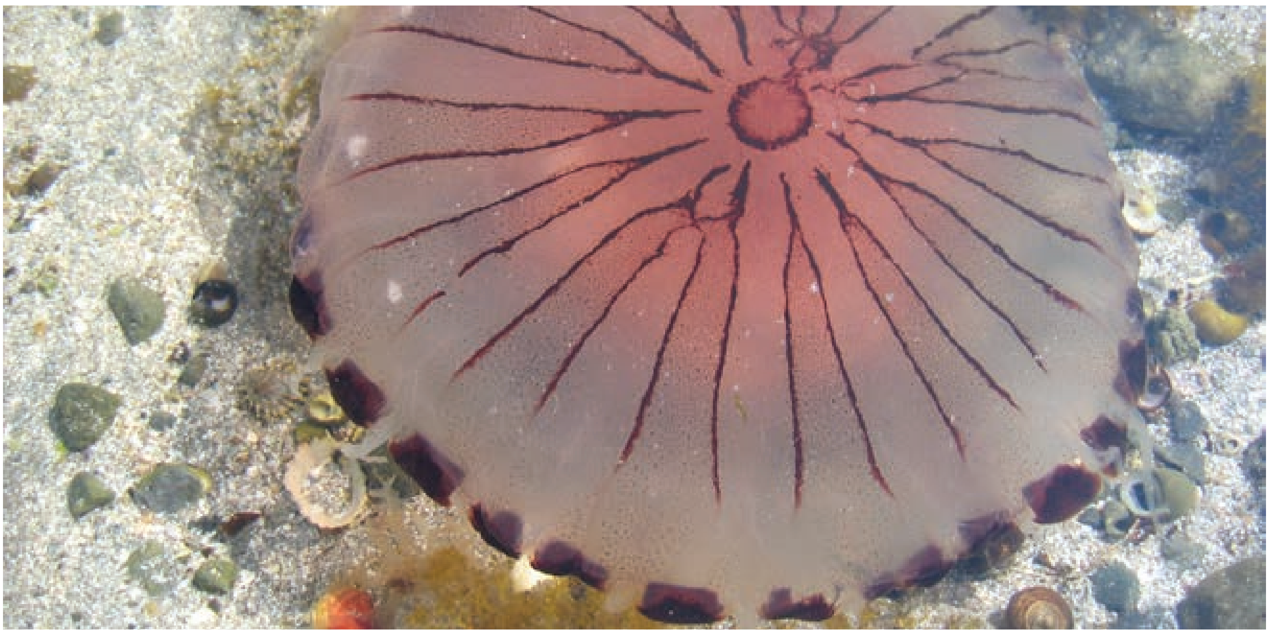
123 Vega, A., and Hynes, S., 2017. Ireland's Ocean Economy, SEMRU, NUI Galway. [Available online: http://www.nuigalway.ie/semru/documents/semru__irelands_ocean_economy_2017_online.pdf]

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. Without an understanding of the working of ecosystems, their functioning and the biodiversity associated with them, the assessment and valuation of ecosystem services may produce poor or in some cases misleading information and values for use in policy and decision-making. It is imperative therefore that those using ecosystem services classification systems, frameworks and values understand the basis of those values and the uncertainty associated with such values. 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 and understanding needed to apply an economic value to certain ecosystem services.

This report examined estimates for a flow of ecosystem services over one year and therefore 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 them in the future. Additionally more research is needed to determine how climate change and ocean acidification will affect other ecosystem services, how much carbon is being sequestered within the marine environment in the long term (rather than being absorbed) and what are the values associated with other greenhouse gases interaction with the marine environment.

For many of the other regulating services such as coastal defence and waste treatment, values used were sourced from international studies. More primary studies are therefore needed to examine how Irish coastal and marine ecosystems provide these services and to examine how exactly Irish society value these services. For the cultural ecosystem services, information about use of the coastal and marine ecosystems by users 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 regulation and maintenance 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.

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 classification system which was initially developed for green accounting purposes which involves the inclusion of ecosystem service values into national accounts. Factoring marine ecosystem service values into ocean economy account frameworks 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 ecosystem services assessment at a smaller spatial scale may 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.



