Appendix 1

Information Gaps in KRC Reports

Report	Information Gap	Page number
KRC report	2016 Appropriate Assessment has "very significant data gaps on species numbers and trends, species distribution within the site and behaviour in relation to existing activities".	2
KRC report	Re waterbird data- insufficient analysis due to inadequate number of good quality counts during the relevant period.	9
KRC report	Trends generated from the long-term data set are necessary to detect long-term changes.	10
KRC report	Insufficient data analysis for modelling population trends for individual species at this site.	16
KRC report	Absence of contemporary multi-year low-tide count data from the site.	19
KRC report	Most comprehensive study on the potential effects of aquaculture on waterbird populations in Ireland was restricted to oyster culture and its concomitant use of trestle structures, and there have been relatively few studies of the effects of bottom-culture Mussel cultivation on inter-tidal flats.	21
KRC Report	2016 Appropriate Assessment explicitly does not assess potential cumulative, in-combination impacts which is a requirement for a full and complete AA.	25
KRC report	2016 Appropriate Assessment states that there are likely to be “significant impacts arising from the cumulative impact of hunting pressures in combination with impacts from aquaculture activities” but data was not available for the assessment.	25
KRC report	The direct loss of habitat of sufficient quality and quantity and displacement due to anthropogenic factors inevitably has mostly negative rather than positive effects- site-specific studies are required to provide the scientific evidence base to prove an absence of negative effects beyond reasonable doubt.	26

KRC report	2016 Appropriate Assessment was mostly based on desk-review and it did not rule out the potential for 'likely significant effects' and was unable to assess the cumulative impact which "could only be prepared when there is a reasonable level of certainty about the likely impacts arising from the activities being assess, which is not the case for the present assessment" (p. xiv). The assessment of cumulative/in-combination impacts is a requirement of Article 6.3 of the Habitats Directive.	26
KRC report	2016 Appropriate Assessment indicated potential impacts where the evidence indicates a high likelihood of significant impacts occurring in the case of bottom mussel culture on (a) Red-breasted Merganser, and (b) Little Tern. In the case of the former whilst the Appropriate Assessment indicates the impact based on predicted displacement, the population-level consequences are unknown. They suggest, in the case of Little Tern, that appropriate adaptive management strategies may mitigate potential impacts- it is clear that this needs to be properly evaluated to assess the potential impacts of bottom mussel aquaculture activities on these QI species.	26
KRC report	2016 Appropriate Assessment identified potential impacts where the available evidence is not sufficient to rule out significant impacts beyond reasonable significant doubt. The uncertainty associated with this means that a complete Appropriate Assessment is not possible.	27

Appendix 2

Interreg
Baltic Sea Region

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Baltic Blue Growth

Baltic Blue Growth – Initiating full scale mussel farming in the Baltic Sea

www.balticbluegrowth.eu #BalticBlueGrowth

Basic facts

- Duration: May 2016 – March 2019
- Total budget: € 4.7 million
- Co-financed by Interreg Baltic Sea Region
- Lead Partner: Region Östergötland, Sweden
- 18 project partners + 20 associated organisations
- Flagship under Policy Area ”Nutri” of the EU Strategy for the Baltic Sea Region
- A SUBMARINER Network project

Interreg Baltic Sea Region

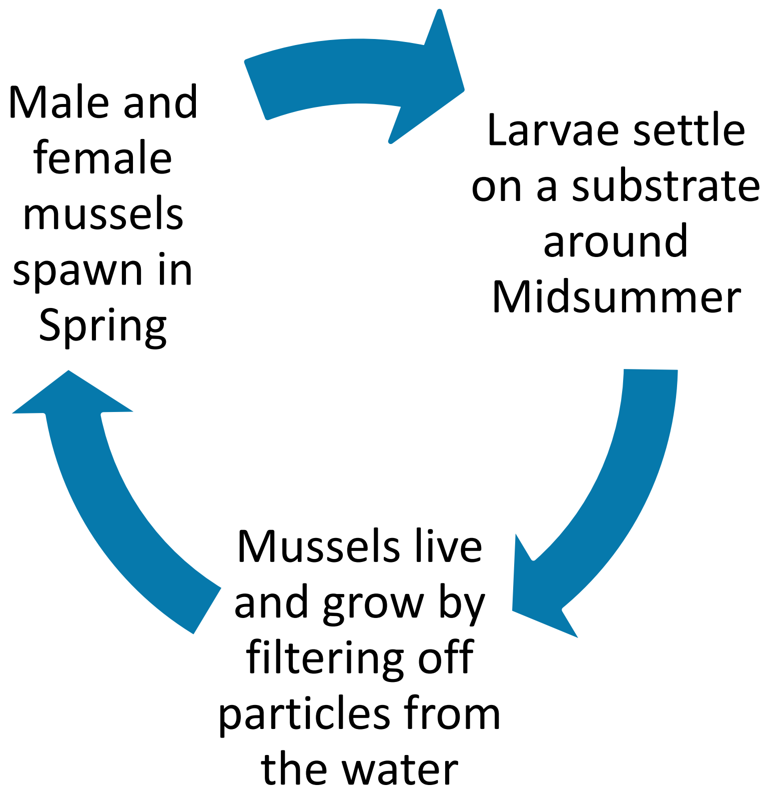
Baltic Blue Growth

EUROPEAN UNION

EUROPEAN REGIONAL DEVELOPMENT FUND

Region Östergötland

Blue mussel farming in the Baltic Sea



- To “farm mussels” means to offer the substrate, typically ropes or nets
- Size and growth rate depend on factors like salinity, temperature and food supply
- Blue mussels in the Baltic Sea are usually harvested 1,5 – 3 years after they settle

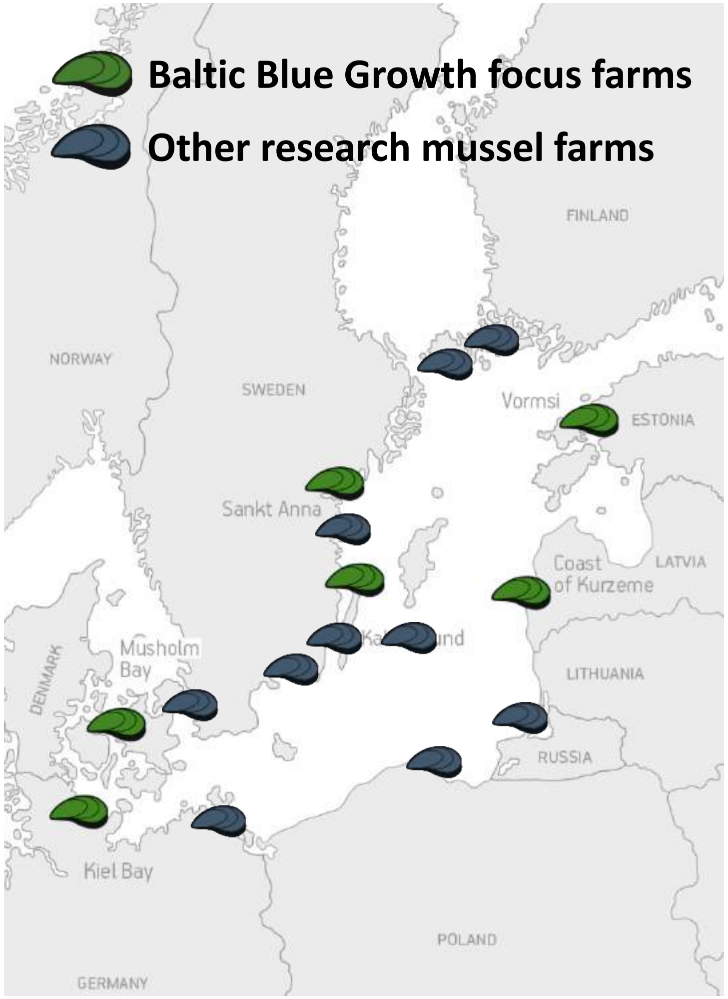
Mussel farming experience in the Baltic Sea

- Research projects assessing mussel farming in the Baltic Sea:

Baltic 2020	2009 – 2012
Submariner project	2010 – 2013
Aquabest	2011 – 2014
Baltic Ecomussel	2012 – 2014
Bucefalos	2012 – 2015
BONUS OPTIMUS	2017 – 2020
MuMiPro	2017 – 2020

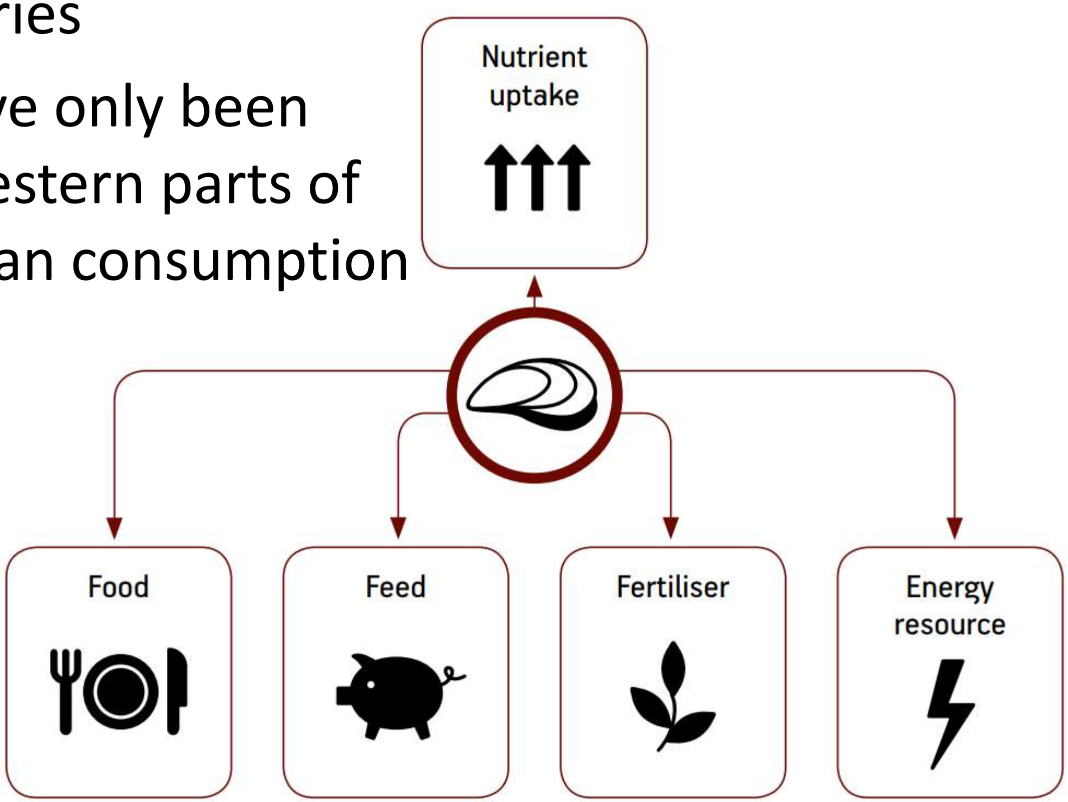
Several other projects with focus on aquaculture or spatial planning

- Baltic Blue Growth will contribute to the step from research to full scale

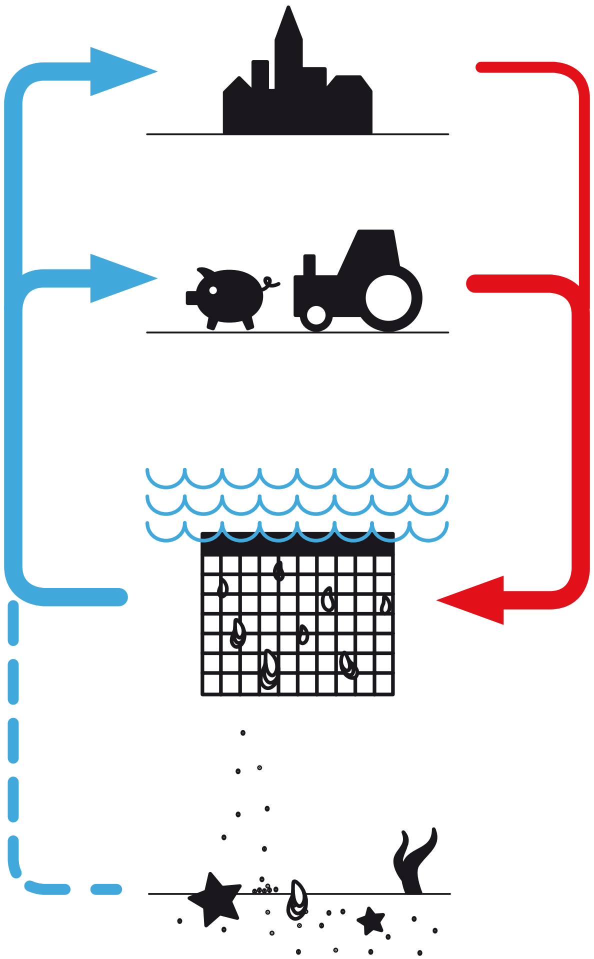


Introduction to mussel farming

- Blue mussels are farmed and enjoyed as fresh seafood in many European countries
- Until now, mussels have only been cultivated on in the western parts of the Baltic Sea for human consumption
- Farms are set up in eastern Baltic Sea to find out if mussels can be farmed for other purposes, f.ex. animal feed



Background: closing the nutrient loop



- Concept of “closing the nutrient loop” by recycling nutrients through mussel farming
- Farming mussels can improve the Baltic Sea water quality by reducing eutrophication

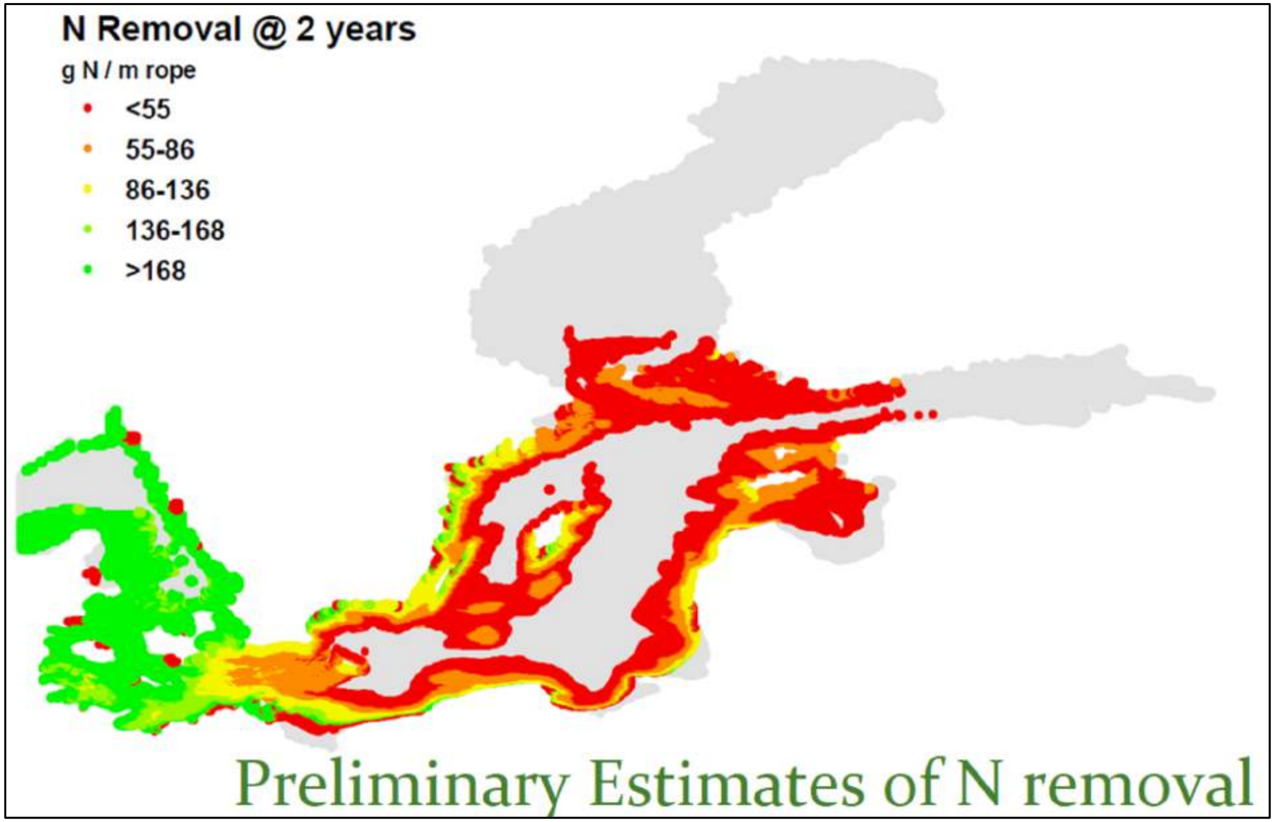
Background: finding a cost-effective mix of nutrient reduction measures

- Cheapest and easiest measures (low-hanging fruits) have already been implemented
- Hence, costs for traditional measures to achieve more reduction will increase dramatically
- Including mussel farming in the mix could decrease the total cost by up to 11%

Measure in the Baltic Sea Region	Reported N removal costs in €/kg N	Reported P removal costs in €/kg P
Mussel farming without sales	10 – 64	150 – 900
Agricultural measures	0 – 150	0 – 10200
Livestock reductions	6 – 842	112 - 5895
Wastewater treatment upgrades	11 – 136	39 – 600
Wetlands	2 – 93	396 – 1518

Background: modelled nutrient removal by farmed mussels

- Mussel farming in the Baltic Sea can remove significant amounts of nitrogen and also phosphorus
- Mussel farming could account for 2-3% of the Swedish nutrient reduction



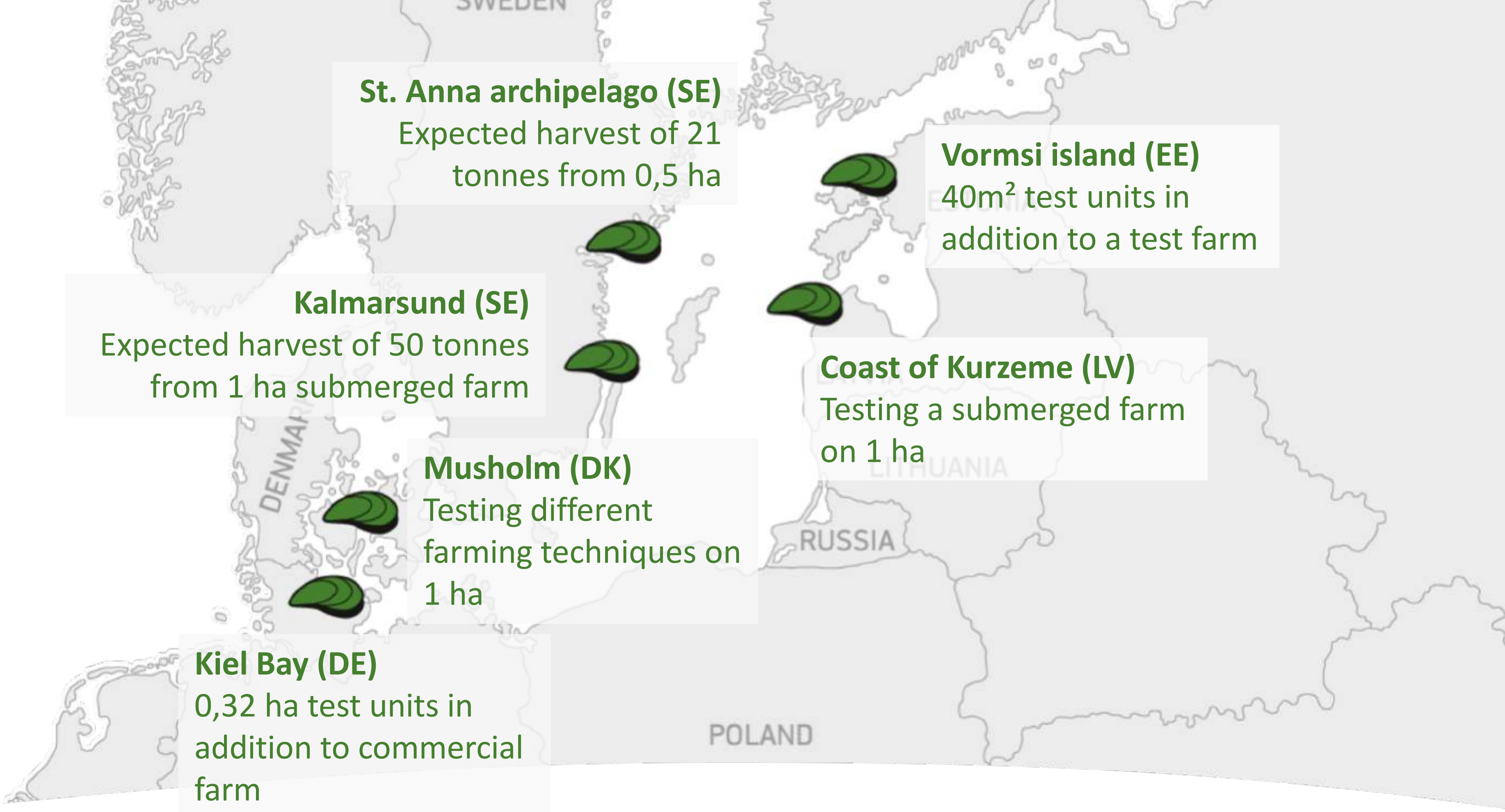
Background: new blue growth opportunities for the feed industry?

- Baltic mussels often too small and fragile for human consumption
- Successful trials of producing mussel meal as animal feed
- New possibilities: mussels as organic substrate for insects larvae as protein source in animal feed

Objective

Advance mussel farming in the Baltic Sea from experimental to full scale to improve the water quality and create blue growth in the feed industry

Baltic Blue Growth pilot farms



Produced outputs and current status

Finished tasks:

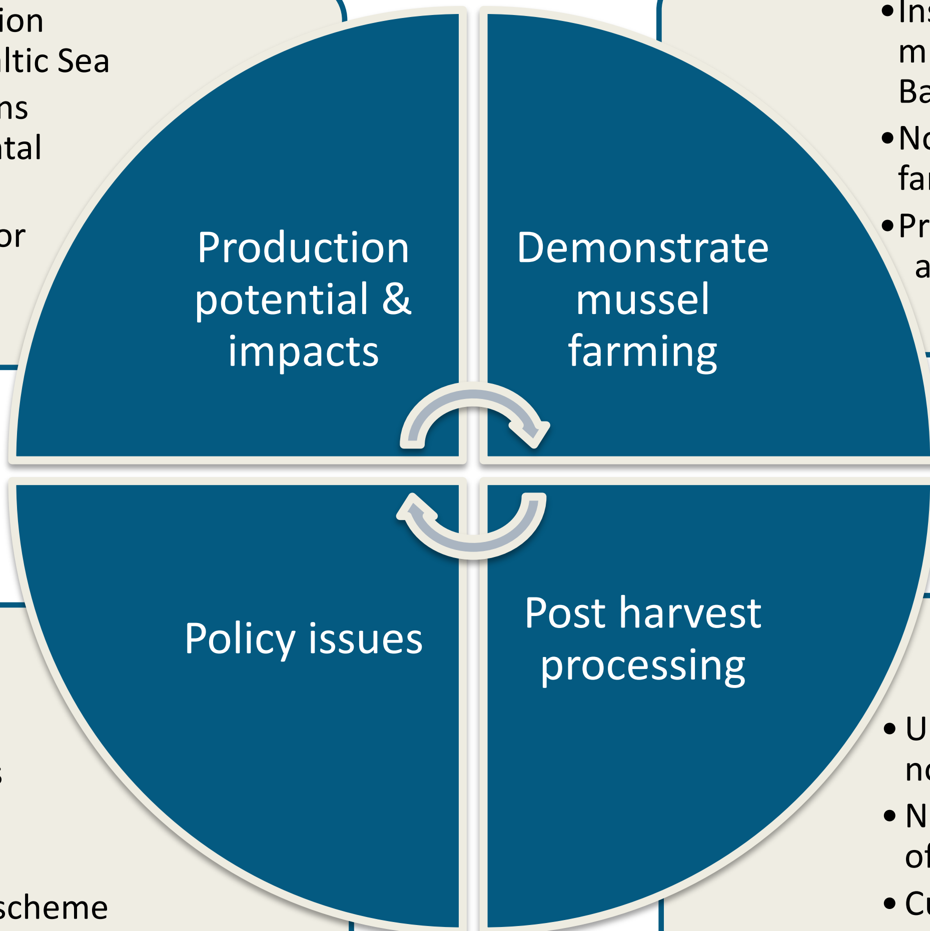
- Pilot version of an Operational Decision Support System (ODSS) available
- Review of available mussel production equipment
- All focus mussel farms in the Baltic Sea established

Ongoing tasks:

- Optimising mussel production
- Developing systems for submerged mussel farms
- Monitoring the effects of mussel farming on water quality
- Developing technology for postharvest processing
- Assessing the value of mussel and larvae meal as animal feed
- Developing relevant business models
- Promoting business opportunities
- Studies on relevant policies

Mussel farming challenges

- Unknown production potential in the Baltic Sea
- Ongoing discussions about environmental impacts
- Lack of guidance for environmental friendly farming



- Insufficient technology mussel farming in the Baltic Sea
- Not enough data about farming techniques
- Problems with ice cover and predation

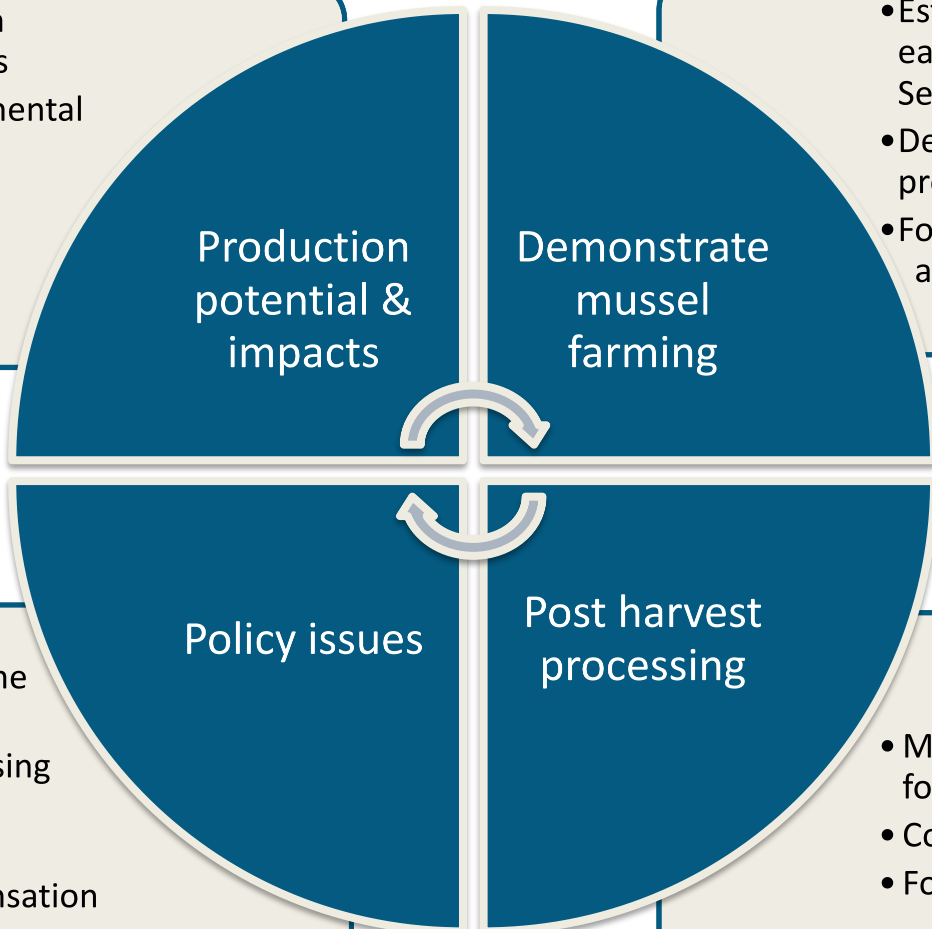
- Not addressed in Marine Spatial Planning strategies
- Unclear licensing processes
- No compensation scheme for the ecosystem service

- Unclear use of produced non-food mussel
- Need for demonstration of possible processing
- Currently no existing markets for feed from mussels

Project structure and activities

- Identify areas with suitable conditions
- Quantify environmental impacts
- Provide decision support for environmentally friendly farming

- Establish mussel farms in eastern and western Baltic Sea
- Demonstrate efficient production techniques
- Focus: submerged systems and avoiding predation



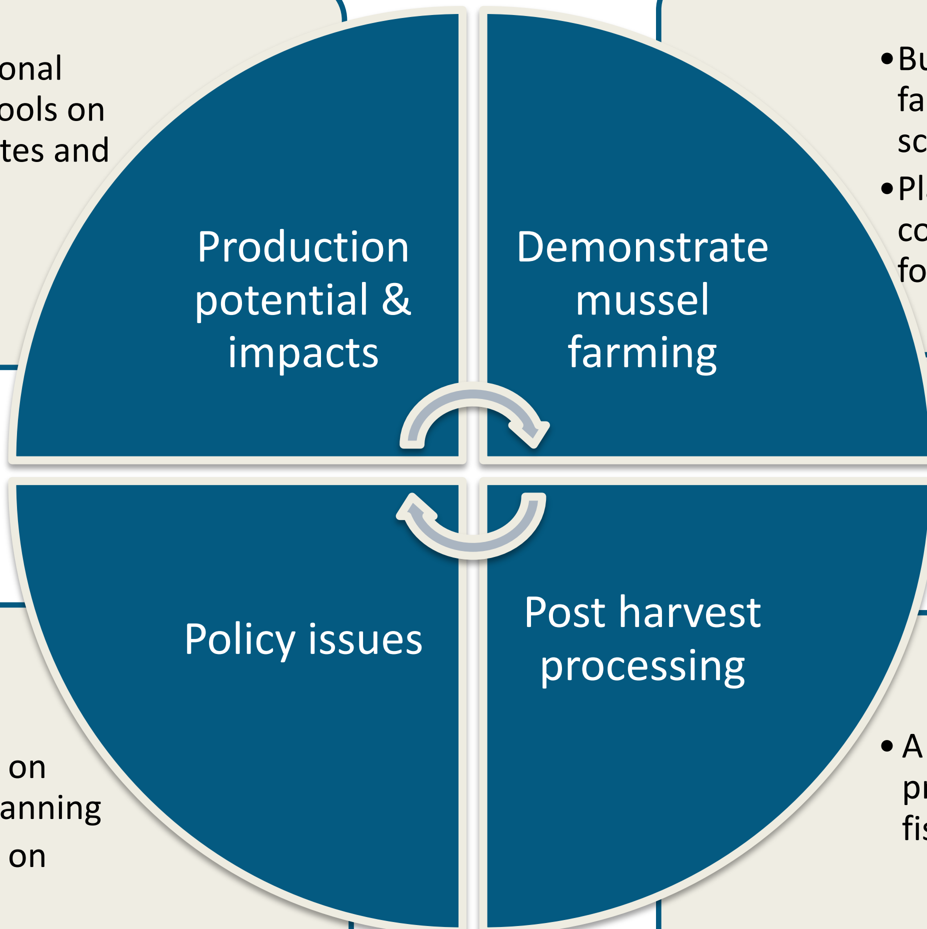
- Harmonize maritime spatial planning
- Guidance for licensing processes
- Suggest suitable ecosystem compensation mechanisms

- Mussel meal production for fish and poultry feed
- Cost-benefit analysis
- Food safety aspects

Expected outputs

- Models and functional decision support tools on suitable farming sites and their production potential

- Business plans and farming manuals for large scale mussel farms
- Plans for long-term commercial viability of the focus farms



- Guide on licensing process
- Recommendations on maritime spatial planning
- Recommendations on ecosystem service compensation measures

- A demonstration line for processing mussels into fish and poultry feed

Expected outputs

Take home messages from Baltic mussels #BalticBlueGrowth

- Mussels grow naturally in the Baltic sea without extra feed or fertiliser and can be combined with other types of aquaculture (e.g. IMTA)
- Production methods have now been adapted to local conditions
- Environmental impacts of mussel cultivation are close to zero
- Mussels provide important ecosystem services by increasing water transparency and decreasing nutrient content in the water
- Provided environmental services can be monetized 0,1 €/kg mussel (from 2 €/ kg N) and be partly paid by compensation schemes
- Mussel farming does NOT collide with or substitute any attempts to reduce nutrient influx from land
- Mussel farming is driving blue growth by providing private business opportunities as:
  - Mussels are suitable for feed and human consumption
  - Positive impacts on tourism, contribution to circular economy and job creation

Baltic Blue Growth partners

Mussel producers, public authorities, policy makers, research institutions and interest groupings from six Baltic Sea Region countries:

+ 20 associated organisations

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www.balticbluegrowth.eu
#BalticBlueGrowth

Interreg Baltic Sea Region

Baltic Blue Growth

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

EU STRATEGY FOR THE BALTIC SEA REGION FLAGSHIP

SUBMARINER NETWORK

Appendix 3

NUI Galway
OÉ Gaillimh

Whitaker Institute

VALUING IRELAND'S BLUE ECOSYSTEM SERVICES

semru
Socio-Economic Marine Research Unit

Authors:

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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).

This report is based upon research supported by the Irish Environment Protection Agency under Grant Award No. 2014-NCMS-1. The technical version of this report; EPA Research Report No 239: Valuing Ireland's Coastal, Marine and Estuarine Ecosystem Services, EPA Publications, Wexford, is available to download at: http://www.epa.ie/pubs/reports/research/water/research239.html. The design of the infographic on page 12 was funded through the Department of Environment, Community and Local Government.

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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'.

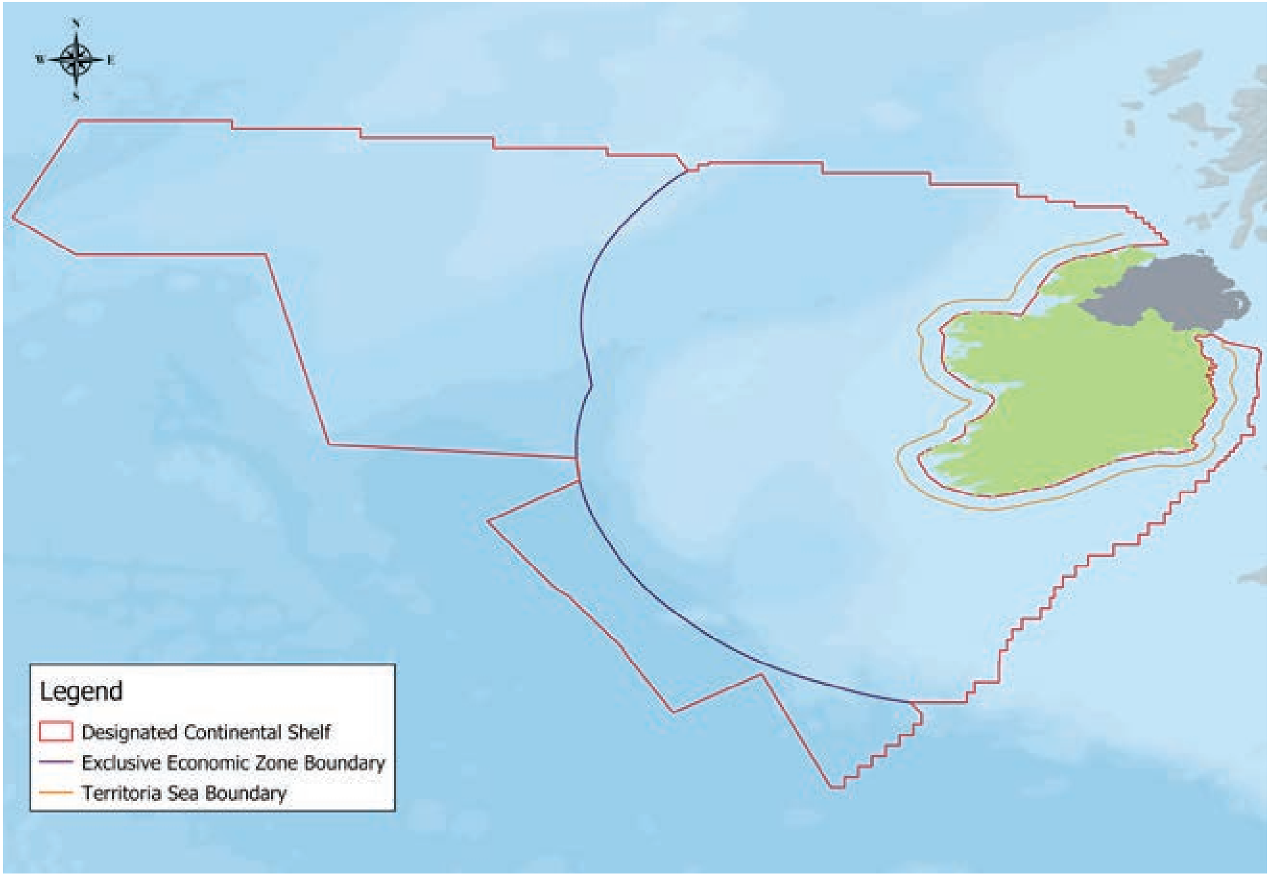
17 Dernie, K.M, Ramsay, K., Jones, R.E, Wyn, G.C., Hill, A.S., and Hamer, J.P., 2006. Implementing the Ecosystem Approach in Wales: Current status of the maritime environment and recommendations for management. CCW Policy Research Report No. 06/9 [Available online: http://ecosystemsknowledge.net/sites/default/files/wp-content/uploads/2012/05/CCW-Policy-Research-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

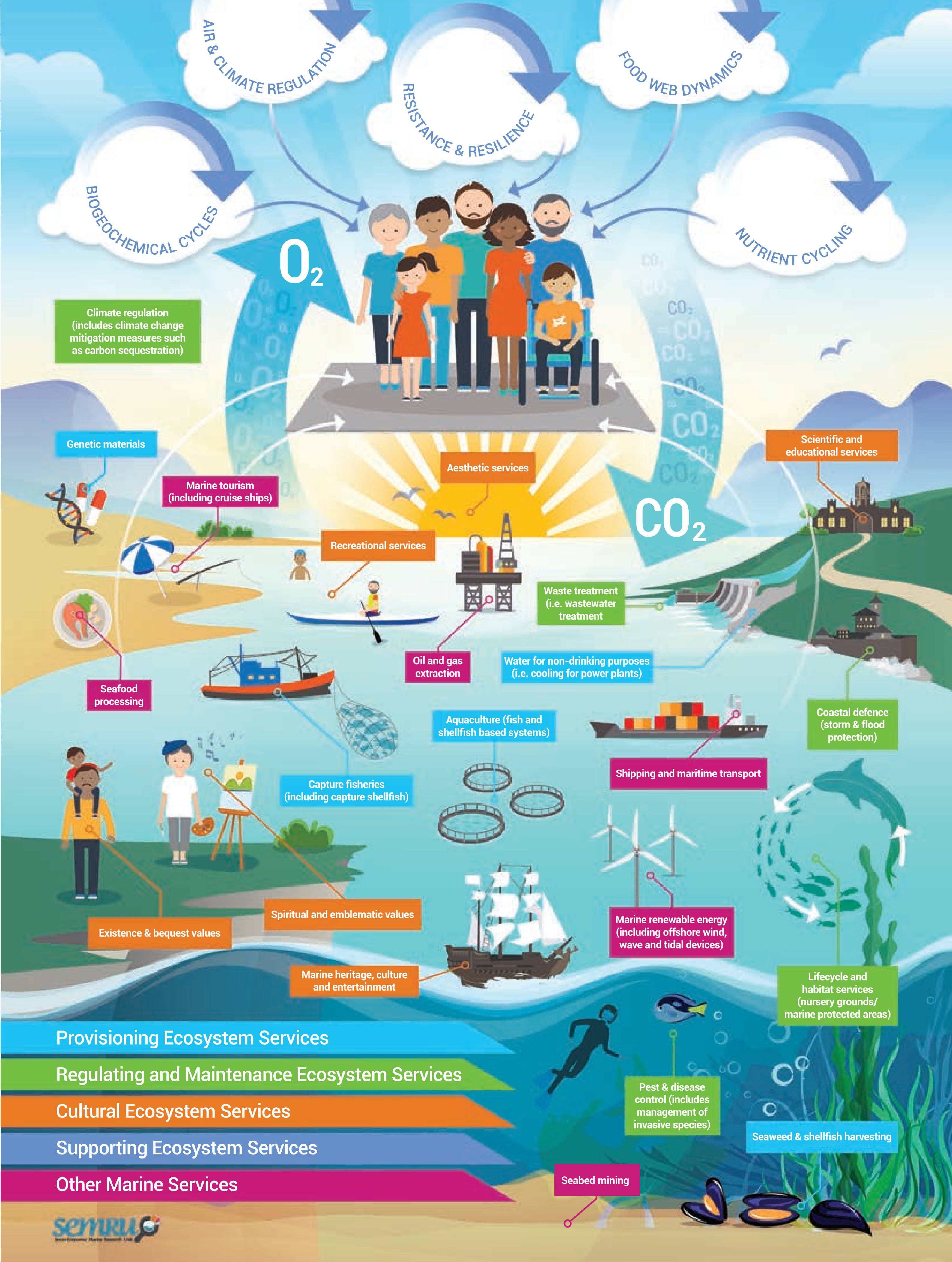
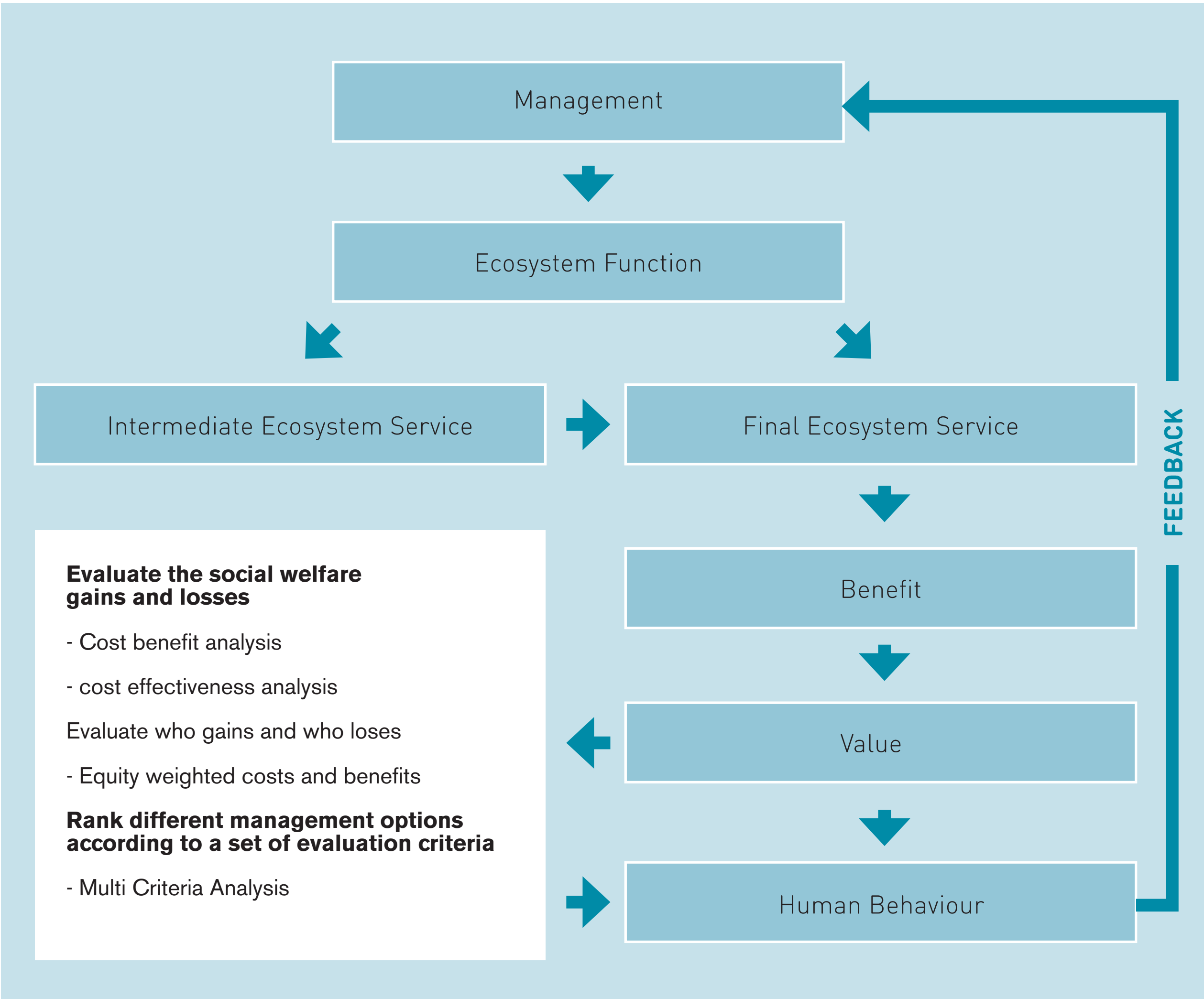


Figure 3. Ecosystem service conceptual framework



(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.

