Natural Capital and Ecosystem Services Mapping

April 2020

Lead Partner: ABPmer

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Operational Programme	European Maritime and Fisheries Fund (EMFF) Operational Programme 2014-2020
Priority	Union Priority 6 – Fostering the Implementation of the Integrated Maritime Policy
Thematic Objective	TO 6 – Preserving and protecting the environment and promoting resource efficiency
Specific Objective	SO1 - Development and implementation of the Integrated Maritime Policy
Measure	Blue Growth & Marine Spatial Planning Scheme
EMFF Certifying Body	Finance Division, Department of Agriculture, Food and the Marine
Managing Authority	Marine Agencies & Programmes Division, Department of Agriculture, Food and Marine
Specified Public Beneficiary Body	Marine Institute
Grant Rate	100%
EU Co-Financing Rate	50%
Legal Basis	Article 79 and 80 EMFF

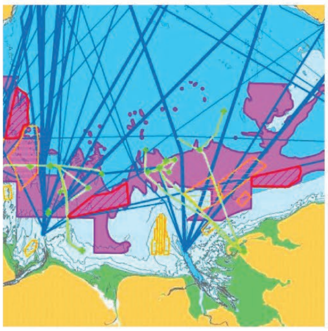
Marine Institute

Spatial Data and Evidence Projects

Project 3 - Natural Capital and Ecosystem Services Mapping

April 2020

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Document Information

Document History and Authorisation		
Title	Spatial Data and Evidence Projects	
	Project 3 - Natural Capital and Ecosystem Services Mapping	
Commissioned by	Marine Institute	
Issue date	April 2020	
Document ref	R.3161	
Project no	R/4608/3	
Date	**Version**	**Revision Details**
13/01/2020	1	Issued for client comment
22/04/2020	2	Issued for client use

Prepared (PM)	Approved (QM)	Authorised (PD)
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Suggested Citation

ABPmer, LUC & PML (2020). Spatial Data and Evidence Projects, Project 3 - Natural Capital and Ecosystem Services Mapping, ABPmer Report No. R.3161. A report produced by ABPmer for Marine Institute, April 2020.

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Non-Technical Summary

Marine Spatial Planning has been identified as an important process for supporting the sustainable development of Ireland's seas and the development of an overarching national marine spatial plan is identified as a Government policy objective in Harnessing Our Ocean Wealth. The draft National Marine Planning Framework was issued for public consultation in November 2019.

The Marine Institute has a key role in relation to technical and scientific input into the development of the Plan, supporting the proposed organisational structures and the process of preparing the Plan. ABPmer and its project partners have been appointed by the Marine Institute to deliver Spatial Data and Evidence Projects to support this process.

This report is one of the outputs of Project 3, which aimed to identify, characterise and map Ireland's marine natural capital and provisioning, regulating and cultural ecosystem services. It builds upon previous research to support the development and agreement of appropriate frameworks for marine natural capital and ecosystem services to support MSP, an initial review of existing frameworks and MSP practices, an expert workshop held at the Marine Institute in 2018, and a characterisation of the Ireland's natural capital and ecosystem service flows.

A marine natural capital framework for MSP has been developed which splits natural capital assets in to four broad categories; habitat, species, abiotic and other capital assets. The framework recognises that ecosystem services are generated by a combination of biotic and abiotic elements and therefore includes a mixture of both elements. The CICES ecosystem services framework (version 5.1) was adopted and built upon for the study, as it has been widely used within Europe, has provided the basis for previous work on marine ecosystem services in Ireland, and it adopts a broad definition of ecosystem services including abiotic services such as energy production and this breadth aligns well with the needs of MSP.

Spatial data on marine natural capital assets, drawing heavily on work completed under Project 2 of the Spatial Data and Evidence projects, underpin the mapping of many of the ecosystem services, based on known linkages between assets and ecosystem service delivery. There is good information on seabed habitats in Irish waters, but more limited information on species assets. Information on abiotic assets and other capital inputs is more readily available.

A series of maps have been developed for a range of ecosystem services, specifically:

- Provisioning services — wild capture fisheries and shellfisheries; seaweed wild harvest; fish and shellfish aquaculture; seaweed aquaculture; mineral substances; non-mineral substances; water for non-drinking purposes;
- Regulating services — climate regulation; waste mediation; regulation of flows;
- Cultural services — recreation and tourism; aesthetic; scientific and educational; cultural heritage; spiritual and symbolic.

Information on the quantity and value of the ecosystem service flows are also provided. Maps were not developed for genetic material, pest and disease control, and lifecycle maintenance, due to a lack of data and clarity for spatialising these services.

An overall value map showing a spatialisation of the value of provisioning and regulating services was also developed on a 10 square kilometre grid. This highlights the importance of the inshore area (coast and estuaries, for mediation of wastes, water for non-drinking purposes, aquaculture), as well as offshore areas on the shelf edge (for fisheries) and deep sea (for carbon sequestration). The overall value of provisioning services was estimated at €2.4 billion per year (gross value added), and for regulating services was estimated at €14.9 billion. Cultural services were not included in the overall value map due to large uncertainties with valuation methods.

The mapping of ecosystem services highlights a number of potential threats, including over-exploitation of fisheries, intensive coastal tourism and recreation, and other anthropogenic pressures, which may affect the potential of the marine environment to continue to deliver ecosystem services into the future. However, there are also opportunities for improving or increasing benefits, including: increasing biotic services such as fish, shellfish and seaweed aquaculture; enhancement or restoration of habitats that provide ecosystem functions such as saltmarsh, sand dunes, bivalve beds and biogenic reefs; mapping of seaweed resources to understand the potential for utilisation; increasing abiotic services such as offshore renewable energy and marine aggregates; and sensitive tourism and recreation development for cultural services.

Marine natural capital and ecosystem services approaches have had limited practical implementation to date — most approaches are experimental and challenging to apply with the limited data and understanding of the complex marine ecosystem processes that occur. However, ecosystem services approaches align well with MSP objectives, integrating data about a range of uses of and benefits from the marine environment.

This project has advanced the evidence base in relation to mapping marine natural capital and ecosystem services in Ireland. This evidence base needs to be further built upon. Mapping natural capital and ecosystem services is challenging and there are still limitations of the available data and understanding of the contribution of natural capital to delivery of ecosystem services. As such, there are various ways in which the current maps can be further improved and expanded upon, and tailored and ground-truthed to Irish societal values. The implementation of marine spatial planning will benefit from information on ecosystem services and its utility to marine decision-making is likely to become more mainstream over the coming decades.

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1 Introduction

1.1 Background

ABPmer and its project partners were appointed by the Marine Institute (MI) to deliver Spatial Data and Evidence Projects to support the development of Ireland's first marine spatial plan. Marine Spatial Planning (MSP) has been identified as an important process for supporting the sustainable development of Ireland's seas. The development of an overarching national marine spatial plan is identified as a Government policy objective in Ireland's Integrated Marine Plan as set out in Harnessing Our Ocean Wealth (HOOW) (Inter-Departmental Marine Coordination Group, 2012). The Maritime Spatial Planning Directive (2014/89/EU) also requires Member States to develop and implement marine spatial plans covering marine water under their jurisdiction by 2021. Ireland has transposed the Directive through Part 5 of the Planning and Development (Amendment) Act 2018. The draft National Marine Planning Framework (NMPF) was issued for public consultation in November 2019 (DHPLG, 2019).

The Marine Institute has a key support role in relation to technical and scientific input into the development of the Plan, supporting the proposed organisational structures and supporting the process of preparing the Plan.

ABPmer and its partners are leading five Spatial Data and Evidence Projects supporting the development of the Plan:

1. Data Discovery, Collation and Gap Analysis for Spatial Representation;
2. Data Prioritisation and Collection for Spatial Representation;
3. Assess and Map Marine Ecosystems Services;
4. Mapping the Potential Impacts of Climate Change; and
5. Best Practice on Modelling and Support Tools for Integrating Marine Spatial Data for Scientific and Technical Advisory Services.

This report relates to Project 3 Map and Assess Marine Ecosystems and Their Services.

1.2 Project 3 objectives

Project 3 is concerned with collating and presenting spatial information on marine natural capital and ecosystem services. Such information is useful within MSP in identifying those aspects of the natural environment that contribute to human well-being and their relative importance. It also helps to implement the ecosystem-based approach to marine management in line with the requirements of the Marine Spatial Planning Directive, Marine Strategy Framework Directive (2008/56/EC) and OSPAR commitments.

Project 3 entailed the following technical tasks:

Task 3.1: Framework development and characterisation of Ireland's marine ecosystem services;
Task 3.2: Data collection;
Task 3.3: Natural capital and ecosystem services mapping; and
Task 3.4: Natural capital and ecosystem services opportunities mapping.

This report is focused on Tasks 3.3 and 3.4 . It describes the development of maps to indicate the locations of natural capital assets and the ecosystem services derived from these assets and seeks to identify potential opportunities for their sustainable use.

The report is structured as follows:

Section 2: A Framework for Marine Natural Capital and Ecosystem Services within MSP;
Section 3: Mapping Marine Natural Capital Assets;
Section 4: Mapping Marine Ecosystem Services;
Section 5: Spatialisation of the value of provisioning and regulating ES in Ireland; and
Section 6: Recommendations for further work

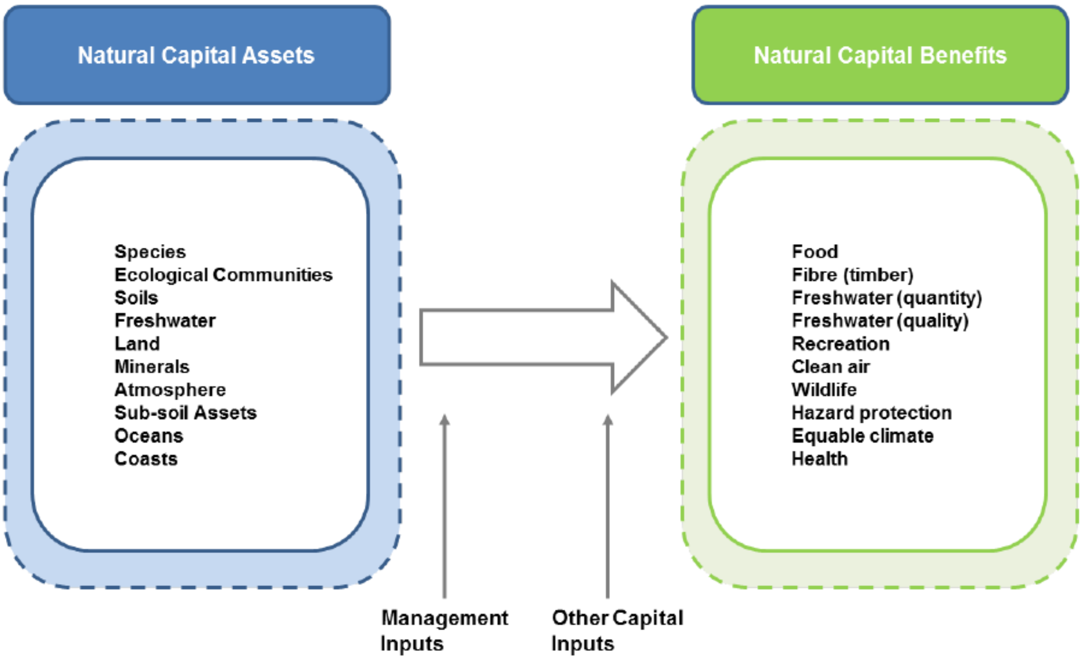
2 A Framework for Marine Natural Capital and Ecosystem Services within MSP

Marine Spatial Planning (MSP) has been identified as an important process for supporting the sustainable development of Ireland's seas. Understanding natural capital (NC) assets and the flows of ecosystem services (ES) as part of MSP allows the implications of changes in ecosystems to be assessed in terms of their impact on humans.

Some initial mapping and assessment of marine ecosystem services in Irish waters has been completed and reported in Parker *et al.* (2016) and Norton *et al*. (2018). Scoping work to develop a suitable natural capital and ecosystem services framework for MSP is reported in ABPmer *et al.* (2018a, b). This included a workshop with invited experts to discuss and agree the framework.

2.1 Marine natural capital

There is currently no single agreed framework for marine natural capital assets and limited work has been undertaken in Ireland. A high-level framework was established by the UK Natural Capital Committee (Natural Capital Committee, 2015) which recognised both biotic assets and abiotic assets as well as 'other capital inputs' that are used to realise ecosystem services benefits (Figure 1). The Mapping and Assessment of Ecosystem Services (MAES) Project (MAES, 2014) and the National Ecosystem Assessment (UK NEA, 2011) have developed partial classifications for biotic natural capital assets. The UK NEA separates coastal margins from marine which helps better define inshore habitats such as shingle, cliffs and lagoons. However, as highlighted by MAES, the UK NEA omits pelagic waters, which MAES defines within its framework, and are important to include within the NC assessment. Hooper *et al*. (2019) further developed a classification for marine habitat natural capital assets building on UKNEA and MAES.



Natural Capital Committee, 2015

Figure 1. High level framework for natural capital assets

Given the broad focus of MSP encompassing environmental, social and economic aspects, it is considered that the framework for natural capital assets used for MSP also needs to be broad, particularly encompassing abiotic assets and other capital inputs. Table 1 below sets out the proposed components to be mapped as part of the natural capital framework. This incorporates the habitat assets framework developed by Hooper *et al.* (2019) as well as defining categories for species assets, abiotic assets and other capital inputs.

Table 1. List of components for inclusion in natural capital framework

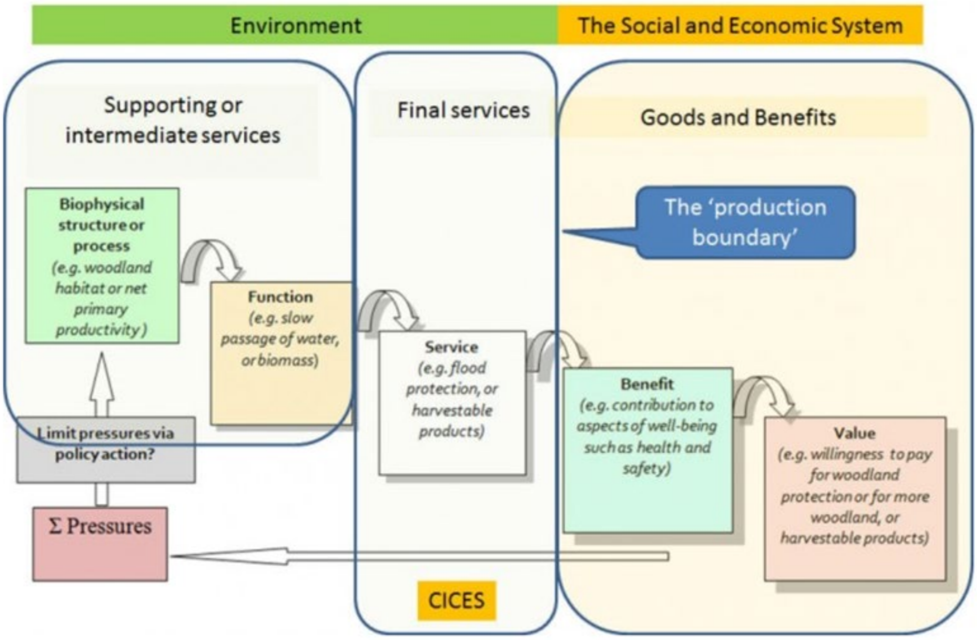
Habitat Assets	Species Assets	Abiotic Assets	Other Capital Inputs
Coastal Margins ▪ Sand dunes ▪ Machair ▪ Shingle ▪ Sea cliffs Coastal ▪ Intertidal rock ▪ Intertidal sediments ▪ Mudflat ▪ Saltmarsh ▪ Littoral seagrass ▪ Biogenic reef Shelf ▪ Subtidal rock ▪ subtidal sediments ▪ Sublittoral vegetated habitats ▪ Biogenic reef ▪ Deep sea rock ▪ Deep-sea sediment ▪ Pelagic	Phytoplankton Zooplankton Macroalgae ▪ Kelps ▪ Wracks ▪ Red algae ▪ Green algae Fish and cephalopods Shellfish ▪ Molluscan ▪ Crustacean ▪ Echinoderms Marine mammals ▪ Cetacean ▪ Seals ▪ Otter Birds	Marine aggregates Oil and gas reserves Offshore wind Wave energy Tidal stream energy Tidal range energy Water surface Seawater Seabed Subsurface geology Seascape	Marine Infrastructure Coastal open space Slipways and marinas Cultural heritage Ports and harbours Vessels Landside Infrastructure ▪ Coastal footpaths ▪ Car parks ▪ Coastal access

2.2 Marine ecosystem services

Figure 2 illustrates the ecosystem services 'cascade model' (Potschin and Haines-Young 2011, 2016) which sets out the way ecosystem services connect to natural capital assets and processes to the benefits and values realised by society, and hence the way human well-being depends on the underpinning characteristics of living systems or biodiversity.

The CICES ecosystem services framework has been widely used within Europe and has provided the basis for previous work on marine ecosystem services in Ireland. This study therefore adopts and builds on this framework. A summary of key marine ecosystem services included within the framework is presented in Table 2. Appendix A provides a complete representation of the CICES framework and how this relates to the key marine ecosystem services identified in Table 2.

There remain some limitations associated with the CICES framework, for example, some abiotic services, such as waterborne transport, are not specifically addressed within CICES. For the purposes of this study, waterborne transport has been considered under the general category of 'Water for non-drinking purposes'. The CICES framework also splits services between biotic and abiotic components. While this is useful for many services, there is often an interaction between these components as well as a conflation of benefits, for example scientific and educational benefits for which individual research projects and data are generally not available that differentiate activities in this way. In this study all scientific and educational research has been considered under the category 'Scientific and educational' and no attempt made to split it between biotic and abiotic components. Unless otherwise specified, reference to 'ecosystem services' in this report includes both biotic and abiotic ecosystem services.



Source: Potschin and Haines-Young, 2011, 2016

Figure 2. Conceptual illustration of the CICES cascade model framework

Table 2. Final ecosystem services defined by the CICES Framework

Provisioning Services	Regulating Services	Cultural Services
Seaweed aquaculture	Mediation of wastes	Recreation and tourism
Fish and shellfish aquaculture	Regulation of flows	Scientific and educational
Wild seaweed harvesting	Lifecycle maintenance	Cultural heritage
Wild capture fisheries and shellfisheries	Pest and disease control	Aesthetic
Genetic material from all biota	Climate regulation and carbon sequestration	Spiritual and emblematic
Water for non-drinking purposes		Existence and bequest
Mineral substances: aggregates, oil and gas		
Non-mineral substances: offshore wind, wave and tidal energy.		

2.3 Linking marine natural capital and ecosystem services

The MAES project (MAES, 2014) presents a common assessment framework that can be applied to link marine natural capital and ecosystem services. This starts by mapping ecosystem distribution and then incorporates both assessment of ecosystem condition and indication of ecosystem service flow (Figure 3).

However, at present there is a major limitation to the inclusion of asset condition within ecosystem service assessment, particularly within the marine environment, as there is currently very limited information with which to assess asset status and very limited understanding of how ecosystem service flows might change in response to changes in asset condition. It is however important to recognise that poor habitat or ecosystem condition could mean that full ES benefits may not be realised.

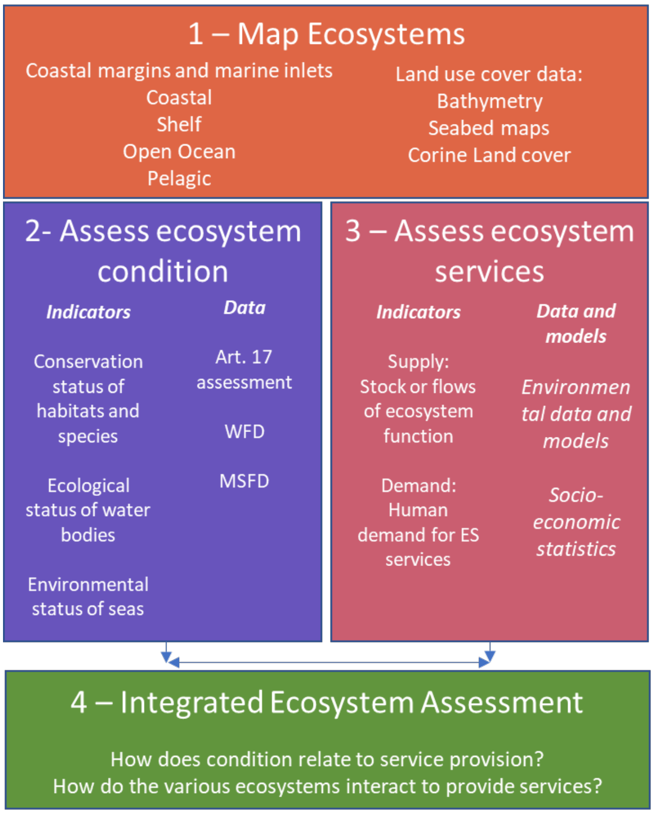


Figure 3. MAES common assessment framework for ecosystem assessment

Potts *et al.* (2014) developed a number of matrices for linking habitat and species natural capital assets to ecosystem service provision, supplying a method to underpin the linkages between biotic assets and ES flows. The study produced two matrices which classified the ability of protected habitats and species to provide ecosystem services. The shading of each cell within the matrices represented an indication of the relative importance of each feature in providing the respective ecosystem service. Where data were unavailable cells were left blank to indicate a data gap. Bullock & O'Shea (2013) similarly developed a matrix to link Irish inshore marine habitats and species to ecosystem services.