Appendix 1: Data Sources

Off shore capture fisheries

Quantities of Ecosystem Service

- STECF Data Dissemination [Available online: https://stecf.jrc.ec.europa.eu/dd/effort/graphs-quarter]

  ICES. Catch statistics: Official Nominal Catches. [Available online: http://www.ices.dk/marine-data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx]

Price of Ecosystem Service

- Gerritsen, H.D. and Lordan, C., 2014. Atlas of Commercial Fisheries around Ireland. Marine Institute. [Available online: http://hdl.handle.net/10793/958]
- MI (Marine Institute), 2015. The Stock Book 2015: Annual Review of Fish Stocks in 2015 with Management Advice for 2016. Marine Institute, Oranmore, Galway

Inshore capture fisheries

Quantities and prices of Ecosystem Service

- MI and BIM (Marine Institute and Bord Iascaigh Mhara), 2015. Shellfish Stocks and Fisheries Review 2014: An Assessment of Selected Stocks. Marine Institute and Bord Iascaigh Mhara. [Available online: http://hdl.handle.net/10793/1063]

Aquaculture

Quantities and prices of Ecosystem Service

- BIM (Bord Iascaigh Mhara), 2016. BIM Annual Aquaculture Survey 2016. Available online: http://www.bim.ie/media/bim/content/publications/BIM,Annual,Aquaculture,Survey,2016.pdf

Algae/ Seaweed harvesting

Quantities of Ecosystem Service

- FAO (Food and Agriculture Organization of the United Nations), 2014. Fishery and Aquaculture Statistics: Capture Production. FAO Yearbook, 2012. [Available online: http://www.fao.org/fishery/docs/CDrom/CD_yearbook_2012/navigation/index_content_capture_e.htm]

Price of Ecosystem Service

- O'Toole, E. and Hynes, S., 2014. An Economic Analysis of the Seaweed Industry in Ireland. SEMRU Working Paper 14-WP-SEMRU-09. [Available online: http://www.nuigalway.ie/semru/documents/14_wp_semru_09.pdf]

Water for non-drinking purposes

Quantities of Ecosystem Service

- EPA. Search for an application, licence or Annual Environmental Report [Available online: http://www.epa.ie/terminalfour/ippc/index.jsp]
- Connolly D. and Rooney, S., 1997. Externe National Implementation, Ireland. A Study of the Environmental Impacts of the Generation of Electricity in Ireland at Europeat 1 and Moneypoint Power Stations. UCD Environmental Institute. [Available online: http://alphawind.dk/download/Energy_Balance_and_ExternE/ExternE%20National%20Implementation.pdf]

Waste services

Quantities of Ecosystem Service

- EPA. Search for a Waste Water Discharge Application, Authorisation or Annual Environmental Report, Database [Available online: http://www.epa.ie/terminalfour/wwda/index.jsp]

Price of Ecosystem Service

- Hernandez-Sancho, F., Molinos-Senante, M. andSala-Garrido, R., 2010. Economic valuation of environmental benefits from wastewater treatment processes: an empirical approach for Spain. Science of the Total Environment 408(4): 953–957

Coastal defence

Quantities of Ecosystem Service

- EPA, Corine Land Cover Mapping. [Available online: http://www.epa.ie/soilandbiodiversity/soils/land/corine/]

Price of Ecosystem Service

- King, S.E. and Lester, J.N., 1995. The value of salt marsh as a sea defence. Marine Pollution Bulletin 30: 180–189

Climate regulation

Quantities of Ecosystem Service

- EPA, Corine Land Cover Mapping. [Available online: http://www.epa.ie/soilandbiodiversity/soils/land/corine/]
- EPA,. WFD data available on Epa Geoportal Site[Available online: http://gis.epa.ie/GetData/Download]
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- NOAA (National Ocean and Atmospheric Association), 2016. Ocean viewer. [Available online: http://cwcgom.aoml.noaa.gov/cgom/OceanViewer/]

Price of Ecosystem Service

- Department of Finance, 2011. Budget 2012 [Available online: http://www.budget.gov.ie/budgets/2012/2012.aspx]

Recreational services

Quantities of Ecosystem Service

- Estimates number of trips for all marine recreational pursuits came from nationwide household survey carried out by RedC Survey Company on behalf of SEMRU in 2012.