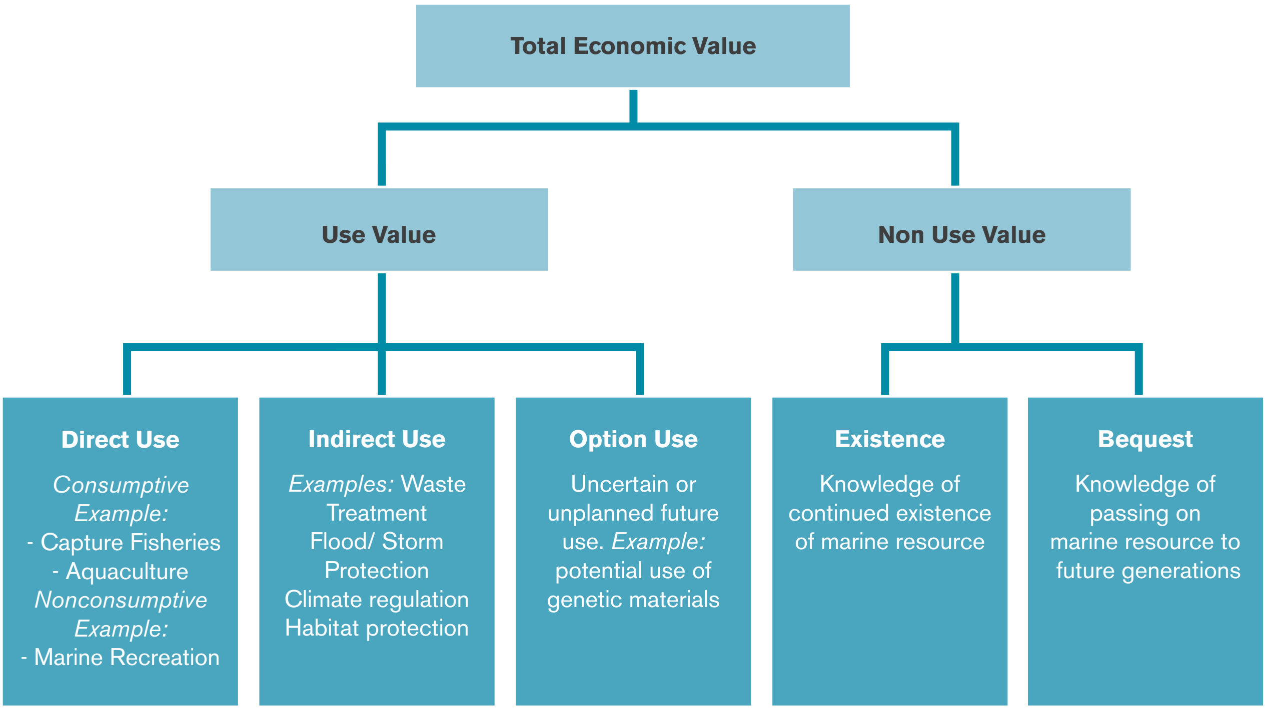
33 Haines-Young, R.H. and Potschin, M., 2010. Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for Integrated Environmental and Economic Accounting. European Environment Agency, Copenhagen.

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]


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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).

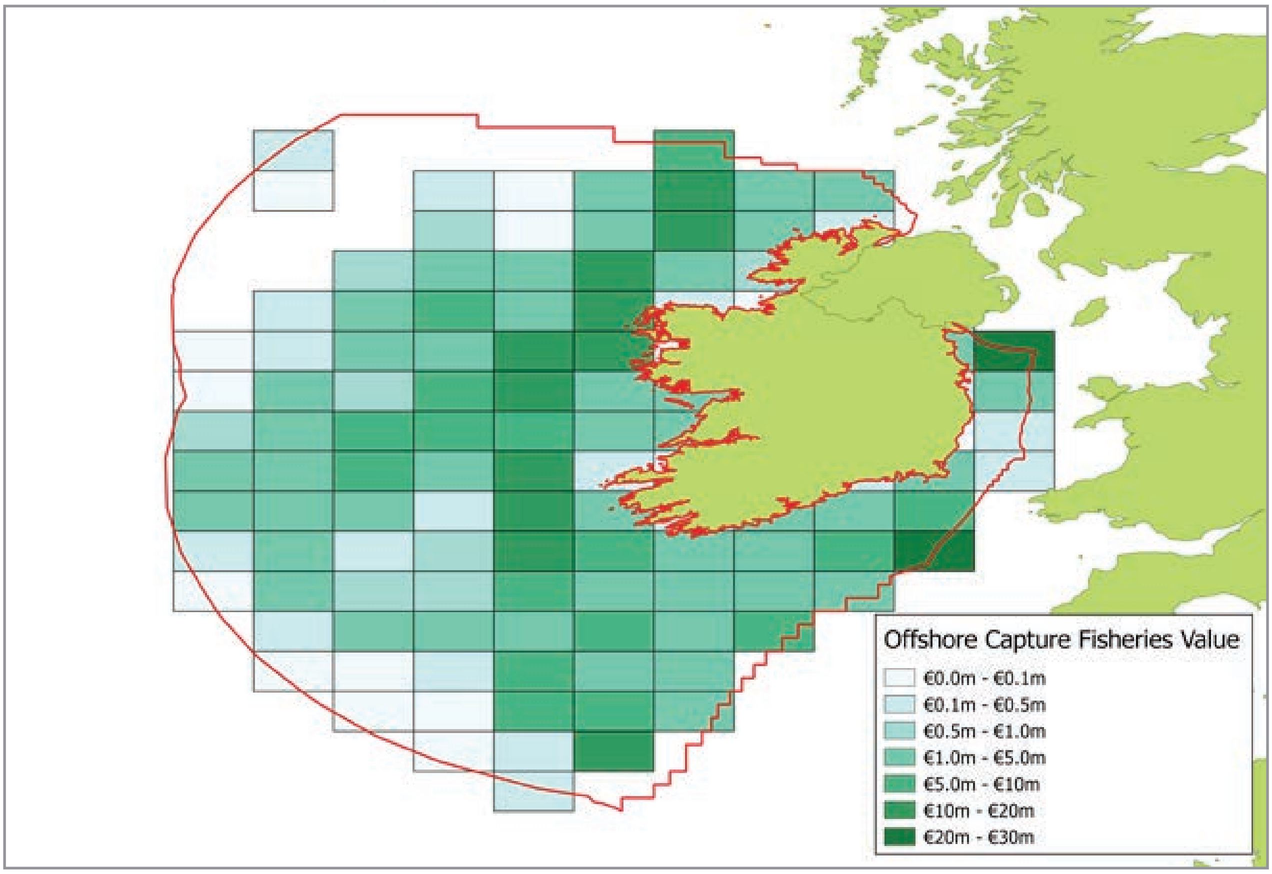


Figure 5 shows the spatial distribution of the value of catch by the offshore fleet. As shown in Table 6 there is significant heterogeneity in the value each species contributes. Looking at ICES rectangle value maps of some of the key species by value (Figure 6) patterns can be distinguished for certain 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).

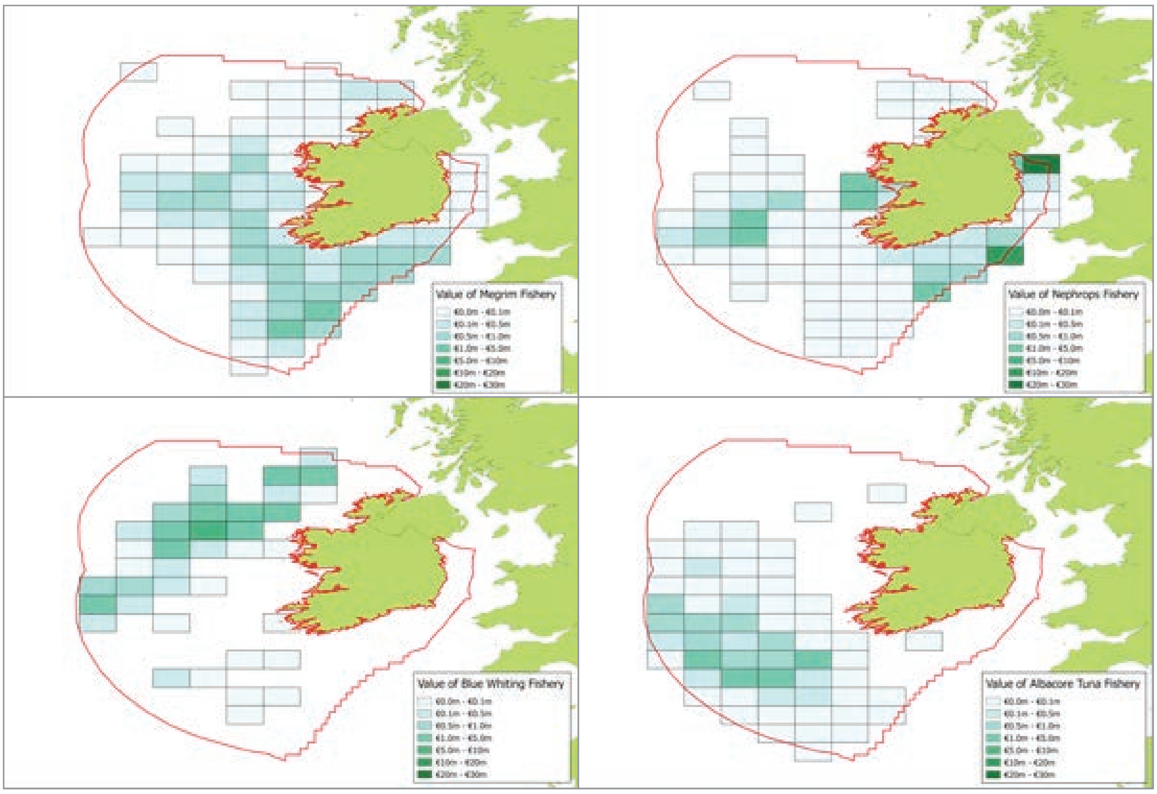


Table 7. Off-shore landings and value by Member State fishing in Irish EEZ, 2014

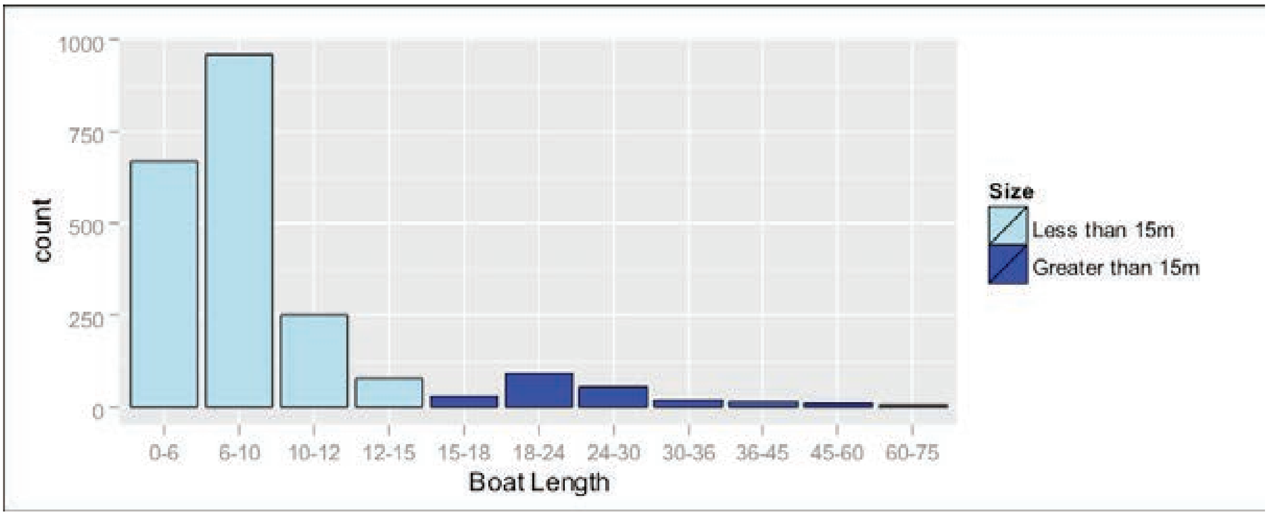
	Estimated Landings (tones)	Estimate Value of Landings	% of total value	% of total landings
Ireland	156,735	€155,879,060	33	33.4
France	41,704	€86,720,080	18.4	8.9
Spain	23,239	€55,057,710	11.7	4.9
Scotland	58,543	€44,017,690	9.3	12.5
England	16,523	€24,183,039	5.1	3.5
Netherlands	34,453	€20,774,560	4.4	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.

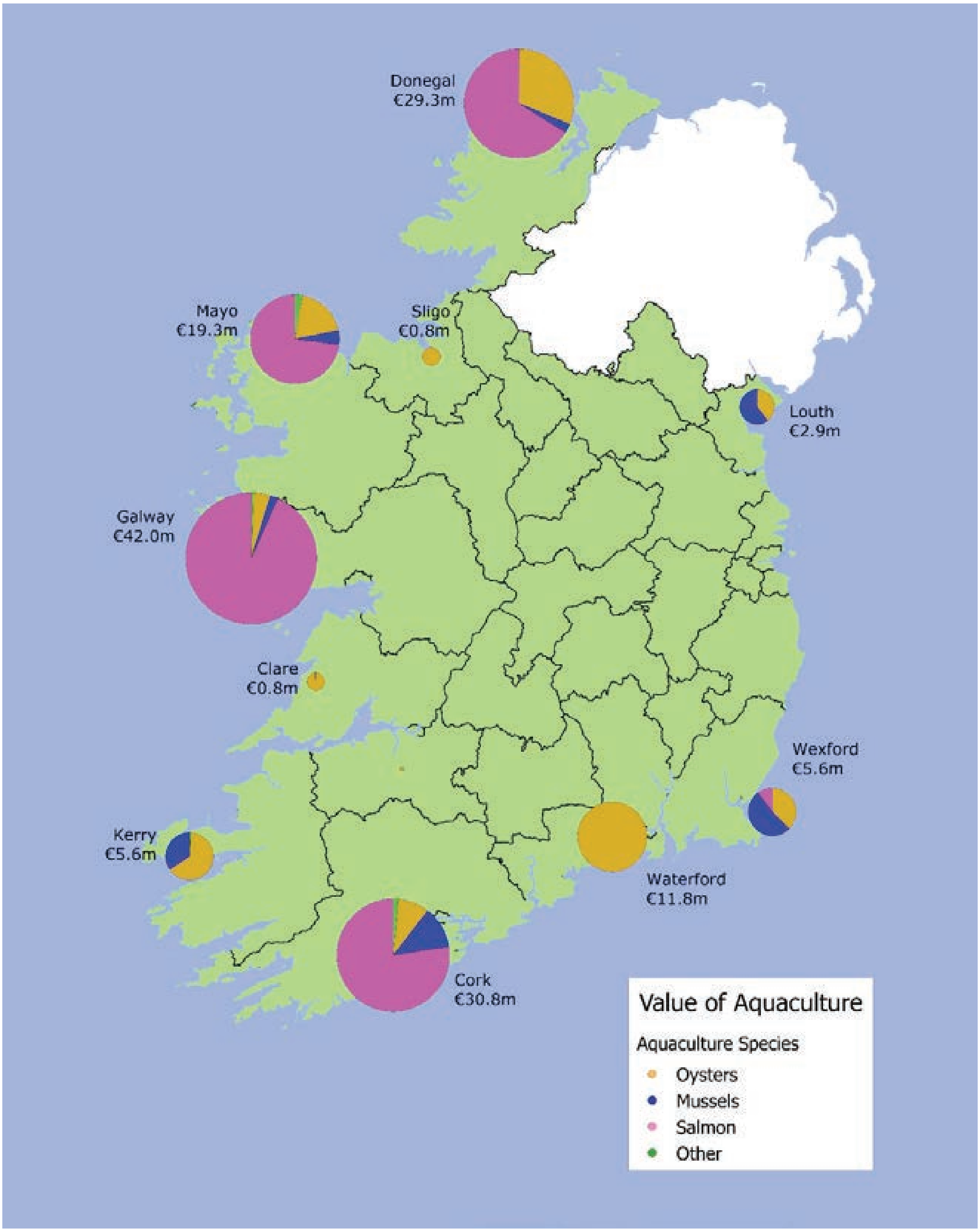
Table 10. Aquaculture by type and county

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

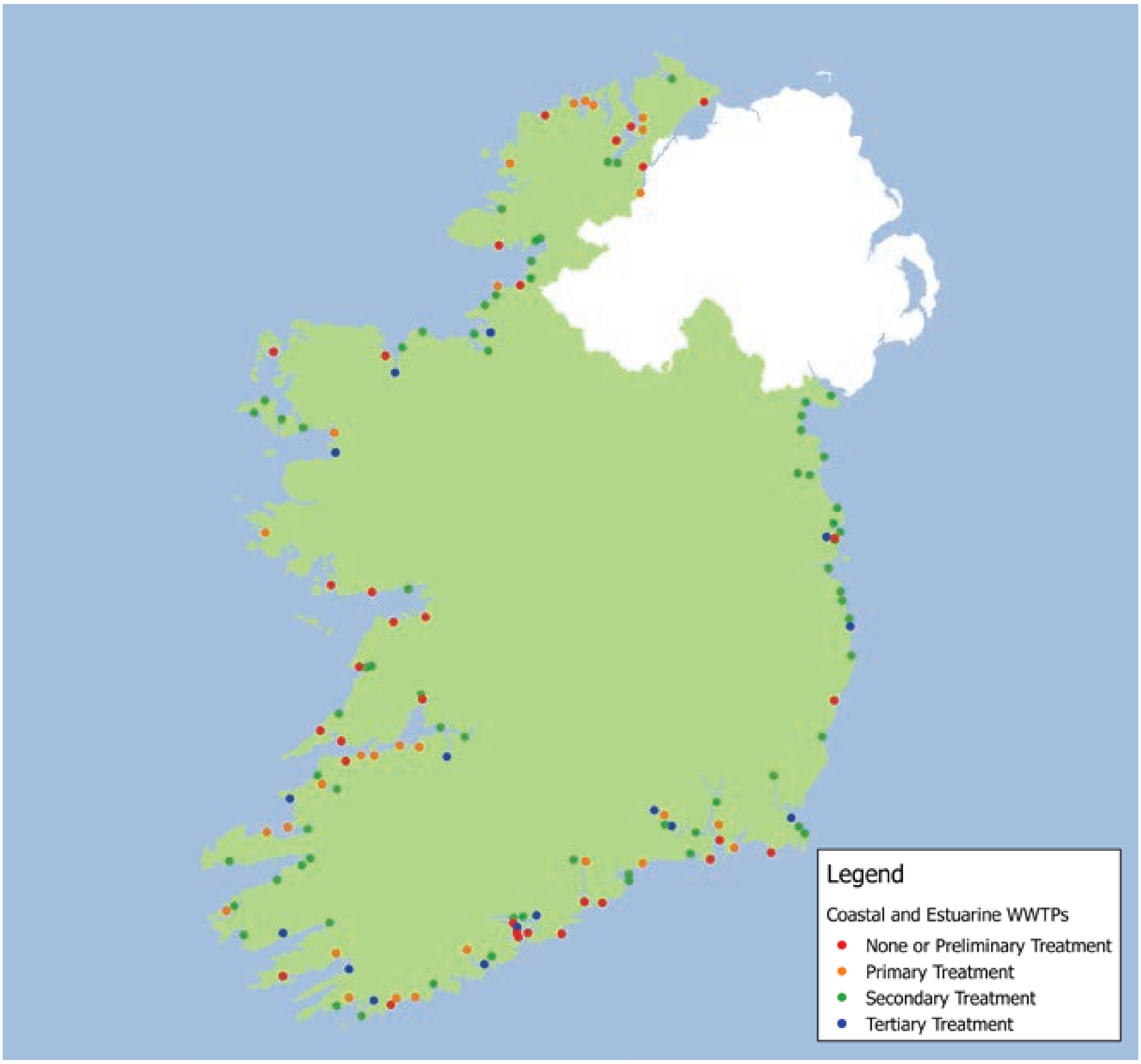
The use of natural ecosystems as a sink for waste products has been common practice for most of history. The oceans with their vastness have often been seen as having unlimited absorption capacity in terms of waste assimilation although it is now known not to be the case. However, storage is not always 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/]

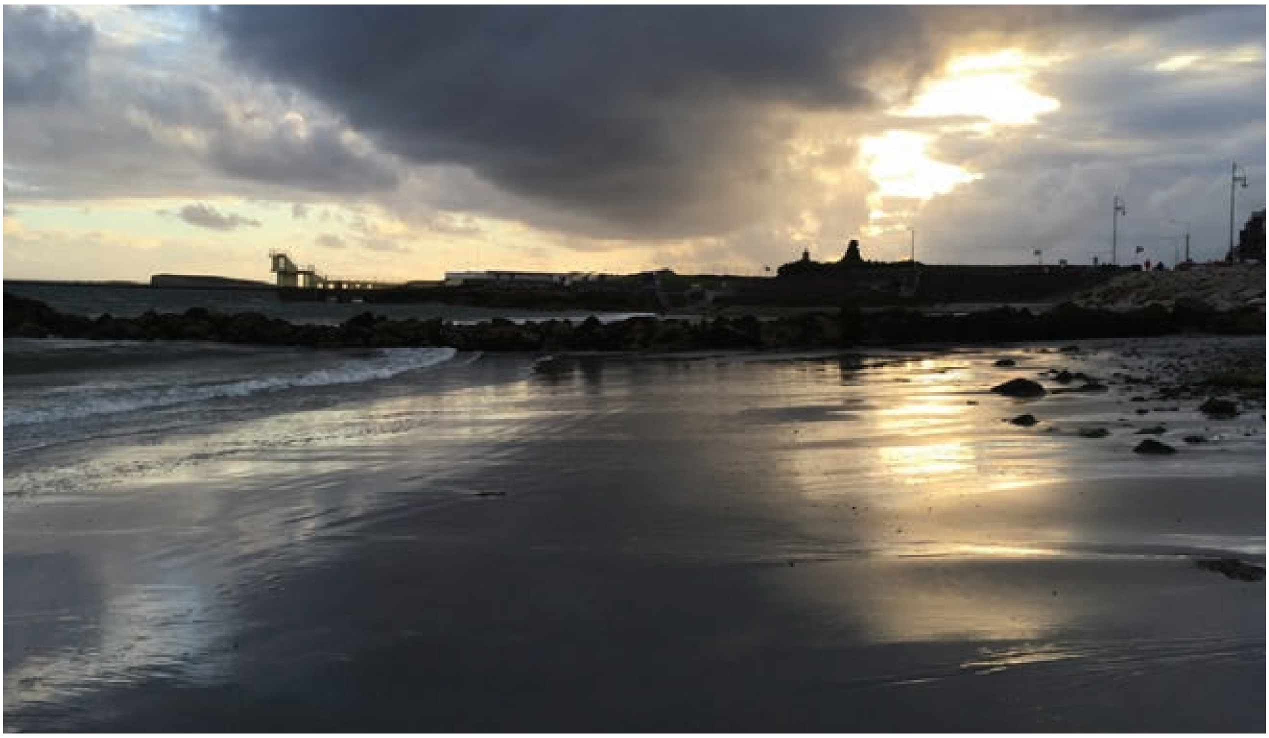
102 Nolan, G., Gillooly, M. and Whelan, K., 2010. Irish Ocean Climate and Ecosystem Status Report 2009. Marine Institute, Oranmore, Galway

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.

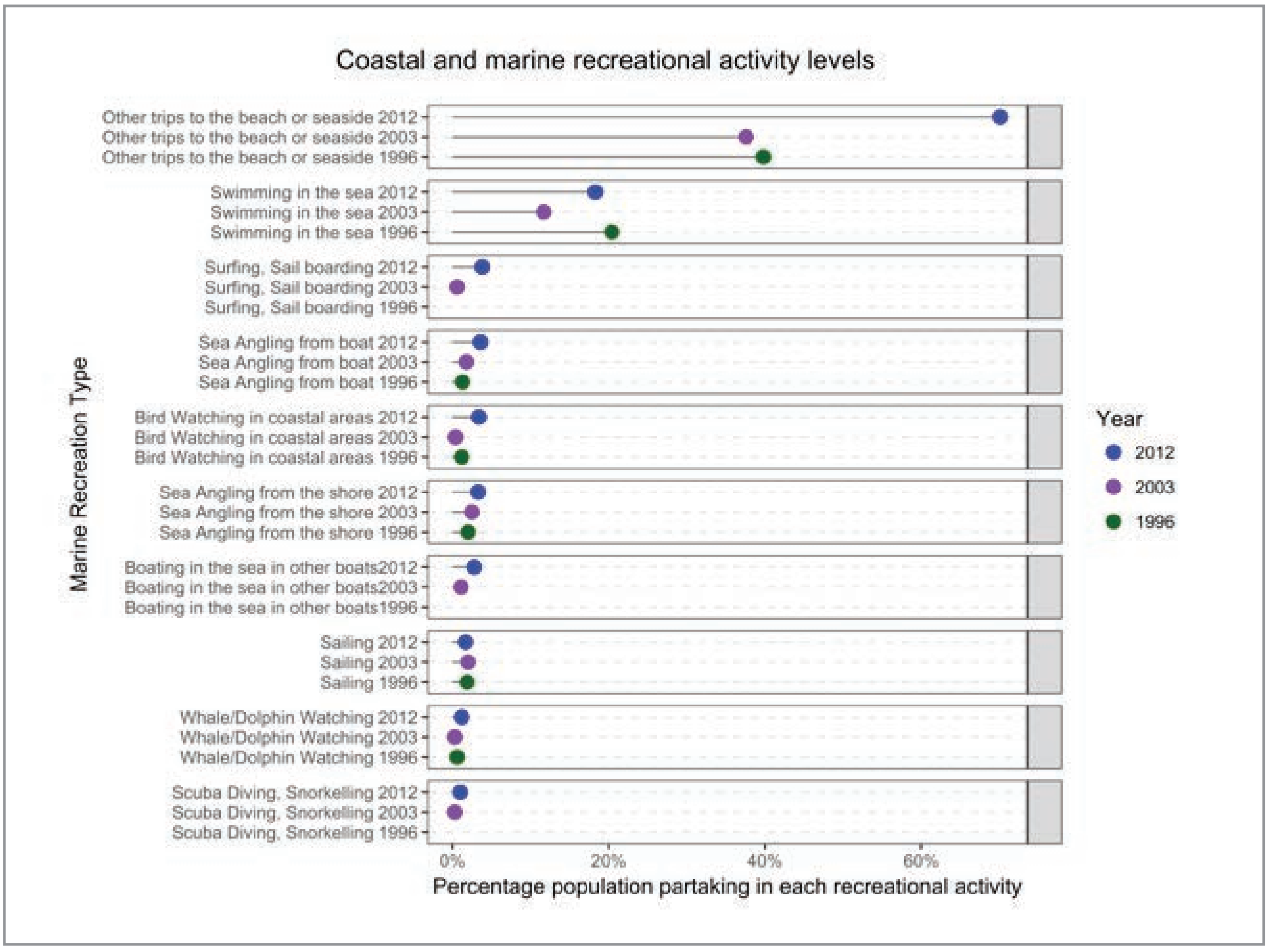
The survey found that during the previous 12 months, 73% of respondents visited the coastline at least once and 38% visited the coastline more than ten times. As shown in Table 20, for those who had visited the coastline at least once, beaches were the most visited type of coastal site.

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.

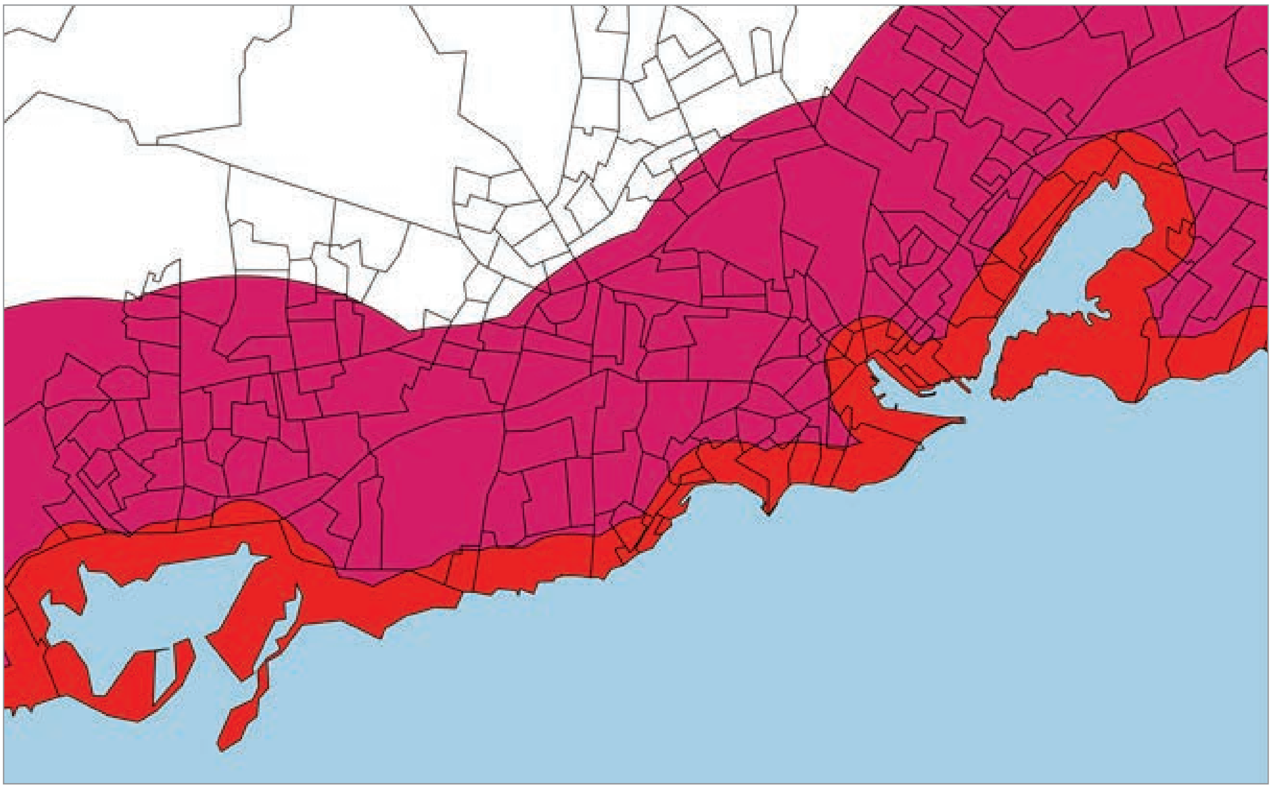


Figure 11. Coastal Buffers

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].

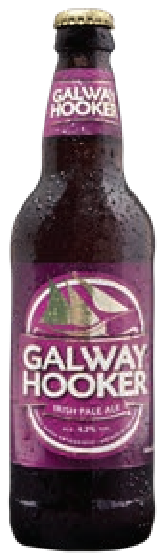
Table 23. Increased value of houses at or near the coast (proxy for aesthetic ecosystem service)

	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.

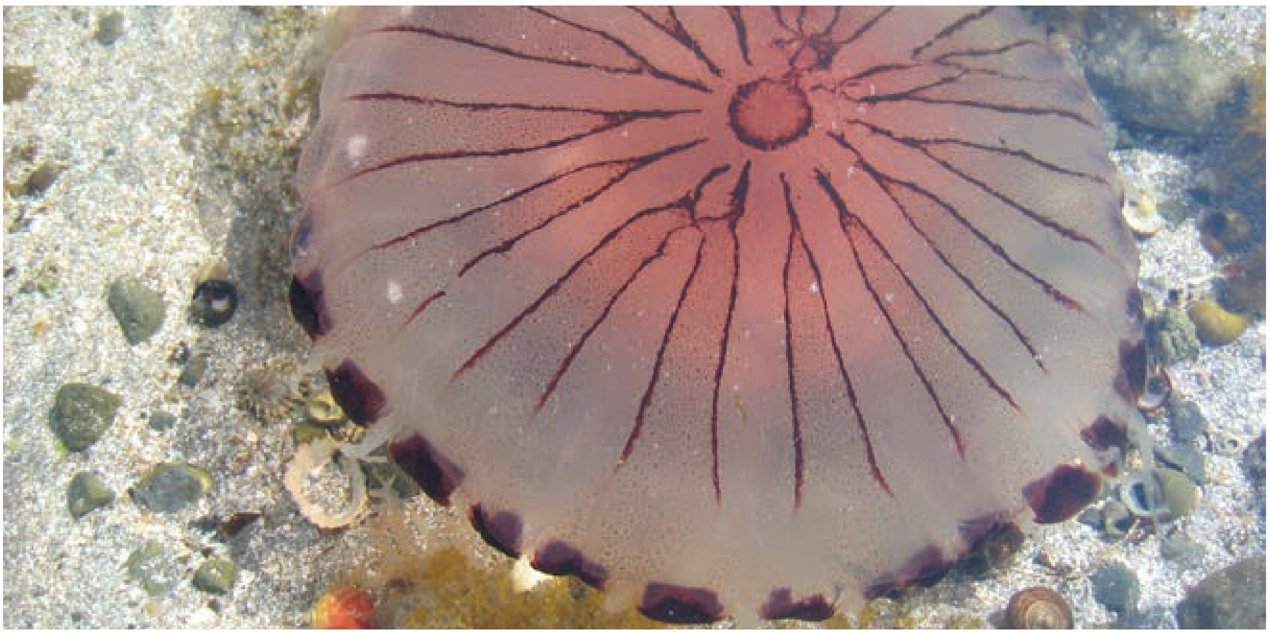
123 Vega, A., and Hynes, S., 2017. Ireland's Ocean Economy, SEMRU, NUI Galway. [Available online: http://www.nuigalway.ie/semru/documents/semru__irelands_ocean_economy_2017_online.pdf]

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]
- 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. & Subak S., 1999. National Inventories of Terrestrial Carbon Sources and Sinks: The UK Experience. Climate Change, 42(3) 505–530.
- Jones, M.L.M., Sowerby, A., Williams, D.L. & 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.
- Chen, C. T. A., & 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
- 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]

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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

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Appendix 4

Leonard, Brona

From: Murphy, CiaraM (ALab)
Sent: Thursday 5 May 2022 15:48
To: 'ceo@bim.ie'
Cc: OToole, Ciar (ALab); Antoinette Conroy (Alab); Francis Dowling (Alab)
Subject: Wexford Harbour
Attachments: Wexford AP 34-48 S47 to BIM Nov 2021.pdf

Hi Lorraine,

Following our phone conversation please see correspondence attached.