Table 3 provides a summary of the services derived from habitat assets defined for this project, based upon the findings from Potts *et al.* (2014) and Burkard and Maes (2017). The number scale indicates the relative importance of the linkage between the habitat and the ecosystem service (blank = not assessed, 0 = no linkage, 1 = low contribution, 2 = medium contribution, 3 = high contribution).

Table 4 provides an equivalent assessment for species.

Table 3. Major marine and coastal habitat types and their links with ecosystem services provisions.

	Goods/ Benefits From													
	Provisioning					Regulating				Cultural				
	Food provision	Fuel/ energy	Materials	Genetic resource	Water (non-drinking)	Climate regulation	Mediation of wastes	Mediation of flows	Lifecycle maintenance	Transport	Recreation	Educational	Spiritual/ Cultural	Aesthetic
Coastal Margins														
Sand dunes	1		1		2	1	1		2		3	1		2
Machair			1		1				2		2	1		2
Shingle					1				2		2	1		
Sea cliffs								2	2		1	1		2
Coastal														
Intertidal rock	2					1	0	3	2		1	1	1	2
Intertidal sediments	2					1	1	2	2		3	1	1	2
Coastal lagoon	1						1		2		2	1	1	3
Saltmarsh	3					3	3	2	2		3	1	1	3
Littoral seagrass														
Biogenic reef														
Shelf														
Subtidal rock	1					0	0	1	2		2	1	1	
Subtidal sediments	2		2				1	1	2			1	1	
Sublittoral vegetated habitats														
Biogenic reef														
Deep-sea rock						1			2			1		
Deep-sea sediment						2			2			1		
Pelagic	2				3	2			2	3	2	1		2

Table 4. Major marine species groups and their links with ecosystem services provisions.

	Goods/ Benefits From													
	Provisioning					Regulating				Cultural				
	Food provision	Fuel/ energy	Materials	Genetic resource	Water (non-drinking)	Climate regulation	Mediation of wastes	Mediation of flows	Lifecycle maintenance	Transport	Recreation	Educational	Spiritual/ Cultural	Aesthetic
Fish and cephalopods	3							3	3		1	1	1	1
Shellfish														
Molluscan	3		1			1	3	1	1		1	1	1	
Crustacean	3		1				1		1		1	1	1	1
Echinoderms									1					
Macroalgae	1		1			1	1	1			1	1	1	
Marine Mammals														
Cetaceans			1								3	3	3	2
Seals											3	3		2
Otters									1		3	3	3	1
Birds	1		1			1		1	1		2	2	1	1

It is recognised that scientific understanding of the nature and scale of ecosystem service benefits derived from biotic assets is currently quite limited. Matrices such as those above can assist in guiding the mapping of where ecosystem services benefits are realised. For consumptive uses of biotic assets (such as commercial fishing or aquaculture) such mapping can also be supported by information on other capital inputs (such as the location of wild fish capture or licensed aquaculture sites).

For abiotic assets, the linkages between the assets, other capital inputs and the ecosystem service benefits tend to be more direct. For example, the location of gas production platforms (a form of 'other capital input') clearly define the locations from which the ecosystem service benefits are derived.

In seeking to develop maps of where ecosystem services benefits are realised in the marine environment, information on the linkages between assets, other capital inputs and ecosystem services benefits has been used in a flexible way, making best use of available data. The methodologies that have been used to quantify and spatialise key ecosystem services are described in Section 4.

2.4 Identifying where ecosystem services benefits are realised

Most marine ecosystem service benefits are generated at sea, but the beneficiaries of these services are on land. It is therefore of interest to seek to identify where ecosystem service benefits are realised on land and to identify who the beneficiaries are. This can be important in terms of identifying the socio-economic benefits of using marine ecosystem services. For example, non-Irish fishing vessels catching fish in Irish waters and landing them in their home ports makes use of the food provisioning service but provides little if any benefit to Ireland from this service. Conversely local artisanal fisheries may supply a local source of fish to local communities and provide additional cultural benefits associated with the continued use of artisanal fishing techniques and maintaining traditional ways of life.

As part of the production of each ecosystem service map, consideration has been given to the manner and extent to which the immediate beneficiaries of the service can be identified and mapped. For example, in relation to wild capture fisheries, this has included consideration of the landing ports and any local processing plants. Further details of the methodologies used are provided in Section 0.

2.5 Identifying where there may be ecosystem services constraints and opportunities

From an MSP perspective it is helpful to understand whether marine ecosystem services are being used sustainably and whether there are opportunities for humans to derive increased sustainable benefits from specific services.

For example, currently very limited benefit is derived from offshore wind, wave and tidal energy resources in Irish waters and there are opportunities to increase renewable energy production from these sources in a sustainable way, subject to commercial viability. Similarly, there is significant potential for aquaculture expansion in Irish waters subject to commercial viability and sustainability considerations. Conversely, some fish stocks are currently fished unsustainably and short-term reductions in landings may be needed to enable stocks to recover to sustainable levels.

3 Mapping Marine Natural Capital Assets

3.1 Introduction

This section defines the framework that has been used to map natural capital assets within the Irish EEZ. The framework is based on a combination of the NCC (2015), Hooper *et al.* (2019), MAES (2014) and UK NEA (2011) typologies.

Table 5 defines the NC assets to be included within the framework and summarises the data sources which have been used to represent these assets. The assets have been broadly split into four categories; habitat assets, species assets, abiotic assets and other capital inputs, which are discussed in more detail in the sub-sections below. The data sources draw heavily on work completed under Project 2 (ABPmer, 2020)

Table 5. Data Sources for Natural Capital Asset Mapping

Natural Capital Assets	Potential Data Sources/ Layers	Data Limitations
Habitat Assets		
Coastal Margins		
Sand dunes	Sand dune layer from Project 2 (DPT046)	
Machair	Sand dune layer from Project 2 (DPT046) machair to be identified as a layer within overall sand dune layer	
Shingle	Used CORINE landcover (EPA) and NPWS data	
Vegetated Sea cliff	Sea Cliffs NPWS data	Primarily desk-based study data using aerial and oblique imagery, and maps
Coastal		
Intertidal rock		
Intertidal sediments (excluding mudflat)	Intertidal mudflats and sandflats layer from Project 2 (DPT018)	Mudflats and sandflats aren't differentiated in the underlying data so they can't be split
Mudflat	Intertidal mudflats and sandflats layer from Project 2 (DPT018)	Not able to differentiate all mudflat from intertidal sediments.
Saltmarsh	Used CORINE landcover (EPA) and NPWS data	The combined data are extensive, but CORINE is of lower spatial resolution
Littoral Seagrass	Distribution of Zostera, maerl and Sea-Pen & Burrowing Megafauna Communities layer from Project 2 (DPT022)	Not all *Zostera* (especially subtidal *Zostera*) has been mapped. Communities with low abundance were not included
Biogenic reef	Reefs layer from Project 2 DPT017	Not all reefs have been mapped. Offshore mapping is heavily dependent on the availability and spatial extent of seabed surveys which are not evenly distributed
Shelf		
Sublittoral rock	Broadscale habitat layer from Project 2 (DPT016)	
Sublittoral sediment	Broadscale habitat layer from Project 2 (DPT016)	
Sublittoral vegetated habitats		
Biogenic reef	Reefs layer from Project 2 (DPT017)	Not all reefs have been mapped. Offshore mapping is heavily dependent on the availability and spatial extent of seabed surveys which are not evenly distributed
Deep sea rock	Broadscale habitat layer from Project 2 (DPT016)	Coarse-resolution data
Deep sea sediment	Broadscale habitat layer from Project 2 (DPT016)	Coarse-resolution data
Pelagic	Pelagic zone defined by limits of marine plan area and bathymetry	
Species Assets		
Fish and cephalopods	Current distribution of migratory fish (DPT028) Current distribution and abundance of key elasmobranch species (DPT029) Current distribution and abundance of basking shark (DPT030)	Data products not be progressed as priority under Project 2. Had to make use of more limited set of existing fish data layers
Phytoplankton and zooplankton	NEMO-ERSEM and POLCOMS-ERSEM model outputs (PML)	
Shellfish (Molluscan, Crustacean, Echinoderms)	Location of shellfish beds layer from Project 2 (DPT032)	Not all beds have been mapped. Offshore mapping is heavily dependent on the availability and spatial extent of seabed surveys which are not evenly distributed. Not all data was sourced from Marine Institute
Macroalgae (Kelps, wracks, red algae, green algae)	This is an acknowledged data gap	Data gap
Marine Mammals (cetaceans, Seals and	Current distribution and abundance of key cetacean species from	Cetaceans - ObSERVE data uses density modelling

Natural Capital Assets	Potential Data Sources/ Layers	Data Limitations
otters)	Project 2 (DPT034) Current distribution and abundance of seals from Project 2 (DPT038)	Seals - Relatively coarse resolution data which heavily depends upon the chosen method of processing the raw data No data on otter
Birds	National inventory of breeding seabird sites from Project 2 (DPT041) Seabird colony foraging areas from Project 2 (DPT042) Tern foraging areas from Project 2 (DPT043) Winter and summer seabird distributions in Irish waters from Project 2 (DPT044)	Modelled data Modelled data ObSERVE data – gap for West coast of Ireland
Abiotic Assets		
Marine aggregates	Marine aggregate resources – (INFOMAR)	Resources currently only partially mapped (IMAGIN project)
Oil and gas resources	Marine Atlas Offshore commercial fields	
Offshore wind resources	Marine Atlas - Offshore Wind Power 100 m OREDP wind technical resource areas (SEAI)	Based on numerical model outputs
Wave energy	Marine Atlas - Mean Annual Distribution of Wave Height (m); Mean Annual Distribution of Wave Period (sec) OREDP wave energy technical resource areas (SEAI)	Based on numerical model outputs
Tidal stream energy	Marine Atlas - Tidal Resource Potential data layers OREDP tidal technical resource areas (SEAI)	Based on numerical model outputs
Tidal range energy	Future Tidal Steam Energy Development from Project 2 (DPT084)	
Water surface	Defined by limits of marine plan area	
Subsurface geology	Marine Atlas Offshore commercial fields	Limited data on subsurface geology in Irish waters
Seabed	Seabed sediment layer from Project 2 (DPT014)	Resolution decreases further offshore
Seawater	Defined by limits of marine plan area and bathymetry	
Seascape	No data available	
Other Capital Inputs		
Landside infrastructure (coastal footpaths, car parks, coastal access)	Location and intensity of coastal walking from Project 2 (DPT156) Coastal car parks are available from OSI	Not all features have been mapped by OSI
Coastal open space		
Slipways and marinas	Location of marine recreational infrastructure layer from Project 2 (DPT158)	

Natural Capital Assets	Potential Data Sources/ Layers	Data Limitations
Marine infrastructure	Aquaculture: ▪ Finfish, seaweed, shellfish from Project 2 Cable and pipelines: ▪ Telephone cables o Telecom Cables and Potential Future Telecom Cables from Project 2 (DPT125 and DPT 126) ▪ Power cables o Power Interconnectors and Future Power Interconnectors from Project 2 (DPT071 and DPT075) ▪ Pipelines o Marine Atlas – Offshore gas infrastructure o Future gas interconnectors (DPT077); ▪ Energy: o Marine Atlas – Offshore gas infrastructure o Offshore windfarms layer from Project 2 (DPT073) o Marine Atlas - Arklow Bank Wind Park Connection Cable; Belmullet Full Scale Wave Energy Test Site; Galway Bay 1/4 Scale Wave Energy Test Site o Future offshore wind, tidal and wave development (OREDP)	
Ports and harbours	Location and intensity of port activity from Project 2 (DPT110)	

3.2 Biotic assets

3.2.1 Habitat assets

There is a range of information sources to support mapping of seabed habitats in Irish waters. The extensive survey programme conducted by INFOMAR has generated good information on offshore seabed habitat types with maps at suitable scale and resolution available through EMODnet. EU Habitats Directive Article 17 reports contain good information on the distribution and condition of certain habitats within Natura 2000 sites. Further work to improve existing data layers has been taken forward through Project 2. Figure 4 illustrates the level of detail on seabed habitats in Irish waters that is available through EMODnet.

3.2.2 Species assets

The availability and quality of information available on the distribution of species assets is more limited than for habitats. Some work to better define the spatial distribution of species assets has been taken forward as part of Project 2, but further work is only likely to be progressed in the medium to longer term. Existing limitations with the species asset data limits the extent to which ecosystem services associated with species assets can be mapped. However, where ecosystem service benefits are dependent on other capital inputs (such as commercial harvesting of fish resources), it is possible to use information on the locations of operation of these other capital assets (fishing vessels) to identify where the ecosystem service benefit (food for human consumption) is realised.

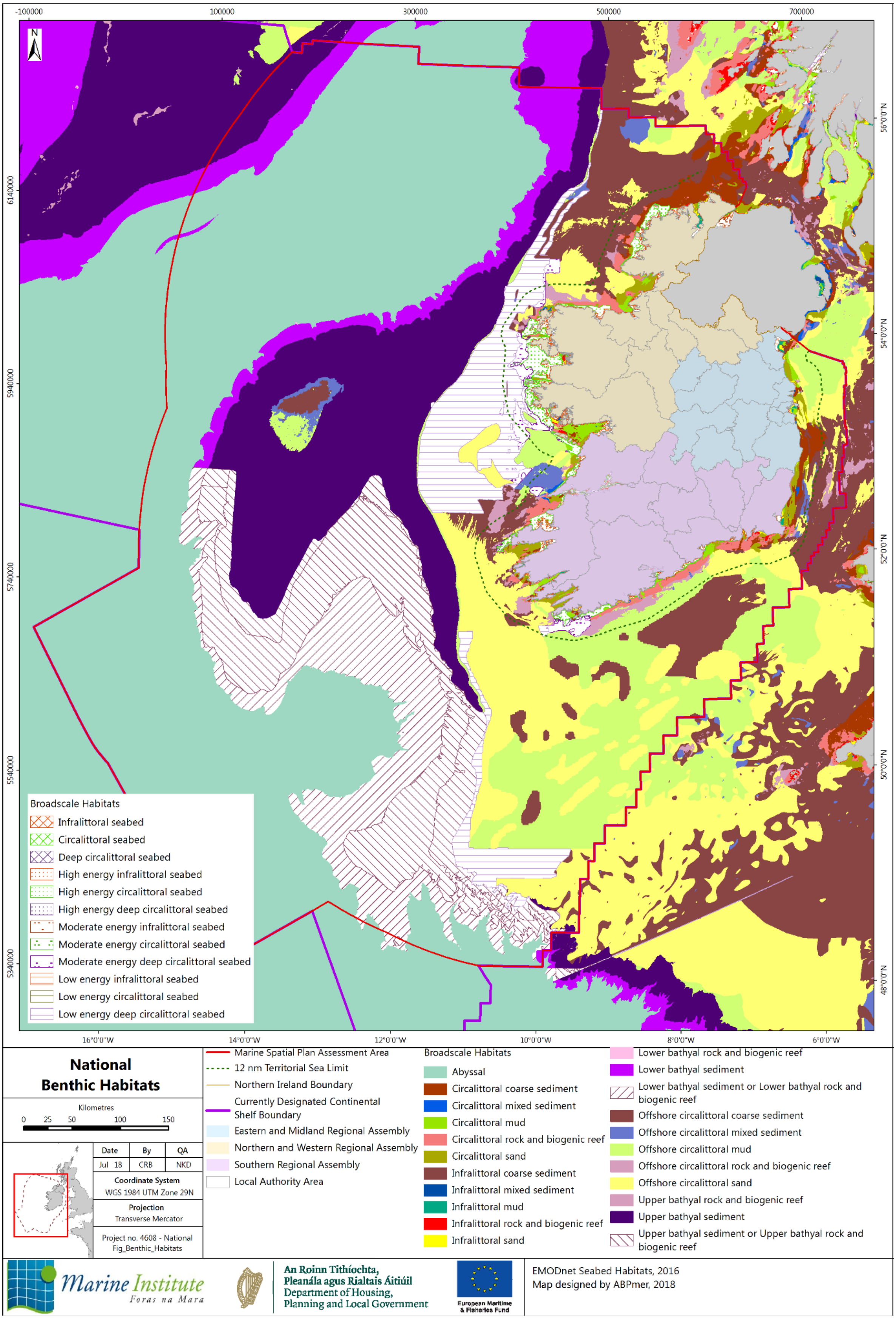


Figure 4. Habitat asset map based upon EMODnet Seabed habitats

3.3 Abiotic assets and other capital inputs

Abiotic assets and other capital inputs are generally easier to map than biotic assets, with more readily available data on the location of the assets and/or where ecosystem service benefits from these resources are realised, for example locations where gas production is licensed.

Figure 5 shows an example of the ports and harbours other capital inputs map, indicating the point location of port and harbours within the Irish EEZ. One of the major limitations of the current map is that locations are only defined as points and it gives no indication of relative size, activity or importance to the supply of ES benefits. To improve the map, the intensity of port activity, mapped as part of Project 2, has been included. Data on the activity and volume of freight were sourced and added to the map. It would be possible to further enhance the map by including better spatial definition of port infrastructure and including information on smaller jetties and facilities, however, such information was not freely available in digital format for use within the current project.

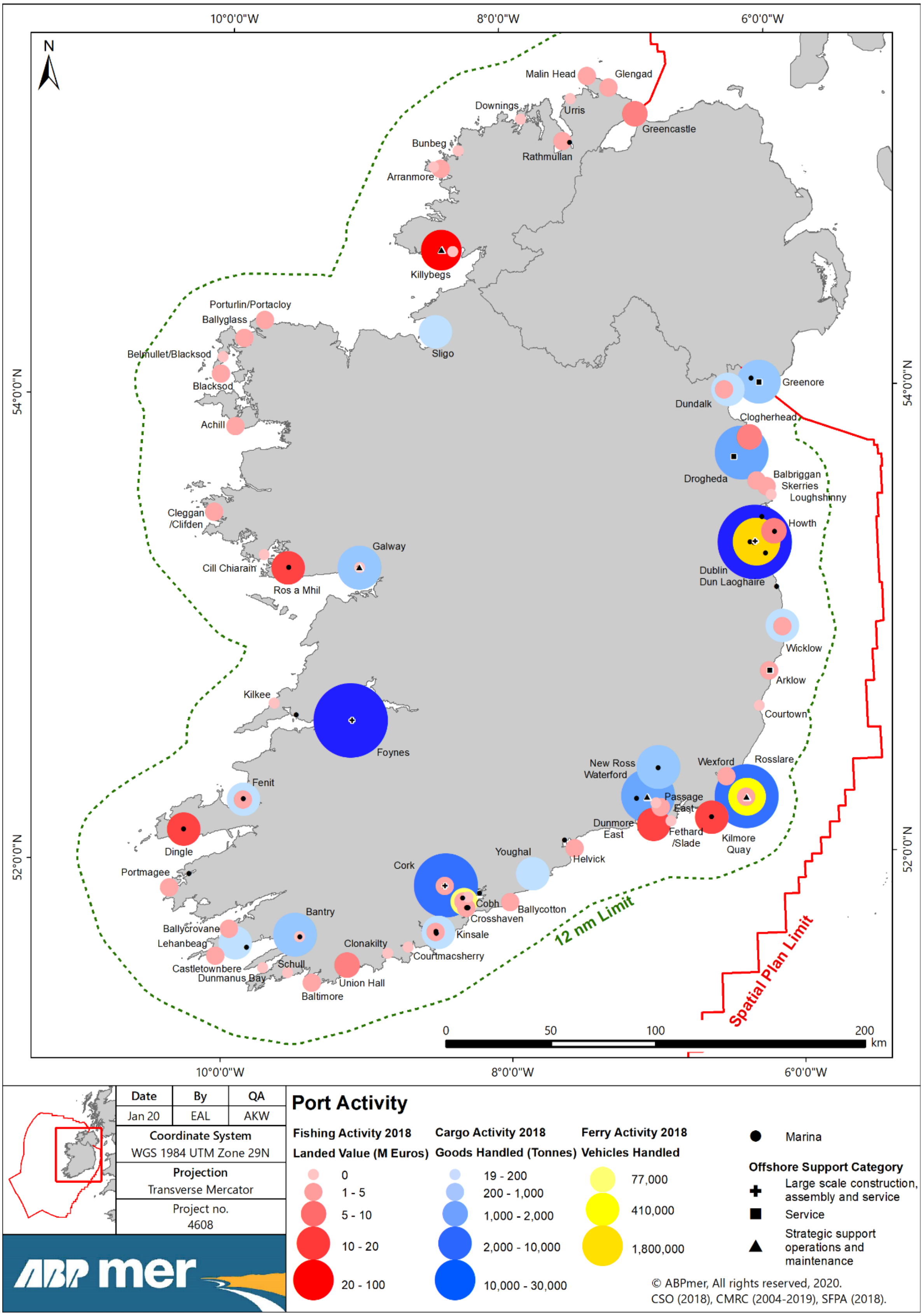


Figure 5. **Main ports and harbours other capital inputs map**

4 Mapping Marine Ecosystem Services

This section provides an overview of the methods that have been used for mapping key ecosystem services provided within Irish waters.