Price of Ecosystem Service

- Estimates of the value of angling from shore and angling from a boat on the sea came from: Hynes, S., Gaeven, R. and O'Reilly, P. (2017). Estimating a Total Demand Function for Sea Angling Pursuits. Ecological Economics, 134, 73–81.

- Estimates of the value of sea kayaking came from: Hynes, S., 2006. Recreational Demand Modelling for Whitewater Kayaking in Ireland, PhD Dissertation, Stirling University, Scotland.

- 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 the development of a meta-analysis that analysed the characteristics of over 200 previous marine recreation valuation studies using a regression model. The resulting model was used to estimate a per trip value for each of the activities listed. The meta-analysis is fully presented in: Hynes, S., Ghermandi, A., Norton, D. and Williams, H. (2017). Marine Recreational Ecosystem Service Value Estimation: A Meta-Analysis with Cultural Considerations. Ecosystem Services. https://doi.org/10.1016/j.ecoser.2018.02.001

Scientific and educational services

Quantities and prices of Ecosystem Service

- Vega, A. & Corless, R. (2016). A Measurement of Third Level Marine Education & Training in Ireland. SEMRU Report Series [Available online: www.nuigalway.ie/semru/documents/semru_marineeducation_training_reportseries_june2016.pdf]

Aesthetic services

Quantities of Ecosystem Service

- Central Statistics Office (CSO) Census 2011 [Available online: http://data.cso.ie/datasets/index.html]

- Lyons, R., 2011. The real value of house prices: What the cost of accommodation can tell policymakers, Conference paper presented to the Statistical and Social Inquiry of Ireland 15th March 2012 at Royal Irish Academy [Available online: http://www.ssisi.ie/RLyons_draft.pdf]

Price of Ecosystem Service

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- Central Bank of Ireland, 2016 [Available online: http://www.centralbank.ie/polstats/stats/cmab/Pages/Retail%20Interest%20Rate%20Statistics.aspx]

Glossary of Acronyms

AER	Annual Environmental Reports
ATLAS	A Trans-AtLantic Assessment and deep-water ecosystem-based Spatial management plan for Europe
BIM	Bord Iascaigh Mhara
BOD	Biochemical Oxygen Demand
BSA	Biologically Sensitive Area
CBD	Convention on Biological Diversity
CE	Choice Experiment
CICES	Common International Classification of Ecosystem Services
CME	Coastal, Marine and Estuarine
CORINE	Coordinate Information on the Environment
CS	Consumer Surplus
DCE	Discrete Choice Experiment
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Agency
ES	Ecosystem Services
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GES	Good Environmental Status
GSI	Geological Survey of Ireland
GVA	Gross Value Added
HOOW	Harnessing Our Ocean Wealth
ICES	International Council for the Exploration of the Sea
ICS	Institute of Chartered Shipbrokers
IMP	Integrated Marine Plan
INFOMAR	Integrated Mapping for the Sustainable Development of Ireland's Marine Resource
ISA	Irish Sailing Association

MCZ	Marine Conservation Zones
MEA	Millennium Ecosystem Assessment
MFRC	The Marine and Freshwater Research Centre
MI	Marine Institute
MSFD	Marine Strategy Framework Directive
MSPD	Maritime Spatial Planning Directive
N	Nitrogen
NMCI	National Maritime College of Ireland
P	Phosphorous
PE	Population Equivalent
PES	Payment for Ecosystem Services
QGIS	Quantum Geographic Information System
RP	Revealed Preference
SA	Small Area
SAC	Special Areas of Conservation
SEEA	System of Environmental-Economic Accounting
SEMRU	Socio-Economic Marine Research Unit
SMART	Strategic Marine Alliance for Research and Training
SP	Stated Preference
SPA	Special Protection Areas
STECF	Scientific, Technical and Economic Committee for Fisheries
TEEB	The Economics of Biodiversity and Ecosystems
TEV	Total Economic Value
UK NEA	United Kingdom National Ecosystem Assessment
VIBES	Valuing Ireland's Blue Ecosystem Services
VT	Value Transfer
WTA	Willingness To Accept
WTP	Willingness To Pay

Tables

Figures

Notes:

Notes:

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