Regards

Ciara Murphy

Aquaculture Licences Appeals Board (ALAB)
An Bord Achomharc Um Cheadúnais Dobharshaothraith
Aquaculture Licences Appeals Board
Cúirt Choill Mhinsí, Bóthar Bhaile Átha Cliath, Port Laoise, Contae Laoise, R32 DTW5
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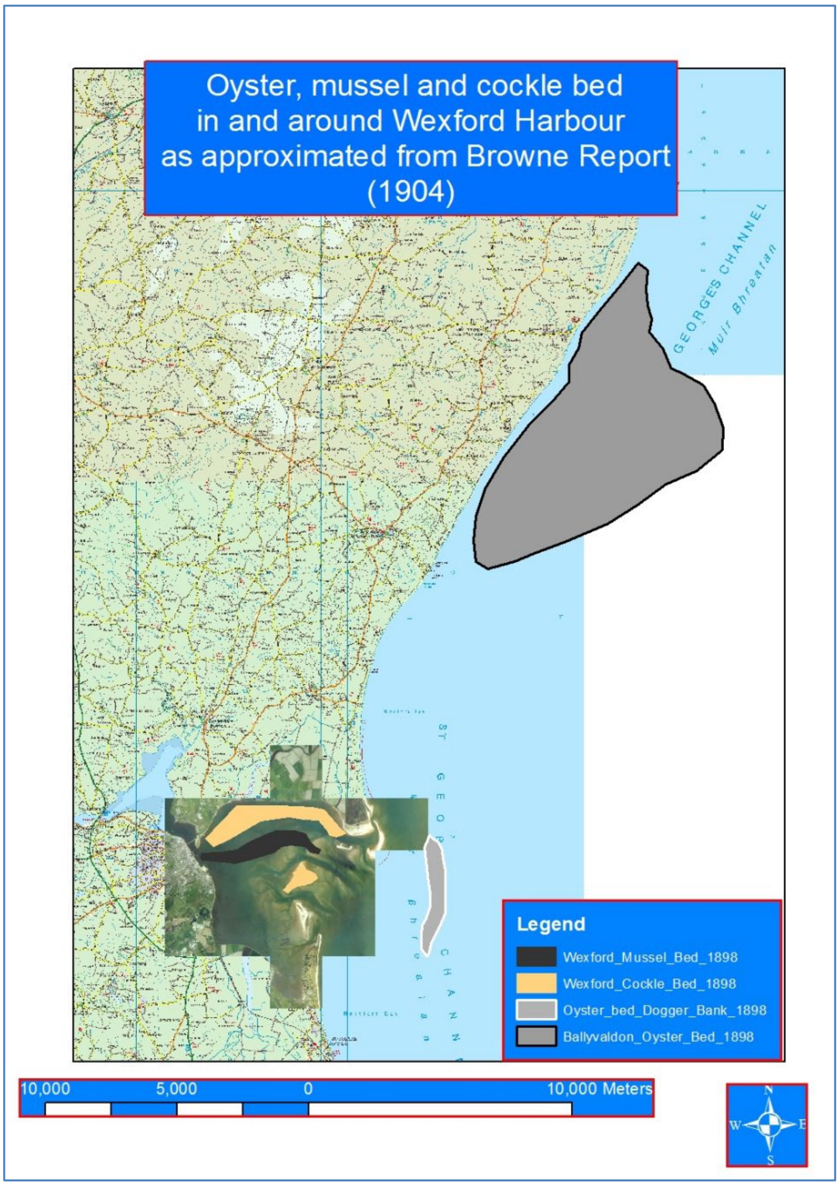
History

It is worth dwelling on the shellfish and mussel industry history somewhat for Wexford Harbour as it was important from a national and European perspective. The birthplace for the bottom mussel industry today in Ireland was in Wexford and the saviour of the European oyster industry in the mid-nineteenth century was from the coastal waters off County Wexford. The pelagic fishing fleet and the schooner fleet also have a rich history but that would be beyond the scope of the Aquaculture Profile.

Shellfish

Shellfish, Wexford Harbour and the Irish Sea off the Wexford coastline have a long and rich history together spanning several centuries. Initially in the 18th and 19th century native oyster beds were the foundation of the shellfish industry in the southeast and this gave way in the late 19th century to mussels and the establishment of the mussel industry particularly in the latter part of the 20th century to the present day.



Map 1: Location of shellfish beds in Wexford Harbour and vicinity as approximated from the Browne Report (1904).

Natural Oyster Beds off Wexford Harbour

There were several natural (native) oyster beds situated at various parts of St Georges Channel, the principal of which were in Brittas Bay (North of Mizen Head), Arklow Bay (North of Arklow Head), Ballyvaldon Oyster Fishery (off County Wexford between Cahore Point and Blackwater Head) and the fourth at the entrance to Wexford Harbour to the east of Raven spit and Dogger Bank and extending between north and south bays. Although some reports say that dredging for oysters was in a continuous line from Arklow to Carnsore Point.

The Ballyvaldon and the Wexford oyster bed are shown on **Map 1** along with the location of cockle and mussel beds within Wexford Harbour as documented in the Browne Report published in 1904 but researched in 1898.

Ballyvaldon Oyster bed.

The Ballyvaldon bed was the largest (8 miles in length and about 2-3miles in breadth) and was probably the largest oyster bed in Europe. It was situated in five to nine fathoms of water and about half a mile distant from the shore. The quantity of starfish on the bed was enormous. At its height the bed had 100 boats dredging on it and apart from sales to UK and Ireland oysters were sent to France for breeding purposes. However by the time of the Browne report in 1904 the total take of oysters was under 5000 from only 3-4 boats fishing occasionally and oysters had become large and coarse and the demand was poor. There were signs that the population of oysters was in a crash scenario as there was no sign of small oysters.

Wexford Harbour Oyster bed

This oyster bed is situated about two miles to the east of the entrance to Wexford Harbour, between the north and south Dogger Buoys, and is about three miles in length by half a mile in width in from three and a half to seven fathoms of water. The bottom formation is similar to that of the Ballyvaldon Bed. Four boats were engaged in dredging for oysters on this bed during the past season (1903). The quantity of oysters taken was about 30,000. Twenty men were employed on the boats. The oysters were purchased by Mr Armstrong, Main-Street, Wexford, and are disposed of locally and in Dublin and Waterford, some being also sent by steamer to Bristol. The oysters as a rule are large-sized and plump well-flavoured fish. The fall of spat is said to be considerable.

In 1859 on September the 01st first day of the oyster season. Oysters fished off the Long Bank just east of Wexford Harbour. Good fishing achieved due to the bringing into law of not using a dredge from May 01 to 1st September off the Wexford Coast. 15000 to 30000 oysters caught that day which would equate to up to 2.55 tonnes of oysters which at today's price would be 12,500 euros.
Some 30 to 60 boats belonging to Wexford, Arklow, Cahore and Rosslare Strand generally fished the grounds. The market for the oysters was in the town, further inland and the Dublin and Cross Channel markets of Liverpool and Bristol.

Wexford Mussel bed (at the end of the 19th century).

(Browne Report) Mussels are dredged from the bed of the river Slaney in Wexford Harbour from a point opposite the Dock Yard at Wexford to near the Raven Point at the entrance to the Harbour. About 20 persons were engaged in dredging operations from October till the end of April. The quantity taken during the season would amount to about 30 tons. They are shipped directly to Bristol and Liverpool (consigned to Beavis, fish dealer, Bristol and Balfour Liverpool). Mr Des Lett, Lett & Company

Ltd. handed me a photocopy of a receipt for mussels sold by John Lett (Fish and Shellfish Dealer, Batt Street, Wexford) to E Beavis for the sum of Two pounds and 5 shillings on Feb 7th 1897, **Figure 1**. Indeed he mentioned that they have a receipt dating back to 1890.

The author could not find any records regarding mussel fishing using cots from 1900 to 1967, however it can be assumed that they were used prior to and after setting up of the mussel


JOHN LETT,
Fish and Shell Fish Dealer,
BATT STREET, WEXFORD.

Received from E Beavis
the sum of Two pounds 5 shill
for Mussels
Feb 7th 1897

Figure 1: Copy of receipt from 1897 showing sale of mussels from Mr John Lett to E. Beavis in England (courtesy of Mr Desmond Lett, Lett and Co.)

processing plant by Lett and Company Ltd. in 1967. There were apparently 15 berths for cots in the harbour around 1964. Each cot was worked by two men who either towed a 2 foot wide dredge or an alternative technique was to anchor and winch in a dredge from the front of the cot towards the anchor point. Presumably in shallow areas sprongs (rakes) were used also to lift mussels into the cots.

Wexford Cockle beds (at the end of the 19th century).

Cockles are collected on the strand at low water from the eastern side of the breakwater opposite Wexford to Raven Point and on the strand inside Rosslare point at the entrance to the Harbour. About 50 persons are engaged collecting them all year. Over 1000 gallons are collected annually and disposed of in Wexford. Periwinkles are collected around the coast outside Wexford Harbour. About 9 tons were shipped annually to Bristol and Liverpool.

Holt in his Report to the Department of Agriculture and Technical Instructions for Ireland: **The Public Oyster Beds on the Coasts of Counties Wicklow and Wexford 1901** attempts to chart the history of the oyster beds. He states that: *I have not been able to learn at what period the fishery commenced to assume importance, and have no knowledge of the number and class of boats by which it was prosecuted in the first half of the nineteenth century. In or about the year 1806 there were complaints of exhaustion of the stock, which may probably have referred only to the beds in the immediate neighbourhood of the ports. It was evident that there was a considerable industry, even in the late 1830's of which Arklow was the headquarters. Wexford men seem also to have occupied in dredging to a considerable extent.*

The Arklow men relayed a considerable proportion of their catch to Beaumaris (Wales) where the oysters were relayed to fatten for the English market. Others were probably relayed in Sutton and Clontarf for the Dublin market. In the 1840' English buyers arrived in Arklow to carry off stock to replenish the Kent and Essex beds. At that time the Dutch and French beds were in bad condition. The habit of relaying at Beaumaris was abandoned when English buyers appeared at Arklow in 1843.

In 1856 marked the inception of oyster culture which resulted in the complete rehabilitation of the French and Dutch Oyster Trades.

In 1862 there were reports of a general scarcity of large deep-water oysters and it seems that French buyers in Arklow working on behalf of their government who were spending considerable money on restocking their public beds and providing broodstock for oyster culture experiments from which resulted the seed industries of Arcachon and Auray.

In 1863 the first actual figures from the beds appeared although at the time the Jersey boats were not landing all of their catch. In fact the Jersey boats were said to have fished day and night weekdays and Sunday, their boats were larger and more efficiently equipped for dredging and were able to fish grounds not accessible by the Irish industry. Needless to say they were not popular with the local industry.

In the 1863 Deep Sea and Coast Fishery Commissioners (Ireland) Report, the fishery by the Arklow boats commenced on the 14th January and ended on the 24th of May. The total catch was 34038 barrels, of which 7988 were disposed of on the Irish coast-chiefly Dublin station; 2,860 on the Welsh coast; 2,600 to France; and the remainder, 20,590, to London and Kent. The total sum realised was £10,829 16s; about 6s. 4d. per barrel, the ordinary herring barrel, holding 6 to 7 hundred, and weighing 1 ¾ cwt. full.

It was probable that the take of 1863 was considerably exceeded in years before and the records show that the take declined in every succeeding season.

So it was in 1901 in response to a request to revive the great oyster beds off the east coast that Holt determined in his survey work that the beds were not only incalculably smaller than in their peak but that the rejuvenated and thriving French and Dutch oyster fisheries (rejuvenated from oysters taken from Ireland!) were now supplying not only their own countries but also England. So it was not feasible to regenerate the oyster industry.

Apart from the shellfish industry Wexford Harbour was an extremely busy Harbour for schooners and trawlers.

Deep Sea and Coast Fishery Commissioners (Ireland) report, 1863 appendix to the report on the state of the registry of fishing vessels on the coast of Ireland to 1st January 1864 states that for the Wexford district from Sluice River to Bannow there are 34 first class vessels employing 161 men and 1 boy and 212 2nd class vessels employing 946 men and 31 boys totalling 243 vessels, 1107 men and 32 boys. By 1864 there was an increase of 5 vessels, 24 men and 8 boys with the observations that Slight improvements in boats in the port of Wexford. Produce must less than the preceding year. Supply and quality of oysters good. No curing establishments. Fishermen orderly and peaceable. Registry perfect. Trawling practised without contention.

History of the Mussels and the Dredger Fleet in Wexford Harbour.

As mentioned previously the mussel industry was well established in the Harbour in the 19th century and continued through the 20th century presumably using cots.

In 1845 Act Passed that allowed the Commission of Fisheries could grant licences for oysters.
There may have been a pre-1870 oyster licence.
In 1884 mussels were added to the act
The extended Lett family continued to fish the harbour for mussels through the 20th century and traded in fresh mussels.
1959 Fisheries Act
1964 Lett & Company Ltd started experimenting with cooked mussel meats and jarring them.
1965 Lett and Company Ltd set about securing a factory. At this point the Slaney Mineral plant and a shed alongside it were being used to process some mussels.
In 1967 Lett and Company Ltd mussel processing plant opened in Batt St Wexford Town. At this time there were berths for 15 cots. Mussels were cooked and meats jarred.
1967-8 6 mussel boats commissioned with inboard engines. 24.5 feet long: St Quentin, Mallard, The Claire, Mussolini, St. Catherine and one other.
1967, 1969 and 1970 BIM, Dept. of Marine and Lett and Company Ltd. explored the best relay areas.
1968-69 Lett and Company Ltd. started to blast freeze some mussels on trolleys and then packed into bags.
1968-1974 Scallans working grounds with cots and small wooden hull boats.
1970's Processing of mussels also took place at Kilmore Quay for a few years. But the vast majority of processing occurred in the Lett and Company Ltd. factory.
1970 The Countess built in Cork and brought in by Ryans.
1972 mussels from East Coast relayed into Harbour in bags.
1973 'Lena Jozina' the first dredger in Ireland was brought in by Letts.
1974 first transplant of seed from East Coast to Wexford Harbour by 'Lena Jozina' (23 loads (40T each) 1200-1300T in total.
1975 Wexford Mussel Fishermen's Association was formed. Noel Scallan was Chairman and Sean Ryan Secretary. Renamed to the Wexford Mussel Growers Association in 1990's but have reverted to the old name since.
1977 'Sea Maid' Ryans
1977 'Naomh Caith' Noel Scallan sold on in 1978 to Waterford
1978 Lett and Company Ltd. brought in the 'Zeemiew'
1978 Lett and Company Ltd. started to experiment with half-shell mussels.
1978 'Vertrouwen 1' brought in by Lett and Co.
1979 'Vier Gebroeders' brought in by Ryans
1979 'Geertruide brought' in by Lett and Co.
1979- Test on growing of pacific and native oysters
1979 Sea Maid to Billy Gaynor
1979 'Lena Jozina' sold to Noel Scallan sold to Waterford in 1993
1980 Fisheries Act.
1982 'Vertrouwen II' brought in by Lett and Company Ltd.
1984 'The Rapid'- Billy Gaynor
1985-1990 The height of the processing factory run by Lett and Company Ltd. 370 people employed mainly full-time in the factory
1986 'Enterprise I' brought in by Lett and Co.
1987 'Ostrea' brought in
1989 'Ostrea' sold to Billy Gaynor

1989 ‘Cornelia’ brought in by Ryans
1994 ‘Vertrouwen II’ sold to Noel and Albert Scallan.
1992 ‘Vier Gebroeders’ sold to Noel and Paddy Cullen
1992-3 ‘Cornelia’ sold to John Foley (left the harbour)
1993 ‘Jana Maria’ brought in by Ryans
1993 ‘Lena Jozina’ sold to Waterford mussel co-op
1996 ‘Olive Rachel’ Flor Sweeney brought in from Holland
1996 ‘Crescent Warrior’ brought in by Crescent Seafoods Ltd.
1997 ‘Janny’ bought by Billy Gaynor off John Lett.
1998 ‘Laura Anne’ brought into Wexford by Alex Mc Carthy for use by John Lett
1998 ‘Noordster’ brought in by Flor Sweeney from Holland
2000 ‘Ebenezer’ brought in by Crescent Seafoods Ltd.
2005 ‘Branding’ brought in by Crescent Seafoods Ltd.
2005 ‘Edenavle’ bought by the Ryans. New boat with stern dredges
2005 ‘Hibernia’ bought by Riverbank mussels.
2005 ‘Laura Anne’ purchased by Scallans and still in operation
2007 ‘Cecilia’ brought in by Loch Garman Harbour Mussels Ltd.
2011-2012 ‘Vertrouwen II’ sold on by Scallans.

Current Functioning Mussel Dredging Fleet

Due to Certificate of Compliance Regulations either new boats were purchased with assisted grants from the State or substantial investments were made to upgrade existing boats to the required standards. The six functioning boats in the Harbour are the Edenvale, Hibernia, Enterprise, Laura-Anne, Cecelia and, Branding. Total dredge width per boat ranges from 7m to 14m with an average of 9.03m. The drafts range from 0.75m unladen to 2m laden with an average unladen draft of 1.04m and an average laden draft of 1.58m. All but one dredger has 4 dredges operating from the sides of the boats. There has been movement out of the harbour in recent times of some of the older boats. During seed fishing periods sometimes dredgers from outside Wexford are paid to help fish and relay seed, but harvesting is only by the boats listed above. The boats tie up at the town side quay and unload over at the Ferrybank quay which has undergone significant redevelopment. On the Ferrybank Quay there are lock ups for equipment and electricity.

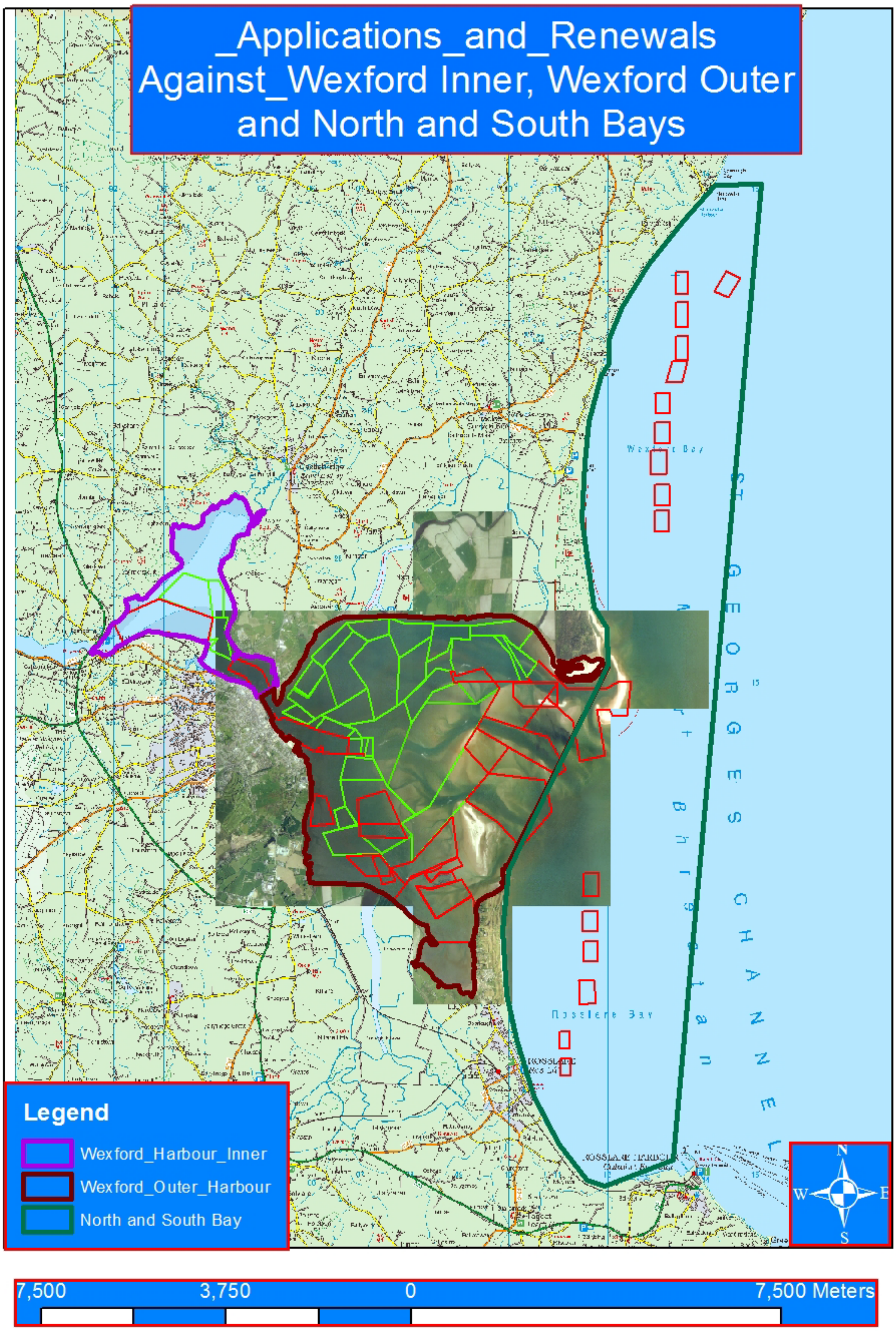
History of Licences.

In 1981 Letts attempted to apply for a licence for mussel farming. It led to a hearing and witnesses were called to give evidence. At this point the fishery was public but as it had never been designated under the 1980 Fisheries Act but was in the 1959 Act. Designation under the 1980 act would have facilitated the licensing of ground to individual producers/companies or at least stood a better chance against being overturned. That attempt faded away and in June 1991 an application for a fish culture licence on parts of Wexford Harbour for farming mussels was made by Sean Ryan. Significant time was spent by the aforementioned dealing with the legal obstacles to licensing and assistance was given by the Irish Farmers Association and private solicitors. Various routes such as forming a Co-op were discussed that might strengthen the application(s). Years passed with still no licences and in 1995 the

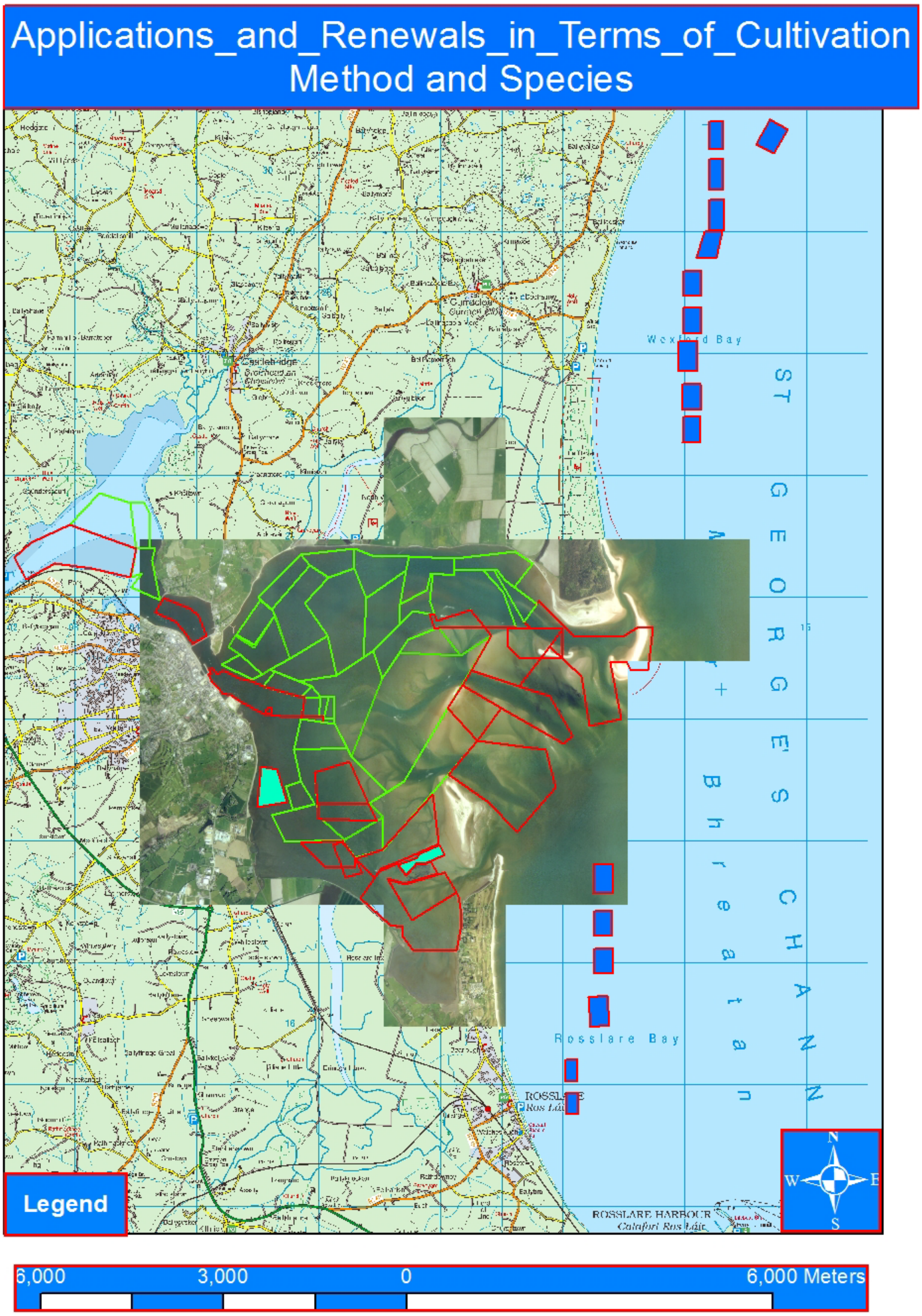
Department of Marine were in the process of redrafting the legislation relating to aquaculture and a test case was coming up from the West of Ireland which would shed light on the actual definitions in legal terms of a public fishery. In August 1995 applications on behalf of all the major mussel producers with the exception of Letts were submitted by the Wexford Mussel Growers Association (WMGA). The concern with lack of licences was that stock in the harbour brought in by the WMGA or bona fide mussel fishermen could be fished by anybody and that this might lead to confrontations where somebody might get hurt. Again due to legal difficulties the 1959 and 1980 Fisheries Acts it was felt by the Department that licences (including foreshore licences) could be overturned. By May 1997 the Fisheries (Amendment) Bill had passed all stages of the Dail which would provide a facility to licence aquaculture developments on a site by site basis and designation would no longer be required. Applications from 9 different companies were on the record as of November 1998 and issues began to appear in the form of overlapping applications, a new outfall pipe for the new town sewerage scheme and a lack of berthing space on the new town quay which was being built. The new legislation arrived in 1998 which finally provided comprehensive measures for the processing of aquaculture licences. However mapping issues had to be addressed and in 1999 a Departmental Engineer mapped out the application sites accurately using GPS technology. When the applications were finally advertised publically there were objections which had to be addressed by the Department and industry. After considerable effort from the producers, BIM and the Department of Marine in addressing these objections licences were issued in 2002 although there were contested overlaps which never got licenced along with some licences applications that had strong objections against them and thus didn't proceed. The licences were issued for a 10 year period.

Current Status of Renewals and Applications within Wexford Harbour and North and South Bays.

Map: 2 shows the status of renewals and applications. There are **30 Renewal Applications covering 1473.03 Ha and 37 Applications covering 1263.86 Ha.** However as in 2002 overlaps in applications have occurred and the area of ground covered by an application only once is 1270.6 Ha. A detailed area analyses is shown in **Table 1.** Renewals are only dealing with bottom mussel culture whereas applications are dealing with bottom mussel culture (dredger, barge boat and cot), intertidal Pacific Oyster Culture and Mussel Seed Settlement on Ropes suspended in the water column **Map 3.**



Map 2: Renewals and Applications within Wexford Harbour Inner and Outer and North and South Bay.



Map 3: Renewals (Green Outline) and Applications (Red Outline) for bottom grown mussels (hollow), rope seed mussel (blue fill) and Intertidal Pacific Oyster farming (turquoise fill).

Table 1: Area Analyses of Renewals and Applications

	Area (Ha)	% of Wexford Harbour	% of Inner Harbour	% of Outer Harbour	% of North South Bay
Area of Wexford Harbour (Ha)	3545.65	100	-	-	-
Area of Wexford Inner Harbour (Ha)	517.23	14.59	100	-	-
Area of Wexford Outer Harbour (Ha)	3028.42	85.41	-	-	-
Area of Renewal Applications (Ha)	1473.03	41.54	-	-	-
Area of Renewal Applications in Inner Harbour (Ha)	100.84	-	19.50	-	-
Area of Renewal Applications in Outer Harbour (Ha)	1372.19	-	-	45.31	-
Area of Renewal Applications in North and South Bay (Ha)	0	-	-	-	0
Area of Applications (Ha)	1387.49	-	-	-	-
Area of Applications (Ha) adjusted for overlaps	1270.6	-	-	-	-
Area of Applications In Wexford Harbour (Inner and Outer)	980.82	27.66	-	-	-
Area of Applications In Wexford Harbour Inner (Ha)	131.22	-	25.37	-	-
Area of Applications In Wexford Harbour Outer (Ha)	849.6	-	-	28.054	-
Area of Applications in North and South Bay (Ha)	289.78	-	-	-	4.99
Area of Renewals Intertidal (Ha)*	228.2	6.44	-	-	0
Area of Applications Intertidal (Ha)*	315.1	8.89	-	-	0
Area of Applications for mussel seed collection (Ha)	196.14	0	0	0	3.38
Area of Applications for Oyster Farming (Ha)	33.6	0.95	0	1.11	0
Area of Applications for Very shallow boat dredging and spronging of Mussels (Ha)	226.52	6.39	0	7.48	0

*More time needs to be spent on this calculation. If anything this is an overestimate

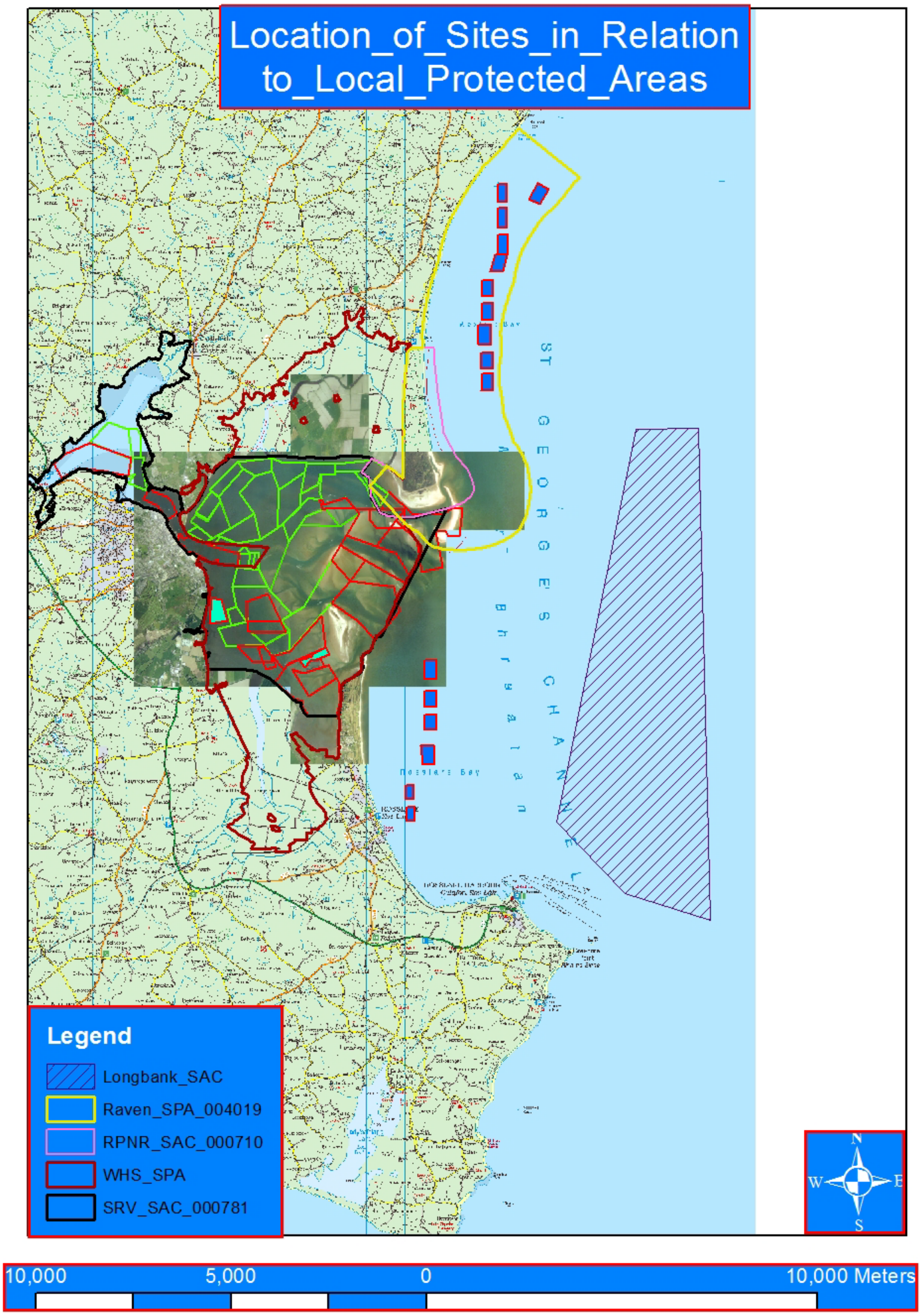
Renewals and Applications in Relation to Protected Areas

The relevant protected areas in Wexford Harbour and adjacent coastal areas are:
The Raven SPA (004019)
Wexford Harbour and Slobs (WHS) SPA (004076)
Slaney River Valley (SRV) SAC (000781)
Raven Point Nature Reserve (RPNR) SAC (000710)
Longbank SAC

The Blackwater Bank SAC has been omitted due to the distance from the applications and renewals. The Longbank SAC has been assessed on a separate appropriate assessment for seed fishing. **Map 4** shows the location of all protected areas in relation to the applications and renewals. The mussel seed collecting applications in the South Bay are not within any protected area. The North Bay ones are within the Raven SPA. The Slaney River Valley SAC and the Wexford Harbour and Slobs SPA overlap. The renewal applications are all within the former but not all within the latter. A detailed analysis of areas of renewals and applications within each protected area is presented in **Table 2.**

Table 2: Area analyses of renewals and applications within protected areas.

	Area (Ha)	Area of Renewals in Protected area (Ha)	% of Protected Area as Renewal	Area of Applications in Protected Area (Ha)	% of Protected area as Application
Raven SPA (004019)	2610.62	7	0.27	298.14	11.42
Wexford Harbour and Slobs SPA (004076)	4751.05	1315.52	27.69	728.62	15.34
Slaney River Valley SAC (000781)	5383.76	1443.77	26.82	975.9	18.13
Raven Point Nature Reserve SAC (000710)	594.52	31.65	5.32	30.18	5.08
Longbank SAC (2161)	3372.38	0	0	0	0



Map 4: Renewals and Applications against Protected Areas

Physical

The River Slaney is the main river flowing into Wexford Harbour. There are two smaller rivers, the Sow and the Assaly, which flow in at the north of the inner Harbour near Castlebridge and at the south of Wexford town respectively. The River Slaney has a catchment area of 1860km2 and includes parts of Counties Wexford Wicklow and Carlow. The River Slaney is tidal from Enniscorthy downstream. The estuary extends over a distance of 26km from Enniscorthy to Wexford town. The estuary widens where the River Sow meets the Slaney just downstream of Ferrycarraig but narrows again between Carcur and Wexford Town. Below Wexford town training walls extend out from the shore confining the main flow. However the training walls are covered by water on certain high tides. The transition from Estuarine waters to Coastal Waters occurs just below Wexford Town and the estuary widens into the broad shallow expanse of Wexford Harbour. See **Map 5.**

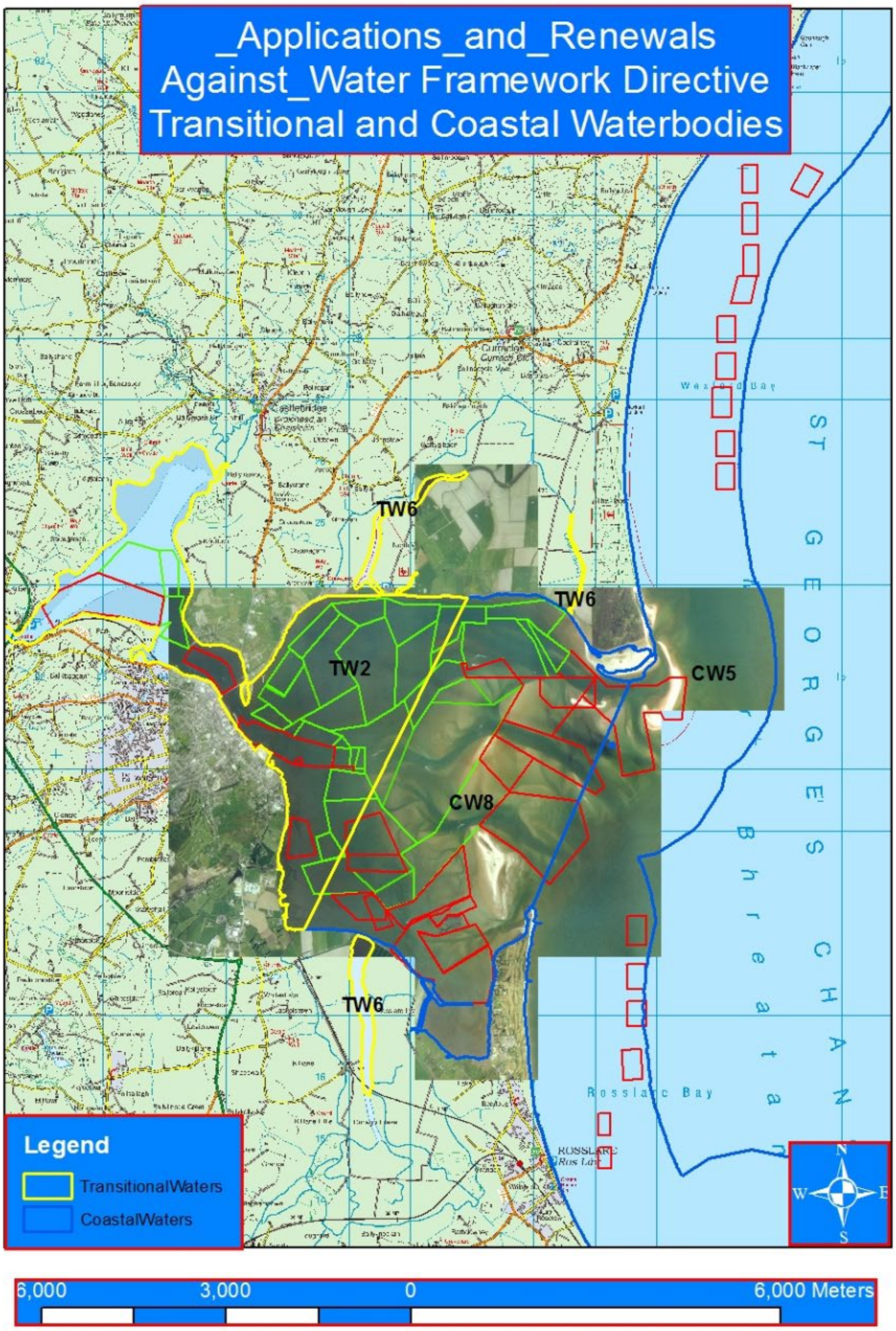
Wexford harbour is approximately 35.46 Km2 from Ferrycarraig bridge to a line drawn between the Raven Point to Rosslare Point. Wexford has about 4% littoral area and is dominated by shallow (<2m), coarser grained sand, gravel and shell sediments. The low % of littoral zone can be accounted for by the reclamation of land from the sea in the mid-19th century which now form the north and south slobs. The slobs are drained into the harbour by pumped drainage channels. Mixing in the harbour is good so stratification only occurs slightly in some of the deeper sections.