Full method descriptions for mapping of each ecosystem service are provided in Appendices B-D. Table 6 provides a summary of the ecosystem services defined in CICES and summarises the methods used to quantify each service and the data layers used for mapping purposes.

Table 6. Summary of approaches for mapping marine biotic and abiotic ecosystem services

Ecosystem Services	Quantity	Value	Key Data Sources For Mapping ES Services
Provisioning			
Wild capture fisheries and shellfisheries	▪ Biomass (t km^{-2}) fish or shellfish ▪ Area (m^2)	▪ Landings values (Euros)	▪ Fishing method by gear type (MI Atlas) – line, mobile bottom, passive, dredge, net, pot etc. Inshore shapefiles from MI through https://data.gov.ie/ ▪ Offshore VMS data from MI. ▪ SFPA landings data provided tonnage and Euro value. ▪ STECF data on tonnage of catches from all EU Member States.
Algae/ Seaweed Harvesting (food resource)	▪ Biomass (t km^{-2}) seaweed	▪ Sales values (Euros)	▪ Licensed harvesting sites (DHPLG)
Aquaculture – finfish and shellfish	▪ Biomass (t km^{-2}) or abundance of fish or shellfish ▪ Area (m^2)	▪ Sales values (Euros)	▪ Finfish by culture and species (DAFM) ▪ Bord Iascaigh Mhara (BIM) – non-spatial ▪ HABs Inshore and Offshore shellfish production areas (MI Atlas) ▪ Shellfish by culture and species (DAFM)
Aquaculture - seaweed	▪ Biomass (t km^{-2}) ▪ Area (m^2)	▪ Sales values (Euros)	▪ DAFM aquaculture licence database.
Non-mineral substances: offshore wind, wave and tidal energy	▪ Energy generation (kWh)	▪ Estimated value of electricity produced (Euros)	▪ Connection cables (MI Atlas) ▪ Offshore tidal resource (DCCAE) ▪ Mean Annual Practicable Power (Wave, Wind) (MI Atlas) ▪ Offshore Wind Farm (DHPLG) ▪ Technical wind, wave and tide resource areas (MaREI) ▪ Offshore Renewable Energy Developments – OSPAR
Mineral substances: aggregates, oil and gas; fibre, ornamental, biochemical	▪ Aggregates – no activity ▪ Gas production volumes ▪ Fibre, ornamental, biochemical - no data	▪ Estimated value of gas sales (Euros)	▪ Oil and gas exploration/ demonstration areas (Petroleum Affairs Division, PAD) ▪ Oil and gas reserves & infrastructure (PAD)
Genetic material	▪ No data	▪ No data	▪ No data for mapping
Water for non-drinking purposes	▪ Water abstraction volume (m^3/s) ▪ Tonnage of goods transported by sea	▪ Water abstraction - use 2% efficiency method ▪ MMO cargo valuation method (MMO, 2019)	▪ Power station locations and abstraction volumes (EPA) ▪ Power station annual electricity generation ▪ Shipping density/distribution ▪ CSO shipping freight statistics
Regulating			
Climate regulation and carbon sequestration	▪ air-sea flux of CO_2 per hectare per year based on a carbon value	▪ Value of non-traded carbon	▪ Important habitat areas: Saltmarsh, sand dunes, estuaries, coastal waterbodies (EPA, NPWS) ▪ NEMO-ERSEM flux model outputs (PML)
Mediation of wastes - water purification	▪ Organic matter (Nitrogen and Phosphorus) in water (mg l^{-1})	▪ Cost-avoided, shadow prices (Hernandez-Sancho *et al.* 2010)	▪ Licensed waste facility (Norton *et al.* 2018) ▪ Riverine outputs data (EPA) ▪ Estuaries (EPA WFD boundaries)

Ecosystem Services	Quantity	Value	Key Data Sources For Mapping ES Services
Regulation of flows - Natural Hazard Protection	▪ Extent of habitats (km^{-2}), protected length of coastline	▪ Avoided cost of defence maintenance	▪ Saltmarsh (NPWS) – All 80 m or thicker saltmarsh was digitised regardless of width ▪ Sand dunes (NPWS) ▪ Shingle (NPWS) ▪ Sea defences (Landside Infrastructure) ▪ CORINE land cover data (EPA)
Pest and disease control	▪ Data not available	▪ No data	▪ Not progressed due to a lack of data
Lifecycle maintenance	▪ Data not available	▪ No data	▪ Not progressed due to lack of clarity on service and limited data with which to spatialise it
Cultural			
Tourism and recreation	▪ Area of protected and designated sites (m^2) ▪ Area of beaches (m^2) ▪ Area of Racing Areas (m^2) ▪ Area of General Sailing Areas (m^2) ▪ Area of airfields (m^2) ▪ Extent of recreational ferry routes (km^2) ▪ Extent of coastal cycling routes (km^2) ▪ Extent of Wild Atlantic Way (km^2) ▪ Extent of coastal walking routes (km^2) ▪ Extent of Recreational Routes for motor/power boating, motorised sailing, unmotorised sailing, personal watercraft, small dayboat/dinghy sailing (km^2) ▪ Number of recreation activity locations and clubs/schools/activity operators. ▪ Number of recreation activity Flickr locations. ▪ Number of Nature Reserves, Wildlife Sanctuaries, Visitor Attractions ▪ Number of Blue Flag and Green Coast beaches; Designated Bathing Water Locations; Scenic Coastal Towns & Villages; Discovery Points; Signature Points; Historic Houses & Castles; Museums and Attractions; National & Forest Parks; Small Airports ▪ Number of Marine Recreation Infrastructure features ▪ Number of Coastal Tourism Accommodation Providers, Food & Drink	▪ Norton *et al.* (2018) estimated that recreational services interacting with the coastal, marine and estuarine ecosystems result in approx. 96 million marine recreation trips by Irish residents with an estimated annual value of €1.7 billion.	On the Water: ▪ Recreational Angling ▪ Kitesurfing ▪ Windsurfing ▪ Surfing ▪ Diving/snorkelling ▪ General Coastal Tourism Activities (Ferry Routes only) ▪ Motor/power boating ▪ Motorised Sailing ▪ Wakeboarding/waterskiing ▪ Parascending ▪ Unmotorised Sailing ▪ Kayaking ▪ Canadian Canoeing ▪ Stand-Up paddleboarding ▪ Dinghy/Dayboat/Small Keelboat Sailing ▪ Personal Watercraft ▪ Wildlife/Bird Watching/Wildfowling On the Beach/Intertidal Zone ▪ General Beach Leisure ▪ Coastal Quad Biking/Scrambling ▪ Sand Yachting/Land Sailing/Land Yachting ▪ Kite Buggying ▪ Marine Recreational Infrastructure ▪ Recreational Angling ▪ Wildlife/Bird Watching/Wildfowling ▪ Climbing/Coasteering/Bouldering

Ecosystem Services	Quantity	Value	Key Data Sources For Mapping ES Services
	Providers, and Arts/Crafts/Souvenir shops		On the Land: ▪ Climbing/Coasteering/Bouldering ▪ Recreational Drone Use ▪ General Coastal Tourism Activities (except for Ferry Routes) ▪ Coastal Cycling ▪ Coastal Recreational Light Aircraft ▪ Visitor Attractions ▪ Coastal Walking ▪ Wildlife/Bird Watching/Wildfowling ▪ Coastal Tourism Infrastructure
Scientific and educational	▪ Area of protected and designated sites (m^2) ▪ Number of education centres offering courses relating to the marine environment; marine training centres; marine research centres and laboratories, marine research stations and test facilities; national marine organisations. ▪ Number of NPWS education centres; museums and OPW National Heritage Sites; Maritime Collections features. ▪ Number of Nature Reserves, National Parks, and Wildlife Sanctuaries.	▪ Vega and Corless (2016) estimate the total turnover of €11.5m for the marine education and training sector in Ireland between 2014-2015.	▪ International designations – SACs, SPAs, Ramsar, MPAs ▪ National designations – NHAs, pNHAs, Ancient & Long-Established Woodland ▪ UNESCO sites – WHS, Geoparks, Biosphere Reserves ▪ National Parks ▪ Wildlife Sanctuaries ▪ Nature Reserves ▪ Local Authority Local Landscape Designations ▪ Maritime Collections ▪ Museums and OPW National Heritage Sites ▪ NPWS Education Centres ▪ National Marine Organisations ▪ Research Centres ▪ Educational Institutions offering courses in the marine environment ▪ Marine Research Stations and Test Facility locations ▪ INFOMAR Surveyed Areas ▪ Irish Sailing Association Training Centres
Cultural heritage	▪ Area of World Heritage Sites (m^2) ▪ Area of National Monuments Zones of Notification (m^2) ▪ Area of Conservation Areas (m^2) ▪ Number of Wreck Extents ▪ Number of 'Heritage Assets' ▪ Number of 'Heritage Sites & Towns' ▪ Number of Sheela Na Gigs	Insufficient information to place monetary values on cultural heritage ecosystem services. ▪ World Heritage Sites & Tentative WHS - Very High ▪ Wrecks – High, Medium, Low ▪ Terrestrial Heritage Assets – High, Medium	▪ World Heritage Sites ▪ Wreck Extents ▪ Heritage Assets – National Monuments, National Monuments Zones of Notification, NIAH, Archaeological Survey of Ireland, Atlas of Hillforts, Protected Structures ▪ Heritage Sites & Towns – Tentative WHSs, OPW National Heritage Sites, Walled Towns of Ireland, Heritage Towns of Ireland, National Parks ▪ Sheela Na Gigs ▪ Local Authority Conservation Areas
Aesthetic	▪ Area of protected and designated sites (m^2) ▪ Area of beaches (m^2) ▪ Area of local landscape designations	▪ Norton *et al.* (2018) estimated the value of aesthetic services to be €68m (flow value of coastal location of housing).	▪ International designations – SACs, SPAs, Ramsar, MPAs ▪ National designations – NHAs, pNHAs, Ancient & Long-Established Woodland, Wildlife Sanctuaries, Nature Reserves ▪ UNESCO sites – WHS, Geoparks, Biosphere Reserves

Ecosystem Services	Quantity	Value	Key Data Sources For Mapping ES Services
	(m^2) ▪ Area of Conservation Areas (m^2) ▪ Extent of 'Scenic Routes' (km^2) ▪ Number of Nature Reserves and Wildlife Sanctuaries ▪ Number of Blue Flag and Green Coast beaches ▪ Number of 'Heritage Sites & Towns' ▪ Number of 'Scenic Locations' ▪ Number of geotagged 'aesthetic' photographs		▪ Scenic Locations – Conservation Areas, Scenic Coastal Towns & Villages, Peninsulas and Islands, Scenic Mountain Trails, Local Authority Scenic Views, Recreational Areas, Local Authority Scenic Locations ▪ Scenic Routes – Wild Atlantic Way, Local Authority Scenic Routes, Local Authority Scenic Views ▪ Heritage Sites & Towns – Tentative WHSs, OPW National Heritage Sites, Walled Towns of Ireland, Heritage Towns of Ireland, National Parks ▪ Landscape Designations - Special Amenity Area Orders, Local Authority Landscape Designations ▪ Beaches – Blue Flag, Green Coast, Beaches ▪ Geotagged photographs of 'aesthetic' ecosystem services – Photos tagged as "nature", "wildlife", "coast", "scenic", "seascapes", "waves", "sand", "shoreline", "sea", "ocean", "rugged", "beach", "cliff", "landmark", "sunset", "sunrise" and "wilderness"
Spiritual and emblematic	▪ Area of Religious Buildings, Burial Grounds & Monuments (m^2) ▪ Area of Gaeltacht Areas (m^2) ▪ Number of Pilgrim Paths; Sacred Sites; Coastal Retreat Centres	Insufficient information to place monetary values on spiritual and emblematic ecosystem services. Spiritual: ▪ Value 5 - High (coastal lagoons, beaches, dunes, sand, bare rocks, intertidal flats, forests & woodlands) ▪ Value 4 (moors & heaths) ▪ Value 2 (agricultural land) ▪ Value 1 – Low (peat bogs, marshes, urban fabric) Sense of Place: ▪ Value 5 - High (coastal lagoons, beaches, dunes, sand, bare rocks, intertidal flats, urban fabric, moors & heaths) ▪ Value 4 (agricultural land, forests & woodlands) ▪ Value 1 – Low (peat bogs, marshes) Wilderness/Solitude:	▪ Pilgrim Paths ▪ Religious Buildings, Burial Grounds and Monuments ▪ Sacred Sites ▪ Coastal Retreat Centres ▪ Gaeltacht Areas ▪ Spiritual CORINE Land Cover ▪ Sense of Place CORINE Land Cover ▪ Wilderness & Solitude CORINE Land Cover

Ecosystem Services	Quantity	Value	Key Data Sources For Mapping ES Services
		▪ Value 5 - High (coastal lagoons, beaches, dunes, sand, bare rocks, intertidal flats, peat bogs, marshes) ▪ Value 4 (forests & woodlands, moors & heaths) ▪ Value 3 (agricultural land) ▪ Value 1 – Low (urban fabric)	
Existence and bequest	▪ Area of protected and designated sites (m^2) ▪ Area of local landscape designations (m^2) ▪ Number of Nature Reserves and Wildlife Sanctuaries ▪ Number of 'Heritage Sites & Towns' ▪ Number of 'Heritage Assets'	▪ Insufficient information to place monetary values on existence and bequest ecosystem services.	▪ International designations – SACs, SPAs, Ramsar, MPAs ▪ National designations – NHAs, pNHAs, Wildlife Sanctuaries, Nature Reserves ▪ UNESCO sites – WHS, Geoparks, Biosphere Reserves ▪ Landscape Designations - Special Amenity Area Orders, Local Authority Landscape Designations, Conservation Areas ▪ Heritage Sites & Towns – Tentative WHSs, OPW National Heritage Sites, Walled Towns of Ireland, Heritage Towns of Ireland, National Parks ▪ Heritage Assets – Wreck Extents, National Monuments, National Monuments Zones of Notification, NIAH, Archaeological Survey of Ireland, Atlas of Hillforts, Protected Structures, Sheela na Gigs

4.1 Provisioning services

4.1.1 Wild capture fisheries and shellfisheries

Figure 6 provides a representation of the location and intensity of wild capture fisheries and shellfisheries activity as an annual average for 2014–2018. Figure 7 indicates the location where the benefit is realised on land in terms of the volume of fish and shellfish landings to ports in Ireland over this same period.

What the service is

This service includes the capture of fish, shellfish and crustaceans from commercial harvesting of wild stocks.

Why it is important

Increasing demand for food provision is putting pressure on the marine ecosystem. Understanding the areas contributing to current food provision is important in marine spatial planning.

In Irish waters, catches of fish and shellfish worth €642 million per year (average, 2012-2016) were made by EU vessels (including Irish vessels). This is based on catch volumes from the European Union’s Scientific, Technical and Economic Committee on Fisheries (STECF) and values per tonne from Eurostat. These can be roughly apportioned to the inshore and offshore parts of the fishery based on vessel length, as follows:

- Offshore fishery: Vessels over 10 m: € 626.6 million
- Inshore fishery: Vessels under 10 m: € 15.5 million

Irish vessels caught and landed 234,000 tonnes of fish and shellfish worth € 257 million (annual average over the period 2015-2018) (SFPA annual statistics).

The distribution of fishing effort in the offshore fishery can be mapped using satellite-based Vessel Monitoring System (VMS) data, which EU-registered fishing vessels over 12 m length are required to use. This records the location, speed and direction of the vessel at least every two hours. The Marine Institute has processed the available VMS data for all vessel nationalities to show average fishing effort (hours per square kilometre per year).

Not all of the catches of fish and shellfish made in Irish waters are landed into Irish ports. Between 2014 and 2018, an average of 298,256 tonnes of fish and shellfish were landed into ports in Ireland, worth €349 million.

How to interpret the map

Figure 6 shows the distribution of fishing effort within Irish waters. The red polylines show the annual average density of offshore fishing effort (hours per sq. km) between 2014 and 2018. This highlights important fishing grounds on the continental shelf and Porcupine Bank and on the shelf slope, as well as in the Celtic Sea. The prawn grounds in the Irish Sea can also be clearly seen. The blue polygon shows the combined area utilised by the inshore fishing fleet (vessels under 15 m length), as mapped in support of the Natura 2000 risk assessment in 2013. We were unable to spatialise the inshore fishing effort as location data are not available for vessels under 12 m, which dominate in the inshore area. Only vessels over 12 m are captured in the fishing effort based on vessel GPS data. Black points show harvesting locations for periwinkles.

Figure 7 shows the average fish and shellfish landings to each port between 2014 and 2018. Pie charts indicate the total tonnage of fish and shellfish landed, and show the proportion of shellfish, demersal, pelagic and deep-water species. Killybegs on the north-west coast of Ireland had the highest total landing volume in the period with 193,542 tonnes landed. Killybegs is particularly important for the pelagic fishery and landings there are predominantly of pelagic species. Across Ireland, pelagic species are the species landed in the highest volumes, followed by demersal species and then shellfish.

How the maps were created

Fisheries data on inshore fishing areas, and fishing effort of over-12 m vessels were sourced from the Marine Institute. Data on landings to ports were provided by the Sea Fisheries Protection Authority. Data on the volume of landings of EU vessels by ICES rectangle were sourced from the STECF through the Joint Research Centre data dissemination tool, and values per tonne were obtained from Eurostat.

The inshore fisheries data shows the combined inshore area of interest for Irish vessels under 15 m. The data includes trawl, line, dredge, net and pot fishing.

VMS data for the offshore fishing effort shows the average fishing effort for vessels over 12 m length for all vessel nationalities from 2014–2018.

SFPA landings data for Irish ports were used to calculate the 5-year combined average landings for Irish and foreign vessels. The port locations were digitised from satellite data. This dataset shows the 5-year combined average tonnes of fish types landed between 2014 and 2018 in Irish ports which had over five landings events in each year. Data for ports with fewer than five landings events in any year were combined ('Combined minor landings') to protect anonymity.

Data limitations

Detailed and up-to-date spatial information on fishing areas by under-12m vessels is not available.

The data on value of fish catches do not include fish caught in Irish waters by non-EU vessels and therefore may under-represent the whole ecosystem service in relation to food provision from wild capture fisheries of Irish fish and shellfish resources. For all EU vessels, value of catches was derived from recorded landings volumes combined with average values per tonne from Eurostat and does not reflect the recorded value of landings from vessels.

Opportunities

Ireland has a large marine area with important fishing grounds for demersal, pelagic, shellfish and deep-water species, which should be taken into account in marine planning policies for their role in food provision to Ireland and other countries. The EU's Common Fisheries Policy means that EU Member States have equal access to European waters beyond 12 nautical miles and can fish against quotas allocated to them. Some Member States also have historical rights to fish in the area between 6 and 12 nautical miles. This means that the overall value of fish and shellfish resource in Irish waters does not accrue to the Irish fishing fleet, nor are all catches landed into Irish ports. Some fish and shellfish stocks are being fished beyond sustainable limits, and there may be opportunities to increase the value of the provisioning ecosystem service from wild capture fisheries and shellfisheries where stocks can be rebuilt to maximum sustainable yield levels.