Estuary at high water is 3431Ha.
Estuary length 9.48km.
Tidal prism 49 million cubic meters.
Volume 136 million cubic metres.
Ratio of prism to volume 0.36.
Freshwater catchment area 184000Ha.
Annualised catchment rainfall (mm) 528.
Annual freshwater inputs (cubic metres per second 31).

Hydrography.
The average tidal excursion is 4.7km on neap tides and 7.1km on spring tides. Ebb tide duration exceeds that of flood by approximately 45-60mins and is typical of the prevailing situation throughout the harbour. The rise and fall of the tide in Wexford Harbour is small by comparison with many Irish coastal areas. The mean tidal range is 1.5m for Spring tides and 0.9m for neap tides.

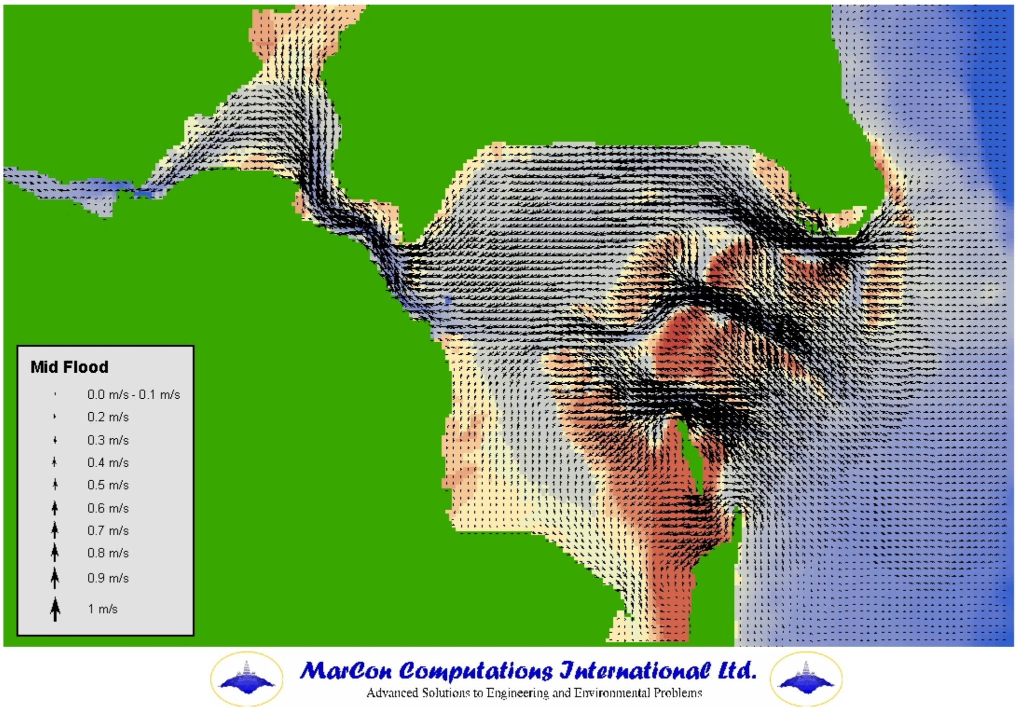
Current Speeds throughout the harbour.

From the UISCE project the model for Wexford Harbour gave mid-flood predictions as graphically presented below **(Figures 2-5**). The UISCE project undertook a bathymetric survey of the harbour and calibrated the model with prolonged current readings from numerous sites throughout the inner and outer harbours.



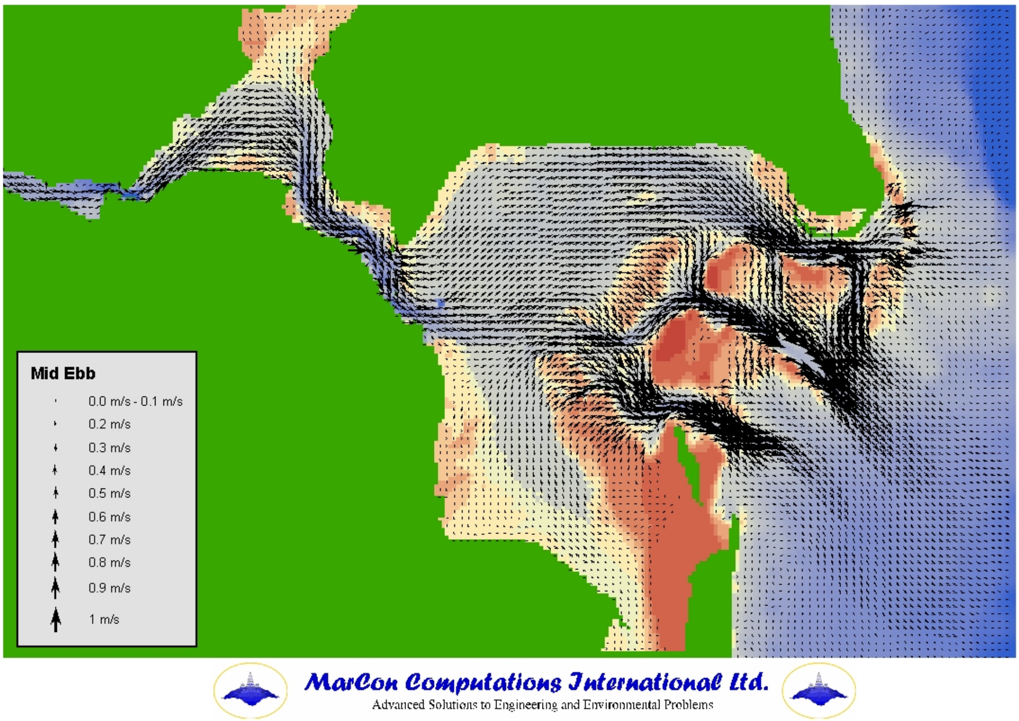
Map 5: Renewals and Applications in Relation to Water Framework Classified Waterbodies.

Figure 2: Mid-flood



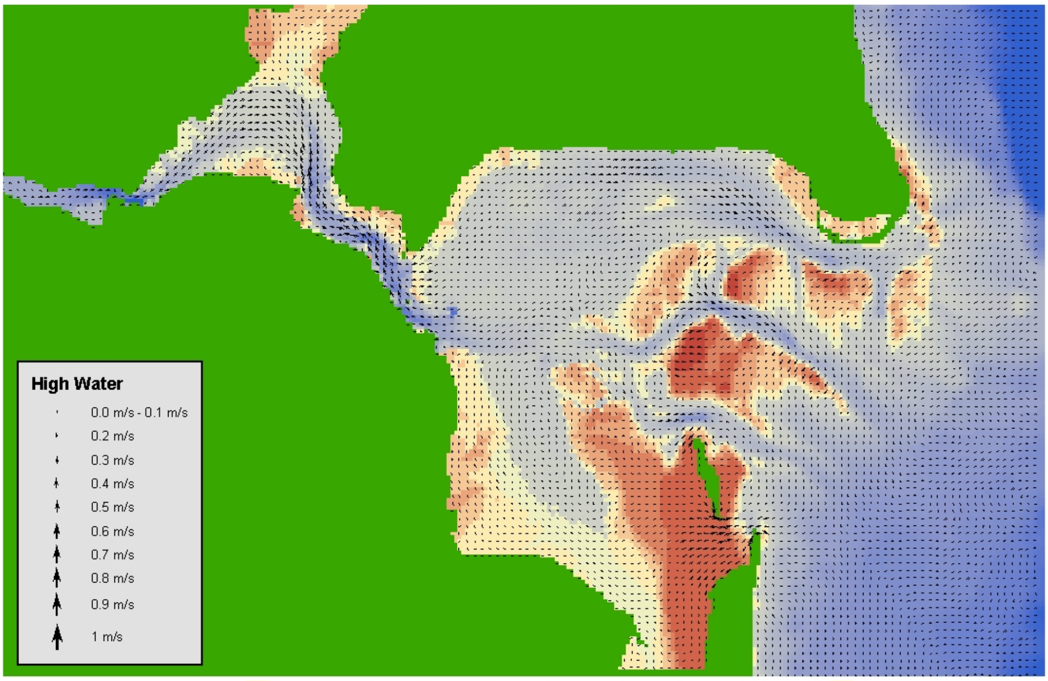
Southern harbour slackest.

Figure 3: Mid Ebb.



Note that at mid-ebb more intertidal area is revealed than at mid-flood.

Figure 4: High Water.



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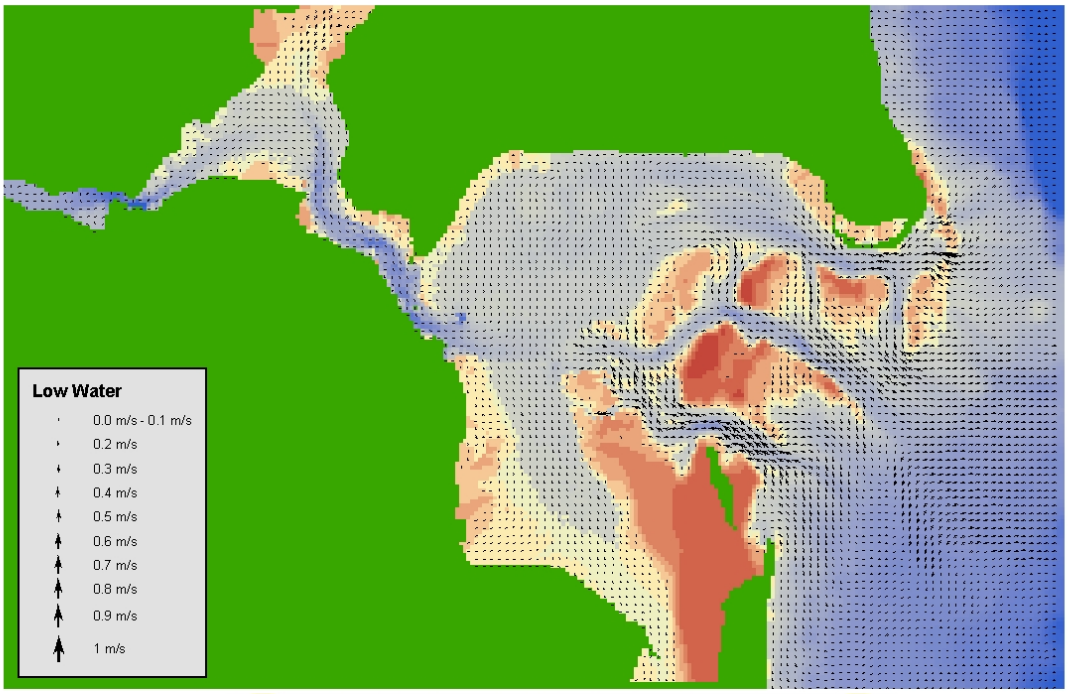
High-water current speeds are very slack throughout most of the harbour.

Figure 5: Low Water



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Low-water current speeds as predicted by the UISCE model. Large areas of the southern harbour and middle outer harbour are revealed.

Bathymetry

Bathymetry is one of the great mysteries of Wexford Harbour. Sandbanks and channels are always dynamic in the harbour and combined with the shallow nature of the harbour means that navigation can be difficult and surveying for bathymetry next to impossible.

The differences between the Ordinance Survey 1:50000 (**Map 6**), the NPWS Slaney river valley SAC intertidal map, the Admiralty Chart (**Map 7**), OSI 2005 orthophotography (**Map 8)**, the GSI Bathymetric Satellite Data (2010) **(Map 9**) the UISCE Bathymetric Data of 2008 (**Figure 7**) and Google Earth Satellite Image (08_09_2012) (**Figure 8**) the Wexford Harbour Masters Chartlet (16th April 2014) (**Figure 9**,) are substantial and significant. This is due to surveying at different times with different equipment and also the very dynamic nature of banks and channels in Wexford Harbour. Channel marking buoys have to be updated regularly. However there are two groupings with the admiralty chart not in either of these groups.

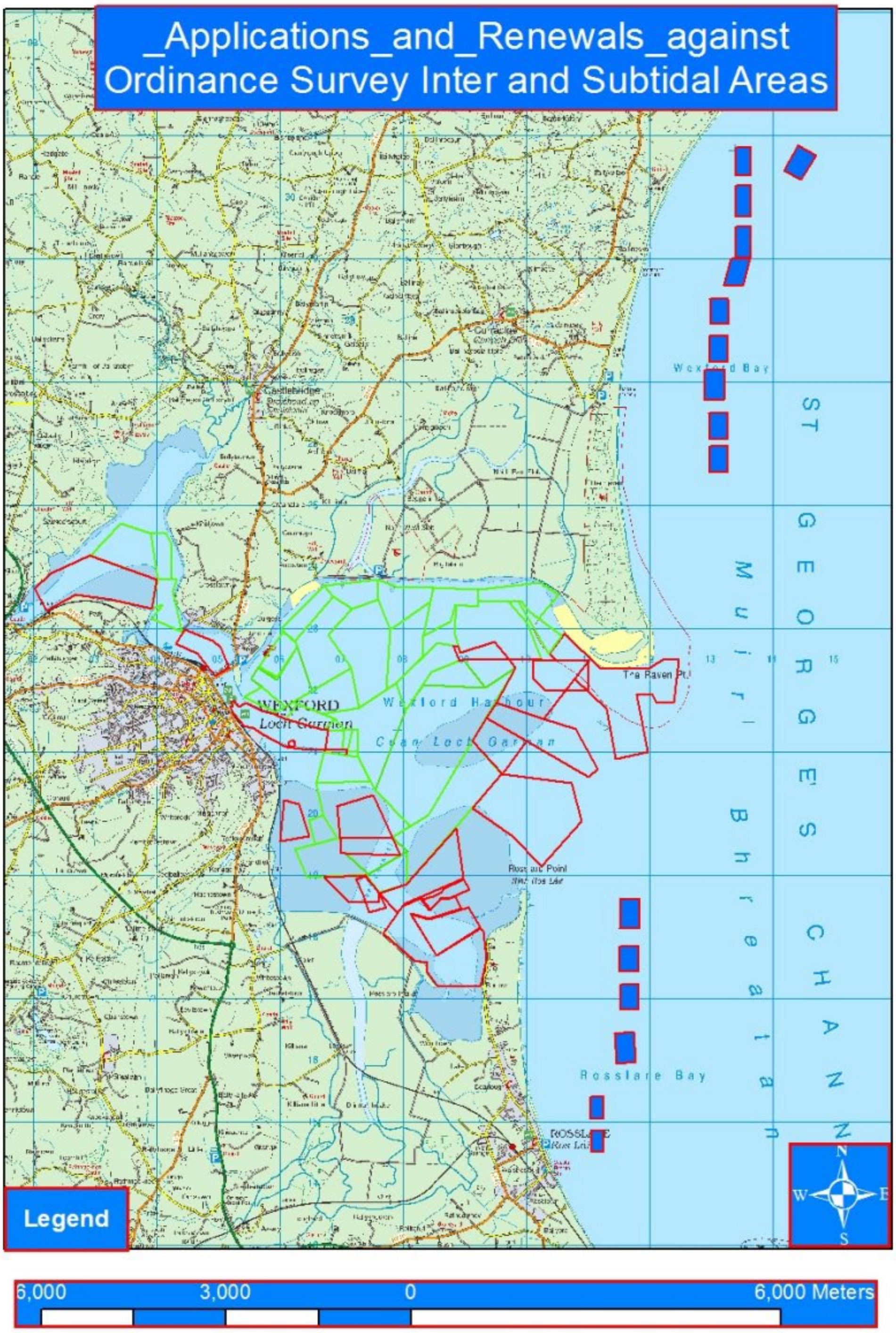
In general the NPWS intertidal interpretation is more aligned to the 1:50000 OS Background and both are incorrect. Apart from the admiralty chart the other sources of bathymetry are closely aligned. Two examples of the differences between the NPWS bathymetry and the other group are firstly they indicate a large intertidal bank in the middle of the bay covering about 35% of application T03/71A. This is clearly not the case as a subtidal channel runs right through the application unbroken from start to finish and is actually the main channel in and out of the harbour and is marked by buoys.

The second main example is the difference between the NPWS's interpretation of the coal channel (in the southern section of the harbour) in that they have it running Northeast to Southwest which would put substantial areas of mussel beds in the intertidal category. This is the same interpretation as the Ordinance Survey 1in 50000 background whereas in the Harbour Masters Chartlet , GSI Bathymetric Satellite Data, the UISCE bathymetric chart, 2005 Orthophotography and google earth would have the coal channel running NW to SE and therefore the same mussel beds would be largely subtidal. Over the years is has been stated by the industry that the channel into the southern section of the harbour has been gradually getting stronger (deeper). The Harbour Masters Chartlet, the GSI Bathymetric Satellite Data and even the 2005 Orthophotography would indicate that a small continuous channel now exists from Rosslare Point into the southern harbour which might improve flow in the area. One bottom mussel producer went as far as to say that the Ordinance Survey Discovery series interpretation of the bathymetry of Wexford and that of the Admiralty chart can be regarded as ridiculous and totally unacceptable. Therefore the NPWS bathymetric interpretation is likewise unacceptably wrong. These can be seen in Maps 6, 7 and 10.

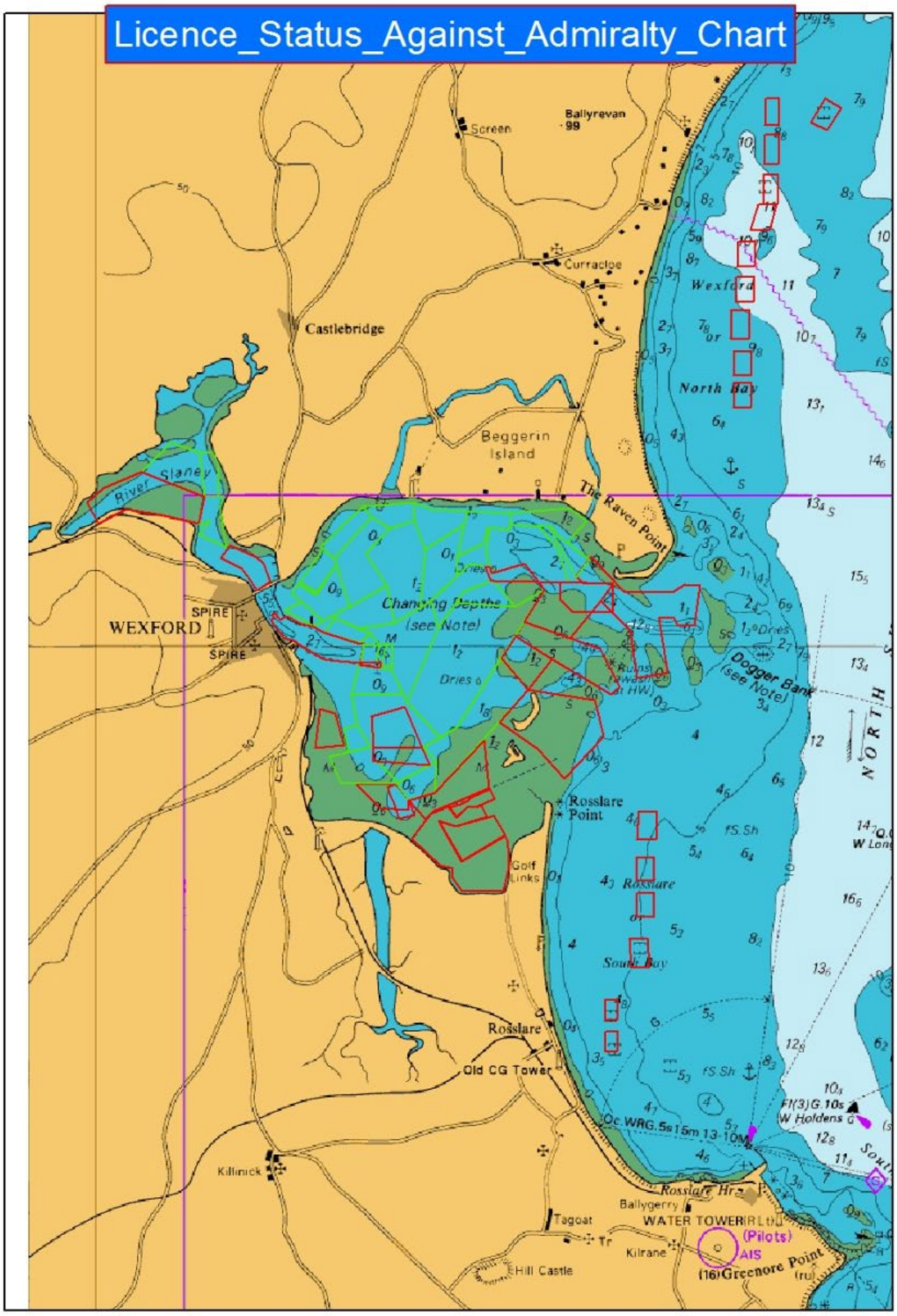
Map 10 shows the difference between the OS and Admiralty intertidal Zones.

So the extent of the harbour that is intertidal is quite difficult to calculate.

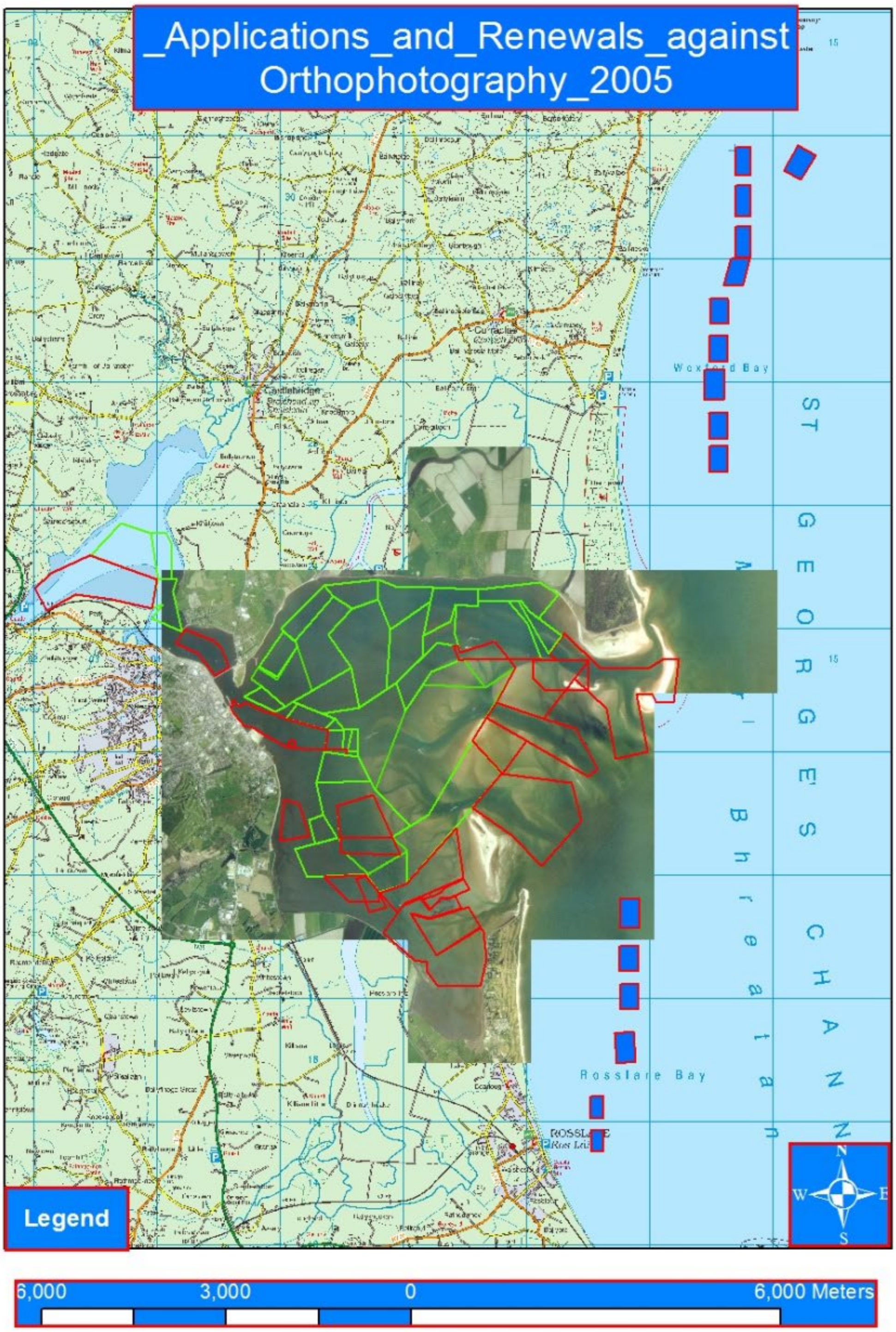
Due to the shallowness of the harbour, dilution and transparency values are low. Intermixing of waters from the southern part of the harbour with the main channel is a relatively slow process also.



Map 6: Renewals and Applications in Relation to Ordinance Survey 1:50000 Background Map

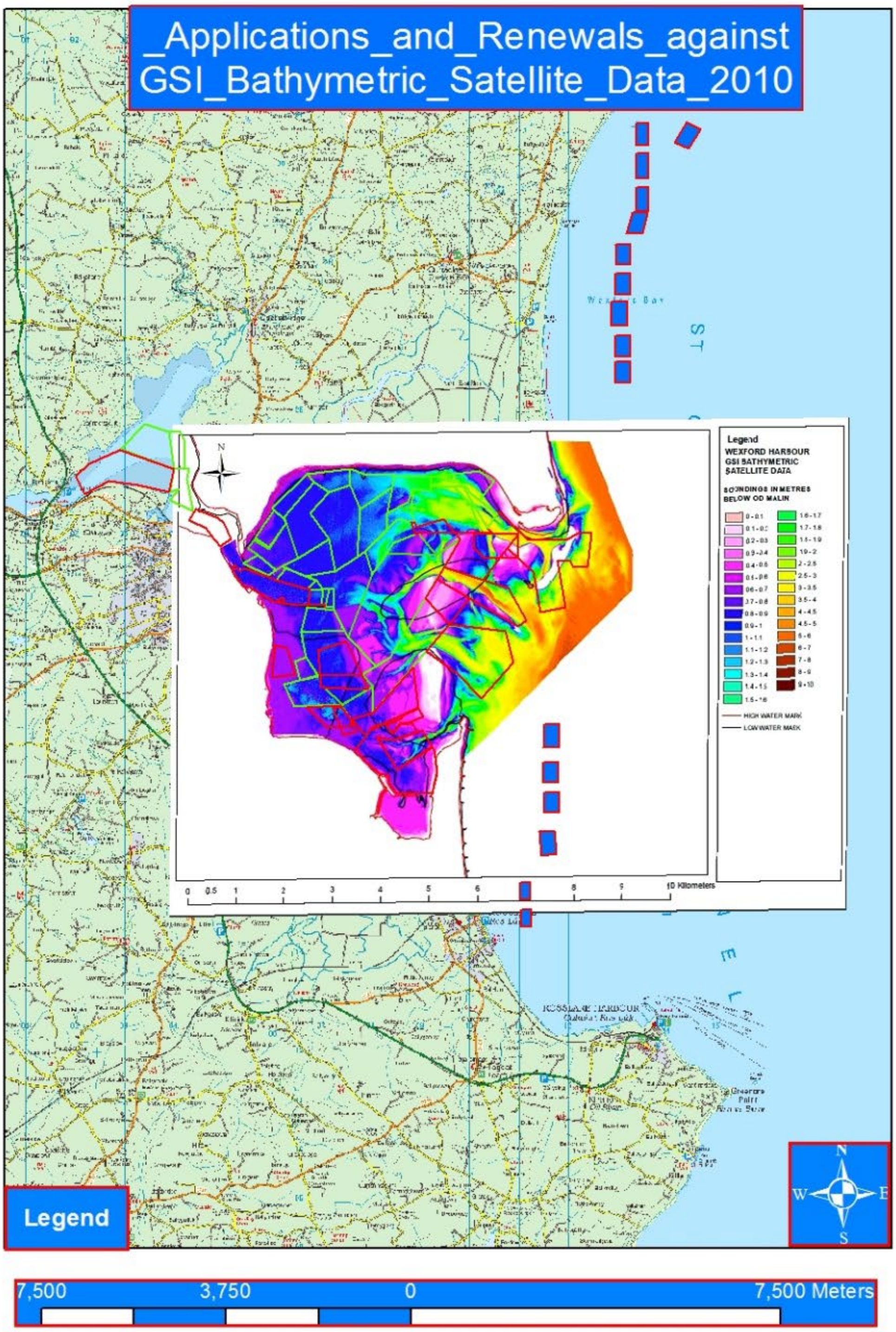


Map 7: Renewals and Applications in Relation to Admiralty Chart for Harbour.



Map 8: Renewals and Applications in Relation to 2005 Orthophotography OSI

Map 9: *Satellite imagery derived bathymetric data for Wexford Harbour courtesy of Archie Donovan* Geological Survey of Ireland undertaken in 2012 in conjunction with Proteus, EOMAP and DigitalGlobe as published in *Developments and Benefits of Hydrographic Surveying Using Multispectral Imagery and georeference as best as possible by the author onto Arcview.*



By: Helen Needham, Technology Director, Proteus Robert Carroll, Representative, Proteus

The data generated by the GSI spectral Imagery Anlaysis should be viewed with the following levels of confidence as shown in **Figure 2.** (Red indicates a low degree of confidence, Green a high degree of confidence and yellow an intermediate degree of confidence.

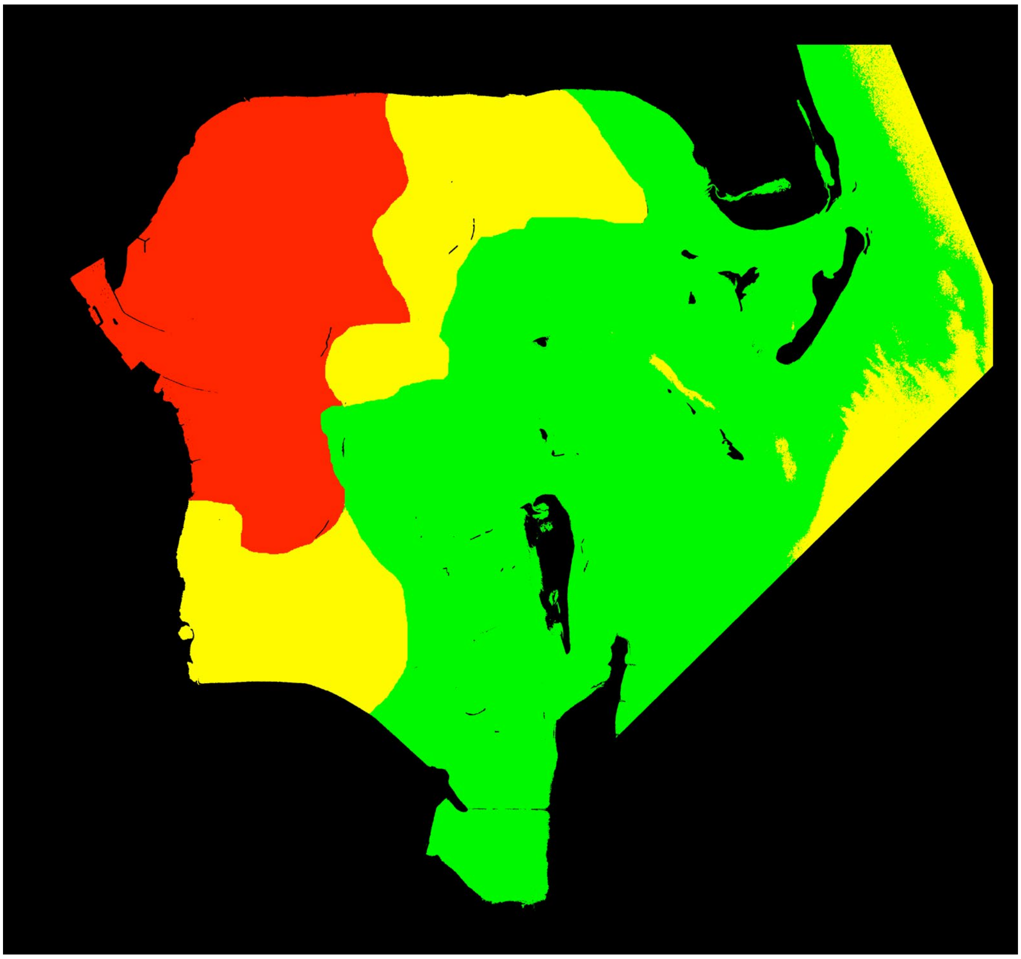


Figure 6: Data accuracy confidence map as from *Developments and Benefits of Hydrographic Surveying Using Multispectral Imagery By: Helen Needham, Technology Director, Proteus Robert Carroll, Representative, Proteus*

Figure 7: Wexford Bathymetry as Generated in 2008 by UISCE project.

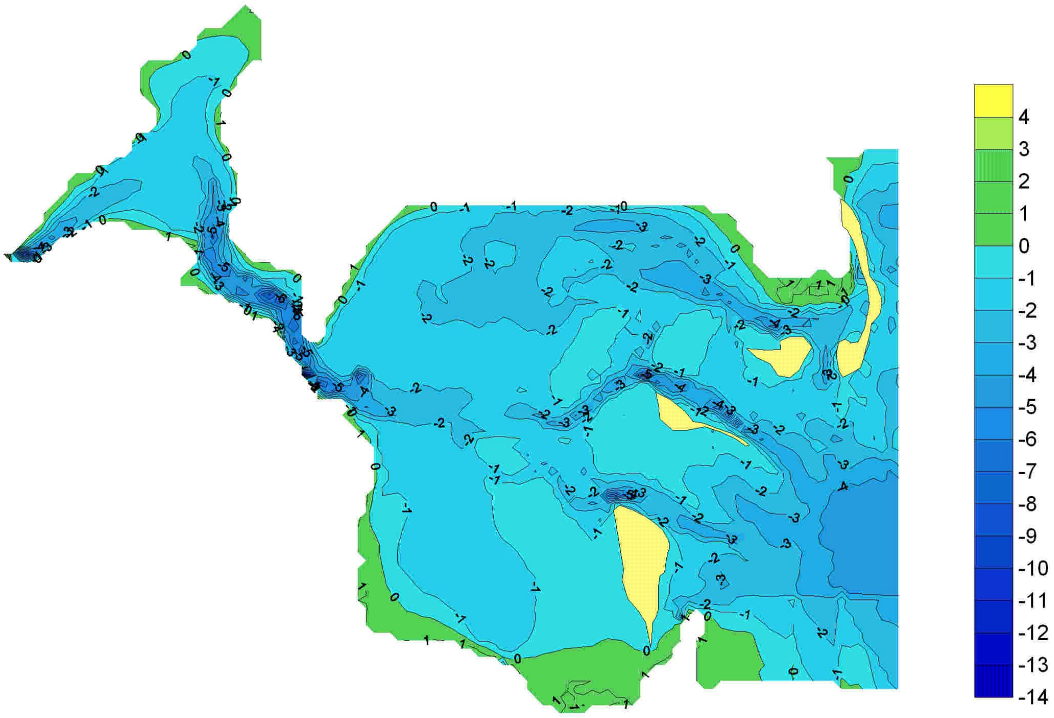


Figure 8: Google Earth Satellite Imagery taken on 08/09/2012

Figure 9: Wexford Harbour Chartlet as produced by Harbour Master on April 26th 2014.

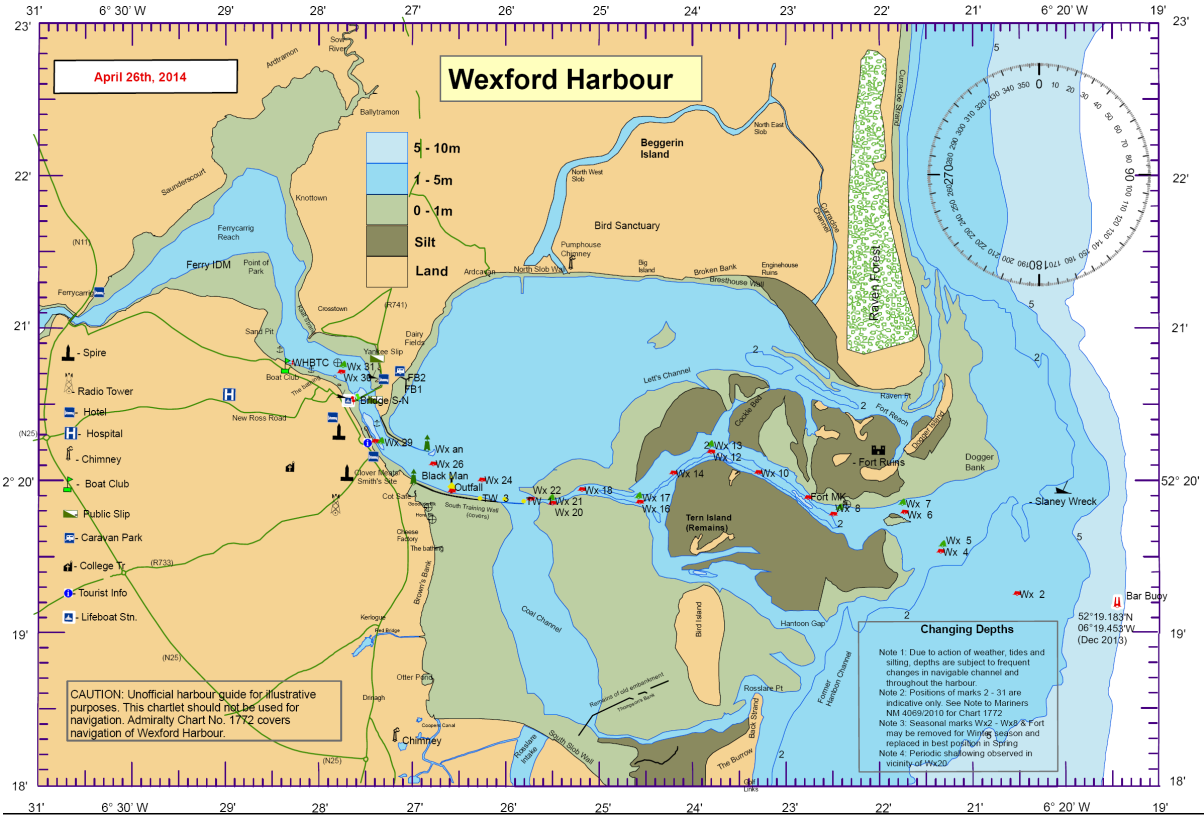
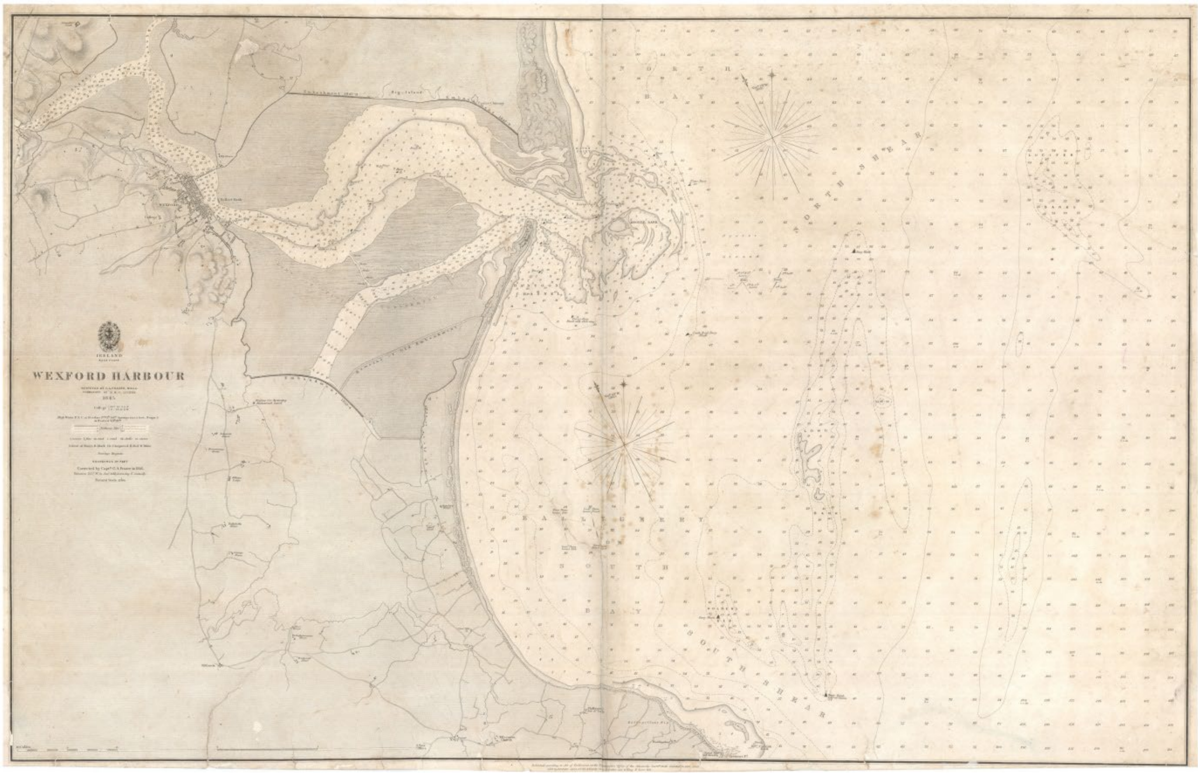
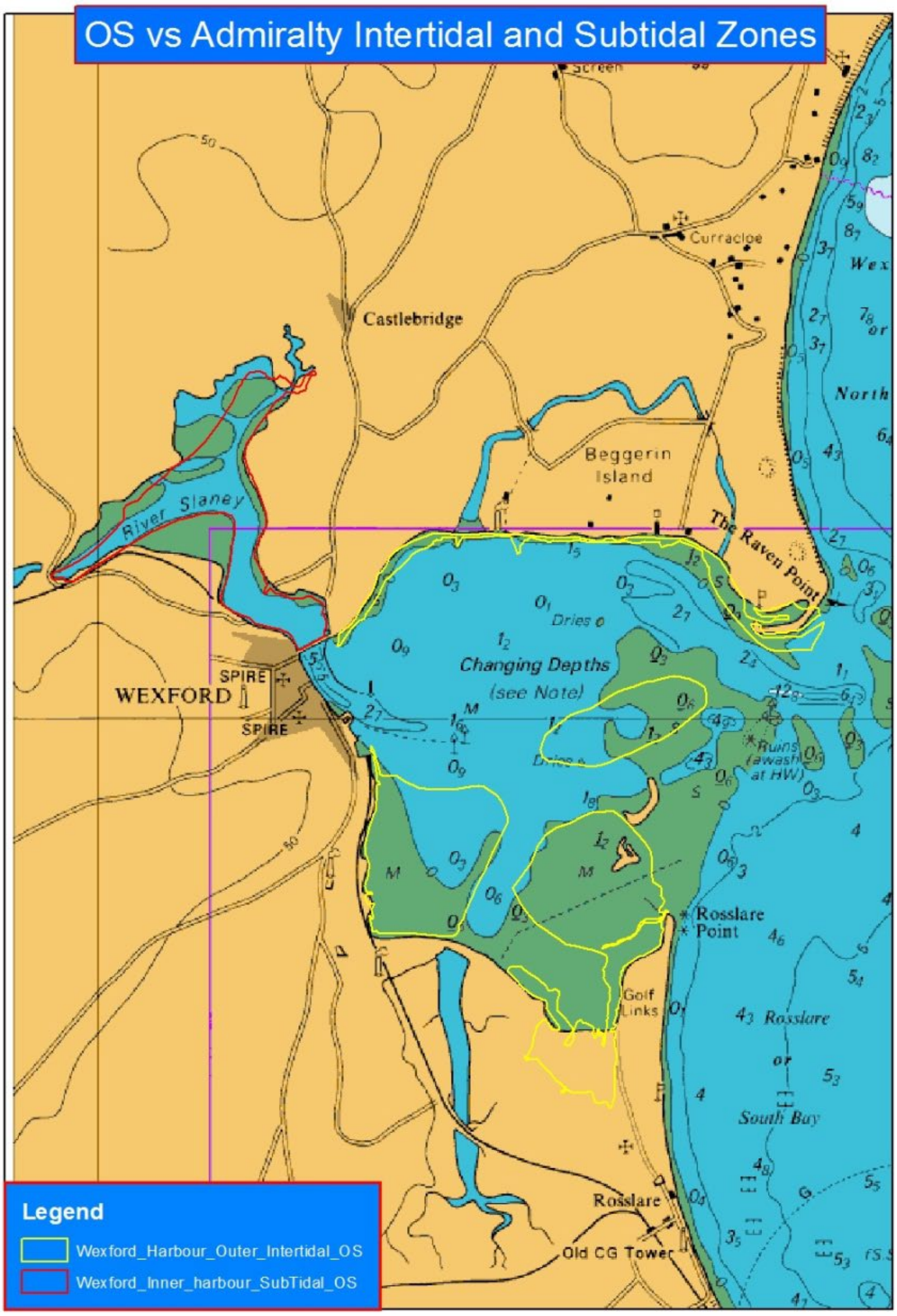


Figure 10: Wexford Harbour Bathymetry by G.A. Frazer of 1845 and corrected by same in 1856 presumably after the embankments for the north and south slobs were built in 1847-1849 and 1853 - 1854 respectively. The Rosslare point ran up much closer to the Raven Point before it was washed away in the early 19th Century (?)





Map 10: Comparison of OS and Admiralty Intertidal and Subtidal Zones.

In-Farm Hydrography from UISCE Field Data

The UISCE model predicted current speeds throughout the harbour but actual data taken over prolonged periods at 5 sites located on farms was collected in 2007 and 2008 **Map 11**. RCM9 current meters reading for Current Speed, Direction, Salinity, Temperature and Pressure at 70cm off the seabed were deployed and sometimes were complimented by datasondes which were reading for salinity, temperature and chlorophyll a. There were two campaigns: 30/11/2007 to 17 January 2008 for Wexford Inner and Outer and then 14 March to 28 March at WXNMS2, WXMMS2 and WXFSS5 concurrently. Readings were taken every 20 minutes. Datasonde readings occurred about 15cm above the mussel beds. The March 08 data covered a neap spring cycle.

Map 11: Location of Current Meter (and Datasondes) during the Winter 2007/2008 and Spring 2008 Campaigns.

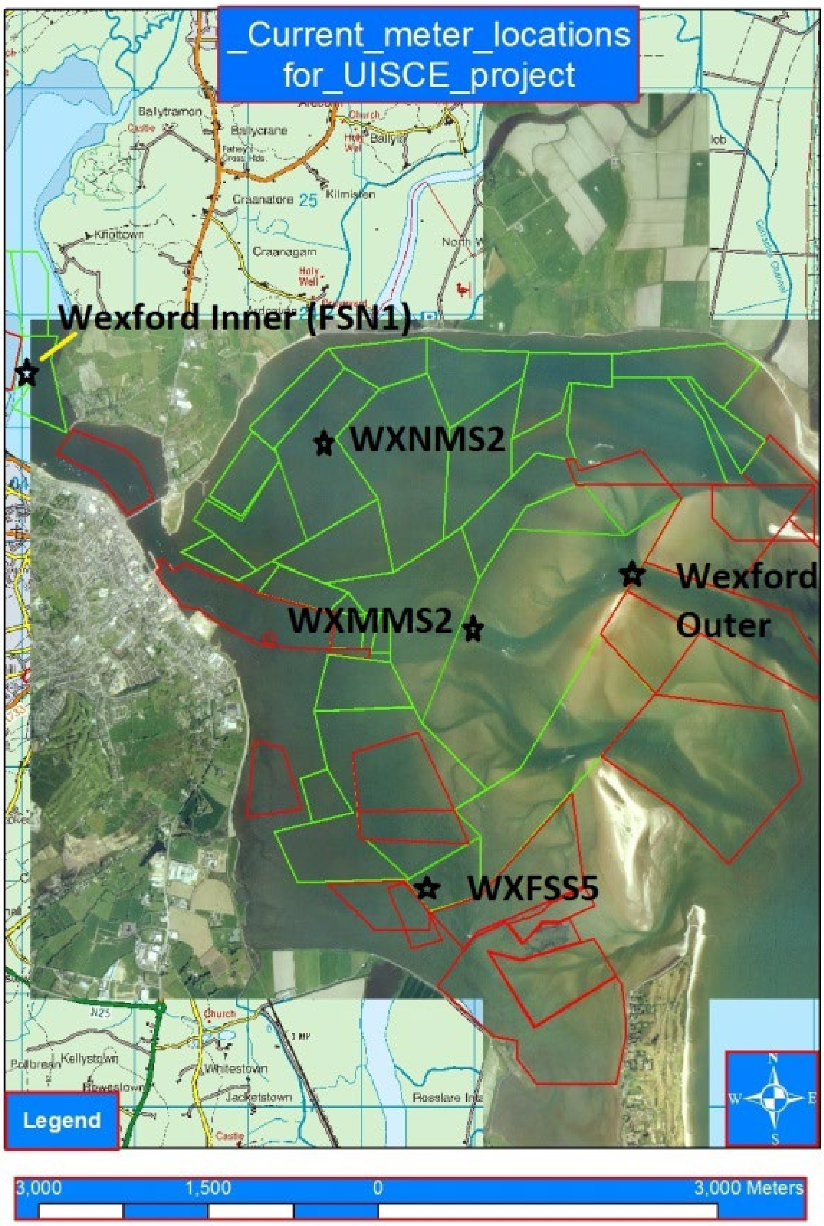


Figure 11: Wexford Outer All Data 30th Nov 07-17 Jan08

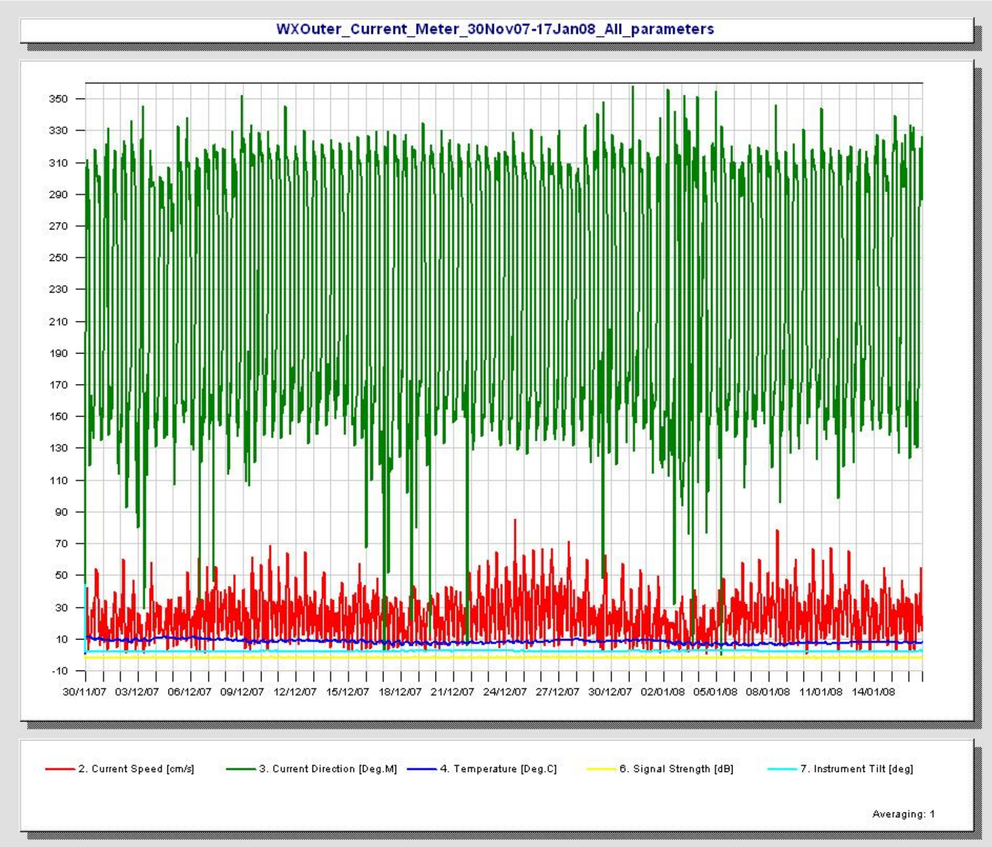


Table 4: Wexford Outer 30th Nov07-17 Jan08 Summary Stats for Current Speed and Salinity

Statistic	*WX Outer Current Speed (cm/s)*	*WX Outer Salinity (ppt)*
Mean	25.09	31.43
Standard Error	0.23	0.07
Median	23.76	32.38
Mode	25.22	34.32
Standard Deviation	13.62	3.25
Sample Variance	185.40	10.56
Kurtosis	0.39	2.50
Skewness	0.68	-1.43
Range	85.06	21.33
Minimum	0.00	13.90
Maximum	85.06	35.23
Sum	86337.31	68932.57
Count	3441	2193

Figure 12: Wexford Outer Current Scatter 30th Nov 07-17Jan08.

Flood is at about 325 degrees from North and Ebb about 140 degrees from North.

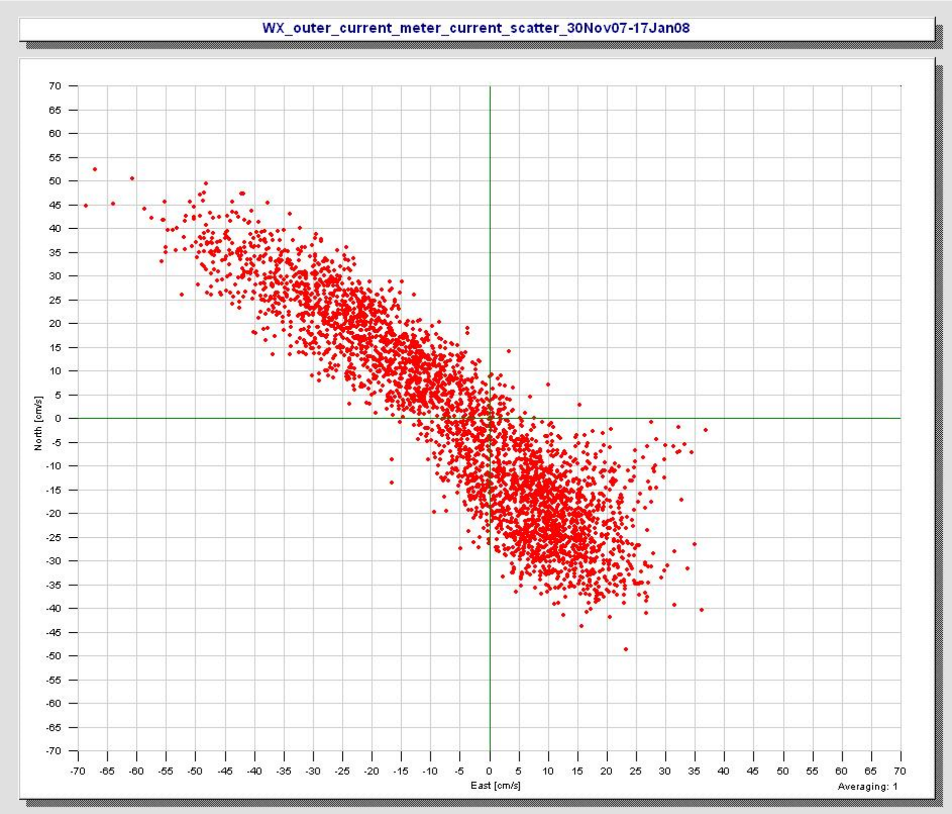
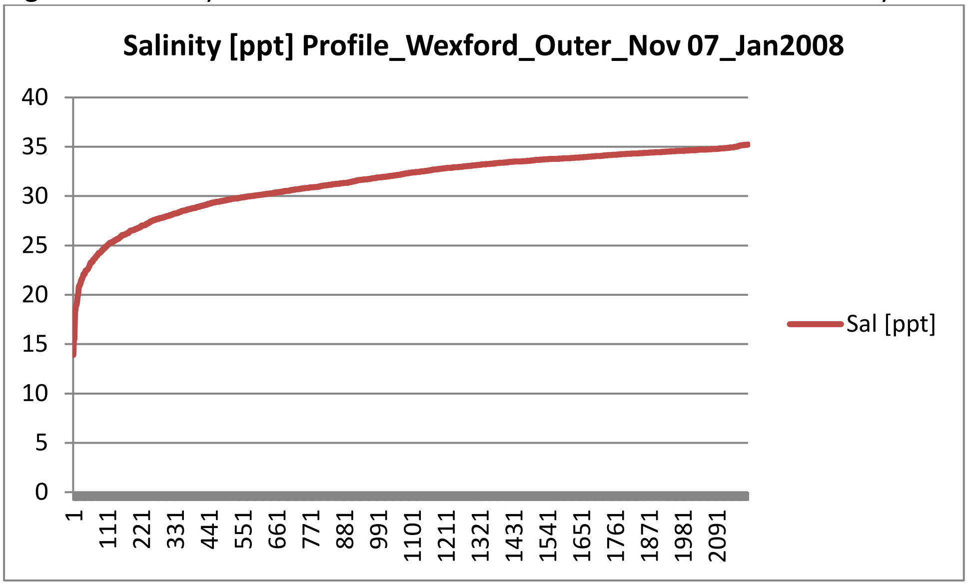


Figure 13: Salinity Profile Wexford Outer 30th November 07 to 17th January 08



Very few readings below 20ppt salinity. About two thirds of readings above 30ppt.

Figure 14: Wexford Inner (WXFSN1) 30th November 07-17th January 08

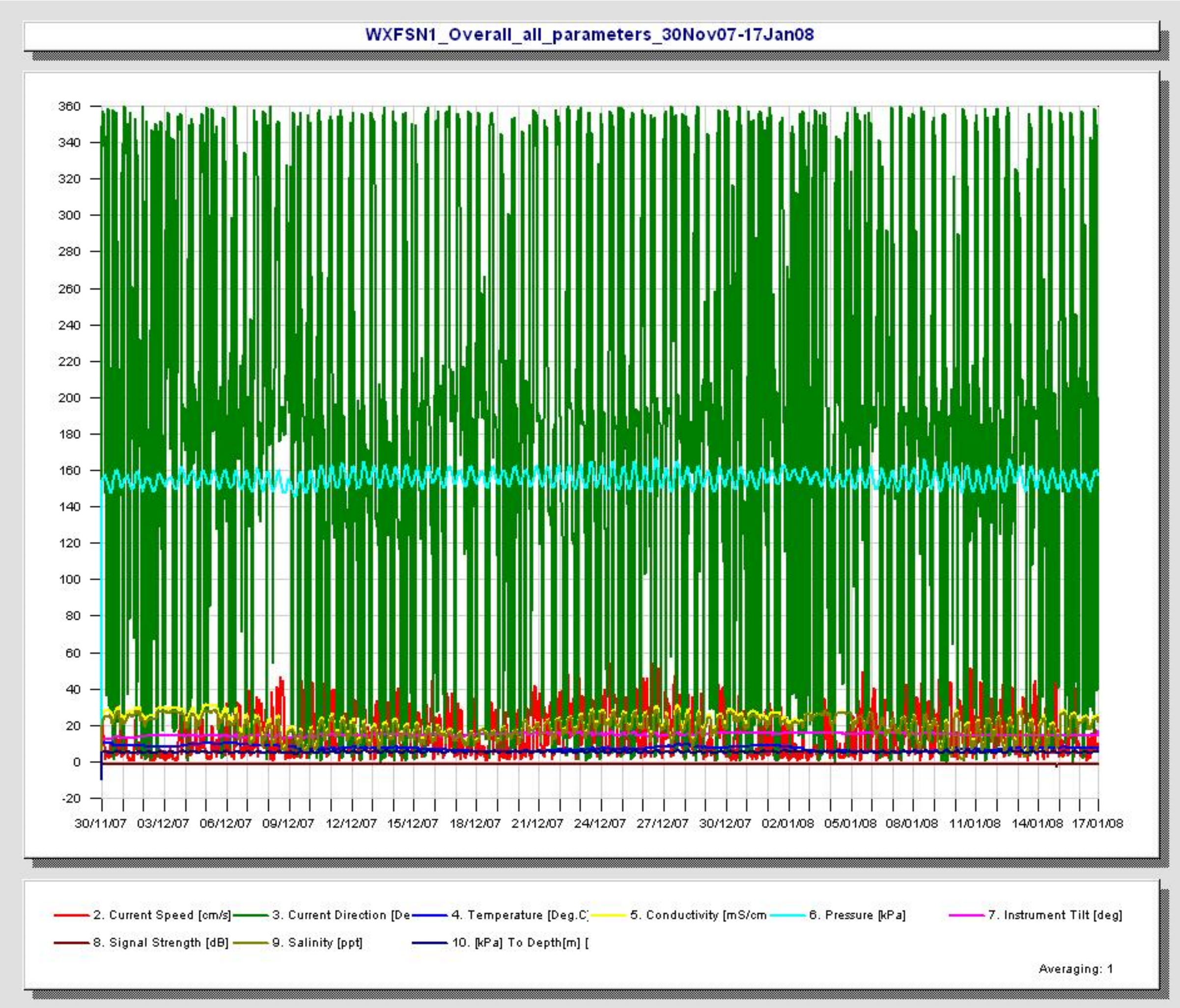
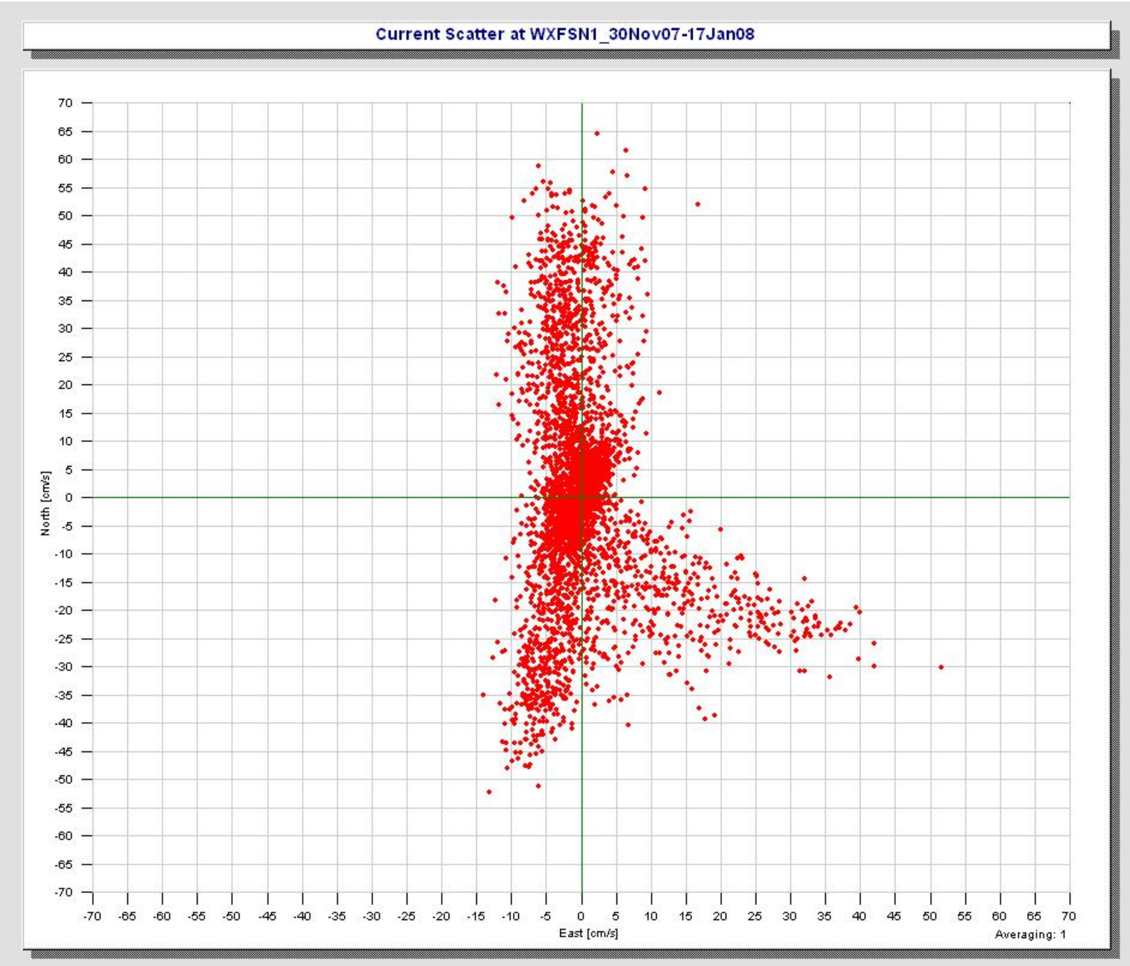


Table 5: Wexford Inner Summary Stats for Current Speed, Salinity and Depth 30th November 07-17th January 08. (note add 60cm to depth stats as sensor was 60cm above seabed)

Statistic	*Wex Inner Current speed (cm/s)*	*WeXInner_Salinity (ppt)*	*Wex Inner_Depth (m)*
Mean	16.43	19.13	5.38
Standard Error	0.23	0.10	0.01
Median	11.73	19.91	5.35
Mode	4.11	24.67	5.15
Standard Deviation	13.50	5.87	0.42
Sample Variance	182.15	34.46	0.17
Kurtosis	-0.43	-0.39	-0.87
Skewness	0.79	-0.53	0.09
Range	64.53	28.25	2.13
Minimum	0.00	0.67	4.38

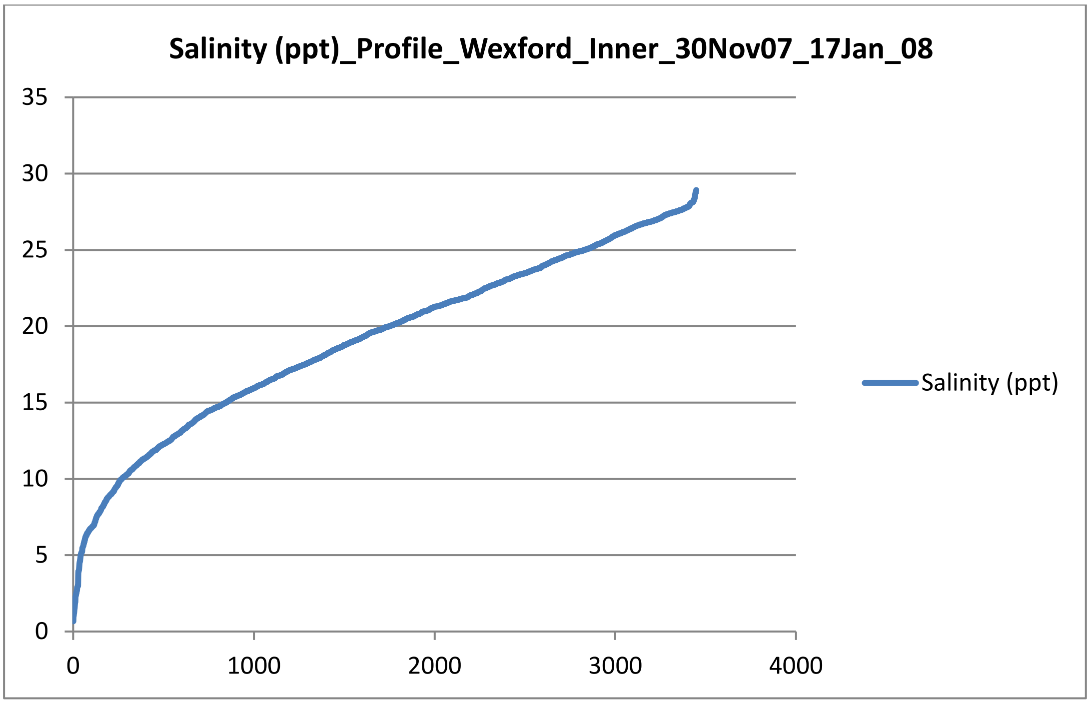
Maximum	64.53	28.92	6.51
Sum	56636.59	65943.06	18535.23
Count	3448	3448	3448

Figure 15: WX Inner Current Scatter 30th November 07- 17th January 08**.**



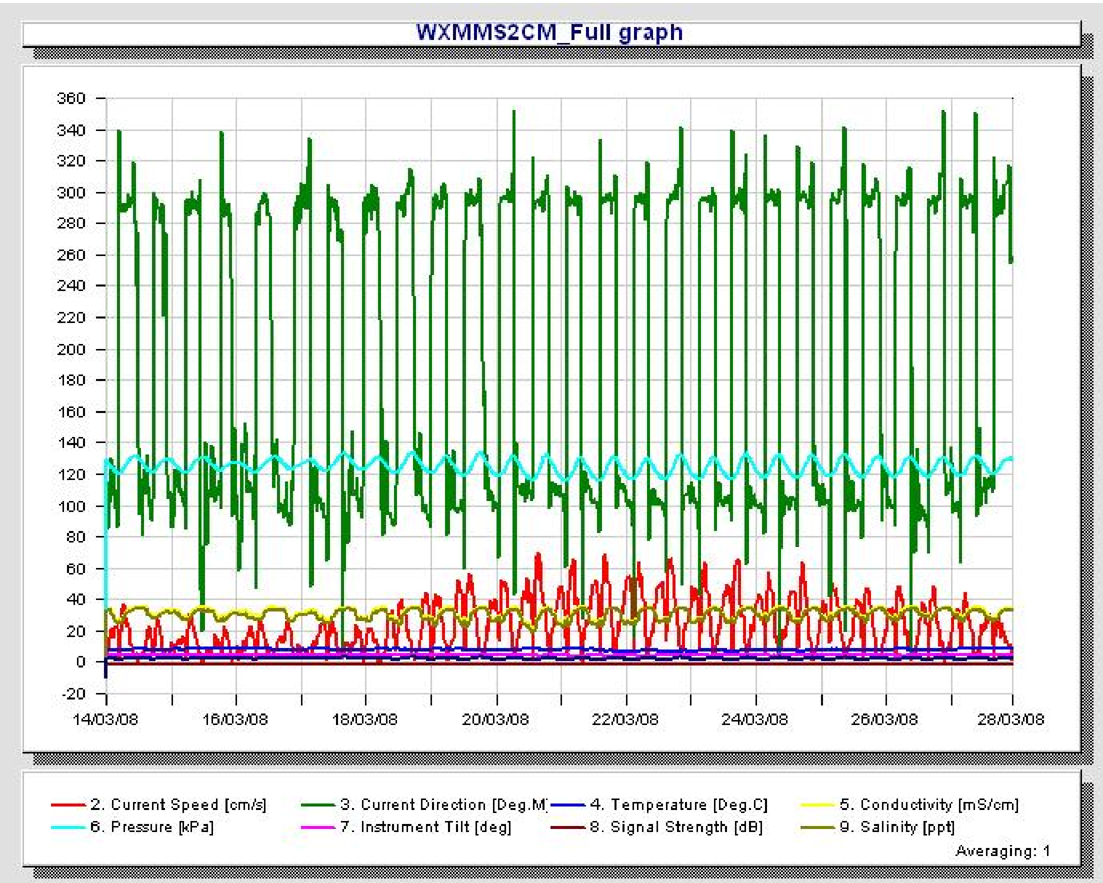
The flood is about 0 degrees from North and the ebb is about 190 degrees from North and is less well defined with changes in direction during the ebb probably to do with the bank at the point of park revealing at a certain stage in the ebb tide.

Figure 16: Salinity Profile for Wexford Inner (from 60cm above seabed).



On a strong spring ebb with wet weather the salinity readings can drop right down but only temporarily during the tidal cycle. However 1/5th of the readings are below 15ppt.

Figure 17:WXMMS2 Full Data Plot 14-28th March 08



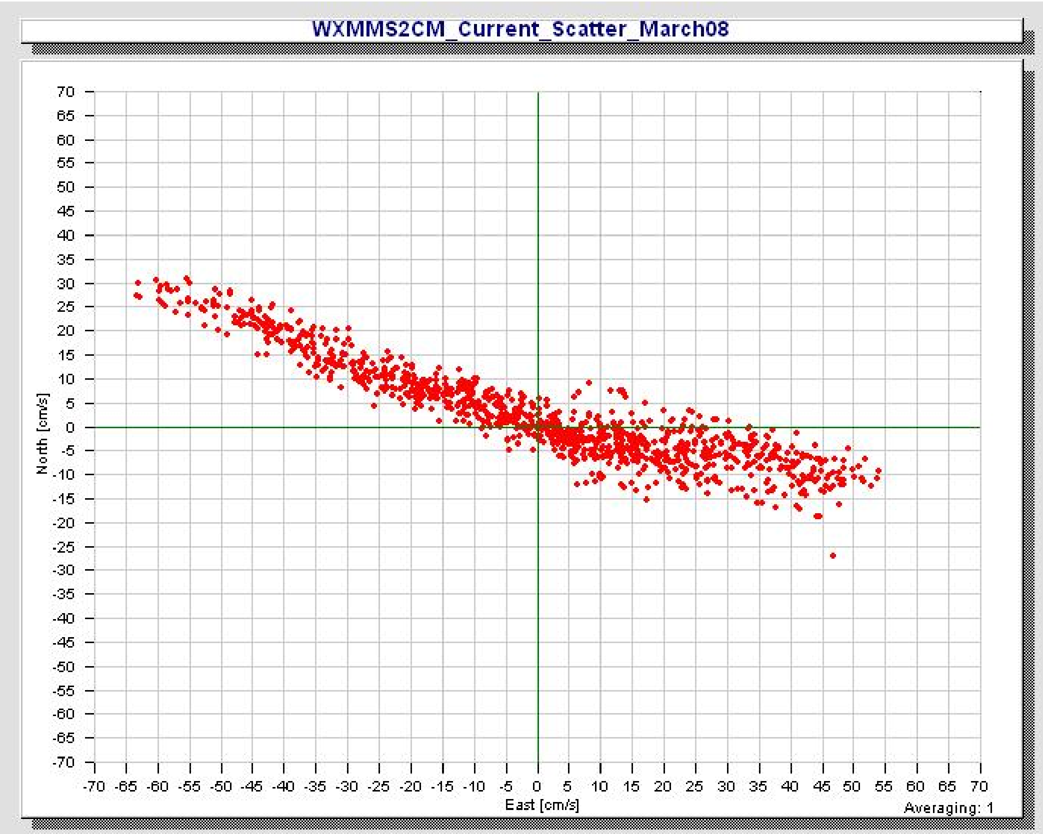
Very clearly defined flood and ebb directions (290 and 110 degrees from north). Spring tide current speeds considerably faster than neap.

Table 6: WXMMS2 Summary Stats for Current Speed, Salinity and Depth 14/03/08-28/03/08 (add 60cm to depth stats)

Statistic	*WXMMS2_Current Speed (cm/s)*	*WXMMS2_Salinity(ppt)*	*WXMMS2_Depth (m)*
Mean	23.81	28.24	2.34
Standard Error	0.50	0.15	0.01
Median	20.82	28.73	2.35
Mode	6.45	34.89	2.83
Standard Deviation	15.99	4.76	0.43
Sample Variance	255.61	22.62	0.18
Kurtosis	-0.54	-0.88	-1.04
Skewness	0.58	-0.38	-0.07
Range	69.52	18.26	1.74
Minimum	0.29	17.26	1.48
Maximum	69.81	35.52	3.22
Sum	23931.28	27958.37	2347.93
Count	1005	990	1005

Ave, Max and Min Depth (m) are 2.94, 3.82 and 2.08.

Figure 18: WXMMS2 Current Scatter 14-28th March 08.



Very clearly defined.

Figure 19: WXMMS2 Salinity Profile 14-28 March08

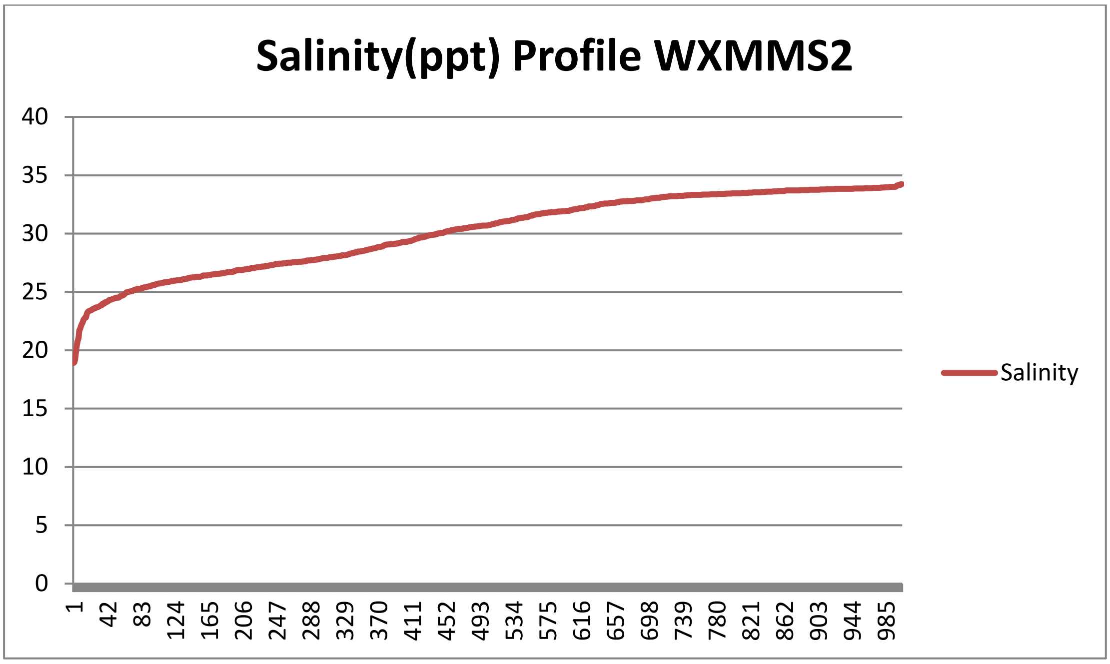


Figure 20: WXNMS2 Full dataplot 15/03/08-28/03/08
Flood about 250 and Ebb about 50 degrees from north but not tightly defined.