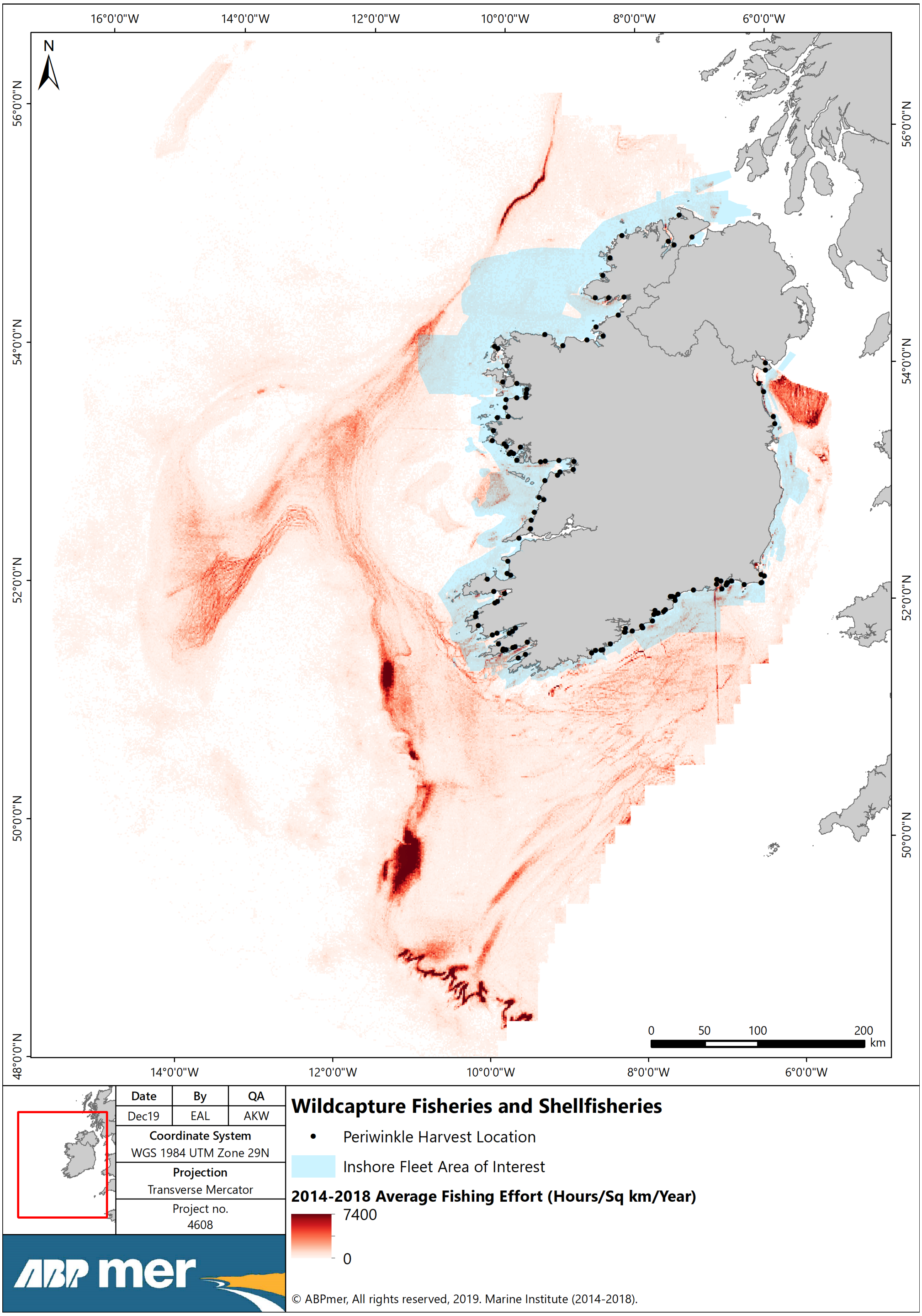


Figure 6. Provisioning Service: Wild capture fisheries and shellfisheries

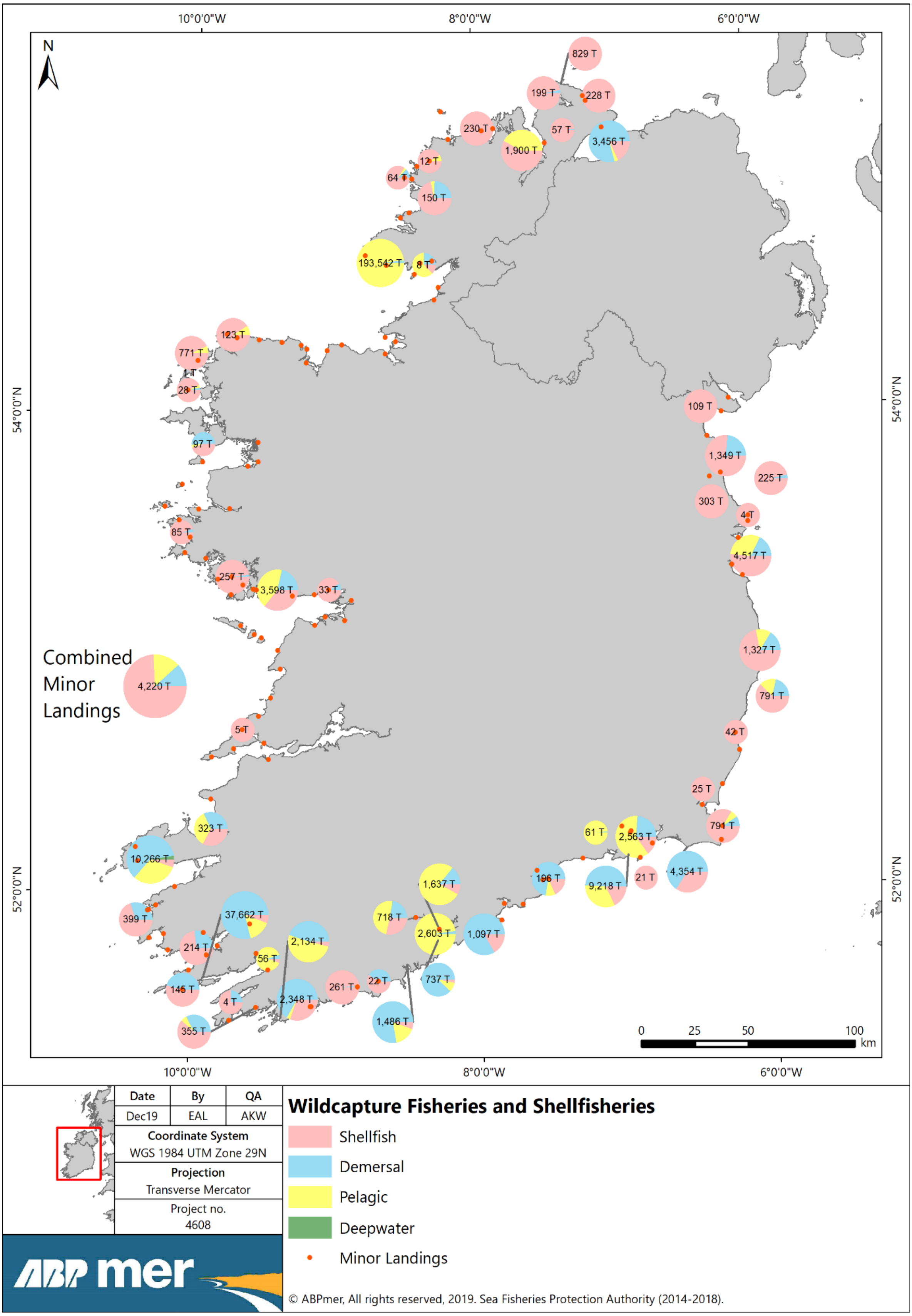


Figure 7. **Realisation of benefits from wild capture fisheries and shellfisheries – Tonnage of fish and shellfish landings into Irish ports**

4.1.2 Seaweed wild harvest

Figure 8 provides a representation of the location wild seaweed harvest within Ireland from foreshore licensing applications.

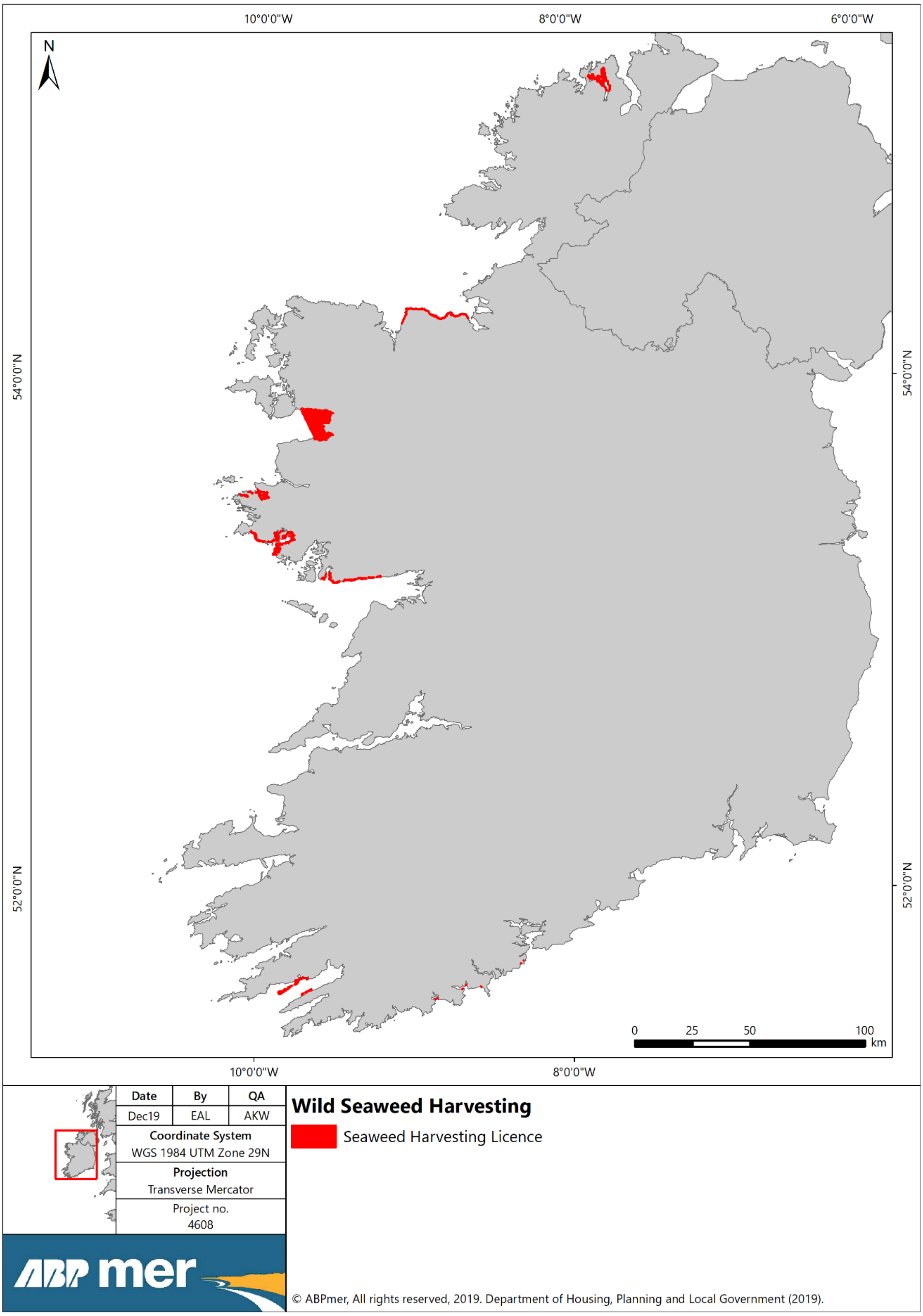


Figure 8. Provisioning Service: Seaweed biomass though wild harvest

What the service is

This service includes the collection and harvest of seaweed from wild harvest only.

Why it is important

There are many uses for seaweed. 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.

In Ireland, following the Foreshore Act 1933 all persons or companies, seeking to harvest wild seaweed must obtain a license from the Department of Housing, Planning and Local Government. There are multiple licensed wild harvesting areas in Ireland, predominantly on the west coast, in the counties of Donegal, Sligo, Mayo, Galway, and Cork. One of the main areas licensed to mechanically harvest kelp is in Bantry Bay in Cork, the licence covers an area of approximately 750 ha. Other key licensed areas are Clew Bay, Co. Mayo, Galway Bay to Ballynakill Harbour, and North Galway Bay & Bertrabui Bay, Co. Galway. However, most wild harvested seaweed is harvested intertidally under existing land rights for which no licence is required. It is estimated that there are around 6,500 such private rights. Data for these could not be sourced and as such are not shown on the map.

It is estimated that around 36,000 tonnes of natural seaweed were harvested annually in Ireland, *Ascophyllum nodosum* is the main species harvested (BIM, 2011; Morrison, 2018). The other less harvested species are *Fucus serratus, Laminaria digitata, Chondrus crispus and Palmaria palmata.* Following the work by O'Toole and Hynes (2014) the value of wild harvested seaweed can be calculated.
In 2012, 29,500 tonnes of seaweed were harvested in Ireland with an overall value of €3,914,000, yielding an average per tonne value of €133 of seaweed harvest. Using this value, the approximate value of wild seaweed harvest in Ireland in 2018 is €4,788,000 (based on 2012 values).

The overall wild harvesting seaweed industry has an estimated sector value of €18 million (BIM, 2011). The agriculture sector is the largest sector in the Irish seaweed industry by volume and sale, estimated to have turnover of in excess of €5 million per annum and use approximately 20,000 tonnes of seaweed per annum. The cosmetics sector is worth approximately €2.5 million per annum and mainly utilises *Fucus serratus* and smaller amounts of *Ascophyllum nodosum*, *Palmaria palmata*, *Chondrus crispus, Lithothamnion corallioides* and *Laminariale* (BIM, 2011).

How to interpret the map

The polygons show the location of current licences for the mechanical harvest of seaweed. There are currently nine registered seaweed harvesting areas.

How the map was created

Data were digitised from foreshore licensing applications for seaweed harvesting from the Department of Housing, Planning and Local Government (DHPLG).

Data limitations

There is a lack of available information on the locations of harvesting carried out under private rights in intertidal areas, it is estimated that there are around 6,500 such private rights. The Property Registration Authority holds information on private rights, but this information is not readily available, and it is understood to be incomplete, the map is therefore an underestimate of the locations under which harvesting is carried out.

There is also uncertainty concerning the volumes of seaweed harvested under these rights and a lack of information on the exact value of seaweed harvested, which will likely vary by species harvested and their ultimate use.

The valuation of current seaweed harvest is based upon an average value across all harvested species. However, the value of individual species varies, with red seaweeds such as *Chondrus crispus* and *Palmaria palmata* having a higher market value. Valuation will therefore vary yearly based upon the species harvested. Additional data on individual species harvest would be required to accurately assess the value of the wild harvest industry. Additionally, the data used to calculate the overall value of the seaweed harvesting sector (€18 million) is unclear and is likely including the added value of products following processing and sale of goods. The value does not include value of seaweed produced from seaweed aquaculture.

Opportunities

Ireland has a large wild seaweed resource. Updated maps of seaweed resource and updated information on existing harvesting rights in the intertidal could be used to identify potential new areas for harvesting. This would enable accurate mapping of the resource and the ability to spatialise volumes and values of seaweed harvested to produce more complete seaweed harvesting ES maps.

4.1.3 Aquaculture: fish and shellfish

Figure 9 provides a representation of the location finfish and shellfish aquaculture within Ireland and shows the value of aquaculture by species for each county in 2017.

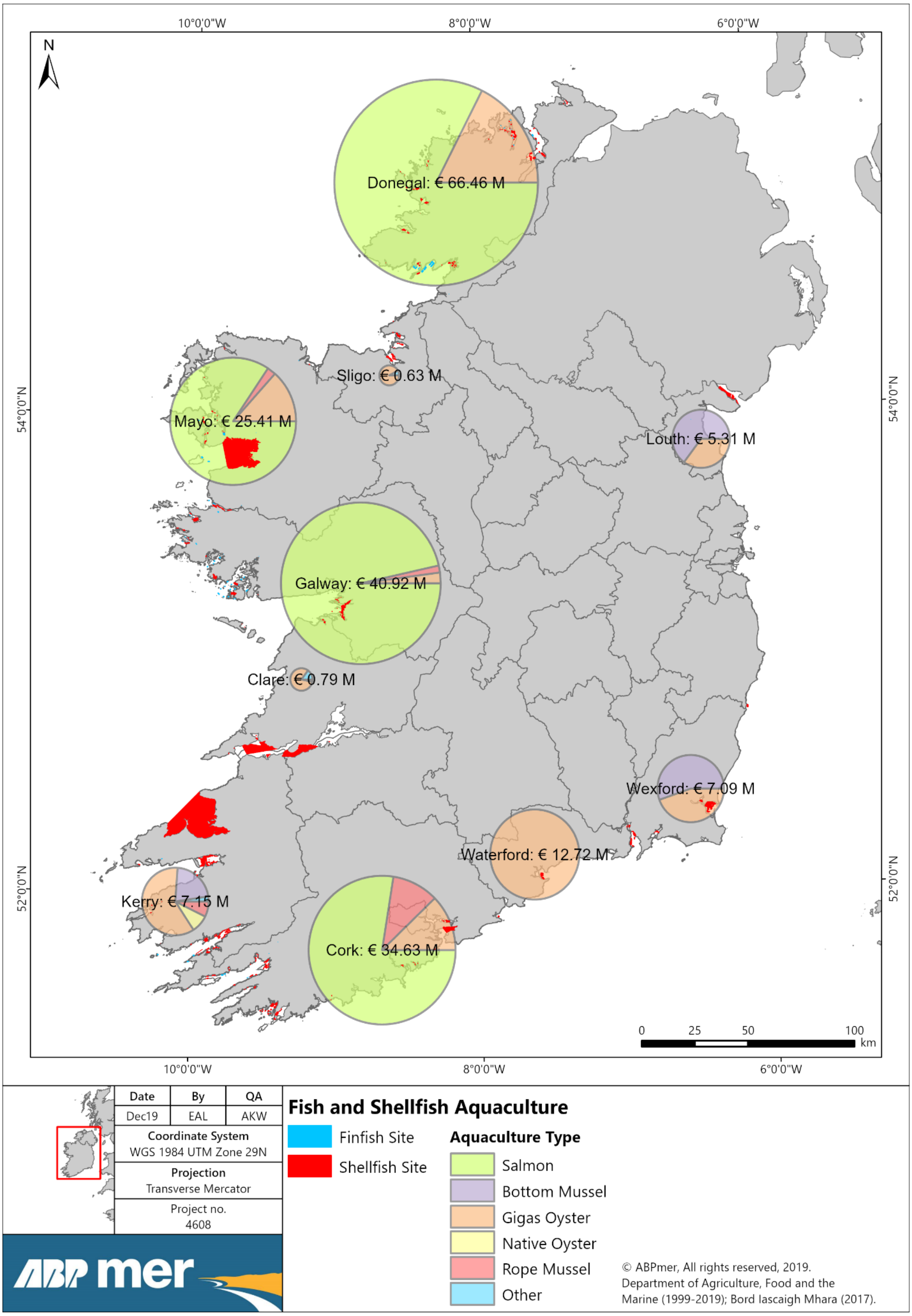


Figure 9. Provisioning Service: Fish and shellfish aquaculture

What the service is

The provision of food through marine fish and shellfish aquaculture.

Why it is important

Harvesting farmed products produced through aquaculture is an important component of food provisioning ecosystem services from the marine environment. In Ireland, Atlantic salmon is the main aquaculture species produced, other key species include Gigas oysters and bottom grown mussels.

Finfish aquaculture sites are located within both coastal waters and onshore facilities across Ireland, however a large proportion of facilities are located within County Galway, County Mayo and Donegal, in the north west of Ireland. Shellfish aquaculture is largely located within nearshore coastal waters on the west coast of Ireland. Donegal is the largest value producer of aquaculture with a value of €68.3 million in 2017. The total estimated value of marine fish and shellfish aquaculture in Ireland is €201 million.

How to interpret the map

Blue polygons show the location of currently licensed finfish aquaculture sites. Red polygons indicate the location of currently licensed shellfish aquaculture sites. The pie charts show the value of aquaculture by species for each county within Ireland.

How the map was created

Data relating to currently licensed or operating aquaculture sites within Irish waters was sourced from the Department of Agriculture, Food and the Marine. These data were interrogated and all records relating to finfish and shellfish aquaculture sites were extracted after the removal of any personal information. Freshwater aquaculture such as freshwater trout and smolt/ova aquaculture have been removed from the analysis, to assess the value of marine aquaculture provision.

Data limitations

This layer is created from the original Aquaculture Licence GIS Data which contains currently licensed or operational aquaculture sites under Section 19A of the Fisheries (Amendment) Act 1997. It does not include any information on pending applications or applications which have been refused, lapsed or withdrawn.

The value of aquaculture produced will vary each year, the most up to date data available were used to produce the maps within this project based upon data from 2017. Data do therefore not reflect the current value of aquaculture which is likely to have fluctuated since 2017.

Due to confidentiality, volume and value of production at an individual site level cannot be published.

Opportunities

There are many opportunities within Irish waters to increase shellfish and finfish aquaculture, however it is very difficult to map specific areas in which this could be achieved. One potential opportunity is to expand aquaculture facilities offshore.

The map can be updated periodically (ideally annually) to reflect any newly licensed sites, and updates to production values. The data on value of production by species type could be presented at a finer spatial resolution, such as for specific bays, depending on data confidentiality.

4.1.4 Aquaculture: seaweed

Figure 10 provides a representation of the location of currently licensed or operating seaweed aquaculture facilities within Irish waters.