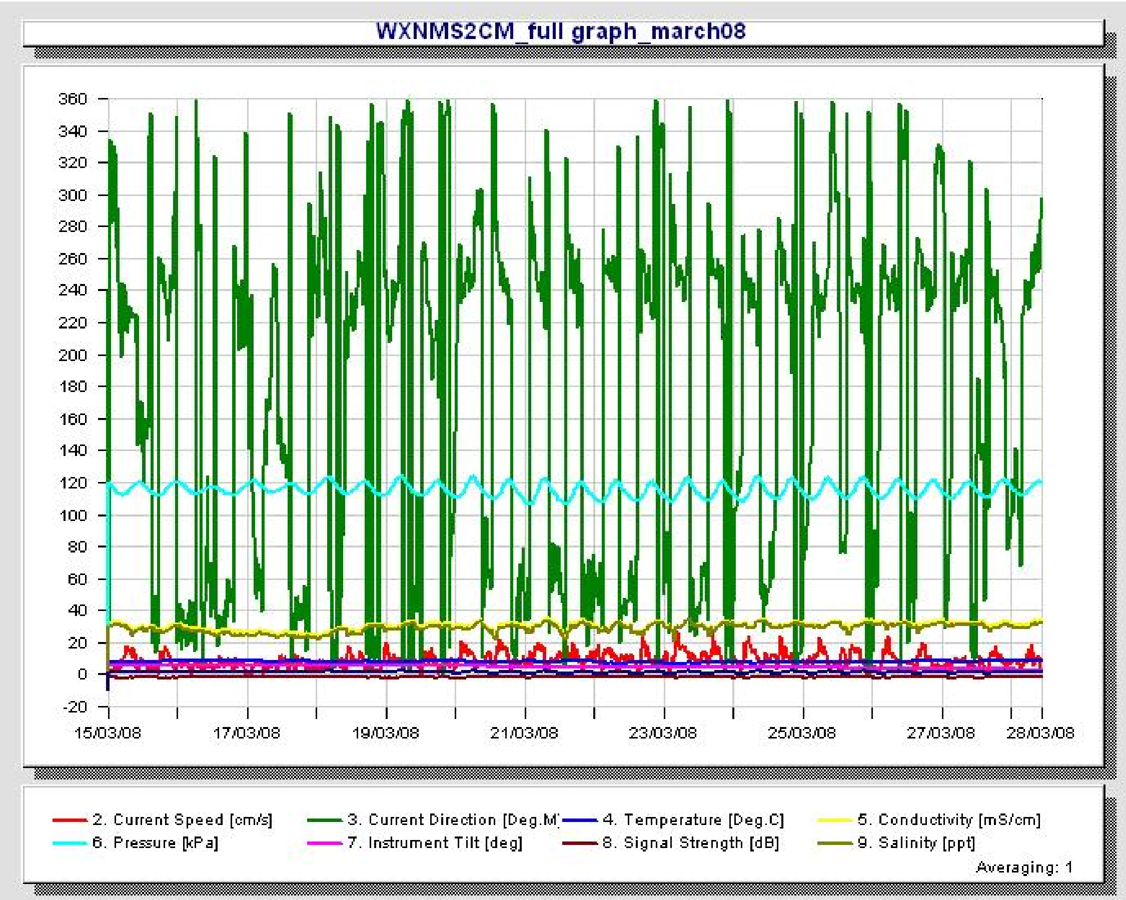


Table 7: WXNMS2 Summary Stats for Current Speed, Depth and Salinity 15/03/08-28/03/08 (add 60cm to depth stats)

Statistic	*WXNMS2_Current Speed (cm/s) Stats*	*WXNMS2_Depth (m)*	*WXNMS2_Salinity (ppt)*
Mean	8.98	1.41	30.67
Standard Error	0.15	0.01	0.08
Median	8.51	1.38	31.08
Mode	9.39	1.86	31.22
Standard Deviation	4.66	0.42	2.65
Sample Variance	21.69	0.18	7.02
Kurtosis	0.47	-1.00	0.22
Skewness	0.67	-0.04	-0.87
Range	28.16	1.74	12.52
Minimum	0.29	0.51	22.62
Maximum	28.45	2.25	35.14
Sum	8700.89	1364.57	30389.82
Count	969	969	991

Current speeds similar to south harbour. Ave, max and min depths: 2.01m, 2.85m and 1.31m

Figure 21: WXNMS2 Current Scatter 15/03/08-28/03/08

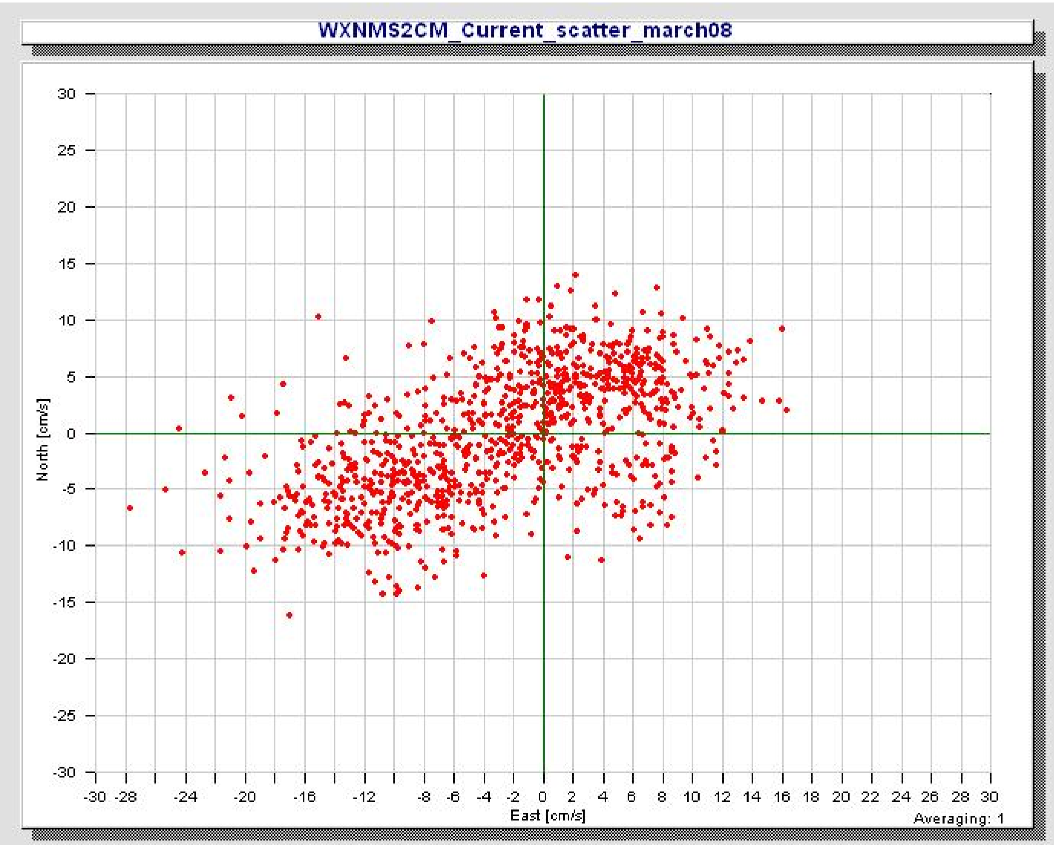


Figure 22: Salinity Profile WXNMS2 14-28 March08**.**

Profile not unlike that for southern harbour.

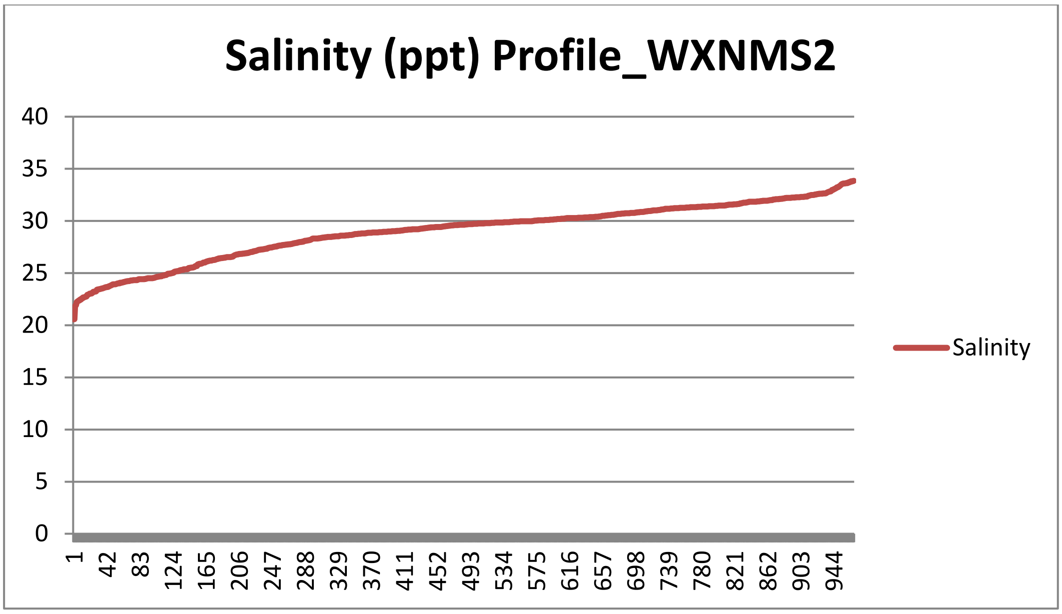


Figure 23: WXFSS5 Full dataplot 14/03/08 to 28/03/08

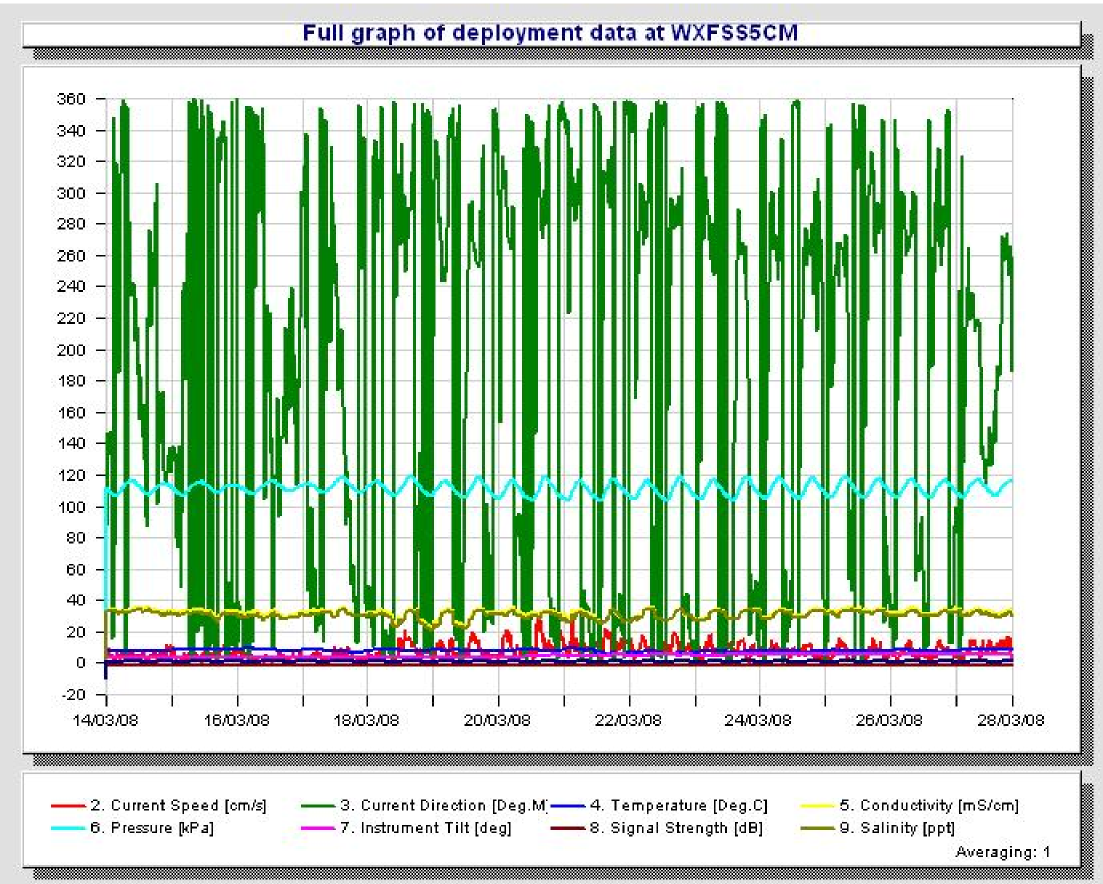


Table 8: WXFSS5 Summary Stats for Current Speed, Depth and Salinity 14/03/08-28/03/08 (add 60cm to depth stats).

Statistic	*WXFSS5_Current Speed (cm/s)*	*WXFSS5_Depth (m)*	*WXFSS5_Salinity (ppt)*
Mean	7.75	0.99	30.59
Standard Error	0.14	0.01	0.08
Median	7.04	0.99	31.04
Mode	5.28	0.80	32.89
Standard Deviation	4.41	0.41	2.54
Sample Variance	19.47	0.17	6.44
Kurtosis	1.77	-1.10	1.41
Skewness	1.02	0.06	-1.13
Range	29.33	1.55	13.41
Minimum	0.29	0.22	21.05
Maximum	29.62	1.77	34.46
Sum	7745.79	988.13	30555.13
Count	999	999	999

Average depth 1.59m, min depth 82cm and max depth 2.37m.

Figure 24: WXFSS5_ Current Scatter 14-28/03/08: Poorly defined and slack

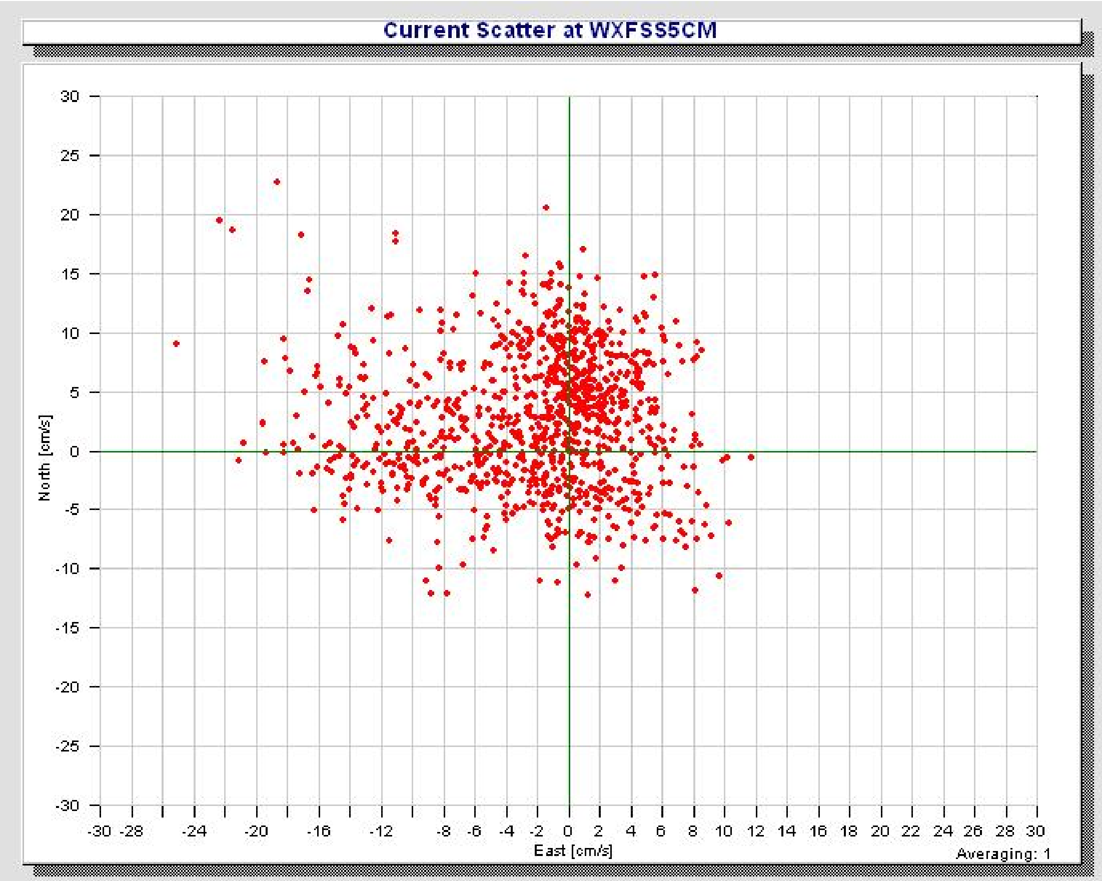
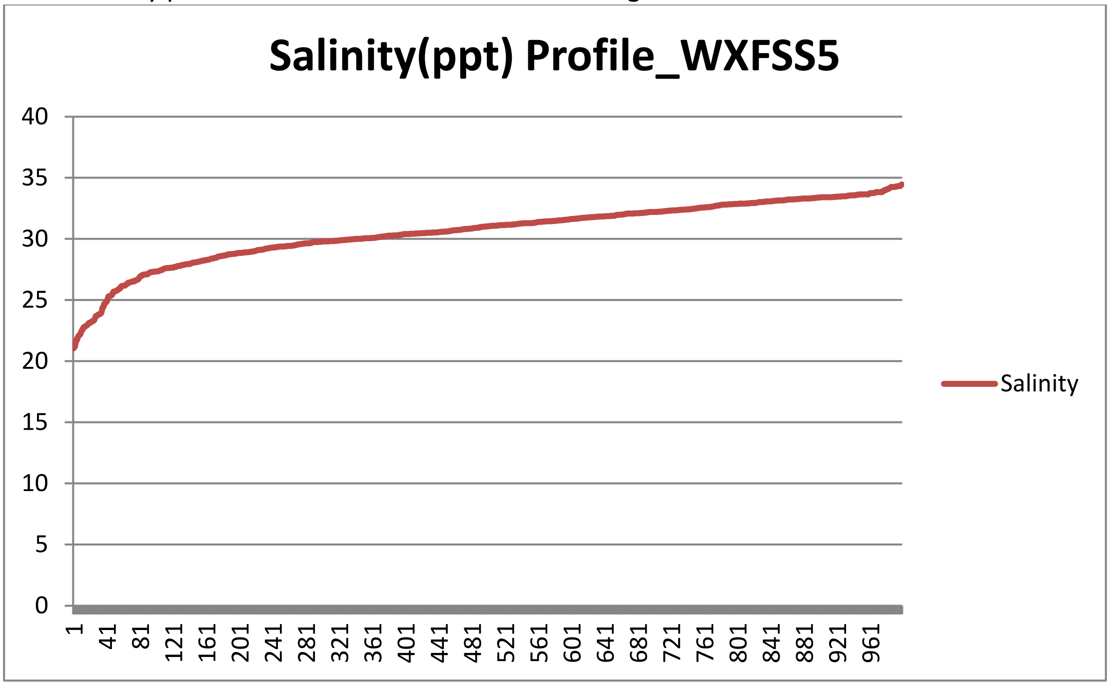


Figure 25: WXFSS5 Salinity Profile 14-28/03/08

Good salinity profile. Freshwater influence not strong.



Shellfish Designated Water Bodies.

Wexford Harbour Inner and Outer are two distinct shellfish designated water bodies. The inner body only covers the extent of the three renewal applications in the inner harbour. The inner harbour is classified as C. The outer harbour designated body again only covers the existing renewal applications plus the main channel opposite the town. It is currently classified as B but has come under threat in recent years. A meeting held recently between Wexford County Council, Irish Water, EPA, SFPA and BIM discussed some of the issues regarding the functioning and maintenance of the waste water collection system, waste water treatment plant and discharge pipe for the Wexford Town agglomeration. The issues raised are currently being addressed. Both designated areas have a pollution reduction programme in place. There is an onus on the Wexford County Council/Irish Water to maintain or improve the water quality in these areas through the operation of a pollution reduction program.

Figure 26: Wexford Harbour Inner Shellfish Designated Area

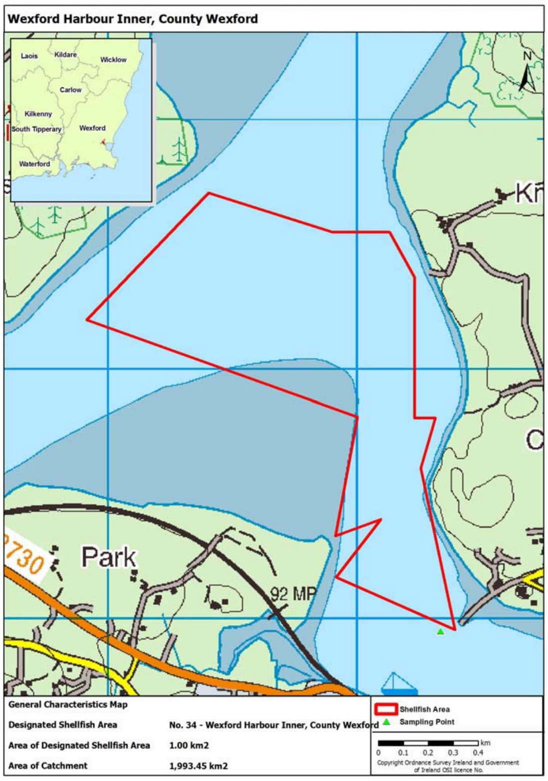


Figure 27: Wexford Harbour Outer Shellfish Designated Area

Transparency

In the EPA report for Water Quality in the Slaney Estuary and Wexford Harbour 2004 51 secchi disc (30cm diameter white disc) readings were made during the summer/autumn surveys and the overall range was from 0.7m to 2.4m. The average was 1.4m. Therefore the transperancy of the water is low probably due to a combination of algae and sediment/sand being resuspended by wave and tide action in the shallow waters.

Salinity
There is a gradual increase in salinity from freshwater to full salinity between Macmine bridge at Oilgate to the mouth of the harbour. Data from the UISCE project shows the salinity profiles at key sectors within the harbour.

Ammonia concentrations have been shown to be high at Ferrycarraig Bridge in the EPA 2004 summer autumn sampling. The landfill site at Killurin was suspected to be the cause of high ammonia at the sampling site. Levels decrease towards the outer harbour.

Nutrient study (Measurement and Modelling of nutrient dynamics of two estuaries in Ireland, Wexford and Cork Harbours).

Water quality data showed significant sources of nutrients in the brackish waters that were not derived from the river or sea. These were presumably derived from outfalls. In this area nutrients were generally in excess of those needed for the growth of phytoplankton. In Wexford Harbour the model showed that phytoplankton biomass extended from the river mouth over the very shallow southern area. A dye release demonstrated the strong effect of wind on water movement in Wexford Harbour, reflecting its shallow depth, large fetch and short water residence time.
Chlorophyll a concentrations can be very high in the southern section of the harbour (up to 100mg/m3).

The drainage channels from the slobs can have elevated chlorophyll levels ammonia too. In past EPA reports it was suggested that the periodic release of the channels into the harbour should be subject to a discharge licence.

The EPA have demonstrated that P (Phosphorus) is the limiting nutrient throughout the estuary except were salinity is greater than 30ppt in which case either N(nitrogen) or P may be equally limiting at 35ppt or N may become limiting at above 30ppt. Dissolved inorganic carbon is not limiting at any salinity.

Mussel Farming in Wexford Harbour.

The vast majority of seed mussels are sourced off the east coast which is regulated by the DAFM. The range of seed size sourced is 15-40mm but the ideal range is 25-35mm. Variations in seed quality among the seed beds do exist within years and between years. For example Cahore seed was usually regarded as more delicate whereas Wicklow seed would in the past have been regarded as tougher. The quantity of seed available on the east coast varies considerably between years and the 2013 year was one of the worst on record. In poor seed years seed intake may be supplemented by rope seed from Ireland or bottom dredged/hand raked seed from Morcambe Bay. The preference is definitely for East Coast Seed.

In general the seed sourced on the east coast beds is brought back into the harbour on the same day for relaying. The opening of the seed beds varies and is dependent on when DAFM authorise it open but in general late summer is normally the seed fishing period.

The stocking density of seed within the harbour varies across each producer and is site dependent. At present the seed stocking density ranges from 10-60 T/Ha with the average around 30 T/Ha. Relaying of seed mussels from the hold is done by water jet through holes in the side of vessel. Once relayed it can take from 12-24 months to reach market size but the average is around 18 months. However the time on the relay plot can depend on the stock level from the previous year, the progression of sales from the previous year's stock, the progression of sales of the current year's stock, the market price and demand and the fluctuations of meat yield levels. Although sales of mussels from Wexford Harbour occur in Spain, Italy, France and Holland, the majority goes to Holland with France coming in second. Marketable mussels are measured by pieces per kg and % meat when cooked. So less than 50 pieces per kilo and meat yields over 35% are regarded as very good mussels and would normally go to Holland. Stock at 80 pieces per kilo and 20% meat yields would be at the lower end of the quality scale. Wexford Harbour has produced stock in the past of 46pieces/kg at 44% meat yields (apparently a record in Yerseke pers communication Mr Des Lett).

Prices achieved on the market depend not only on the quality achieved within the harbour but also the availability of mussels in Europe. Mussels sold have to be purified and degritted as Wexford Harbour outer is classified as B. Wexford Inner is classified as C and mussels from here would have to be moved out into the outer harbour for finishing to have them classified as B mussels. Otherwise they would have to be cooked before selling which does not happen as it is not economically viable.

During the ongrowing period after relaying of seed, stock can be fished for starfish and green crab although not all producers do this. There are two boats fishing for green crab across the harbour on sites where they have permission to or own. Starfish are generally confined to the outer sections of the harbour closer to the Raven Point.

Some producers move stock between sites e.g. they may have ground that is good for fattening and will ensure to finish their stock on such grounds however not everyone does this. Cleaning of the sites is normally done through the action of harvesting. Most harvesting is done from September to April with many operators finished up by Christmas. Some harvesting can also be done during the summer months also depending on the market. The slack time is normally February to June. During this time monthly sampling occurs to keep a track on the progression of the stock quality. However during the harvesting period sites would be accessed more frequently and this varies considerably among the producers and is probably dependent on the quantity of stock the producer normally exports. During the harvesting season access varies from 1 to 6 times per week. Access to sites usually happens between half flood to half ebb where the tidal restriction is 3 hrs either side of high tide and for some sites the restriction is greater (1.5 hours before and after high tide). On existing renewals it is important to note that dredgers do not access sites at low water unless the site is a deep site such as in parts of Wexford Inner Harbour and along the main channel from the bridge down to the end of the training walls.

During harvesting and relaying the dredgers move slowly over the site. With dredges trailing about 30m behind which when full are winched in and the contents emptied into the hold. Dredges do not dig deep into the seabed but rather lift the mussels and up off the bed of the layer of pseudofaeces that the mussels sit on. Once in the hold mussels are moved up a conveyor belt through a washer and crabs/starfish are picked off along with stones/waste. The mussels are then directed by conveyor to one tonne bags hanging in the other part of the hold. Normally about 20Tonnes are harvested for a lorry going out to the continent. Unloading from the boat is either done by an onboard crane or using a crane on a lorry onto wooden pallets which are then loaded into a transport lorry.

Of the 8 companies and one sole trader that currently have renewal applications in place, there are 6 functioning dredgers within the harbour. They are the Edenvale, The Enterprise, The Hibernia, Cecelia, Laura Anne, Branding. The Ostrea is still moored on the quays but does not appear to be used. The number of meters of dredge per boat ranges from 7m to 14m with an average of 9m. All except one dredger have 4 dredges operated off the sides.

Production and Employment

There are currently 35 Full-time, 1 Part-time and 6 Casual jobs within the Wexford Bottom Mussel Industry. The companies involved in the harbour are either solely Irish owned or Dutch/Irish or Dutch owned. As mentioned there are 8 companies and one sole trader.

Table 10: Wexford Harbour Production History 1996-2013 (data provided by John Dennis BIM)

Years	Seed Input (T)	Production volume (tonnes)	Value (€)	Average price per ton (€)
2014	4260	_	_	_
2013	2050	1458	2,293,000	1572.702
2012	3185	2855	2,810,585	984.4431
2011	3311	4950	5,571,280	1125.511
2010	2283	5256	4,168,660	793.124
2009	5025	4546	3,685,700	810.7567
2008	3885	3324	4,090,015	1230.45
2007	5952	2213	3,255,485	1471.073
2006	2168	3433	6,592,615	1920.366
2005	3385	8316	7,480,350	899.513
2004	8180	6324	4,714,447	745.485
2003	7965	6222	4,701,855	755.6823
2002	8015	9246	6,854,850	741.3855
2001	11960	7501	3,747,866	499.6488
2000	6700	6854	2,935,800	428.3338
1999	6616	3675	_	_
1998	4630	4936	_	_
1997	4945	3563	_	_
1996	3710	3055	_	_

In general from a national viewpoint Wexford Harbour can produce anywhere from between 20-40% of the national production figure and is a stalwart of the national bottom mussel industry.

Industry Experience and Potential

Letts of course stand out with a mussel fishing/farming history of 115 years. N&A Scallan Mussel Suppliers have been in continuous operation since 1965. Wexford Mussels Ltd since 1969. Billy Gaynor farmed mussels on ground since 1979 and in the intervening years ground has exchanged ownership and the modern companies although relative newcomers (e.g. 2003) are working ground that has been worked since the early 1970's. So there are hundreds of years of company history invested in the mussel grounds of the harbour.

With the new applications one can see that there has been a shift towards other methodologies and species. The seed mussel settlement applications are ideally positioned in the north and south bays to potentially capture a percentage of the vast numbers of larvae that exit the harbour after spawning in Spring and sometimes Autumn. If it wasn't for the stock spawning in the harbour there would be very few seed beds on the East coast for the industry nationally to avail of. There definitely could be a role for locally sourced rope seed mussel to compliment the seed harvest from the east coast seed beds. Access to these applications would be concentrated in spring to late summer (in and around 100 days).

Oysters were brought into the harbour before in 1979 (both Ostrea Edulis and Crassostrea Gigas) and verbal accounts say they grew very rapidly. So there is the potential for good oyster production in the intertidal applications in the southern harbour. The southern harbour is high in food for shellfish although the currents are slack so an appropriate stocking density is important. Oyster farming in the harbour would be by boat access on fortnightly spring tides. It would be at low density due to slack currents in the southern section of the harbour to avoid sediment build up.

The intertidal/ very shallow water mussel farming in the southern harbour can potentially give those applicants (who either never had a dredger or had to sell out due to the cost of COC upgrades for their dredger) the chance to continue earning some income through mussel farming.

The UISCE project did show that channel areas further towards the mouth of the harbour would be productive so these areas could enhance production in the harbour if licenced.

It is important to emphasise again that as it stands at present none of the dredgers relay mussels onto intertidal areas of their licence. This is for two reasons. Firstly the mussel would grow slower intertidally and secondly relaying onto these areas would be very tricky due to a greatly reduced tidal window. However that does not mean that a licence shouldn't cover such areas because what is intertidal in one season might not be in the next season due to the very dynamic nature of the sediments in the harbour.

As an example the Stock Assessment from the UISCE project showed that there were 13241 Tonnes of seed relayed in 2006 and 2007 combined over 515 Ha giving an average stocking density of 25.7 T/Ha. This included UISCE project test seed on test sites. 515 Ha is about one third of the licenced ground that was available in those years. So it is important to highlight that not all of the licenced ground is ever relayed with mussels in any given year due to (1) intertidal zones and (2) the lack of seed that would be required to fill all subtidal licenced ground. One might argue why licence anymore if that is the case well the case could also be made that opening up new grounds in areas of good flow will maybe give a more uniform level of stocking across the bay. The current mussel seed allocations for the companies with their existing ground is 9210 Tonnes from the east coast seed beds.

If all the applications were granted with the renewals it is possible that another 15 Full-time, 9 part-time and 10 casual jobs could be created after several years of successful production. Additional production might be in the order of 1500 tons of mussels, 200-300 oysters and rope seed mussels in the order of 1600-2600 T some of which would be sold as seed and some relayed within the harbour.

Wildfowl Reserve

The slobs have been in existence since 1847-1853. Greenland white-fronted Geese were first recorded in the area around 1910 and numbers built up to several thousand in the 1940s Greenland White-fronted Geese are the most numerous and important goose species on the reserve. Numbers fell by the 1970s to around 5,000 birds but increased protection resulted in an increase to up to 10,000; one third of the world's population. Since 1999 there has been a slight decrease, accompanied by smaller broods of young birds. The decline may be due to climate change in Greenland; displacement from nesting sites by Canada Geese and pressures on migration routes. Numbers have only been large since the 1940's. Mussel farming in the harbour is by the vast majority unseen and unheard by birds in the Wildfowl Reserve. Even boats that operate on sites that are close to the reserve can be hardly be heard and only partially seen from the reserve. The closer the flocks go towards the seawall the more of an impossibility it becomes to see a dredger due to the height of the seawall. The reserve also has active farming taking place and also organised shooting events.

Seals

By all accounts the seal population in Wexford Harbour is blossoming very well. Mussel farming does not appear to be hampering their activities.

Environmental Services Provided by Mussel Farming in Wexford Harbour

Nitrogen, Phosphate and Carbon removal.

Mussels are a sink for Nitrogen, Phosphate and Carbon. Mussels contain 1.0%N by weight and 0.1%P by weight. The average tonnage of mussels harvested from Wexford Harbour between 1996-2014 was 4873 tons. So removing 4873 tons of mussels from Wexford Harbour annually is the equivalent of removing 48,730 Kg of N and 4873 Kg of P. In America the average person produces 5.44Kg N/year. So the annual harvest of mussels in Wexford harbour equates to the annual production of N from 8958 people (Americans). However a figure of 3.57kg of N per year is used in recent literature thus that would equate to the annual production of N from 13650 people (untreated). Wexford Town has 19,913 people as of the 2011 census. The cost of removing N from sewage has been estimated to be anywhere between 13 to 300 $ per kg of N removal. So 48730 kg of N removal equates to a removal cost of between 633490 – 14619000 $. Removal of phosphate from wastewater is even more expensive (about 10 times more) than N removal and mussels are about 0.1% Phosphate by weight. So 4873 Kg of phosphate is removed annually from Wexford Harbour through mussel harvesting and the cost of removing this would equate to the cost of removing the N removed through mussel harvesting annually. Apart from the cost of this service the mussel stock in the Harbour are controlling phytoplankton blooms by preventing algal cell counts reaching environmentally detrimental levels. The role of mussel farms in protecting Wexford Harbour from eutrophication should not be underestimated. Carbon sequestering is also a service provided by shellfish. In an era when agriculture is seeking to expand yet reduce carbon emissions already the idea of shellfish farmers selling carbon credits is being talked about.

Benthic-Pelagic Coupling

Unassimilated food from mussels is deposited to the bottom and is food for deposit feeders such as worms and crustaceans that are food in turn for fish. Increased biodeposition in turn leads to increased bacterial denitrification in which nitrate and ammonia are transformed into harmless nitrogen gas. There is the possibility that N removal via this pathway could dwarf that removed in mussels directly.

Water filtration

Mussels will remove viruses, bacteria and silt. They improve the clarity of water and thus light transmission to submerged aquatic vegetation and sea grasses. They improve the microbiological quality of the water body.

Increased biodiversity

The physical structure of mussel beds themselves can provide a habitat for other small species which in turn can be eaten by fish.

Social Cohesion and Economic Activity.

Coastal dwelling humans are an endangered species also in Ireland and one cannot discount the very positive affect mussel farming has to the economy of the area and the employment and social cohesion it provides in areas that would otherwise be quite depressed economically.

Increased monitoring and environmental awareness

The mussels are produced within a classified Shellfish Designated water body and as such are subject to strict monitoring to very high standards. Being designated means that there is an onus on the County and Town Councils(now Irish Water) to develop a pollution reduction programme and also maintain/ enhance the water quality within the designated area. Mussel farmers who have a lot invested in their stock are usually the first to alert the relevant authority of pollution problems and incidents and as such are highly motivated and present guardians of water quality.

For the reasons above some researchers have argued that shellfish aquaculture in coastal waters is of significant ecological importance in efforts for mitigating the effects of coastal development and human induced increases in nutrient loading (Folke and Kautsky 1989, Ulanowicz and Tuttle 1992, Rice 2000).

Acknowledgements

A special thanks to Mr Desmond Lett (Lett and Company Limited) and Mr Sean Ryan (Wexford Mussels Limited) who both made major contributions to the historical aspects of mussel farming in Wexford Harbour. Thank you also to all the existing producers and applicants who took the time to answer all the questions that were put to them and which fed into the Appropriate Assessment.

Appendix 5

Draft Fishery Natura Plan

Irish Sea Seed Mussel Fishery

***for the years* 2023-2027**

Date of submission of the amended FNP: 11/05/2023

Table of Contents

1.0 Legal Basis

The Irish Sea, Seed mussel fishery occurs in areas designated as both Special Areas of Conservation (SAC's) and Special Protected Areas (SPA's). This draft Fisheries Natura plan relates exclusively to mussel seed fishing in the area over the five-year period 2023-2027, subsequent husbandry practices are considered in bay specific assessments.

The Minister for Agriculture, Food, and the Marine, as a public authority under regulation twenty-seven of the European Communities (Birds and Natural Habitats) Regulations 2011 (SI 477 of 2011), must exercise his functions so as to ensure compliance with the requirements of the Habitats Directive, the Birds Directive and the 2011 Regulations.

The European Union (Birds and Natural Habitats) (Sea-Fisheries) Regulations 2013 (SI 290 of 2013) as amended provide for the submission of a draft fisheries Natura plan and the appropriate assessment of a plan to identify where sea-fisheries may be allowed to proceed within appropriate guidelines to address risks to protected species and habitats (Regulation 5 assessment) to enable the fulfilment of the Minister's obligations.

The Minister for Agriculture, Food and the Marine also must exercise his functions so as to ensure compliance with the requirements of the Common Fisheries Policy (Regulation (EU) No. 1380/2013), with an emphasis on the article 2 objectives of aiming for the environmental sustainability of fisheries in the long term and applying the precautionary approach to fisheries management.

The plan was drafted by the Secretariat of the Bottom Grown Mussel Consultative Forum (BGMCF) in consultation with Bord Iascaigh Mhara (BIM), and industry members of the Bottom Grown Mussel Consultative Forum (persons affected by the designation).

The draft plan covers fishing in the period 1st January 2023 to 31st December 2027.

2.0 Rationale for Mitigation

The potential generic ecological effects on the qualifying interests of the site relate to the physical and biological effects of dredging shellfish species which overlap with invertebrate communities found in inter-tidal and sub-tidal.

Bird populations may also be affected by these habitat changes and by disturbance caused by fishing vessels and by changes in the availability of prey species as a result of changes in habitat brought about by shellfish production.

Using the mussel seed sustainably, to ensure a continuing and prosperous fishery, is in line with Government and EU policy.

3.0 Seed Mussel Fisheries

3.1 Introduction

In the context of this plan "Seed fishing" refers to the sub-tidal and inter-tidal collection of mussels for relaying on aquaculture sites, seed mussel is not suitable for direct human consumption. The plan covers all areas of suitable substrate for seed mussel fishing within the protected sites under consideration.

The Irish Sea blue mussel seed fishery has been exploited since the late 1960's, when the Irish Sea Fisheries Board (BIM) provided support to what was considered a sustainable opportunity for the development of bottom growing culture of seed mussel that was re-located to inshore, protected environments where yield would be improved compared to the wild fishery.

The bottom grown mussel industry relies on a consistent settlement of mussel spat to provide seed which is then relayed and on-grown on sheltered inshore and licenced beds. Settlement of mussel seed varies (volume, location & exact time of settlement) annually (Figures 1,2,3). Furthermore, identifying the locations of mussel settlement in the southern Irish Sea is particularly challenging and all beds are not formally identified in advance of fishing

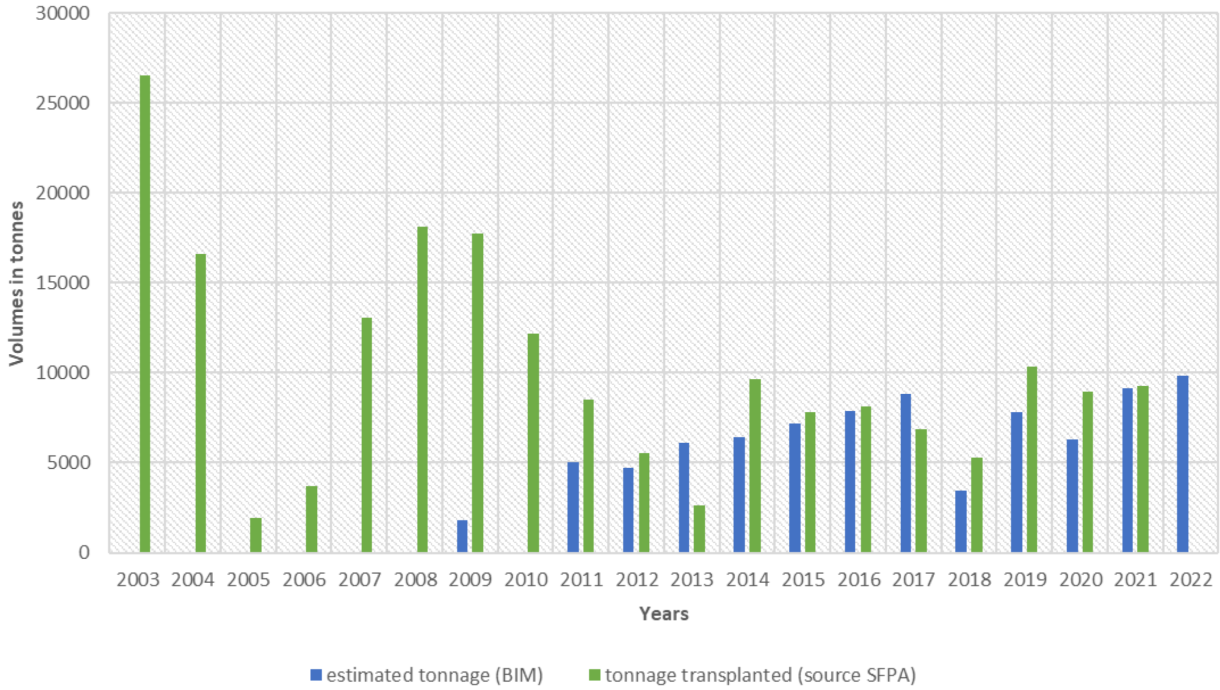


Figure 1- Estimated and Transplanted Subtidal Seed Mussel in the Irish Sea 2003 to 2021

There are two types of natural mussel beds, a 'permanent or stable mussel bed' which receives regular (or periodic) spat settlement, and thus contains mussels from a range of age classes; and the second is a 'seed mussel' bed – an area in which there is periodic settlement of spat, which may survive a few months or until the following winter but which is then frequently lost or dispersed by winter storms (highly energetic) or predators. As the relayed stocks spawn prior to harvest relayed mussels continue to contribute to the spawning stock within the Irish Sea post fishing.

The exploitation of these two types of seed beds will have different consequences for the overall mussel population, because while permanent beds can be expected to be a source of larvae, seed mussel beds will not produce large volumes of larvae, since mussel mortality in these beds is very high before mussels reach reproductive maturity[1]. It is thus preferable to exploit these seed beds, rather than permanent mussel beds.

BIM have been undertaking sub-tidal seed surveys in the Irish Sea since the 1970's. The historical surveys are the best source of available scientific information on the nature and extent of seed beds in the Irish Sea, these records were examined to assess the assertions that stable "overwintering" beds exist in this area. The data indicates that while seed beds do sometimes overwinter, no currently identified beds consistently overwinter in all years and therefore no currently identified beds can be described as "permanent or stable."

The absence of "permanent" beds is thought to be due to the highly energetic nature of the Irish Sea when compared with the location of stable beds elsewhere in Europe where they occur in much more sheltered locations, and the level of starfish predation. Also, literature indicates that the longevity of sub-tidal mussel beds in relatively sheltered water is 2.3 years[2].

Given the dynamic nature of the environment and the type of dredge used, repeated seed surveys of the Irish Sea have found that seed fishing leaves no permanent tracks on the areas fished. And repeated settlements on the same ground as shown in figures 2 and 3 shows fishing activity does not prevent settlement of seed in the same area in the following years.

3.2 Spatial Extent

Mussel fishing activity occurs in or adjacent to the following SAC's, but the spatial extent is severely limited by substrate type.

- Long Bank SAC
- Blackwater Bank SAC
- Wicklow Reef SAC
- Rockabill to Dalkey Island SAC
- The Murrough Wetlands SAC
- Carnsore Point SAC
- Wicklow Head SPA
- Howth Head Coast SPA,
- Malahide Estuary SPA
- Dundalk Bay SPA
- Skerries Islands SPA
- Lambay Island SPA
- Ireland's Eye SPA
- North Bull Island SPA
- Dalkey Island SPA
- Rockabill SPA

[1] Maguire, J A., Knights, T., Burnell, G., Crowe, T., O'Beirn, F., McGrath, D., Ferns, M., McDonough, N., McQuaid, N., O'Connor, B., Doyle, R., Newell, C., Seed, R., Small, A., O'Carroll, T., Watson, L ., Dennis, J., and O'Cinneide, M., 2007. 'Management Recommendations for the sustainable exploitation of mussel seed in the Irish Sea.'
Marine Environment and Health Series. 3.1.

[2] Troost, K., van der Meer, J., & van Stralen, M. (2022). The longevity of subtidal mussel beds in the Dutch Wadden Sea. Journal of Sea Research, 181(May 2021), 102174. https://doi.org/10.1016/j.seares.2022.102174

- The Murroughs SPA
- Raven SPA

Mussel seed is targeted in areas of sands, muds, coarse sands, and mixed bivalve shell. In sandbank areas dredging does not occur on the tops or slopes of the banks as seed mussel is not found in these areas and the gear is not effective on such grounds. Mobile gear cannot be deployed in rocky or reef areas therefore these areas are not targeted.

Seed may occur in other areas of suitable substrate during the 5-year period covered by this plan. In addition to the mapped areas below seed has been documented as occurring on suitable inter-tidal substrates in the Rockabill to Dalkey Island SAC at Howth, Lambay and Skerries and at Dunany point immediately adjacent to the Dundalk Bay SPA

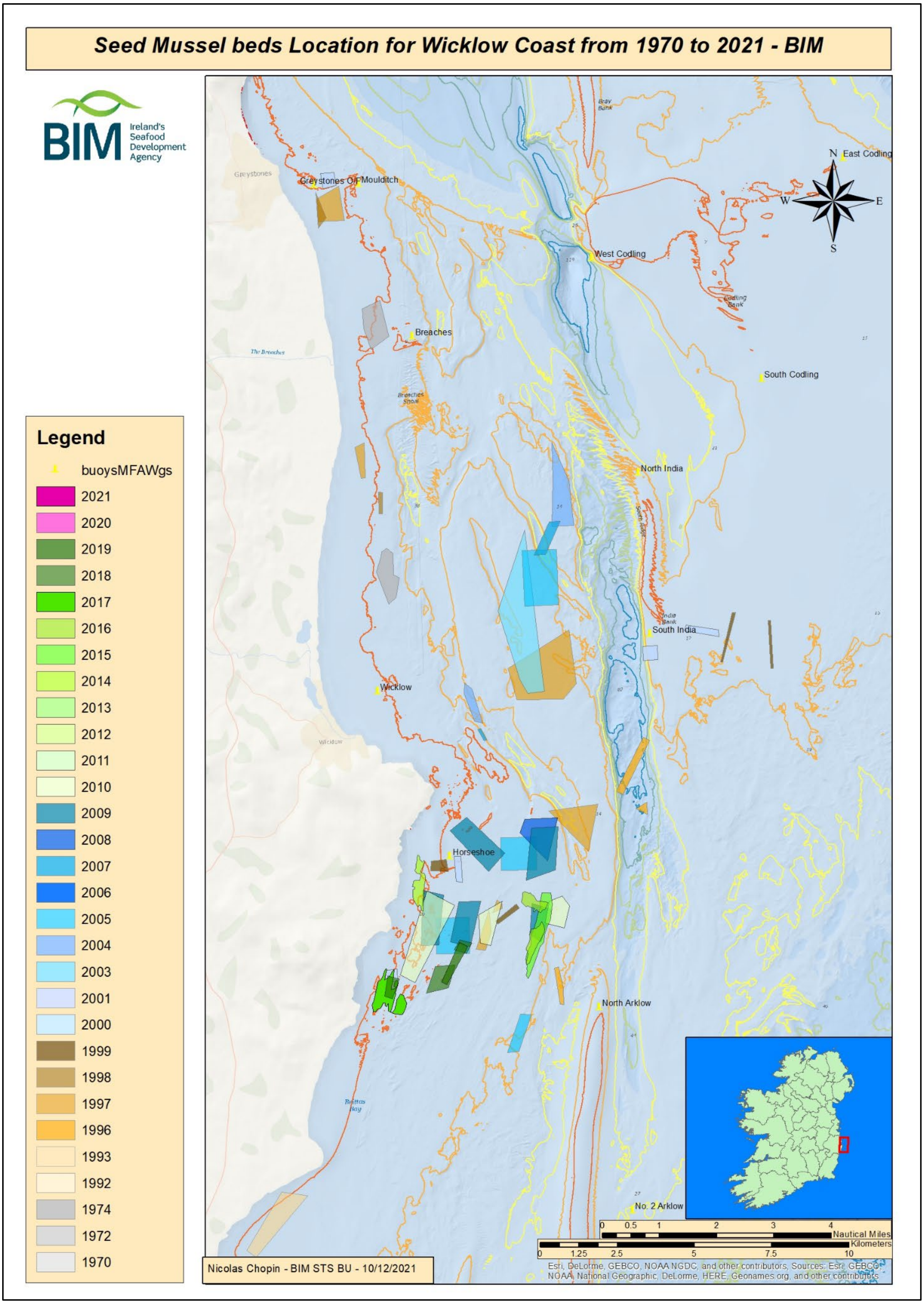


Figure 2 Historical spatial extent of seed fishing areas southern Irish Sea 1970-2021

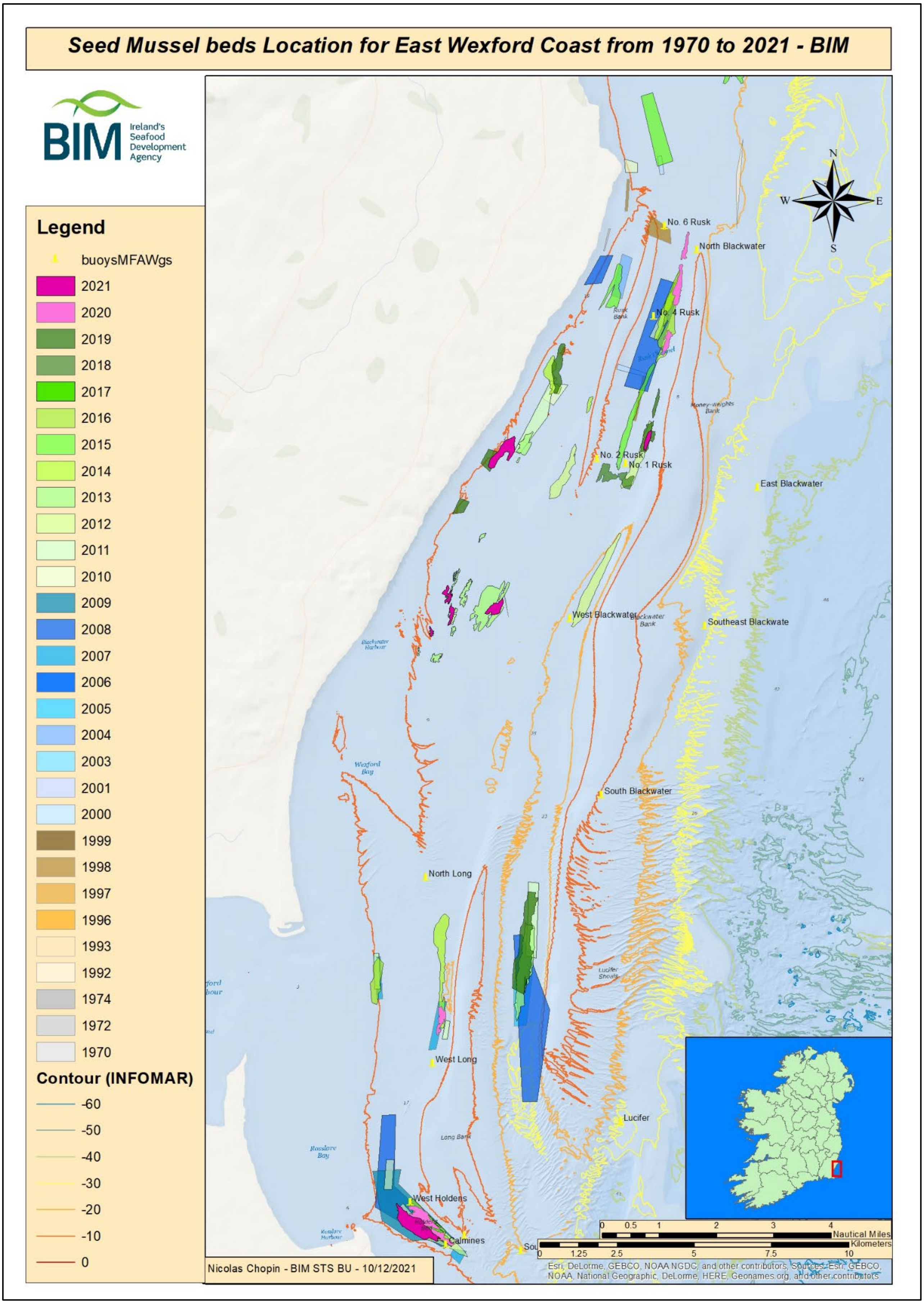


Figure 3 Spatial extent of seed fishing areas southern Irish Sea 1970-2021

3.3 Temporal Extent

Fishing takes place on suitable neap tides (<7m as predicted in the Llanelli tide tables) subject to seed availability, allocation, and suitable weather conditions. Suitable tides will be agreed at the fist meeting of the BGMCF in the calendar year. Fishing generally takes place in the early spring (2 tides) and autumn (August to December) subject to seed availability. Also, a force majeure clause may be initiated, and a request made to the Minister through the Bottom Grown Mussel Consultative Forum to have the area opened outside these periods, if the bed is subject to high predation pressure.

Maximum permitted fishing days in a given year is seventy and fishing is only conducted from 6.00 to 18.00.

Fishery Profile	2017	2018	2019	2020	2021
Total Seed fished (Net)	6851	5286	10345	8921	9270
Days fished	21	15	21	20	16
Vessels	23	16	21	21	18

Table 1 – Seed fishing statistics (tonnes) NI and ROI waters 2017-2021

3.4 Vessel Numbers

The number of permitted vessels in a given year is at a maximum level of thirtyfive however not all vessels participate every year – Please see Table 1 above.

Dredging of mussel seed by Irish registered vessels and reseeding of the seed for the purposes of on growing within the exclusive fishery limits of IE may take place only on issue of a licence under the Mussel Seed (Conservation of Stocks) Order 1987, (S.I. No. 118 of 1987) as amended by the Mussel Seed (Conservation and Rational Exploitation) Order 2003 (S.I. No. 241 of 2003). Fishing outside the baseline is permitted by NI registered fishing vessels which have a proven economic link to Northern Ireland, and which hold a seed fishing authorization issued by DAERA. Northern Irish vessels may not fish within the baseline."

3.5 Gear Type

Seed Surveys

Seed surveys seek to identify seed areas in advance of the fishing season. Seed may not be fished outside the permitted tides and all surveys conducted by industry members must be notified in advance to the SFPA. If seed is found this is also reported to the SFPA.

Surveys are conducted by industry members using ground discrimination software onboard the vessels and commercial fishing equipment to "ground truth" results. Surveys are generally conducted on 1-2 available tides in advance of the defined opening periods in May and August. Surveys will only be conducted in areas of suitable substrate.

BIM surveys are conducted from May to September (inclusive) and are divided into three steps. The first step consists of surveying previously known beds to assess potential remaining stock following the winter or recently settled spat. This survey yields acoustically generated imagery from a side scan sonar system which identifies relevant features which are then ground-truthed using a 1 meter dredge. The second step consists of estimating the available seed mussel biomass. The extent of the settlement is mapped using acoustic imagery analysed on GIS. Random sampling points (approximately forty per bed) are generated within the bed and samples are collected using a Day grab with a $0.1m^2$ footprint. Position and weight of mussel per grab is recorded and a density map is produced using IDW interpolation[3]. Estimated biomass is then calculated, providing the extent of the

[3] Hervas, A., Tully, O., Hickey, J., Keeffe, E. O., & Kelly, E. (2008). *Assessment, Monitoring and Management of the*

bed in hectares and an estimated tonnage for the area. The final step consists of carrying out a post fishery assessment using the methodology detailed above. Seed survey reports are published on the BIM website as they become available.

Given the large areas of the potential fishery and the ephemeral nature of the resource, not all beds are identified by a formal survey in advance of fishing. Beds may be discovered and exploited during the fishing season by industry members, however all seed fishing locations are reported via logbook and SMS returns as per the management measures discussed in section 4.0 below.

Harvesting

Mussels are harvested by industry members in compliance with the management measures presented in section 4.0 below. Mussel seed fishing is conducted using a variety of equipment types. By far the most commonly used dredge is the modified Dutch design.

Depending on size, vessels deploy four dredges at a time. The dredge is composed of a fixed bar (of between 2 and 4 meters in length, the bar is round and without teeth) and a frame with a net bag attached, which is 2-3 meters in length to retain the seed mussel catches. The dredge is designed to skim the surface of the substrate and separate mussels from the underlying sediment. This mud bar in effect 'peels' the overlying seed mussel 'mat' away from the underlying substrate and in doing so removes the mussel seed which is caught in a bag which follows the bar.

The bottom part of the bag is a made up of either a chain link matrix or a nylon mesh. The upper part is made of nylon mesh. In the case where a chain link matrix is used on the lower part of the bag it is common practice for a rubber mat or rope dollies (bits of chafed ropes) to be attached to the belly of the dredge to minimize disturbance of the substrate. The dredge is towed with a steel cable. The length of this cable during fishing operations is usually three times the water column depth, although this varies according to the speed of the current and the seed mussel bed type.

Historically hand raking of seed is also conducted along the Louth and North Dublin Coast (See Section 3.2)

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*Dundalk Bay and Waterford Estuary Cockle (*Cerastoderma edule*) Fisheries in 2007. Fisheries Resource Series* (Vol. 7).

4.0 Management Measures

The fishing of seed mussel and the operation of mussel dredgers is controlled primarily by the following legislation: the Sea-Fisheries and Maritime Jurisdiction Act 2006 (No 8 of 2006); the Mussel Seed (Fishing) Regulations 2006 (S.I. No. 311 of 2006); the Molluscan Shellfish (Conservation of Stocks) Regulations 2006 (S.I. No. 345 of 2006); the European Communities (Health of Aquaculture Animals and Products) Regulations 2008 (S.I. No. 261 of 2008); the European Communities (Natural Habitats and Birds) (Sea-fisheries) Regulations 2013 (S.I. No. 290 of 2013).

Working from this legislative base and from a fishery conservation point of view, and in the interests of minimising any possible adverse environmental impact, the following are the general terms and conditions that will apply to all vessels involved in the sub-tidal fishery in the areas under assessment 2023-2027;

- Surveys will be conducted by BIM and by industry members following notification to the SFPA. In conjunction with industry members and BIM, the BGMCF advises the Department on decisions to open or close seed mussel beds on conservation grounds, i.e., if the seed is too small or fragile to transport. Mortality of seed would prevent the relayed stock contributing to the spawning stock in the Irish Sea.

- All vessels participating in the fishery will hold a Mussel Seed Authorisation particular to that vessel. The vessel must have the correct authorisations and licences on board at all times of operation.

- Prior to the issuing of seed allocations, hull markings and tracking systems will be certified by an authorised officer. All vessels will have each side of the stowage hold marked in 0.5m segments from the bottom to the top; 0m being the bottom or floor of the hold to facilitate estimation of catches on-board.

- Operators will nominate for the Department's approval which vessels will be fishing the seed allocation on their behalf. The vessels will be registered and licensed to fish mussel seed and the authorisations to fish and move seed are linked to the aquaculture operators.

- Mussel vessels over 15m in length are required to have the EU Vessel Monitoring System ('Blue box'). This system allows the vessels to be monitored and tracked on a more continuous basis and allows detailed tracks and locations to be recorded

- Reg 1224/2009, article 10, requires that all vessels exceeding fifteen meters shall be fitted with and maintain in operation AIS. This is an autonomous and continuous vessel identification and monitoring system used for maritime safety and security which allows vessels to electronically exchange with other nearby ships and authorities ashore the vessel identification data, position, course, and speed.

- Member States may use AIS data for monitoring and control purposes.

- All vessels fishing seed mussels will maintain EU logbooks as required.

- The seed fishing authorisation further requires that "In addition to the requirement to keep the EU fishing logbook, the master of the authorised boat shall keep and record all catch in a mussel spat book, which shall be submitted to a sea-fisheries protection officer at the end of each tide, or on request."

- In line with SI311/2006 the master of a vessel must "inform a sea-fisheries protection officer at least 4 hours in advance of his or her intention to fish for mussel seed and give the officer the name of the holder of the authorisation on whose behalf he or she intends to fish".

- The authorization states also requires that the “1The Master of the authorised boat or his agent shall give to the Fisheries Monitoring Centre not less than 4 hours’ notice of his intention to transplant mussel seed” and that “A sea-fisheries protection officer may direct that the authorised boat proceed to a specified port for inspection prior to mussel seed being transplanted on any licensed aquaculture site”.

- The authorisation holder shall send a record on each day of fishing via SMS to 0035387 9885116 in the format: The name of the authorised boat; The source of the seed; The destination of the seed, including aquaculture licence number and bay; Gross tonnage; Net tonnage; the number of the Mussel Seed Authorisation”

- Operators recognise that under the Health of Aquaculture Animals, S.I. No. 261 of 2008 European Communities (Health of Aquaculture Animals and Products) Regulations 2008, that authorized officers have the authority to prevent the movement of animals if they feel there will be unresolved increases in mortality.

- Fishing will only be taken place between the hours of 06.00 and 18.00

- Fishing will only take place on defined tides

Appendix 6

DCU
Ollscoil Chathair
Bhaile Átha Cliath
Dublin City University

DCU Water Institute

WaterBlitz 2022 Report

FRESHWATER Watch
earthwatch

Comhairle Cathrach
Bhaile Átha Cliath
Dublin City Council

Local Authority Waters Programme
vibrant communities | catchment assessment | healthy waters

SMART DUBLIN

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Cover photo: Castle Lake, Bailieborough,
Co. Cavan - Friends of Castle Lake

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Price: Free

Dear Citizen Scientists,

We would like to thank you for your participation in the 2022 WaterBlitz!

The WaterBlitz is a co-created research project between DCU Water Institute and Citizen Scientists in Ireland in partnership with Earthwatch Europe. The aim of this long-term project is to investigate how public engagement can facilitate water restoration.

This year has seen the largest WaterBlitz yet with over 700 participants and 697 samples taken across Ireland.

We have analysed the data from samples you have collected and we are very happy to share the findings in this report.

Your contribution has helped us build an important picture of the condition of Ireland's water bodies, in particular those that are never monitored. Your valuable effort provides data that can inform how this important resource can be protected into the future.

Prof Fiona Regan,
Water Institute Director

Kilmastulla river, Silvermines, Co. Tipperary - John O'Sullivan

2022 WaterBlitz Key Findings

Ireland's largest WaterBlitz took place in **2022**

108 community and water interest groups took part nationally

Freshwater samples tested in all **26** counties

73% of participants believe they have the power to improve or maintain good water quality through citizen science

70% of participants feel their contribution can help build greater understanding of water quality in Ireland

The Facts

697
samples taken

720
participants over 4 days

40
of 46 EPA river catchments nationwide sampled

Who participated?

23 river/lake groups

13 environmental groups

20 Group Water Schemes

16 Tidy Towns groups

8 community groups

16 schools (8 primary, 7 post primary and one 3rd level)

6 swimming groups

4 kayaking/ paddle boarding groups

1 angling group

1 sub aqua group

What types of waterbodies were sampled?

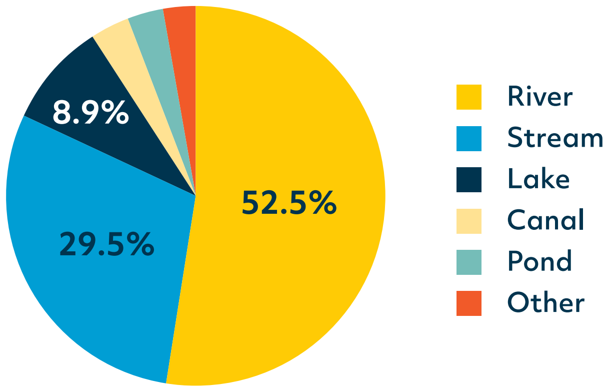


Figure 1. Variety and predominance of waterbody types sampled during the 2022 WaterBlitz. 'Other' includes springs, wells, wetlands and ditches.

What did we measure and why?

In this project we invited citizen scientists to use a simple tool to measure nitrate and phosphate levels in freshwater. Locations were chosen by the citizen scientists to determine if waterbodies are impacted by the presence of these nutrients. These measurements provided a snapshot in time of the water quality in the waterbodies sampled. These waterbodies drain a catchment, and so the measurements within the waterbody are affected by what is happening higher up within the catchment itself.

Water pollution can come from several sources within the catchment. Phosphates and nitrates can have different pathways to get to our water courses. When we fertilise our farmland, we put these plant nutrients of phosphates and nitrates onto the land surface. Phosphates tend to accumulate at the top of the soil, and so can be easily washed into streams and rivers by surface runoff. In some cases, high phosphates can also indicate the presence of domestic sewage. Nitrates are easily picked up by water as it moves through the soil, and so nitrates tend to find their way into rivers, lakes and streams through baseflow contributed by groundwater. Where nutrients are found to be present in freshwater in large amounts, 'eutrophication' can occur leading to an increase in the presence of algae and a reduction in the amount of oxygen in the water available for aquatic species.

While monitoring water quality, participants also noted the land use in the vicinity of the sampling site. Land use can have a direct effect on local waterbodies; for example where there is increased urbanisation (which increases surface runoff), agricultural activity (which may involve fertiliser use on the land), or diverse habitats along a river bank which can filter nutrients. Therefore land use can be helpful as an indicator of what the potential pathway for the nutrient might have been.

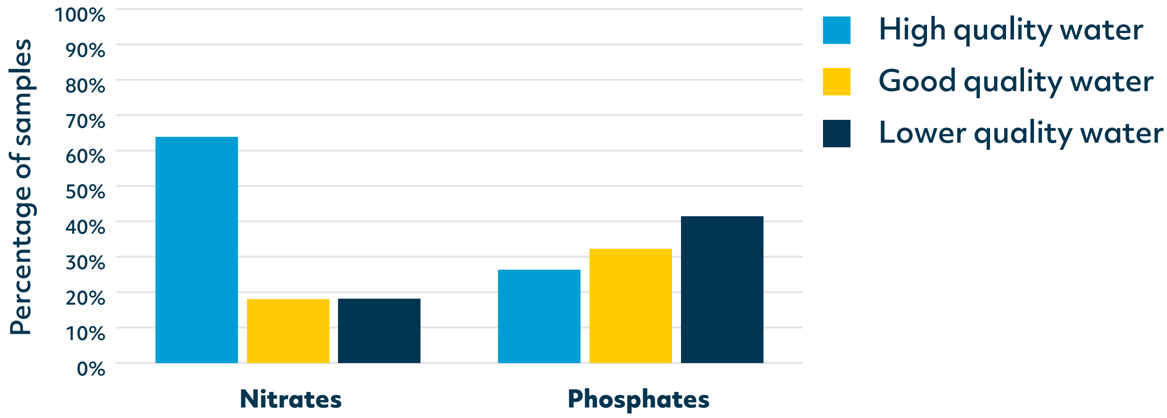


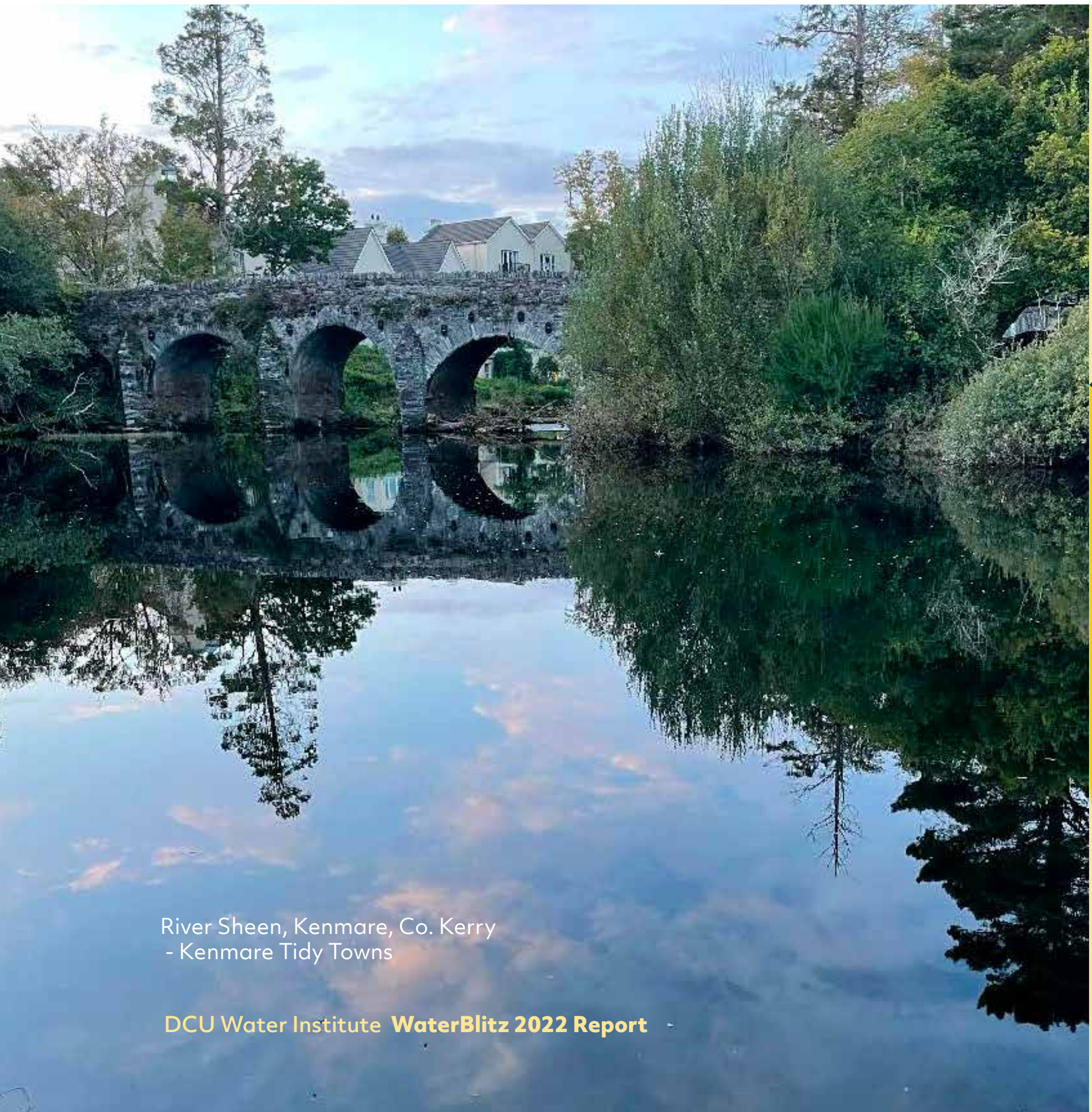
Figure 2. Levels of nitrates and phosphates recorded during the 2022 WaterBlitz.

The categories used for high, good and lower quality water are based on the criteria used by the EPA for categorising these nutrient levels. For nitrates (measured as nitrate-nitrogen), high quality is <0.9 mg/l NO3-N, good quality is <1.8 mg/l NO3-N, and lower quality is >1.8 mg/l NO3-N. For phosphates (measured as orthophosphate as phosphorous) high quality is <0.025 mg/l PO4-P, good quality is <0.035 mg/l PO4-P, and lower quality is >0.035 mg/l PO4-P. How this translates to the ranges used by Freshwater Watch is shown in the table below.

Table 1: Ranges used for graphs in this report.

	Lower quality water	Good quality water	High quality water
Phosphates (PO4-P, mg/l)	0.05–0.1 0.1–0.2 0.2–0.5 0.5–1	0.02–0.05	0–0.02
Nitrates (NO3-N, mg/l)	2–5 5–10	1–2	0–0.2 0.2–0.5 0.5–1.0

DCU Water Institute has carried out analytical validation in the laboratory of the kits by citizen scientists to ensure that the kits used record the nutrient values accurately. After data collection, we have cleaned the data, to ensure that the sample is plotting where you report that you have taken the test, and to check for any other anomalies in the data.



River Sheen, Kenmare, Co. Kerry
- Kenmare Tidy Towns

What does the data say?

From the data you gathered it was found that 82% of all waterbodies had high or good quality water when tested for nitrates, while this figure for phosphates was 59%. Ireland is committed to the Water Framework Directive, which requires us to have a minimum of 'good water quality' in all of our water resources by 2027.

1 in 10 sample locations recorded water quality of less than good. These were mostly in the southeast and south, with 51% of these being within counties Dublin and Cork. Many of the samples that recorded poor water quality were taken along multiple points of the same water body. For example, 6 samples which recorded poor quality of water were taken along the Delvin river in Dublin, while 4 samples with poor water quality were taken along the Tramore river in Cork, as it passes through an industrial estate south of the city.

From this work, we can see that there are still a lot of water bodies to protect and restore. Having local communities involved in monitoring and protecting their freshwater bodies is a key part of the Water Framework Directive.

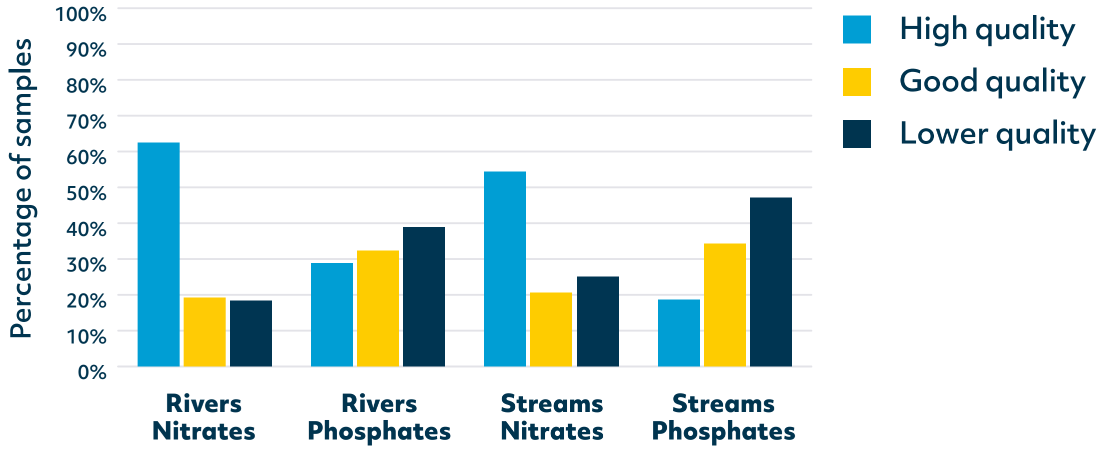


Figure 3. Levels of nitrates and phosphates recorded in rivers and streams in the 2022 WaterBlitz.

Participants were asked to record the freshwater body type from which they took the sample. The decision to mark a waterbody as a stream or a river was left to the discretion of the citizen scientist. We have not altered categorisation of the waterbody type for this report, as the local citizen scientist will have recorded what they deemed was most appropriate.

Ticket Office at Royal Canal, Ballymahon, Co. Longford - Herbert Farrell

At waterbody level, **18% of river samples had high levels of nitrates indicative of lower water quality, while 39% of samples taken at rivers had levels of phosphates indicative of lower quality water**. Because natural waters contain very low background levels of phosphates, any rise in phosphates can make a big difference and may cause increased algae growth. The higher levels of nutrients, and particularly phosphates, across the country is a cause for concern. In the most recent EPA report on water quality in Ireland, they identify a trend of increasing phosphate levels particularly in the south of Ireland.

Meanwhile, **25% of streams tested for nitrates, and 47% tested for phosphates also had lower quality water**.

What type of landuse did you see?