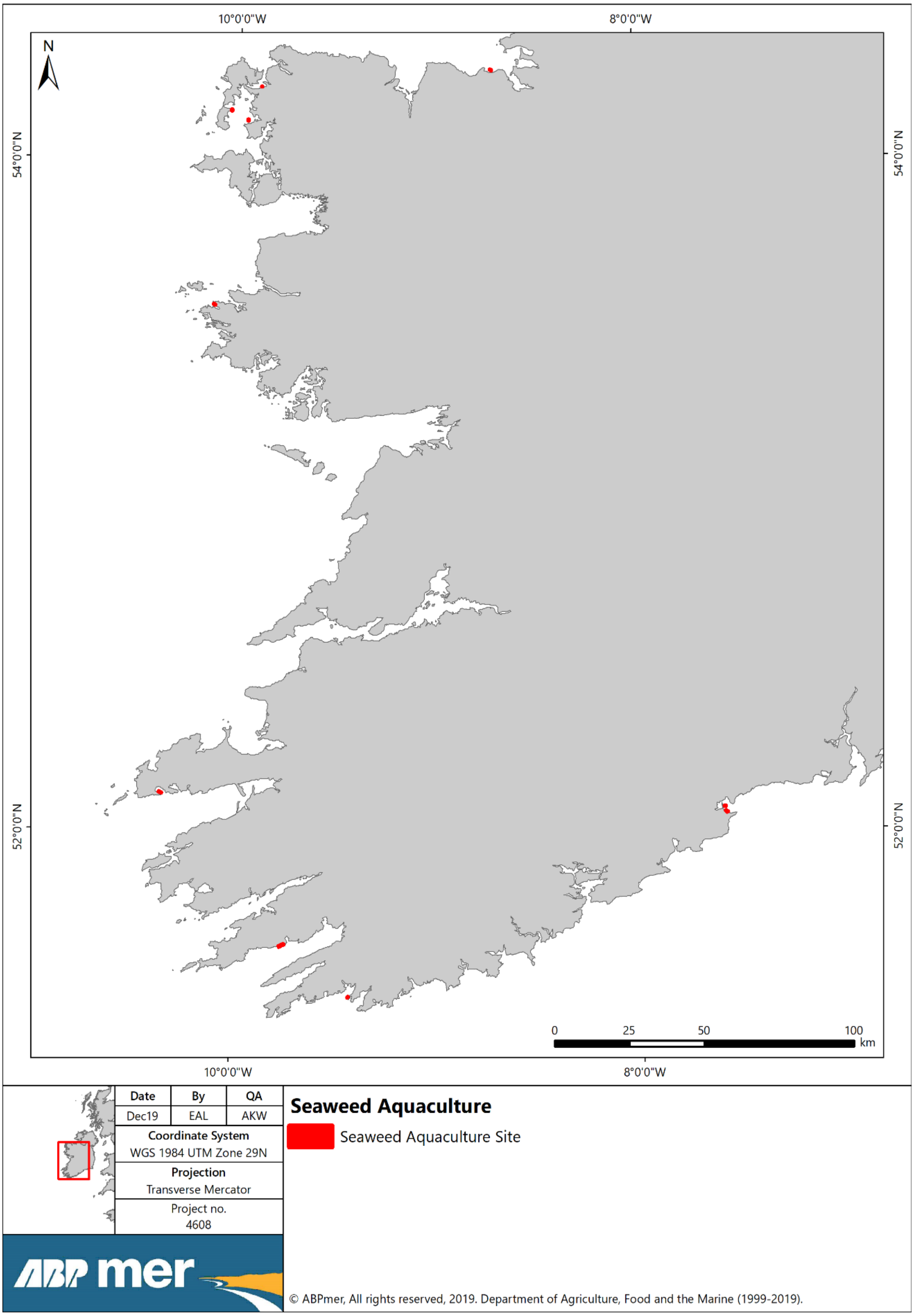


Figure 10. Provisioning Service: Seaweed aquaculture

What the service is

The production of biomass from seaweed aquaculture.

Why it is important

There are many uses for seaweed. 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.

In 2012 the UN Food and Agriculture Organisation calculated that globally, 25 million tonnes of seaweed were produced annually with a commercial value of $6.4 billion, with an approximate value of $256 per tonne (€230; December 2019 currency conversion) of seaweed.

Data sourced from DAFM shows that in Ireland there are currently 13 licensed aquaculture areas covering approximately 106 ha of licensed seaweed aquaculture. Based on best known performance, yield is 6 tonnes wet harvest / ha per year (however this varies with water depth and line density) total harvest could be as high as 636 tonnes of wet harvest per year (BIM, 2019). As such, the current Irish seaweed aquaculture industry is valued at €151,000 (2019 value).

Atlantic Wakame (*Alaria esculenta*) is the most common seaweed farmed in Ireland, with other species including *Palmaria palmata, Laminaria digitata and Porphyra sp.*.

How to interpret the map

Red polygons indicate the locations of currently licensed seaweed aquaculture sites. The main sites for seaweed aquaculture are located on the south and west coasts of Ireland.

How the map was created

Data relating to currently licensed or operating aquaculture sites within Irish waters was sourced from the Department of Agriculture, Food and the Marine. These data were interrogated and all records relating to seaweed aquaculture sites were extracted after the removal of any personal information.

Data limitations

This layer is created from the original Aquaculture Licence GIS Data which contains currently licensed or operational aquaculture sites under Section 19A of the Fisheries (Amendment) Act 1997. It does not include any information on pending applications or applications which have been refused, lapsed or withdrawn.

Opportunities

Based upon data from BIM (2019) there is approximately 130 ha of licensed seaweed aquaculture capacity in Ireland, which would provide a total harvest capacity of 780 tonnes of wet harvest per year. This is above the calculated current capacity in this project (from DAFM data) and suggests additional areas are not being currently utilised.

Additionally, in 2014, seven aquaculture licences were in place with 23 applications with DAFM. There are now currently 13 licensed seaweed aquaculture sites, but the number of applications in 2014 suggests a significant resource which could be further utilised.

The Sea Change Strategy set a target that Ireland's seaweed sector should be worth €30 million by 2020 with the cosmetics sector thought to be an area of significant growth potential (BIM, 2011, 2019).

4.1.5 Mineral substances

Figure 11 shows the location of gas production from natural capital gas assets and the other capital assets such as pipelines, platforms and processing infrastructure required for mineral substances ecosystem services provision.

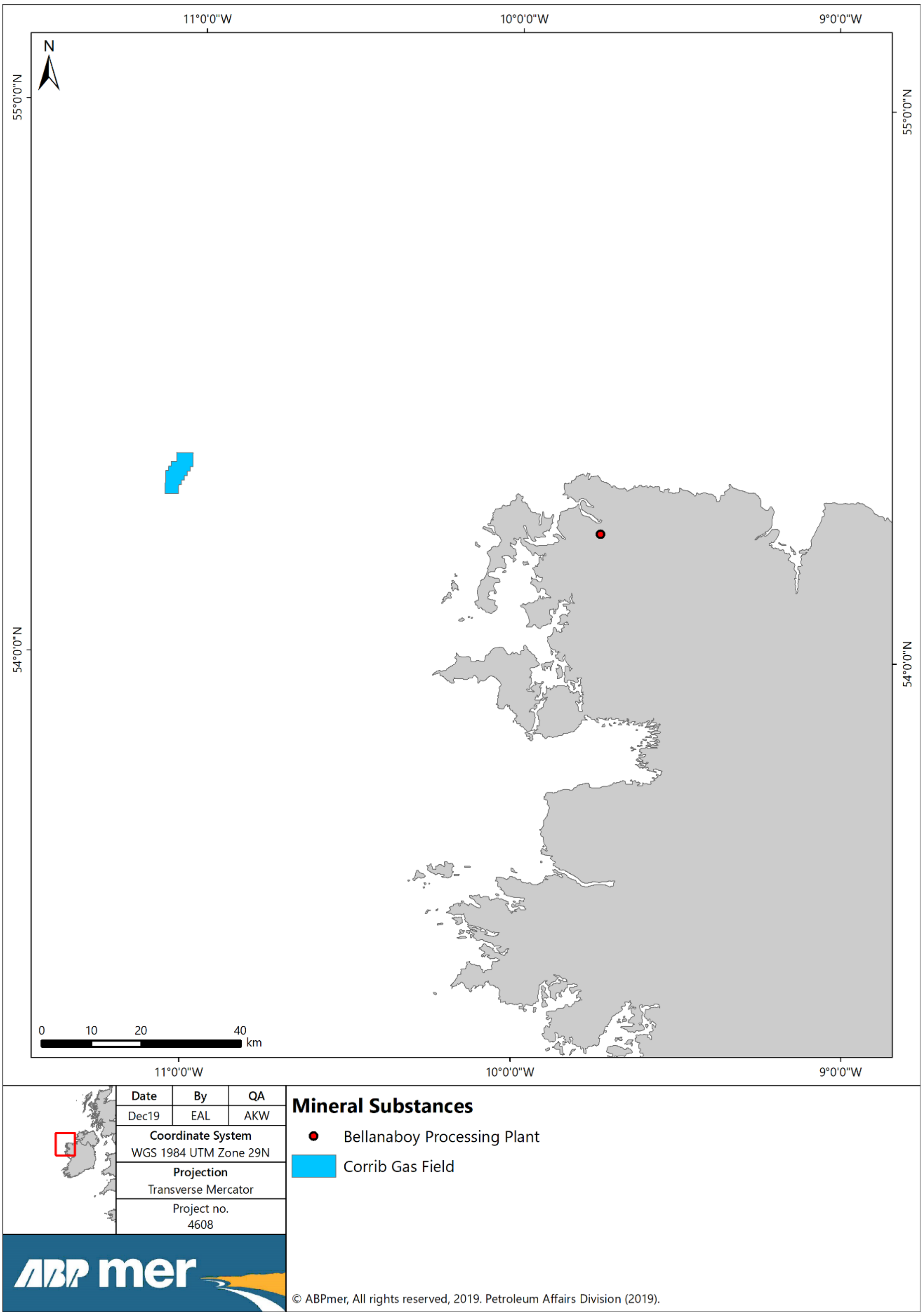


Figure 11. Provisioning Service: Mineral substances

What the service is

This service refers to the variety of raw materials which can be collected in the marine environment for uses such as ornaments, medicines and other pharmaceutical products, and construction materials.

Why it is important

Natural gas plays a critical role in Ireland's energy mix and economy, providing around 30% of Ireland's total primary energy requirement and generating about 50% of Ireland's electricity. Furthermore, Ireland's dependence on gas will increase when the use of coal and peat for electricity generation ends in around 2025/2030.

Ireland requires approximately 53 TWh/yr to power the 650,000 homes which use natural gas[1]. The Corrib Gas field produces around 56% of Ireland's gas requirements, equating to a supply of around 30 TWh/yr. The Corrib field therefore supplies energy to approximately 364,000 homes across Ireland. Based on the wholesale gas price for January-June 2018 of €0.64/therm (CRU, 2018), the supply of 30 TWh/yr. from Corrib equates to a wholesale value for 2018 of €563 million.

How to interpret the map

The blue area depicts the location of gas production within the Irish EEZ. The only significant gas production facility is the Corrib gas field, off the northwest coast of Ireland, County Mayo. The red point shows the location where gas is bought ashore for processing at the Bellanaboy processing facility before being distributed via the national grid network.

How the map was created

The location of the Corrib Gas field was sourced from Oil and Gas Authorisation from the Petroleum Affairs Division. The location of the Bellanaboy Processing Plant was digitised for mapping purposes.

Data limitations

Aggregate extraction has not been included on the map. Although some material from navigational dredging is used for fill and construction purposes this is not the primary purpose of the activity so has not been included.

Precise production figures for the Corrib gas field are not publicly available and production will vary from year to year. Additionally, wholesale prices are calculated on the latest available data but are also subject to variation. Valuation of gas production is therefore only an indicative figure.

Opportunities

Corrib is the only commercially exploitable gas field in Irish waters, it started exporting to the grid in 2015 and has an estimated production life of 15 years, with supply ceasing around 2030.

There is potential to identify opportunities for exploration of gas reserves under Irish licensing rounds. There are no oil reserves identified in Irish waters and Ireland is committed to phasing out oil exploration.

1 https://www.export.gov/article?id=Ireland-Energy-Oil-Gas

4.1.6 Non-mineral substances

Figure 12 shows the location of currently operating renewable energy facilities within Ireland and the associated capital asses required to provide non-mineral substances ecosystem services.

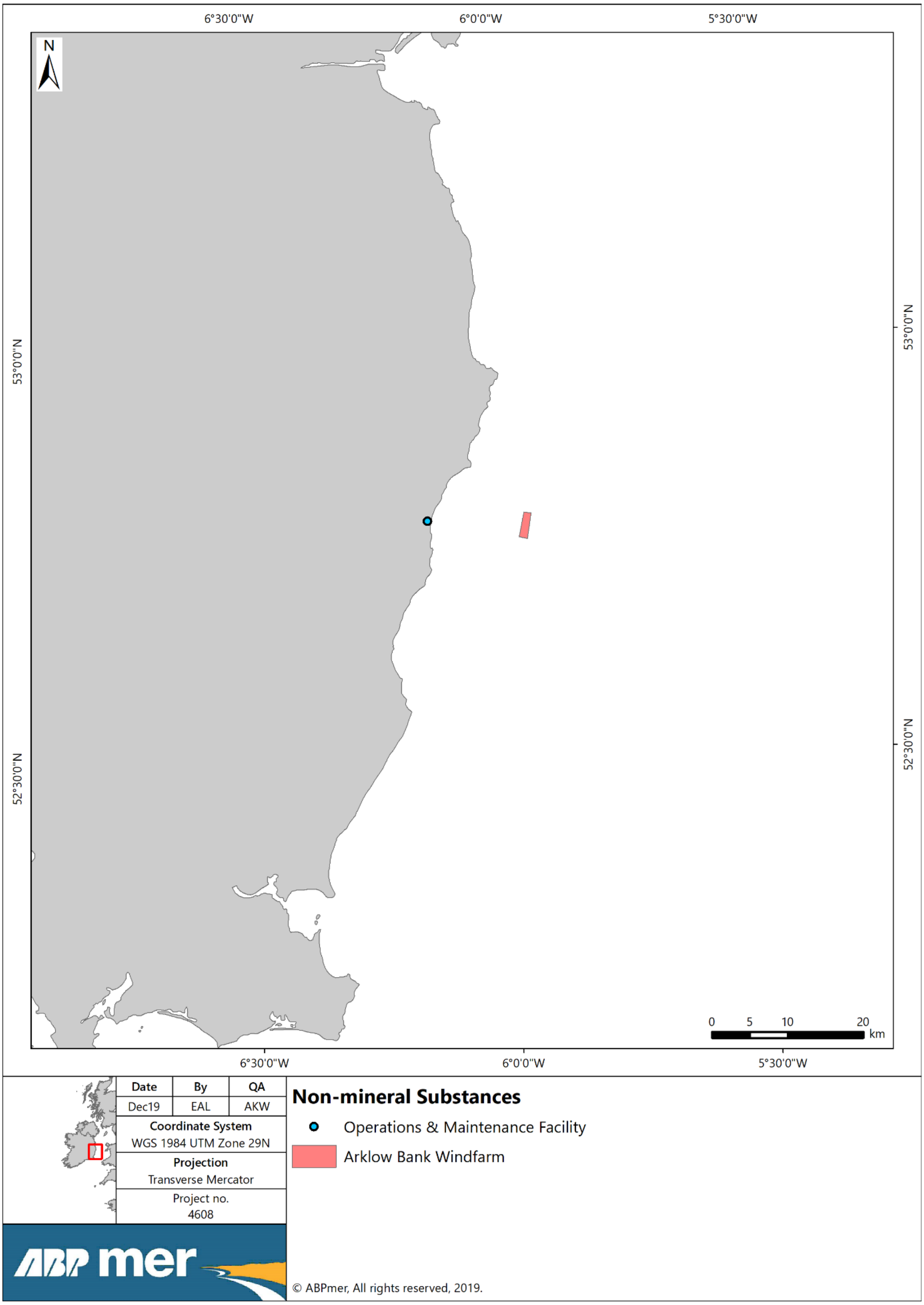


Figure 12. Provisioning Service: Non-mineral substances

What the service is

This service is the provisioning of non-mineral substances, which considers renewable energy technologies including wind, wave, tidal, thermal and geothermal energy. It also includes the location of other capital assets and infrastructure including wind turbines, cables and onshore distribution networks which facilitate electricity production and distribution.

Why it is important

Natural resources are key for providing energy in the form of electricity and heat. The Irish government's climate plan, published in June 2018, called for at least 3.5 GW of offshore wind by 2030.

Arklow Bank offshore wind farm is located 13 km offshore and currently consists of 7 turbines with a capacity of 25.2 MW. Based on a load factor of 40 % (BEIS, 2019) this equates to an annual generation of around 88 GWh. Wholesale electricity prices for January-June 2018 are available from the Commission for Regulation of Utilities (CRU) (2018). The average whole sale price for electricity was €58.33 per MWh, equating to a value of €5.15 million.

Arklow Bank is predicted to generate enough energy to power approximately 16,000 homes (45% of households in County Wicklow)[2].

How to interpret the map

The red polygon shows the location of Arklow Bank offshore wind farm, the only renewable energy development currently supplying electricity. The blue point shows the landfall location and operational and maintenance facilities for Arklow Bank.

How the map was created

Data on the location of the Arklow bank offshore wind farm was sourced from DHPLG. Data on the location of the Arklow bank O&M facilities was digitised from reference base maps.

Data limitations

The figure shows only offshore wind farms which are currently supplying electricity to the grid and does not show the location of demonstration sites, or proposed licence areas.

Opportunities

A second phase of Arklow Bank is currently being progressed by SSE Ireland, which will increase installed capacity from 25 MW to 520 MW. It is expected to be operational in 2020. Once the full project is completed Arklow Bank is predicted to be capable of producing 1.75 TWh/yr, enough energy to power 420,000 homes.

Additionally, Oriel Wind Farm is a proposed offshore windfarm in the north-western Irish Sea. The 28 km² licence area lies 22 km off the coast of Dundalk, County Louth. The proposed development will have an installed capacity of 330 MW powering around 250,000 homes. Figure 13 shows areas for potential future windfarm development within Irish waters. Data were sourced from MaREI and indicate the different consenting stages for each proposed development.

[2] https://www.mresearch.com/pdfs/docket4185/NG11/doc32.pdf

There are substantial opportunities for implementing renewable energy technologies including wind, wave and tidal developments within Irish waters. Currently, electricity is only generated from offshore wind resources. Figure 14 maps opportunity areas for future tidal stream and wave energy renewable energy development, data were sourced from SEAI.