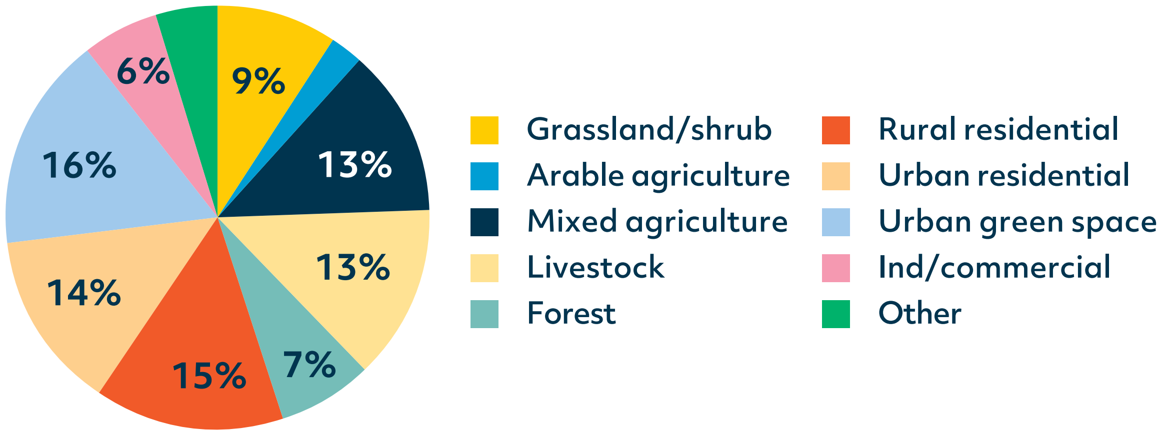
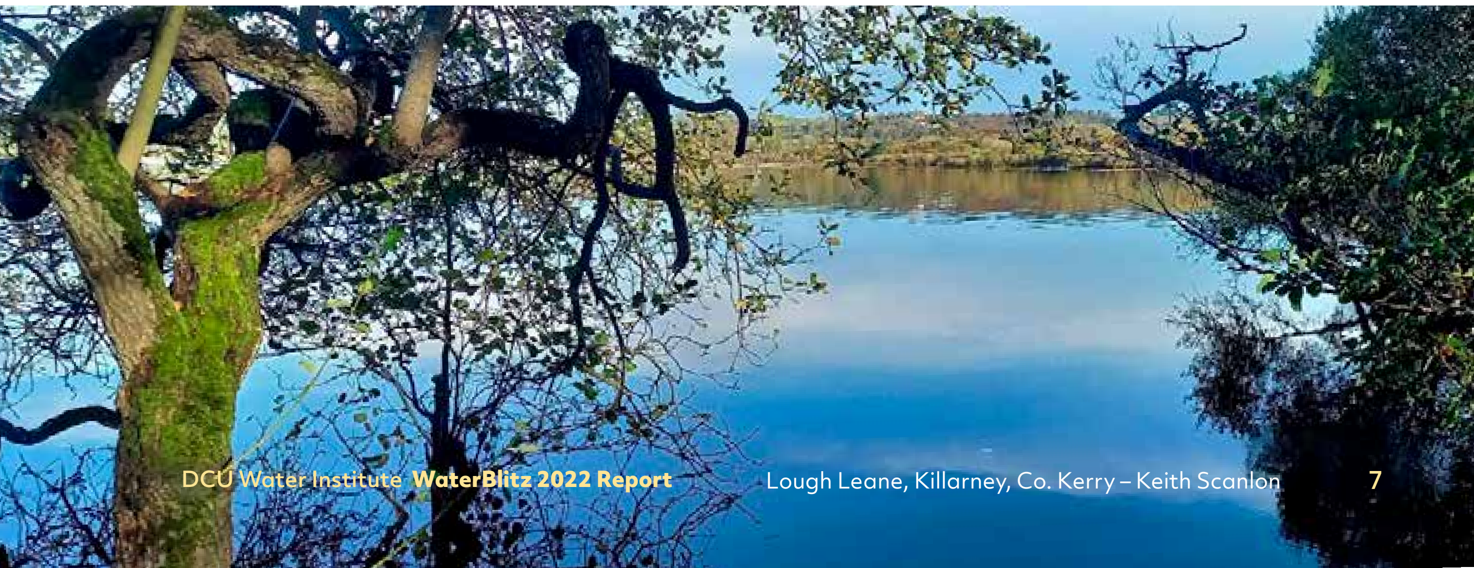


Figure 4. Land use recorded at sampling locations during the 2022 WaterBlitz.

Land use may influence nutrient occurrence. For the 2022 WaterBlitz, additional land use categories were introduced, such as rural residential and different types of agriculture – mixed, livestock and arable. It was found that 81% of waterbodies in agricultural locations (28% of sampling points) had high or good quality water when tested for nitrates, with 19% lower quality. Phosphate tests indicated just 50% of locations had high or good quality water, while 50% had lower quality water.

Urban green spaces and urban residential areas comprised 30% of sampling locations. Nitrate tests at these locations showed that 60% had high quality water while 20% had lower quality water. Testing for phosphates indicated that just 20% had high quality water while 38% also had lower quality water.



Lough Leane, Killarney, Co. Kerry – Keith Scanlon

Catchments Map

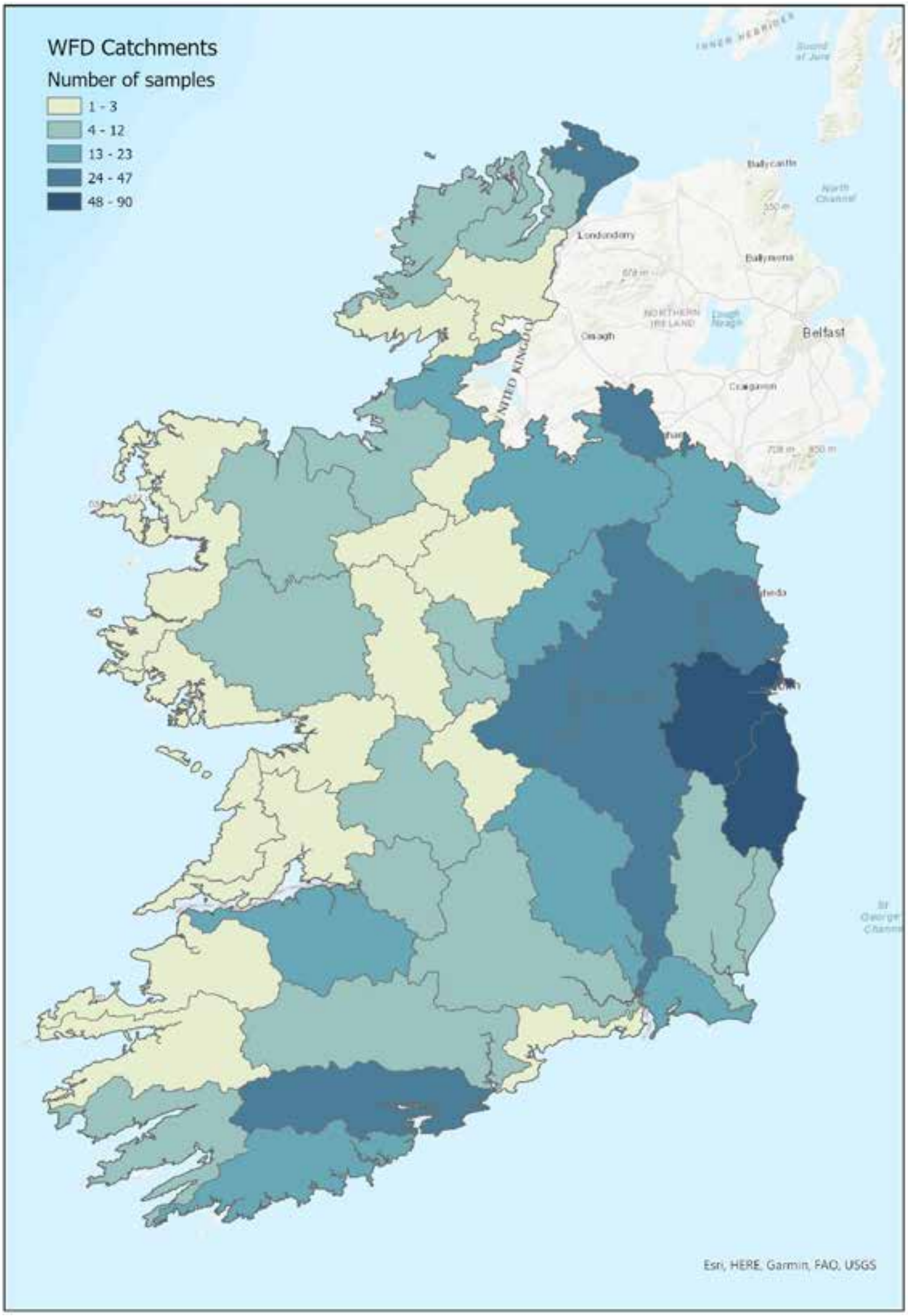


Figure 5. Number of WaterBlitz 2022 sampling sites within Water Framework Directive river catchments

The intensity of sampling during the WaterBlitz in catchments in the Greater Dublin Area and into the Barrow, the Upper Shannon, and the Lower Bann catchment, as well as the Lee and Bandon catchments in the south, will allow for greater analysis of the water quality in these catchments. The higher sampling rates in these catchments is also indicative of the number of community groups within these catchments that got involved in the WaterBlitz.

Nitrate Findings

Figure 6 below shows the ranges of nitrates measured over the course of the weekend of the WaterBlitz. Nitrate levels are higher in the southeast, where more intensive agriculture is practiced, and close to some urban areas – in particular Cork city and around Drogheda. Some of these areas are shown in Figure 7. In instances such as the river Lee, there is an increase in nitrate levels (and therefore a decrease in water quality) as the river approaches Cork city. The same can be observed as the river Delvin approaches Balbriggan in north county Dublin. In contrast to these areas, samples taken from freshwater sources on the Inishowen Peninsula in county Donegal show lower levels of nitrates. Over the coming months, this data will be further analysed.

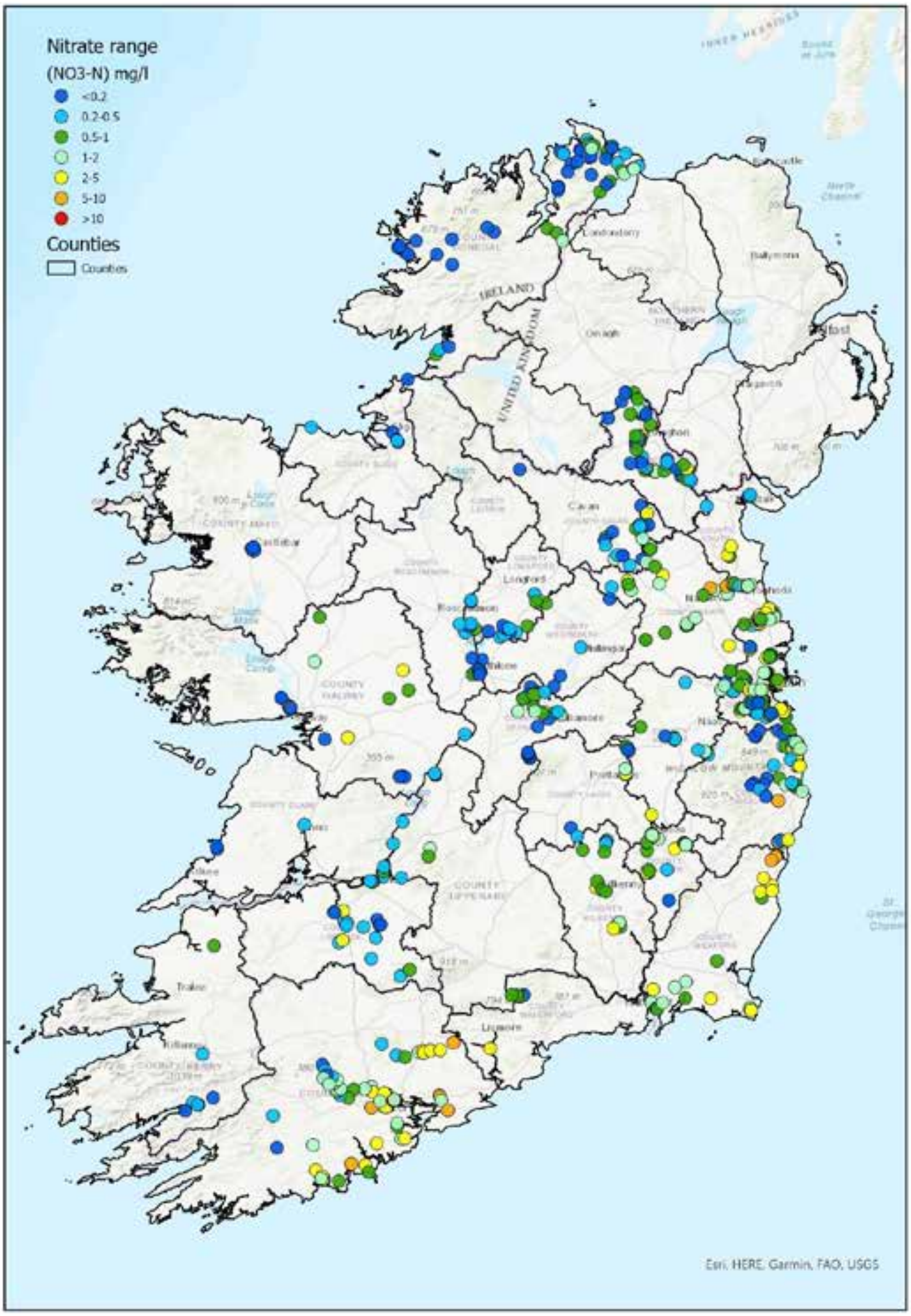


Figure 6. Nitrate ranges recorded across the country during the 2022 WaterBlitz

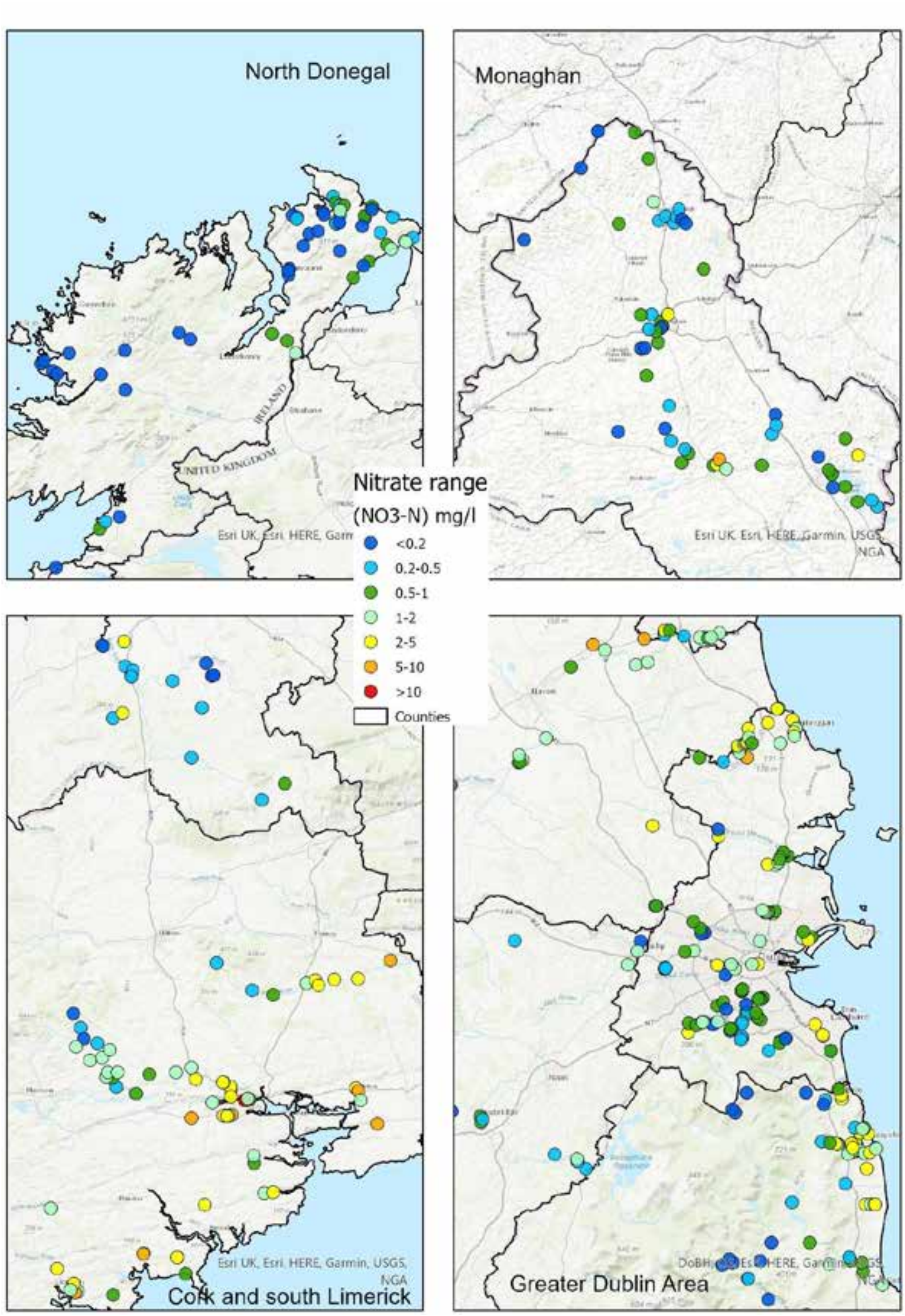


Figure 7. Closer look at nitrate ranges of samples at different locations during the Waterblitz.

Phosphate Findings

Levels of phosphate are seen in figures 8 and 9, and in many areas show a similar geography to nitrate levels. It is worthwhile pointing out that, as mentioned above, small changes in phosphate have a greater effect on algae growth. Therefore, any phosphate ranges greater than 0.05-0.1 mg/l PO4-P are indicative of lower quality water. Very high concentrations of phosphates were also recorded in Wexford, at Aughboy. This river has been identified as having high phosphate levels by the EPA.

The importance of your work can also be seen on the Delvin river, particularly where it flows through the Naul in north county Dublin, where high concentrations of phosphates were also recorded. These areas will be the focus of further research and analysis by the DCU Water Institute team.

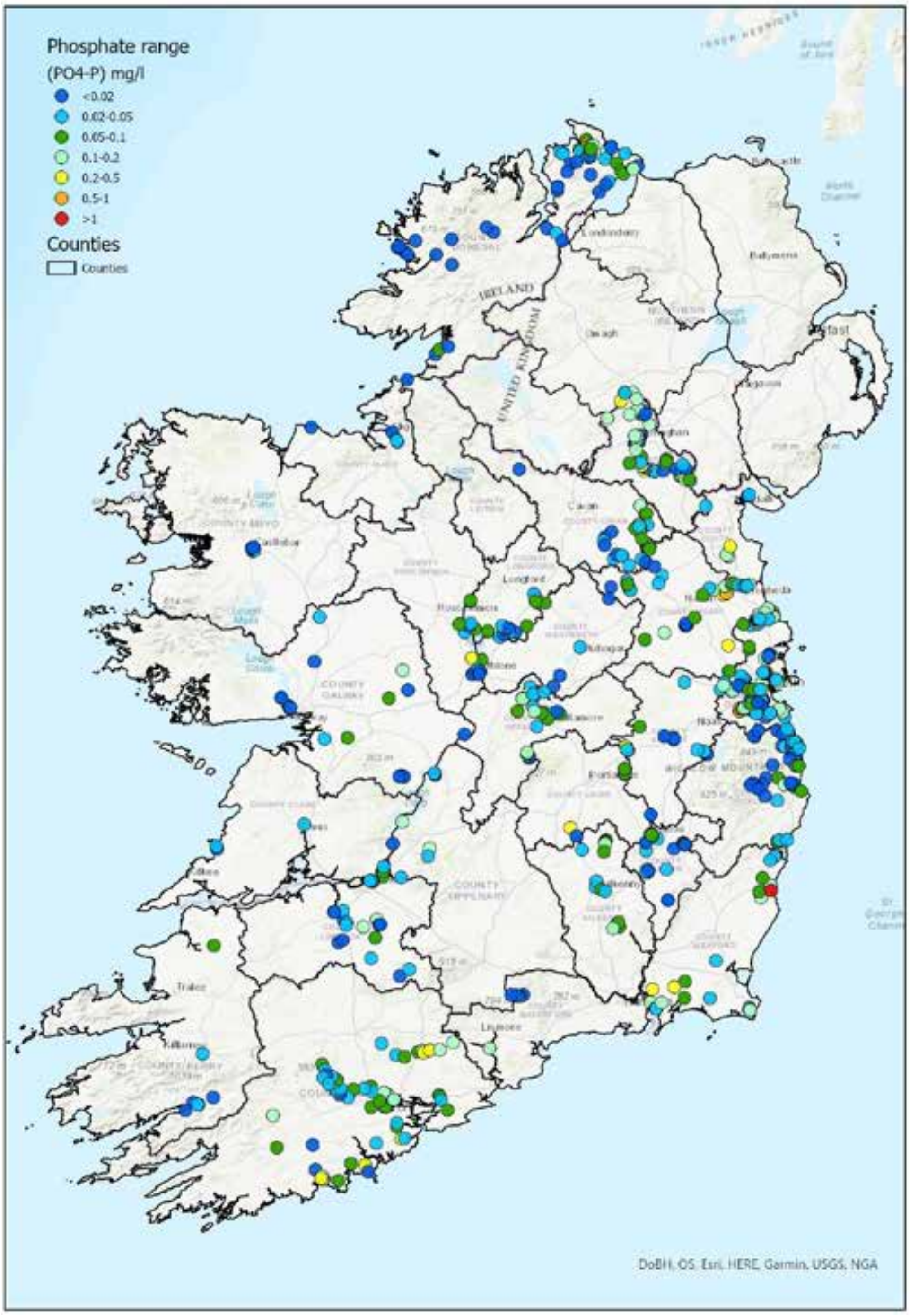


Figure 8. Phosphate ranges recorded across the country during the 2022 WaterBlitz.

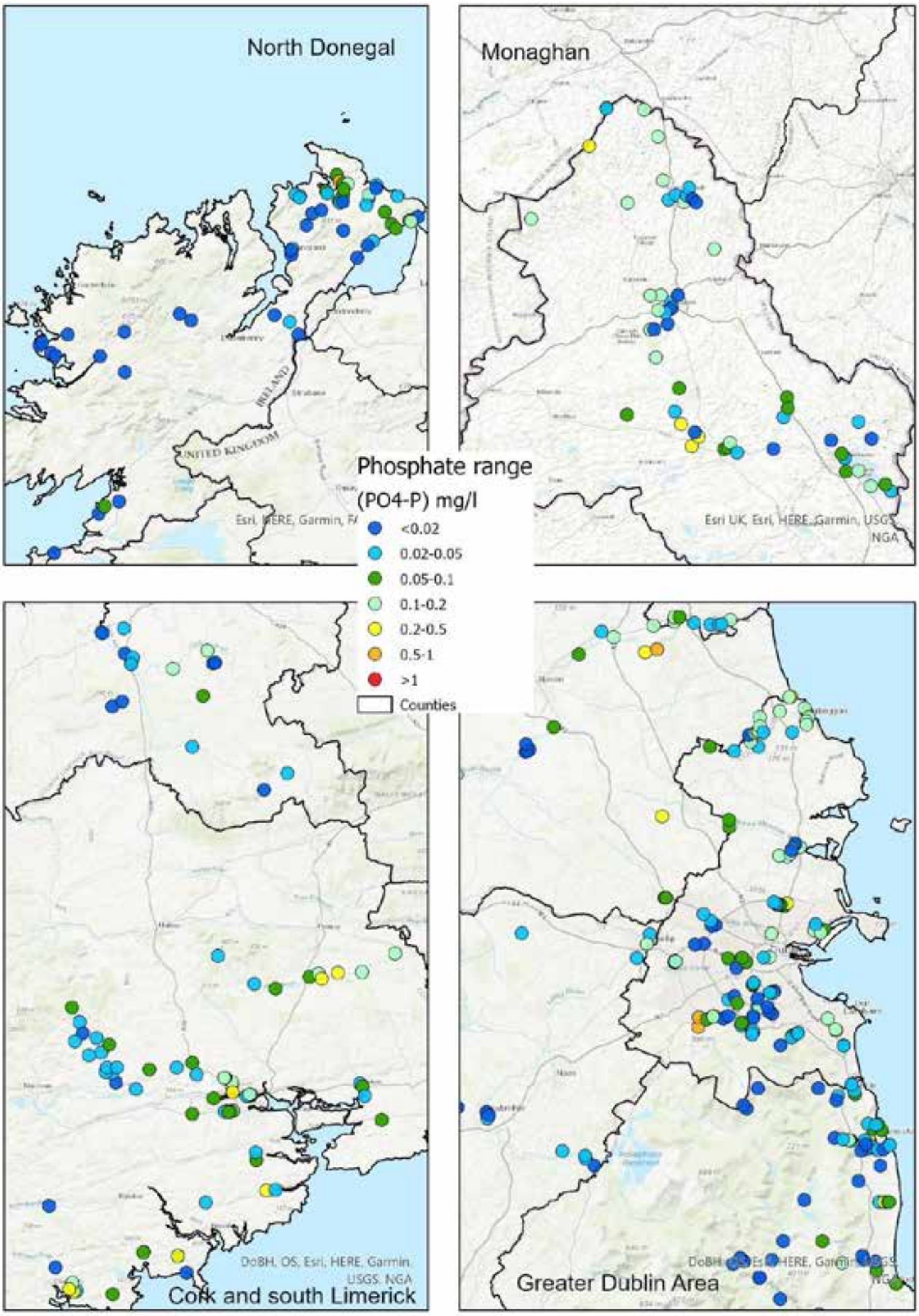


Figure 9. Closer look at phosphate ranges of samples at different locations during the Waterblitz.

This Waterblitz would not have been possible without the efforts of the many community groups. Figure 10 shows some of the communities that participated in this event.

Figure 10. Some of the many groups located around the country who took part in the 2022 WaterBlitz.

Survey

We asked all WaterBlitz participants to complete a general survey after the Waterblitz. Here are some of the findings:

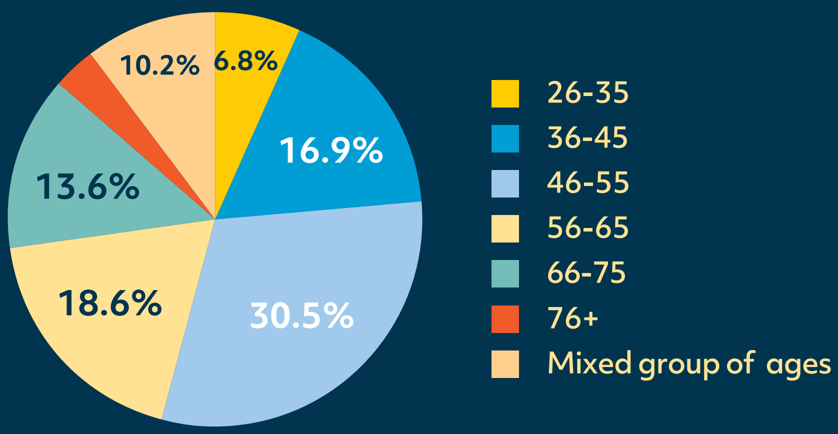


Figure 11. Age groups involved in the WaterBlitz. Data collected from survey at the end of the WaterBlitz.

The spread of age groups involved in the WaterBlitz shows that environmental monitoring is important to all age groups. A total of 17% of those who participated were from the older population, while 10.2% of people participated in a group with a mixture of ages. Given that many of the groups who participated were local community groups, which would include people of many ages from the local community, this is not surprising. It is noticeable that those of the 18-25 group either did not participate outside of a larger group, or did not complete the questionnaire. This is something we will investigate further.

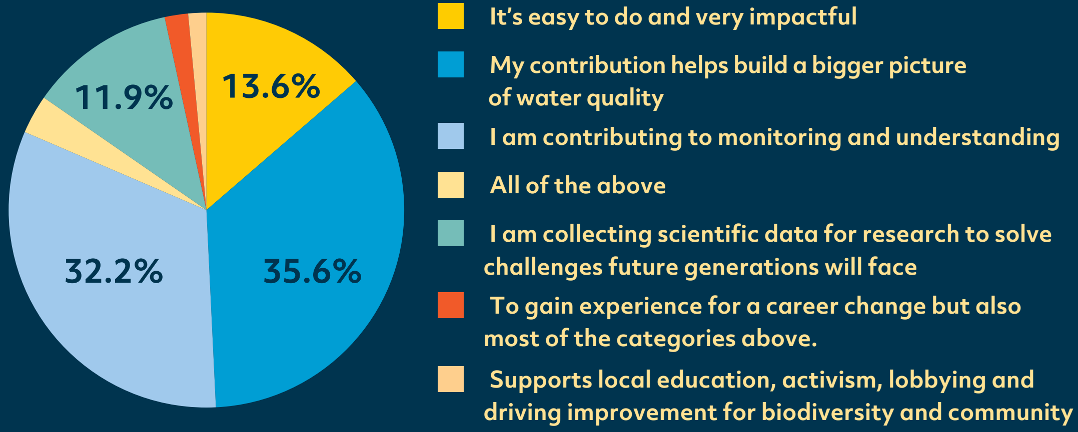


Figure 12. Why does citizen science interest people?

Most people who answered the survey referenced the importance of citizen participation in collecting data and monitoring water quality. This was interesting, as the primary motivation for citizen science was not simply educational, but people wanted to contribute to the scientific community and to make an impact with their contribution. In the DCU Water Institute, we have seen how local communities have become organised to take stewardship of their local freshwater resources. Citizen science can help them achieve this, and, when partnering with researchers, the data gathered can be analysed, enabling communities to tell a story about the local resource for impact.

action engaging educational engagement citizen science CONNECTED enjoyable FUN interactive informative environment community

I felt I was doing something positive to improve my local river which has been very poorly treated

Shared my love of nature with my daughter

Visiting streams and areas which I don't often visit. Seeing the data coming in from around the country demonstrates that people do care about our rivers.

Time together as a family whilst contributing to a better understanding of the local water systems

Taking the learning of chemistry out of the classroom and make it "real" for my students.

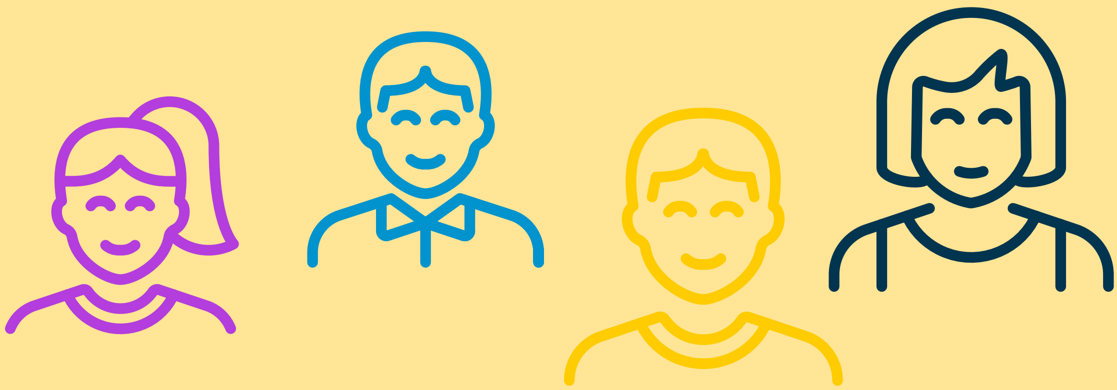
Empowering us to help with the environment and educating my children

Just the involvement bringing a level of responsible citizenship to the students I teach in a real world practical manner

Feeling like I was partaking in a national effort to help the environment

The sense of contribution and hopefully increasing interest in water quality within our kayaking group.

Being out in the countryside and the feeling that I am contributing to society



Sponsors Thank you

Thank you!

This year the DCU Water Institute team was astounded at the number of samples taken across the country. We thank you for your interest and participation. Every Citizen Scientist has played a role in growing our knowledge of water quality nationally, to help towards protecting our resources and ecosystems. With this information, we can identify areas of higher risk and help inform how these bodies of water can be protected.

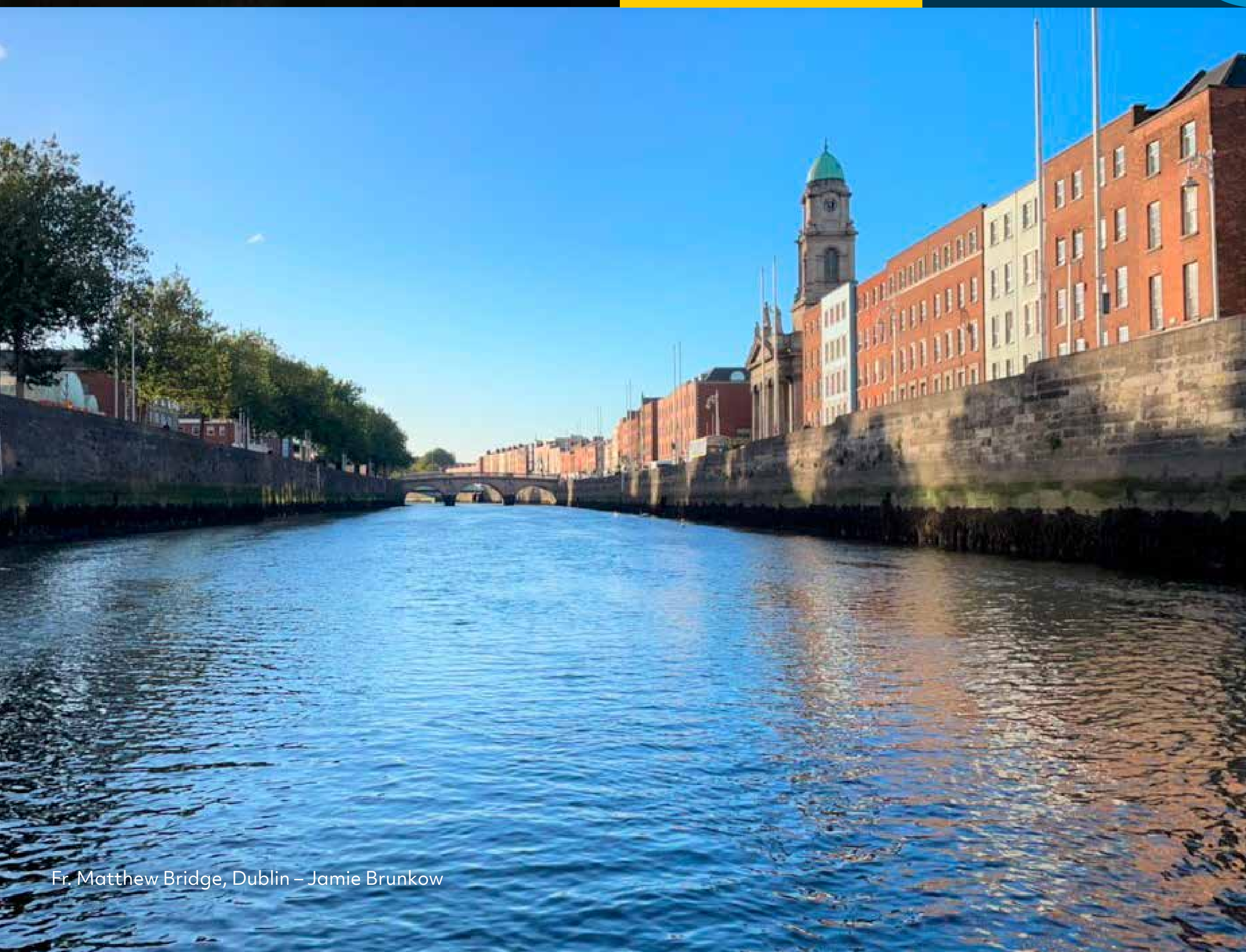
We are very grateful for your enthusiasm and hope that you will participate in future events.

Our sincerest thanks to Dublin City University for supporting the Citizen Science activities of the Water Institute and the teams behind the scenes who work so hard to deliver our campaign.

Thanks also to Earthwatch Europe and FreshWater Watch for facilitating our involvement in this project. We would also like to thank Smart Dublin and Dublin City Council for sponsoring this project and who support our vision of collecting water quality results in real time. We would also like to sincerely thank Thomas Carolan and the team at LAWPRO, who also sponsored the project and connected us to a range of water groups across Ireland.

Dungloe Lough, Co Donegal - Maria Delaney

Arrigle River, Jerpoint, Co. Kilkenny – Ollie Price



Fr. Matthew Bridge, Dublin – Jamie Brunkow

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Glendasan River, Glendalough, Co. Wicklow – Justin Ivory

Appendix 7

History of the Mussels and the Dredger Fleet in Wexford Harbour

Year	Event
1845	Act Passed that allowed the Commission of Fisheries could grant licences for oysters. There may have been a pre-1870 oyster licence.
1884	Mussels were added to the act. The extended Lett family continued to fish the harbour for mussels through the 20th century and traded in fresh mussels.
1959	Fisheries Act
1964	Lett & Company Ltd started experimenting with cooked mussel meats and jarring them.
1965	Lett and Company Ltd set about securing a factory. At this point the Slaney Mineral plant and a shed alongside it were being used to process some mussels.
1967	Lett and Company Ltd mussel processing plant opened in Batt St Wexford Town. At this time there were berths for 15 cots. Mussels were cooked and meats jarred.
1967-8	6 mussel boats commissioned with inboard engines. 24.5 feet long: St Quentin, Mallard, The Claire, Mussolini, St. Catherine and one other.
1967, 1969 and 1970	BIM, Dept. of Marine and Lett and Company Ltd. explored the best relay areas.
1968-69	Lett and Company Ltd. started to blast freeze some mussels on trolleys and then packed into bags.
1968-1974	Scallans working grounds with cots and small wooden hull boats.
1970's	Processing of mussels also took place at Kilmore Quay for a few years. But the vast majority of processing occurred in the Lett and Company Ltd. factory.
1970	The Countess built in Cork and brought in by Ryans.
1972	Mussels from East Coast relayed into Harbour in bags.
1973	'Lena Jozina' the first dredger in Ireland was brought in by Letts.
1974	First transplant of seed from East Coast to Wexford Harbour by 'Lena Jozina' (23 loads (40T each) 1200-1300T in total.
1975	Wexford Mussel Fishermen's Association was formed. Noel Scallan was Chairman and Sean Ryan Secretary. Renamed to the Wexford Mussel Growers Association in 1990's but have reverted to the old name since.
1977	'Sea Maid' Ryans
1977	'Naomh Caith' Noel Scallan sold on in 1978 to Waterford
1978	Lett and Company Ltd. brought in the 'Zeemiew'
1978	Lett and Company Ltd. started to experiment with half-shell mussels.
1978	'Vertrouwen 1' brought in by Lett and Co.
1979	'Vier Gebroeders' brought in by Ryans

1979	‘Geertruide brought’ in by Lett and Co.
1979	Test on growing of pacific and native oysters
1979	Sea Maid to Billy Gaynor
1979	‘Lena Jozina’ sold to Noel Scallan, sold to Waterford in 1993
1980	Fisheries Act
1982	‘Vertrouwen II’ brought in by Lett and Company Ltd.
1984	‘The Rapid’- Billy Gaynor
1985-1990	The height of the processing factory run by Lett and Company Ltd. 370 people employed mainly full-time in the factory
1986	‘Enterprise I’ brought in by Lett and Co.
1987	‘Ostrea’ brought in
1989	‘Ostrea’ sold to Billy Gaynor
1989	‘Cornelia’ brought in by Ryans
1994	‘Vertrouwen II’ sold to Noel and Albert Scallan.
1992	‘Vier Gebroeders’ sold to Noel and Paddy Cullen
1992-3	‘Cornelia’ sold to John Foley (left the harbour)
1993	‘Jana Maria’ brought in by Ryans
1993	‘Lena Jozina’ sold to Waterford mussel co-op
1996	‘Olive Rachel’ Flor Sweeney brought in from Holland
1996	‘Crescent Warrior’ brought in by Crescent Seafoods Ltd.
1997	‘Janny’ bought by Billy Gaynor off John Lett.
1998	‘Laura Anne’ brought into Wexford by Alex Mc Carthy for use by John Lett
1998	‘Noordster’ brought in by Flor Sweeney from Holland
2000	‘Ebenezer’ brought in by Crescent Seafoods Ltd.
2005	‘Branding’ brought in by Crescent Seafoods Ltd.
2005	‘Edenavle’ bought by the Ryans. New boat with stern dredges
2005	‘Hibernia’ bought by Riverbank mussels.
2005	‘Laura Anne’ purchased by Scallans and still in operation
2007	‘Cecilia’ brought in by Loch Garman Harbour Mussels Ltd.
2011-2012	‘Vertrouwen II’ sold on by Scallans.