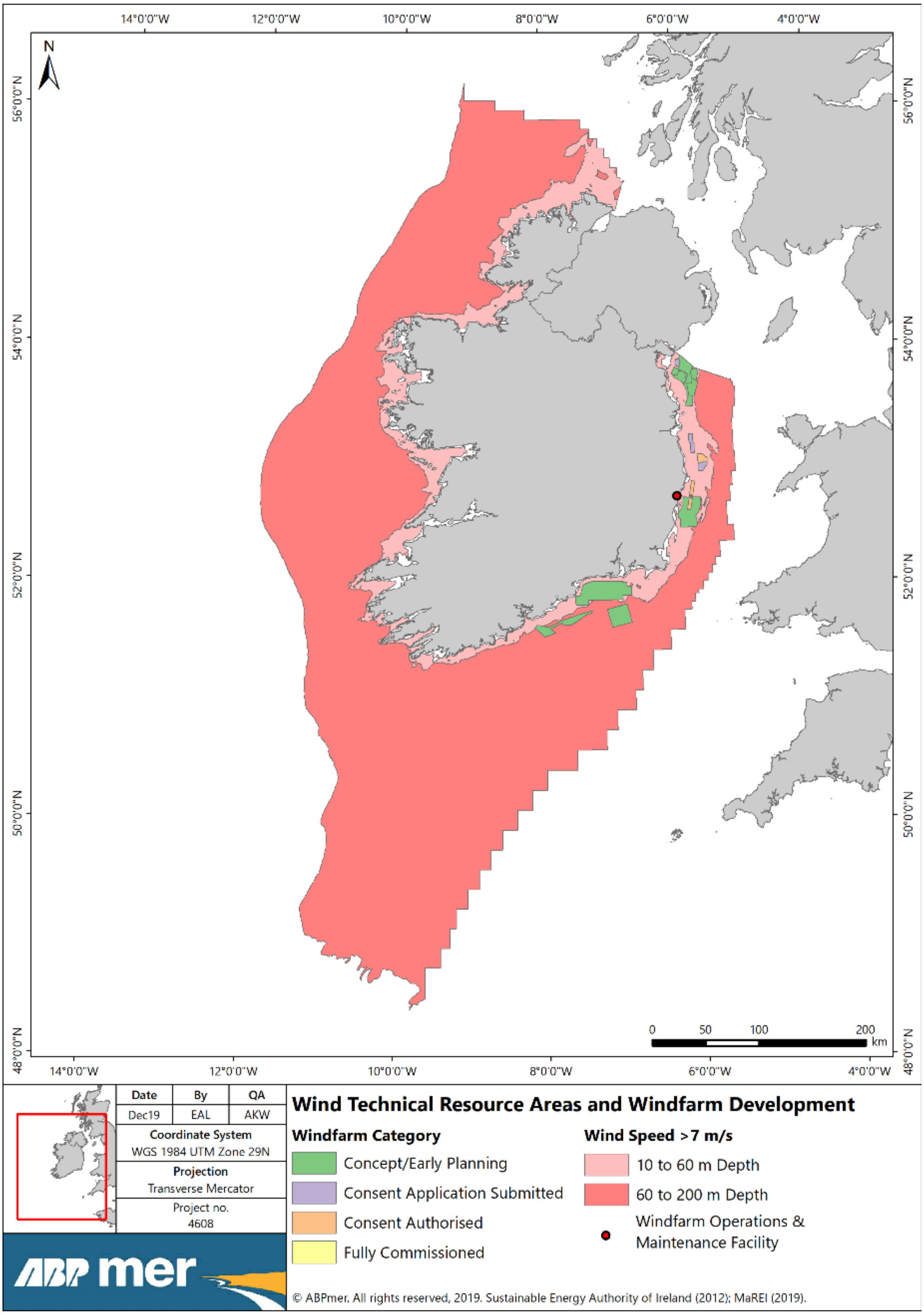


Figure 13. Offshore wind development and technical resource areas

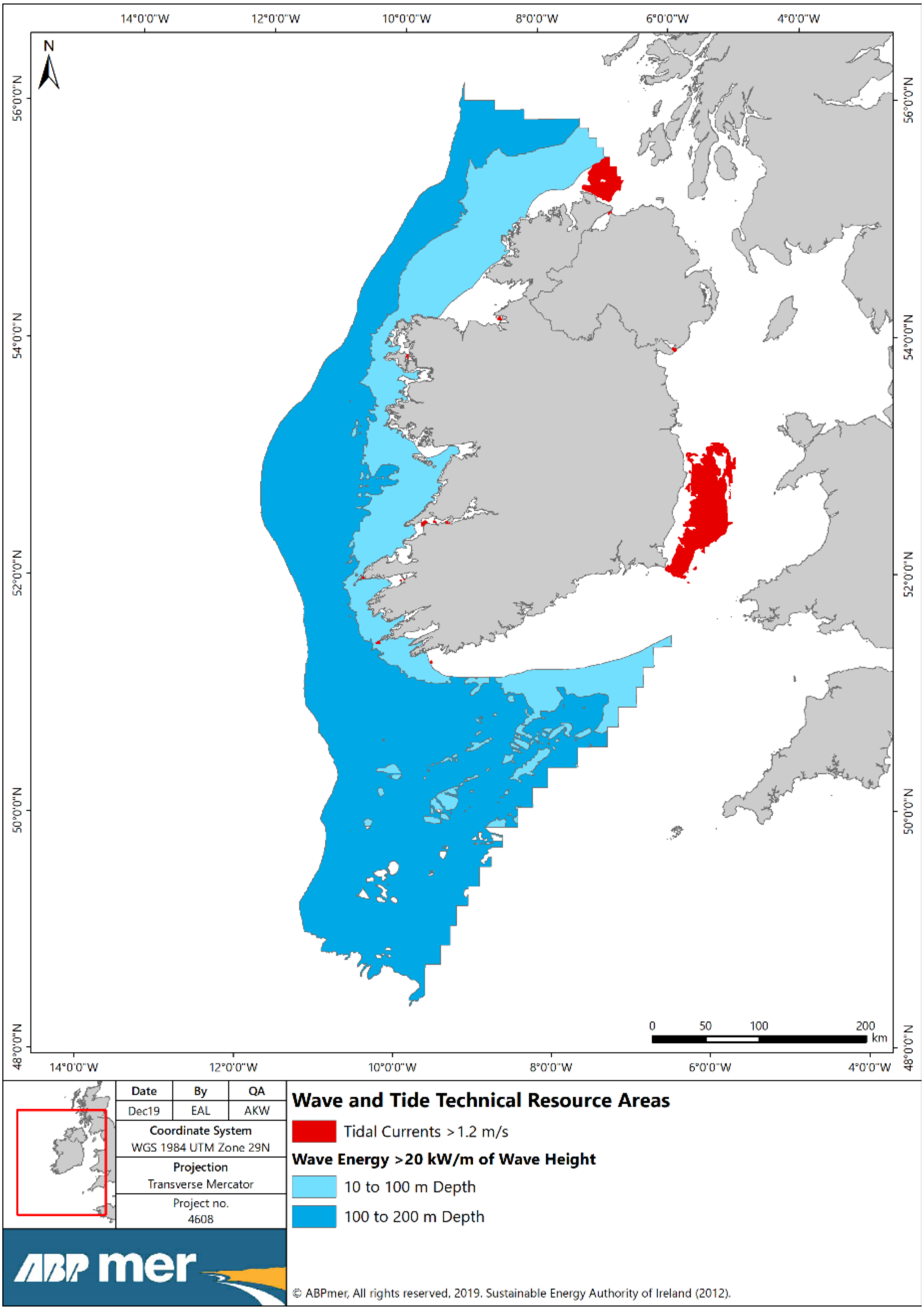


Figure 14. Future tidal and wave technical resource areas

4.1.7 Water for non-drinking purposes

Figure 15 provides a representation of the location and intensity of water used for non-drinking purposes, through either water abstraction for cooling water purposes or for waterborne transport.

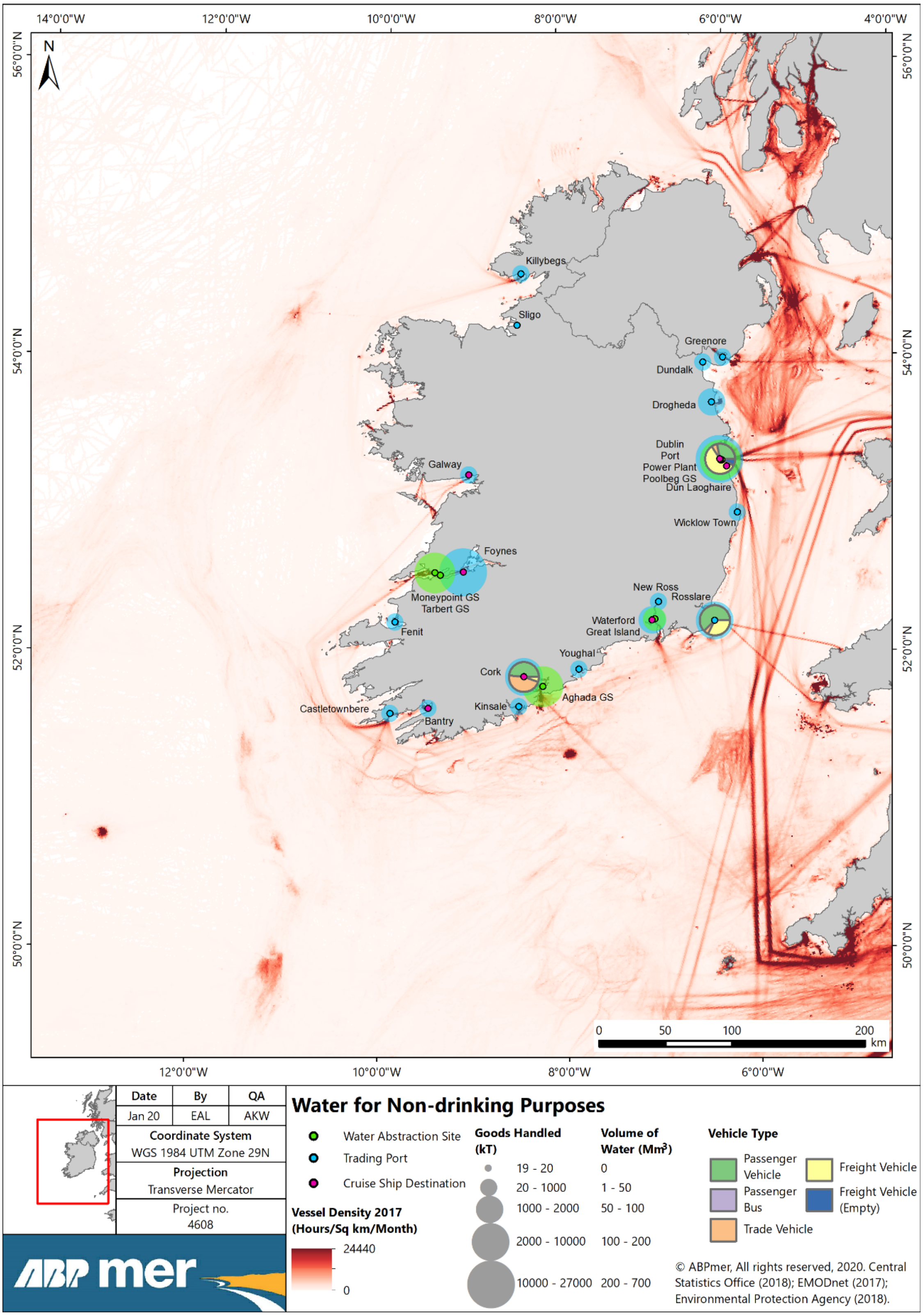


Figure 15. Provisioning Service: Water for non-drinking purposes

What the service is

Seawater is used for cooling in some coastal power stations and also plays a vital role in waterborne transport.

Why it is important

The role of sea water in waterborne transport is a particularly valuable service which provides significant environmental, social and economic benefits.

Across all Irish ports 12,964 vessels arrived in 2018 with a total of 55,087,000 tonnes of goods handled (Table 7). In addition to the cargo vessels above, 300 cruise ships, transporting 398,505 passengers, arrived at Irish ports in 2018 (Central Statistics Office, 2019).

Using the method developed by the Marine Management Organisation (MMO, 2019), which aims to assign value to shipping cargo flows, the average value of each type of cargo has been calculated. By assigning a value to the total goods handled at each port, and/or the number of passengers on a cruise vessel, a value of waterborne transport can be calculated, and then assigned to the port where the ecosystem service value is realised.

The total value of goods and passengers handled by all Irish ports in 2018 was €113.5 billion.

Table 7. Goods handled and number of cruise ships at each Irish port in 2018.

Trading Port	Total Goods Handled (000's Tonnes)	Total Number of Goods vessels	Total Number of Cruise Ships	Value of Goods and Passengers (€)
Bantry	542	15	9	€ 177,341,552.76
Castletownbere	57	19		€ 26,555,508.80
Cork	9,518	1,394	93	€ 15,303,865,790.26
Drogheda	1,455	446		€ 317,241,087.12
Dublin Port	26,332	7,710	150	€ 85,862,018,517.78
Dundalk	113	54		€ 19,474,275.36
Dun Laoghaire	-	-	3	€ 96,532.80
Fenit	28	18		€ 12,819,900.80
Foynes	10,681	513	3	€ 2,087,566,074.90
Galway City	582	171	15	€ 184,281,561.42
Greenore	906	143		€ 208,501,279.52
Killybegs	32	15		€ 14,333,586.24
Kinsale	47	15		€ 8,099,919.84
New Ross	390	130		€ 67,670,537.58
Rosslare Harbour	2,143	1,647		€ 6,794,927,979.80
Sligo	19	13		€ 7,271,644.00
Waterford	1,995	497	18	€ 2,400,030,520.16
Wicklow Town	193	137		€ 83,511,991.84
Youghal	53	27		€ 24,266,240.80
Total	**55,087**	**12,964**	**291**	**€113,599,874,502**

Seawater is used for cooling in some coastal power stations. The volume of water abstracted for use in cooling for electricity generating stations in Ireland is shown in Table 8.

Table 8. Water abstraction for cooling in Irish estuaries

Station Name	Estimated Maximum Output (MW)	Estimated Volume (m^3)
Aghada generating station	960	231,620,000
Poolbeg generating station	463	50,642,736
Dublin bay power station	403	213,385,570
Tarbert generating station	626	Not estimated
Great Island	240	89,964,820
Monet point generating station	849	603,880,200
Total	**3,541**	**1,189,493,326**

Norton *et al.,* 2018

Turnpenny *et al.* (2010) indicate that there is a 2% increase in power plant energy efficiency for once-through cooling water systems compared to cooling towers. This can be used to estimate the net benefit in additional electricity generated from power stations with once-through cooling water systems based on the estimates of electricity generated by each power station.

The average energy efficiency for most power stations is 40% (Turnpenny *et al.* 2010). If there is a 2% increase in power efficiency for once through cooling water systems, efficiency increased to 42%. Across all 6 power stations this equates to an additional energy production of 621 GWh. Using the wholesale electricity price of €58.33 per MWh from CRU (2018; January-June 2018) the additional 2% increase in power efficiency provides a total value of water abstraction in Ireland of €36.2 million.

The total value of the ecosystem service water for non-drinking purposes in Ireland is €113.6 billion.

How to interpret the map

Darker areas represent areas which support a higher shipping density and therefore provide increased waterborne transport capacity. Lighter areas provide lower transport services.

Green point data show the locations of water abstraction sites used for cooling purposes, the size of the point indicates the relative amount of water (m^3) extracted for cooling purposes. The larger the point, the more water that is being extracted. Port locations and the volume of goods handled is shown on the map, with pie charts symbolising the types and volume of wheeled vehicles being handled at each port on ferries on an annual basis.

The majority of water extraction sites are located on the south and east coast of Ireland, however the largest volume is extracted at Moneypoint generating station in County Clare,on the west coast of Ireland, which extracts 604 M m^3 per year.

The highest density of vessel traffic is located on the east coast of Ireland in the Irish Sea along key shipping routes between Ireland, Scotland and England. Port locations also show high density areas of shipping traffic. Of interest is a small area off the south coast of Ireland, County Cork, which shows a high density of vessel traffic associated with the Kinsale Head gas field. This field has now ceased production.

How the map was created

Data on the location of water abstraction sites was digitised from coordinates in Norton *et al.,* (2018).

Shipping density data, including goods, passenger and commercial vessel statistics, were obtained from EMODnet and analysed to assess provision of waterborne transport. Density grids for the Irish EEZ were produced based on the number of vessels per month per kilometre grid cell.

Data limitations

Valuation for waterborne transport has been calculated using average cargo values from the MMO (2019). However, overall tonnage of goods transported by each vessel could not be obtained and therefore accurate values could not be calculated.

In addition, only cargo vessels (split into: liquid bulk, dry bulk, lift-on/ lift-off, roll-on/ roll-off and break bulk good) and passenger vessels could be included within the valuation. The value of recreational craft and other vessels using Irish waters has not been included. Total value of waterborne transport is therefore an underestimate.

Ports are a key location on land where the benefits of shipping are realised, this method has been able to assign a value to each of the ports within Ireland. However, with increased resolution AIS data this method could be used to value the flows of good and people throughout the Irish EEZ.

Opportunities

Opportunities are likely to change over time based upon changes in trade and resultant changes in shipping patterns. In general, there are minimal constraints to the provision of waterborne transport. Additional increased opportunities for waterborne transport will be in areas of increased renewable resources which require access and servicing.

With the increase in renewable energy development, the requirement for coastal power stations is likely to decline and therefore the volume of water abstracted for cooling purposes is also likely to decline.

4.2 Regulating services

4.2.1 Climate regulation

Figure 16 provides a representation of value of climate regulation services within the Irish EEZ.

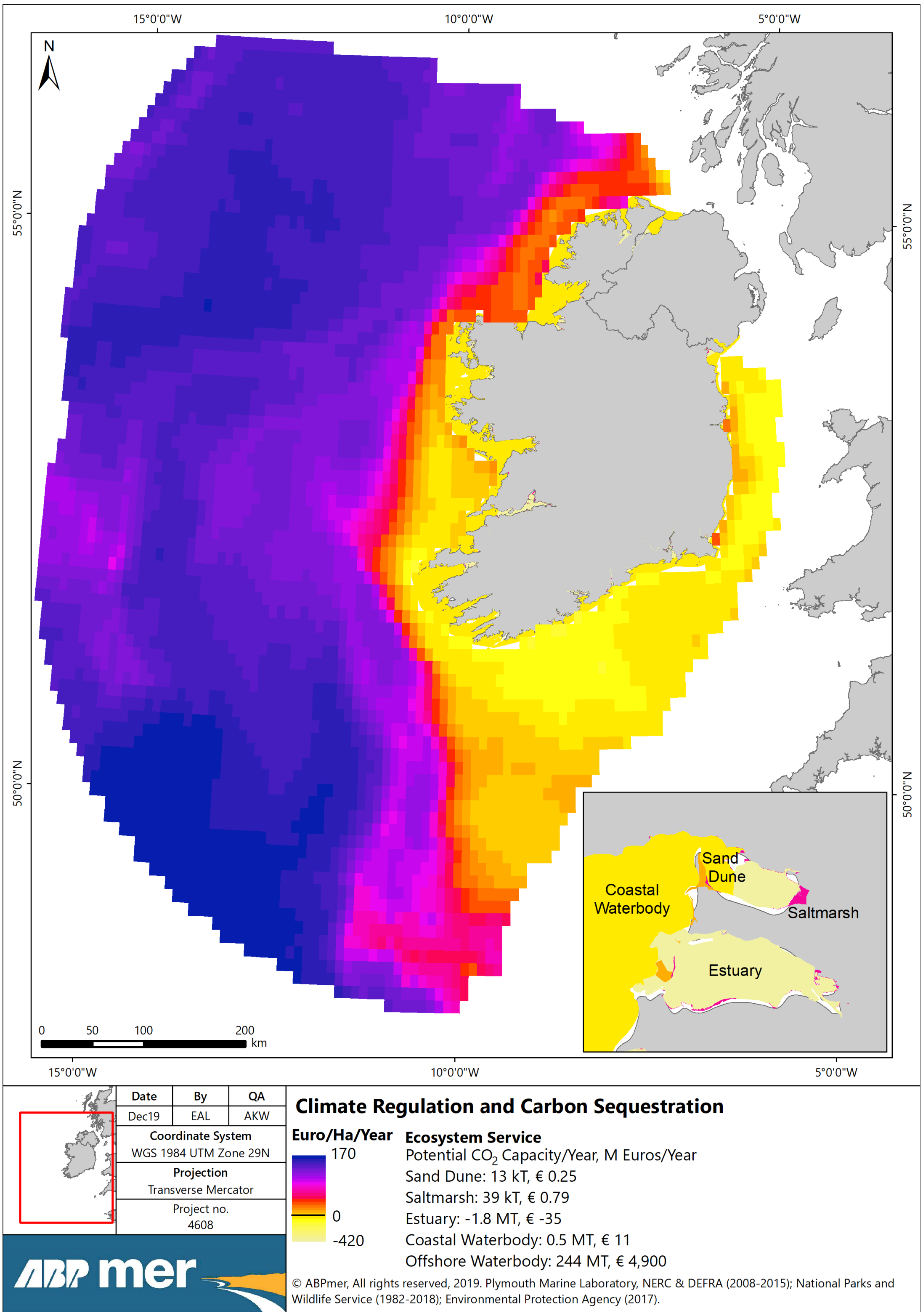


Figure 16. Regulating Service: Climate regulation and carbon sequestration - Carbon flux

What the service is

Climate regulation: Atmospheric carbon is stored and sequestered in the marine environment via dissolution and storage within marine sediments and biota. It is difficult to adequately map carbon storage and sequestration in the marine environment due to limited data and evidence on key processes. In this assessment air-sea flux of CO_2 has been used as an indicator of the spatial distribution of the climate regulation service, together with information on carbon storage/sequestration functions of saltmarsh and sand dune habitats.

Why it is important

The sea plays a key role in storing and sequestering carbon, which helps reduce atmospheric concentrations of CO_2 and other greenhouse gases.

How to interpret the map

The final map shows the value (€) of air-sea flux of CO_2 per hectare per year based on a carbon value of €20 per tonne of CO_2-equivalent (Department of Finance, 2011). The darkest colours represent locations of positive air-sea flux within the marine environment. Lighter yellow colours represent areas where air-sea flux is negative (i.e. carbon is being released from marine waters to the atmosphere).

Data analysis identified areas of significant positive CO_2 flux in offshore waters surrounding Ireland, additionally, areas of saltmarsh habitat in coastal water have a positive carbon storage potential. Nearshore coastal waters, and in particular estuaries, indicate a negative air-sea CO_2 flux, in part because they are processing significant quantities of organic material of riverine origin. It is considered that the pattern of air-sea flux in coastal and offshore waters is indicative of the likely pattern of carbon sequestration.

Within shallow shelf seas, carbon fixed in the water column tends to be recycled rapidly either through degradation in the water column or at the sea bed. This maintains a relatively neutral air-sea flux. In deeper waters off the continental shelf, organic carbon falling to the deep-sea bed becomes isolated from surface waters resulting in net storage/sequestration within deep sea sediments.

The total net air-sea flux of CO_2 can be used to estimate the value of the climate regulation service provided by Irish waters. This is estimated to be €4.77 billion p.a., significantly greater than the €818.7 million estimated by Norton et *al.* (2018) (Table 9). The value is sensitive to assumptions on carbon values. This analysis has used €20 per tonne of CO_2-equivalent but other higher values are in use elsewhere, for example, for Ireland's Emissions Trading Scheme, Motherway & Walker (2009) used a value of €39 per tonne of CO_2-equivalent.

Table 9. Comparison of estimated value of total carbon absorbed by Irish coastal and marine ecosystems per annum (€)

Habitat type	This Report	Norton et al., 2018
Sand Dunes	250,000	500,000
Saltmarsh	790,000	500,000
Estuary	-35,000,000	-34,000,000
Coastal waterbody	11,000,000	10,500,000
Offshore waters	4,800,000,000	841,200,000
Total	**€4.77 billion**	**€818.7 million**

How the map was created

This map was created using a combination of datasets including data from NPWS of sand dune and saltmarsh location, and WFD Transitional and Coastal Waterbodies data. Layers were merged to create a map layer.

Data from PML on modelled air-sea carbon flux estimates for marine waters (2008-2017) were utilised as a proxy for CO_2 exchanges with the water column and then converted to calculate the t CO_2 /ha/yr. for offshore marine waters. For coastal water bodies, estuaries and inshore habitats, values from Norton *et al.* (2018) were utilised as follows:

- Sand dunes: + 2.1 t CO_2 /ha/yr.;
- Saltmarsh: + 5.2 t CO_2 /ha/yr.;
- Estuaries: - 21.1 t CO_2 /ha/yr.; and
- Coastal water bodies: + 0.4 t CO_2 /ha/yr.

A value layer was then created based on the Irish carbon tax of €20 per tonne, which was used as a proxy for social cost of carbon in Ireland. The final map shows the value (€) of carbon 'sequestered' per hectare per year but should be interpreted as showing the best information using the data currently available.

Data limitations

The data on modelled air-sea carbon flux estimates are not well resolved in estuaries due to the resolution of the data model being too coarse to accurately capture estuaries and due to the reliability of data on organic carbon within estuaries to inform the wider model. Therefore, data from Norton *et al*. (2018) was used as it is of a more suitable resolution and captures specific habitat features, however there are some gaps in spatial coverage between the two sources.

Opportunities

Habitat restoration of sand dune and saltmarsh habitat will increase the ability of these habitats to sequester carbon leading to increases in the level of the climate regulation service. Inclusion of additional habitats identified as blue carbon stores could also enhance the assessment of climate regulation services.

Seagrass and kelp forest habitats have been identified as areas of significant carbon storage potential, as they store significant amounts of carbon. Burrows *et al*., (2014) found that kelp had an average carbon storage rate of 685 g C/m^2/yr. which is the equivalent of 25 t CO_2 /ha/yr. Accurate mapping of kelp distributions could be used to enhance the assessment of carbon storage, although little of this carbon is likely to be sequestered for any length of time. Additionally, as seaweed aquaculture practices increase in Ireland there is the possibility for greater carbon storage potential. Seagrass also provides carbon storage potential as it has a slow biomass turnover time and its sediment trapping and binding capacity makes this habitat a potential sink for carbon. Burrows *et al*., (2014) reported an average net sequestration rate of 83 g C/m^2/yr. which equates to 3.1 t CO_2/ha/yr., although this relates more to Mediterranean *Posidonia* meadows where sequestration rates are much higher than for *Zostera* beds present in Ireland.

4.2.2 Waste mediation

Figure 17 provides a representation of the value of waste mediation and water purification services within the Irish EEZ, based upon the costs avoided for treating waste water.

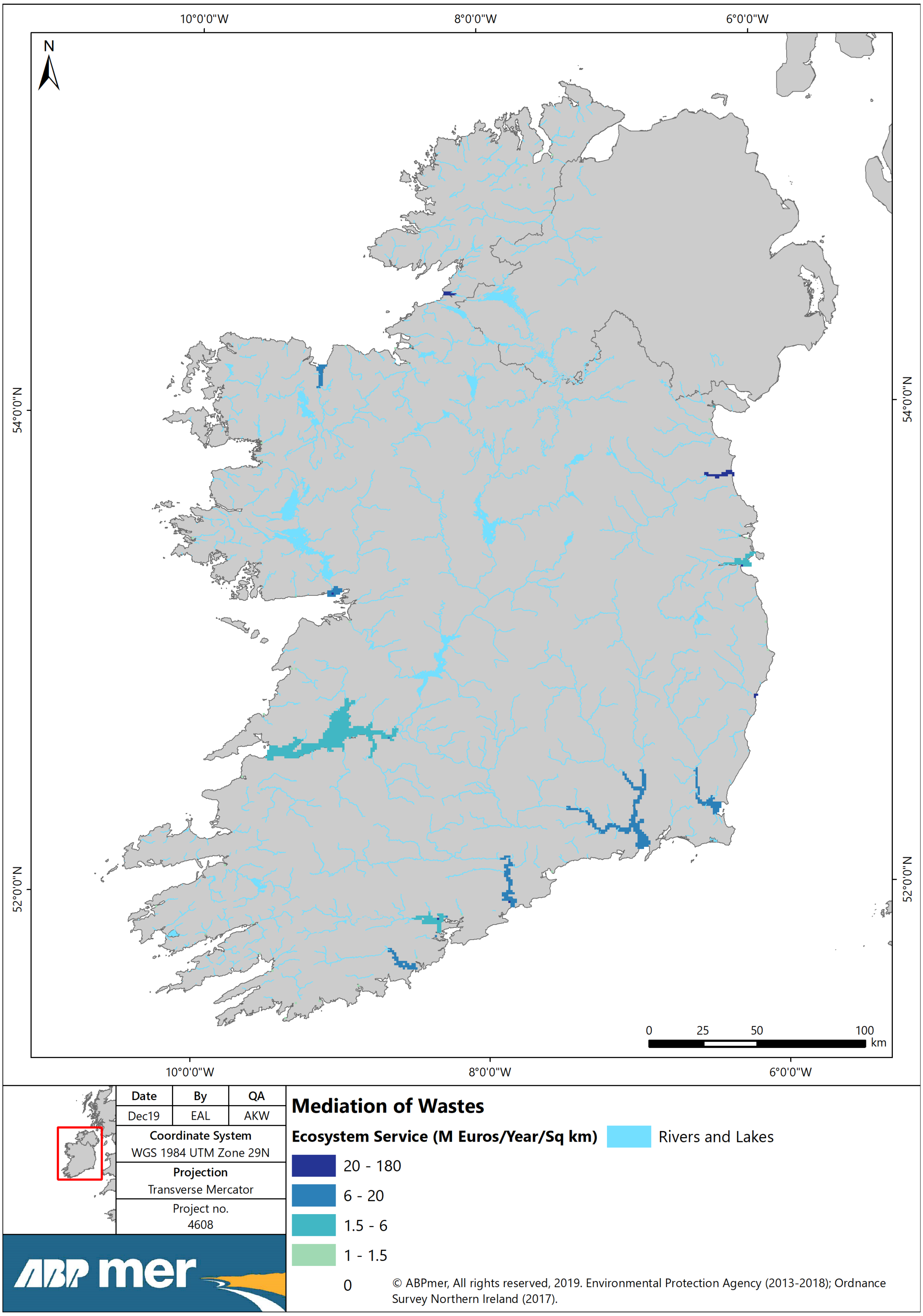


Figure 17. Regulating Service: Mediation of wastes

What the service is

Coastal habitats which provide water purification and regulation of water quality services, to clean the water of pollutants such as organic wastes, nitrogen and phosphorus.

Why it is important

Clean, well purified water is essential for human health and underpins the health of the environment. Clean coastal waters also provide recreational services. The value of waste water treatment can be calculated through cost avoided of treating water, by using the shadow prices of Hernandez-Sancho *et al*. (2010) 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.

Table 10. Shadow prices of removing each pollutant

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 estimated total value of waste mediation services is €8.22 billion.

How to interpret the map

Blue areas show the locations of rivers and lakes which have a direct connection to coastal waterbodies and are therefore flowing into the marine environment.

Polygons show the value of waste mediation services per km^2 per year, from the combined nitrogen and phosphorous WWTP discharges and riverine input data. Lighter colours are areas with lower value and therefore low ability to mediate riverine waste input. Darker colours indicate a higher ecosystem service value where there are higher levels of mediation of wastes and pollutants.

How the map was created

Multiple data sources were collated to create this layer. The location of rivers and lakes within Ireland was sourced from EPA. Rivers and lakes within Northern Ireland which flow into coastal waters within Ireland were also included, these were sourced from Ordnance Survey Ireland. To identify the location of estuaries, WFD transitional water bodies data was utilised. This was combined with riverine input data from the EPA to assess the nitrogen and phosphorus inputs into transitional waterbodies.

The location of waste water treatment plants was also included within the assessment. This data was sourced from Norton *et al.* (2018), data relating to the level of wastewater treatment prior to discharge was also sourced from Norton *et al.* (2018).

Data limitations

Not all waste water treatment plants have data associated with them and therefore there are limitations in the assessment of nitrogen and phosphorous input into the waterbody. Additionally, not all rivers have data associated with them so total N and P input might not be accounted for. Data could also not be sourced to assess the Biological Oxygen Demand (BOD) for rivers, so the removal of BOD has not been included. The values have been estimated using value transfer based on Hernández-Sancho *et al*. (2010). This study relates to rivers and values for estuaries may be different. The map should be interpreted as showing the best information with the current data available.

Opportunity

Enhancement or restoration of assets which contribute to water purification services can enhance the mediation of wastes. For example, the restoration of bivalve beds and biogenic reefs can increase bentho-pelagic coupling allowing waters to assimilate increased levels of waste.

4.2.3 Regulation of flows

Figure 18 provides a representation of the location and value of coastal defence or natural hazard protection provided by coastal habitats within Ireland.

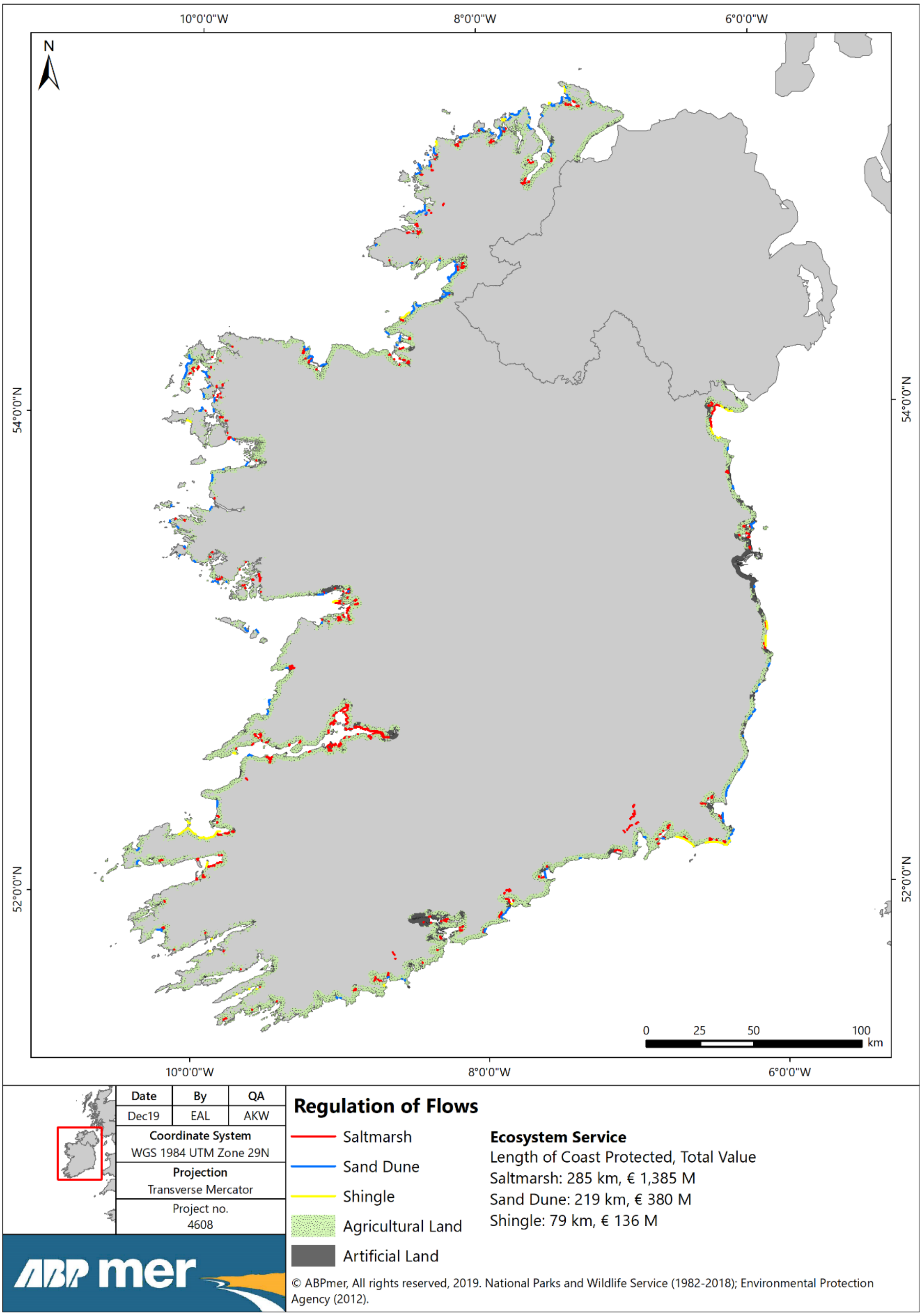


Figure 18. Regulating Service: Regulation of flows

What the service is

Natural habitats provide regulating ecosystem services through a moderating effect against natural hazards e.g. tidal surges or storms, thereby having a value for coastal defence and natural hazard protection.

Why it is important

Climate change is likely to increase the risk of extreme storm events and coastal flooding. Natural habitats can act as a physical barrier to dampen or reduce the level of harm imposed on life, health or property in coastal areas by reducing the impact from storms, storm surges and flooding events.

Habitats such as reefs, seagrasses, kelp beds/ forests, dunes and saltmarshes attenuate both waves and storm surges thereby reducing the energy reaching the seashore, which in turn means that the flood defences needed may be less heavily engineered than those required on an exposed shoreline. For example, wave attenuation by saltmarsh is significant at low water depths, approximately 87% attenuation, and respectable still at greater depth at 72% (Moller *et al.,* 2001).

Norton *et al.,* (2018) calculated an average per linear meter saving of capital costs (i.e. the value of putting in coastal defences if there was no saltmarsh) of seashore protected by saltmarsh of €4800, and maintenance cost saving of €64 per metre length per year.

ONS (2016) similarly calculated the capital cost saving value of sand dunes and shingle habitats. Costs were calculated by scaling the coastline length and accounting for costs of maintaining natural habitats. They calculated the natural sea defence value of dunes and shingle habitats at £1,734 (€2,063; December 2019 currency conversion) and £1,712 (€2,037) per meter of dune and shingle respectively.

The total length of coastline protected by saltmarsh, sand dunes and shingle is 583 km. Multiplying these protected lengths by the calculated capital cost saving provides an estimated ecosystem service value of €1.9 billion per year.

How to interpret the map

Polylines indicate the extent of saltmarsh (red), sand dunes (blue) and shingle (yellow) habitats around the Irish coastline. Green polygons show the extent of agricultural land and grey polygons artificial land. These were used to define the areas where coastal habitats are providing coastal protection ecosystem services.

How the map was created

This map was created using a combination of datasets. Habitat information was derived from NPWS data for saltmarsh, sand dunes, shingle. Coastal protection services were estimated by digitising the seaward extent of saltmarsh, sand dune and shingle habitats, indicates the protected length of coastline over which coastal protection services are being supplied.

Only saltmarshes over 80 m in width were included in the analysis, the coastal protection services provided by narrower widths of saltmarsh are uncertain (King and Lester, 1995, Norton *et al.*, 2018). Additionally, sites were deemed not to provide a coastal defence ecosystem service if they were adjoining coastal lagoons and were not exposed directly to the sea, such areas were therefore removed from the analysis.

Additionally, following the methods of Norton *et al.* (2018) habitats were only considered to provide coastal protection service in areas backed by agricultural land or artificial land. This data was sourced from CORINE land cover data and was used to clip the extent of saltmarsh, shingle and sand dune habitats.

Data limitations

As only saltmarsh of width greater than 80 m was considered, the accuracy of data can limit mapping purposes. Some smaller saltmarshes may also still provide valuable coastal defence ecosystem services in certain areas, but the level of service is uncertain, and may present an area for future research.

Also, the presence of saltmarsh, sand dunes or shingle habitat does not necessarily equate to coastal protection services. Habitats need to be preventing damage to human assets to be providing a regulating service. Although this has been accounted for to some level in the analysis, for example areas of habitat adjoining coastal lagoons were removed, a more thorough knowledge of human assets in combination with such habitats is needed to accurately map ES provision.

Following the methods ascribed in Norton *et al.* (2018) only areas backed by agricultural land were considered within the analysis. Therefore, if tourist destinations, areas of important cultural significance, or areas of valued habitat outside of these areas may not have been included within map, which may undervalue this ecosystem service.

Opportunities

Restoring habitats such as saltmarsh from areas where it has been lost will help increase the level of coastal protection service. Additionally, enhancing and restoring sand dune systems which attenuate wave power, reducing the risk of flooding or damage from storm surges will further enhance service provision.

Kelp forest habitats have also been identified as providing coastal protection functions by attenuating waves along the coast, however the value of this service has not been quantified. Further research to accurately map the distribution of kelp forest habitats within Irish waters, and quantification of the level of wave attenuation, and therefore protection service, would enable kelp habitats to be accounted for within the coastal protection service.

4.3 Cultural services

4.3.1 Recreation and tourism

Figure 19 to Figure 22 illustrate the tourism and recreation ecosystem services delivered by the coastal environment. Figure 19 provides an overall heatmap of recreation and tourism services within Irish waters. Figure 20 to Figure 22 show the density of recreational and tourism activities on the beach, on land and on the water, respectively.

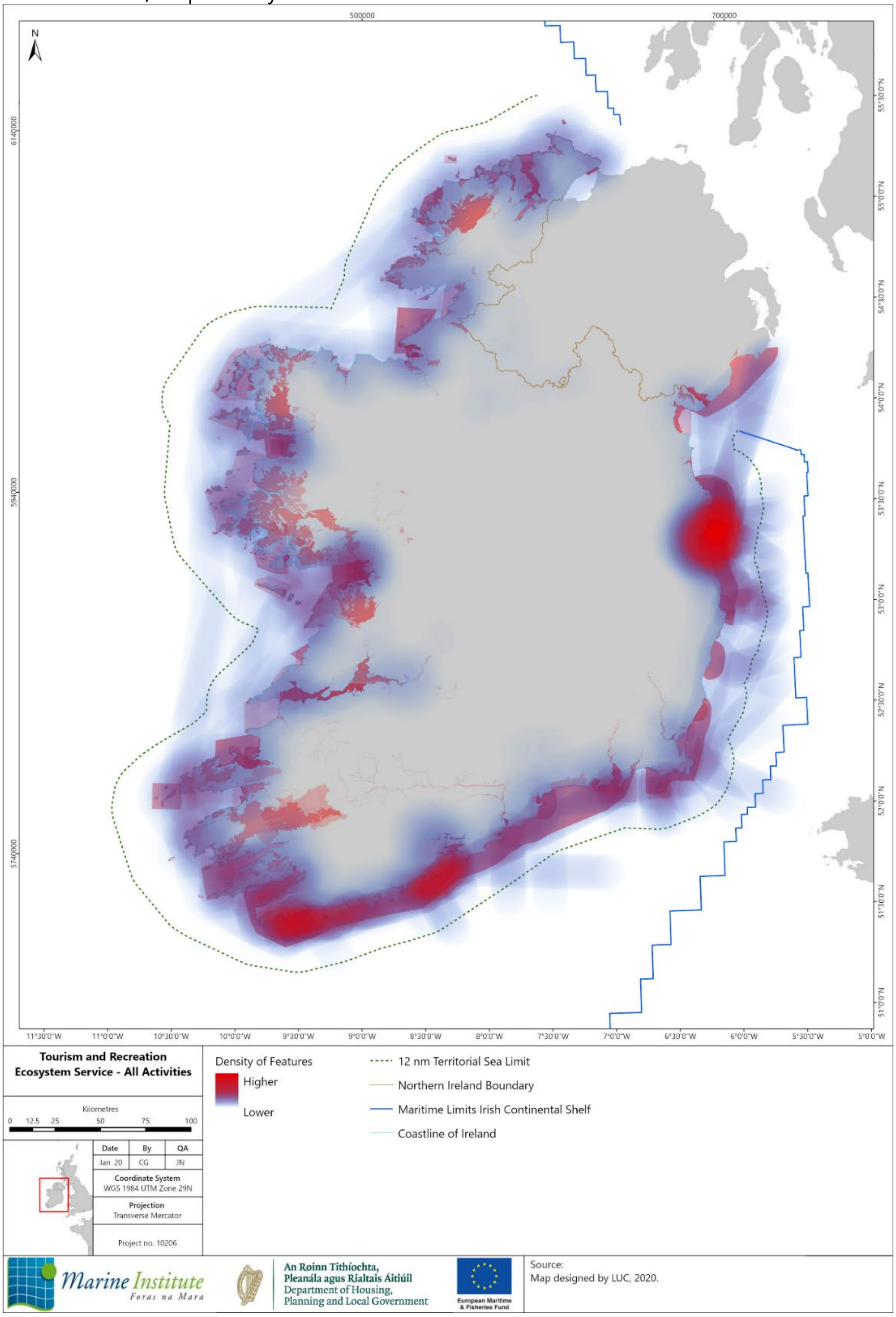


Figure 19. Cultural Services: Tourism and recreation all activities

What the service is

Tourism and recreation CES represent an important way that people derive benefit from the natural environment and are particularly relevant to the marine and coastal environment.

Why is it important

Tourism and recreation cultural ecosystem services are important since they represent a key way in which people experience and enjoy the marine and coastal environment, they contribute to people's health and wellbeing, support other cultural services relating to history, sense of place and local identity, as well as making a significant and positive contribution the economy at local and national scales.

How to interpret the maps

Due to the large number of data layers created illustrating tourism and recreation activities (86 different data layers), heat maps rather than locational maps were prepared to illustrate the different hotspots around Ireland for activities undertaken on the water, on the beach/intertidal zone, and on land.

Therefore, four separate maps were created to capture the tourism and recreation cultural ecosystem services delivered by the coastal environment:

- Tourism and Recreation – All Activities;
- Tourism and Recreation – On the Water;
- Tourism and Recreation – On the Beach/Intertidal Zone; and
- Tourism and Recreation – On the Land.

These four heat maps illustrate the recreation and tourism ecosystem services delivered by the marine and coastal environment. To indicate the different hotspots for activities undertaken on the water, on the beach/intertidal zone, or on land, a colour ramp from red to blue to white indicates the most popular locations for activities to the least popular locations.

Water-based activities are primarily concentrated in Dublin and along the southern coast, particularly in County Cork and Waterford Harbour (Waterford).

Beach recreation activities are primarily concentrated in Dublin, Dingle Bay (Kerry), Ballinskelligs Bay (Kerry), Galway Bay (Galway), Achill Island (Mayo), and Donegal Bay (Donegal). Clare, Limerick, Cork, Waterford, and other parts of Galway, Kerry, Donegal and Mayo are also popular locations for beach recreation activities.

The greatest concentration of land-based recreation activities and coastal tourism infrastructure is primarily concentrated along the west coast extending from Donegal to Kerry, with Dublin, Wexford and Cork also identifying as hotspots. It should be noted that this heat map incorporates coastal tourism infrastructure (e.g. accommodation, food and drink providers, arts/crafts/souvenir shops) which may partially explain why the main coastal cities (e.g. Dublin, Cork, Wexford and Galway) are identifying as hotspots due to a greater concentration of tourism infrastructure in these areas.

Overall, Dublin and Cork are the most popular locations for all marine and coastal tourism and recreation activities with Waterford, Wexford, the Shannon Estuary, Kerry, Galway, Mayo and Donegal also popular locations for all types of marine and coastal tourism and recreation activities.

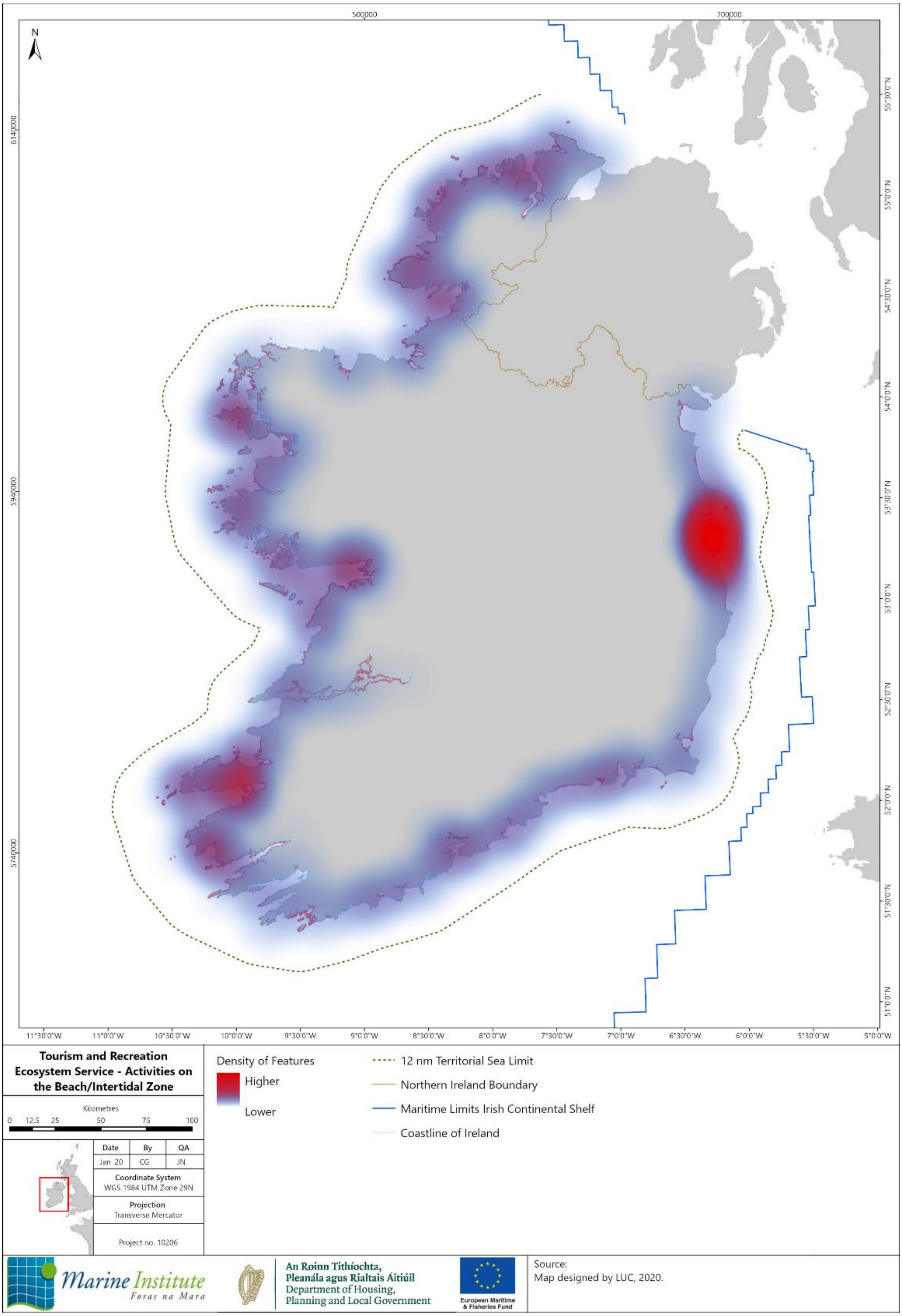


Figure 20. Cultural Services: Tourism and recreation on the beach

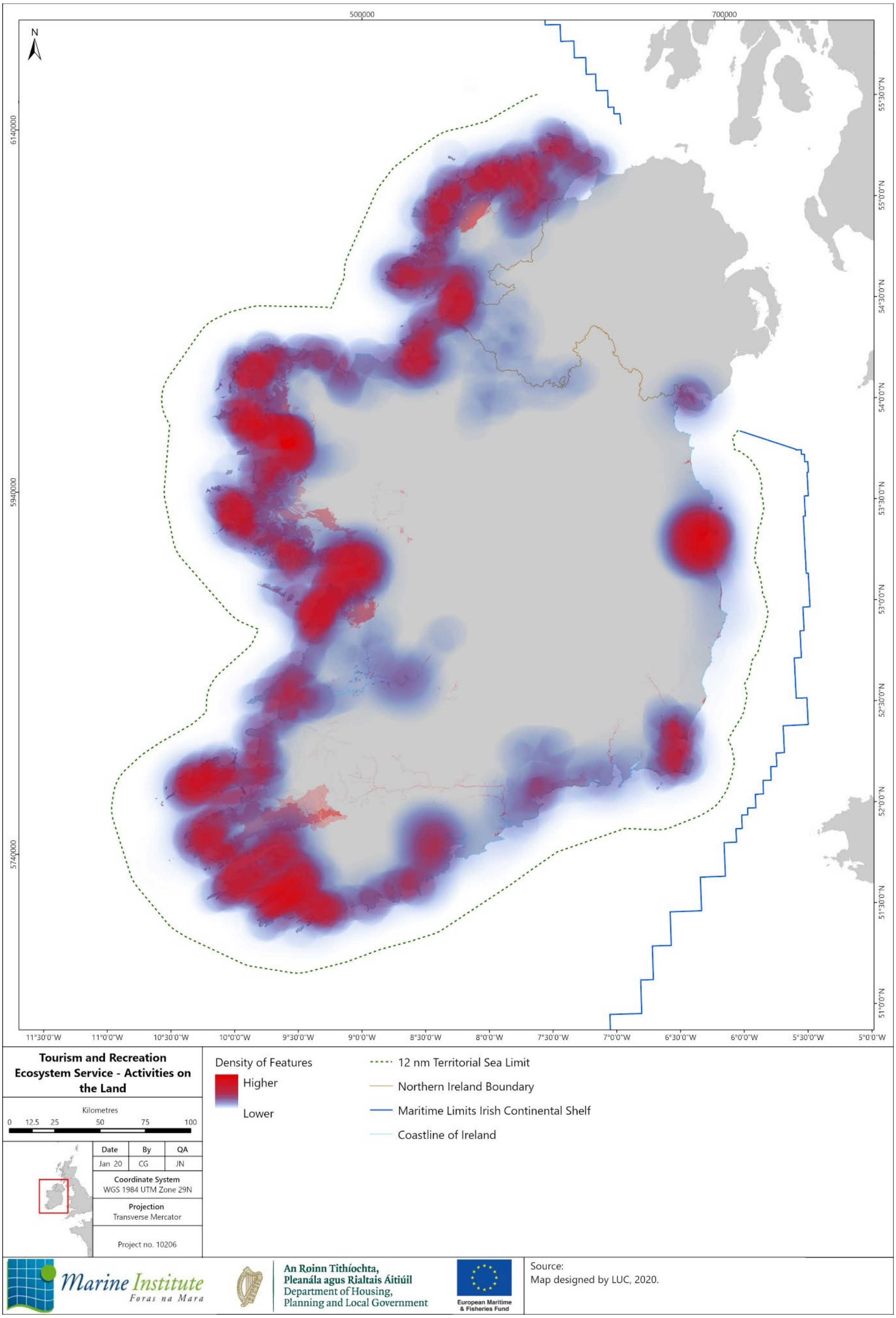


Figure 21. Cultural Services: Tourism and recreation on land

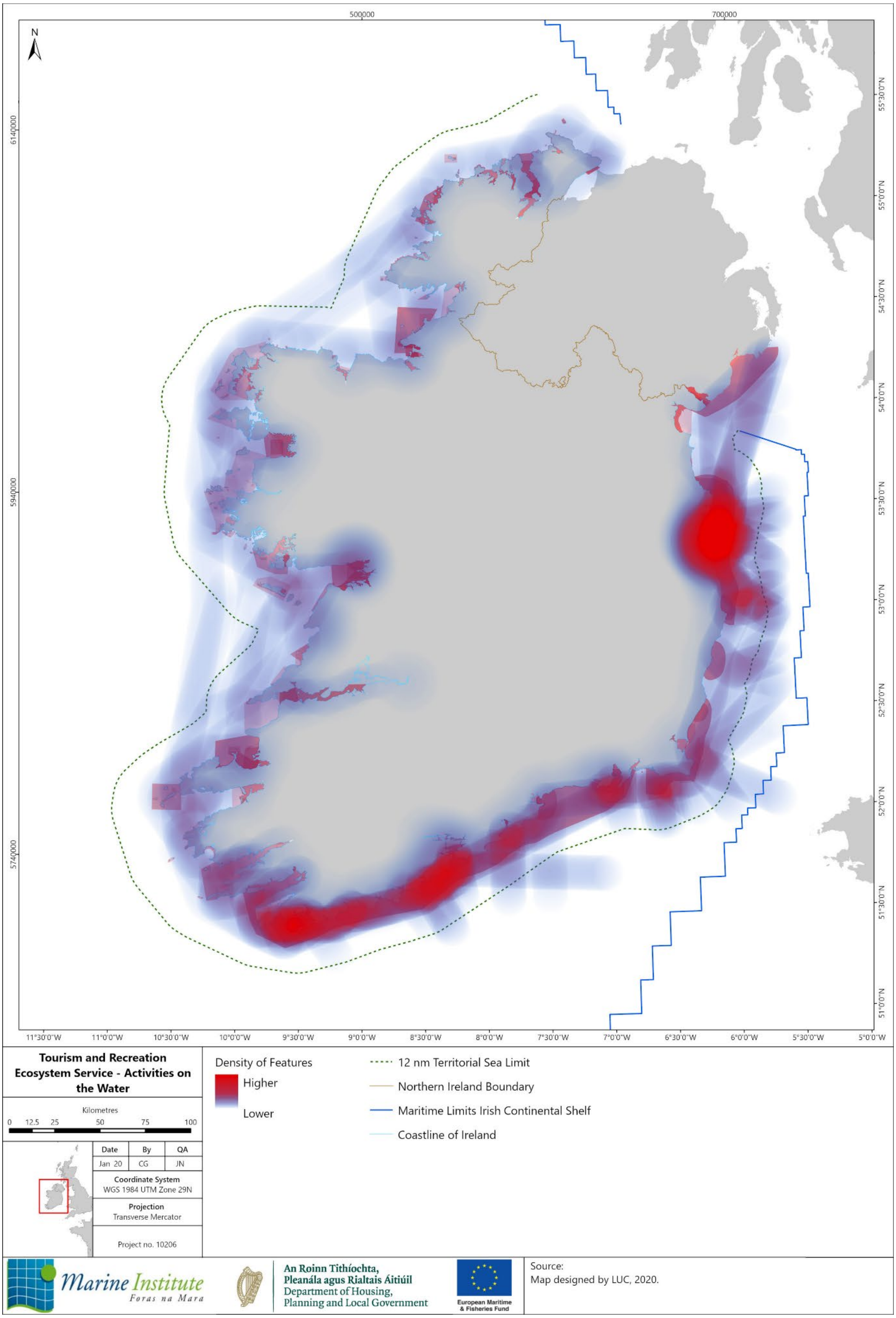


Figure 22. Cultural Services: Tourism and recreation on the water

How the map was created

Table 11 outlines the various tourism and recreation activities that informed each heat map.

Table 11. Tourism and recreation activities identified on each tourism and recreation ES map

On the Water	On the Beach/ Intertidal Zone	On the Land	All Activities
▪ Recreational Angling ▪ Kitesurfing ▪ Windsurfing ▪ Surfing ▪ Diving/ snorkelling ▪ General Coastal Tourism Activities (Ferry Routes only) ▪ Motor/Power Boating ▪ Motorised Sailing ▪ Wakeboarding / waterskiing ▪ Parascending ▪ Unmotorised Sailing ▪ Kayaking ▪ Canadian Canoeing ▪ Stand-Up Paddleboarding ▪ Rowing / sculling ▪ Dinghy / Dayboat / Small Keelboat Sailing ▪ Personal Watercraft ▪ Wildlife / Bird Watching / Wildfowling	▪ General Beach Leisure ▪ Coastal Quad Biking / Scrambling ▪ Sand Yachting / Land Sailing / Land Yachting ▪ Kite Buggying ▪ Marine Recreational Infrastructure ▪ Recreational Angling ▪ Wildlife / Bird watching / Wildfowling ▪ Climbing / Coasteering / Bouldering	▪ Climbing/ Coasteering / Bouldering ▪ Recreational Drone Use ▪ General Coastal Tourism Activities (except for ferry routes) ▪ Coastal Cycling ▪ Coastal Recreational Light Aircraft ▪ Visitor Attractions ▪ Coastal Walking ▪ Wildlife / Bird Watching / Wildfowling ▪ Coastal Tourism Infrastructure	▪ All activities

As the heat maps were generated using three different types of spatial geometry (points, lines and polygons), it was necessary to perform multiple types of analysis and combine the results into one summary dataset. For the points, a kernel density estimation was applied in order to generate a continuous surface extrapolating the density based on the number of points present across the study area. For the lines, a simple line density calculation was performed, which calculates the units of length within set distance of each pixel in the output raster. A weighting was applied to those with relevant attributes (e.g. level of traffic in the Irish Sailing recreational routes), in order to pull out variations in the importance of the features. These two datasets were then normalised to remove any difference in scale between them, and then combined to give a single pixel value for each location. Due to the spatial nature of polygonal data, it is not possible to create a meaningful density map from that type of features. Instead, a heavy transparency (80%) was applied to them and they were overlaid onto the density map. This has the effect of darkening the areas with multiple overlapping polygons to show their prominence, without affecting the accuracy of the overall density map.

A range of data layers were used to create the maps. A full list of layers is provided in Appendix D.1.1.

To create the 'On the Water' map, 54 data layers were used in total. These included layers for a range of recreational activities using photo location data from Flickr and data layer on the location and intensity of recreational activities such as those presented in Table 11. Data layers showing the location and intensity of wildlife bird watching were clipped to only show the offshore elements of the SACs, SPAs, NHAs, pNHAs, MPAs, Geoparks, Biosphere Reserves, Wildfowl Sanctuaries, and Nature Reserves, to depict bird and wildlife watching 'on the water'.

Weighting was applied to the recreational routes for motor boating, sailing, unmotorised sailing, personal watercraft and small keelboat/dinghy sailing to denote heavy, medium and light traffic routes.

To create the 'On the Beach/Intertidal Zone' map, 25 data layers were used in total. Data layers showing the location and intensity of wildlife bird watching were clipped to only show elements of the SACs, SPAs, NHAs, pNHAs, MPAs, Geoparks, Biosphere Reserves, Wildfowl Sanctuaries, and Nature Reserves within 500 m of the coastline to depict bird and wildlife watching 'on the beach/intertidal zone'. A 500 m buffer was used as an approximate indication of the beach/intertidal zone as there was no dataset available which identified high and low tide marks.

To create the 'on the land' map, a total of 31 data layers were used. Data layers showing the location and intensity of wildlife bird watching were clipped to only show elements of the SACs, SPAs, NHAs, pNHAs, MPAs, Geoparks, Biosphere Reserves, Wildfowl Sanctuaries, and Nature Reserves within 2 km of the coastline to depict bird and wildlife watching 'on land' (excluding offshore elements). The designations within 2 km inshore have not been clipped and show the full extent of the designations' boundary.

The 'All Activities' ES map was created using all 86 data layers.

Data limitations

There are some general limitations to mapping recreation and tourism CES. Generally, spatialisation is challenging because data on the location and intensity of some activities is often lacking. Additionally, some ecosystem services are more easily mapped than others therefore some services may be under-appreciated.

Due to the spatial nature of polygonal data, it is not possible to create a meaningful density map from that type of feature – instead, a heavy transparency (80%) was applied to them and they were overlaid onto the density map. This has the effect of darkening the areas with multiple overlapping polygons to show their prominence, without affecting the accuracy of the overall density map.

Temporal change is a key issue when mapping CES – the frequency of an activity, e.g. the seasonality of recreational activities, is not recorded.

For the 'On the Beach/Intertidal Zone', no dataset was available to identify high and low tide marks and therefore a 500 m buffer was used as an approximate indication of the beach/intertidal zone.

Due to the large study area, the metadata for a significant number of photographs was required which required considerable time to process. Additionally, the automatic tagging in Flickr is prone to error. Incorrectly assigned tags can only be removed by the person who uploaded the photo. It should also be noted that the photo-sharing community may not be representative of specific social groups: impacted by education, age, user's ability/willingness to correctly geotag the photos. There are also more popular photo sharing websites (i.e. Instagram) which would yield more robust results, however, this platform restricts research availability.

There were also more specific limitations and gaps associated with specific data layers used within the analysis. For example, data from Fisheries Ireland and Angling Council of Ireland was unavailable and

therefore there may be additional recreational angling locations that are not plotted. Also, data from Maps.ie was unavailable and therefore there may be additional locations for a range of recreational activities that are not plotted, including kitesurfing, windsurfing, surfing and coasteering, among others.
A full list of limitations identified for each data layer is provided in Appendix D.1.1.

Opportunities

Participatory methods are commonly used in order to capture people's perception on plurality of the CES values and are recommended for any future studies on recreation and tourism CES. This approach has also been followed by several studies addressing marine and coastal ecosystems, which demonstrate the multiple values of CES based on interviews and participatory mapping (e.g. Gee & Burkhard, 2010; Klain & Chan, 2012; Brown & Hausner, 2017). Examples of benefits include the generation of trust between policy makers and knowledge holders and strengthening management plans through the inclusion of community held knowledge.

4.3.2 Aesthetic

Figure 23 and Figure 24 illustrate the aesthetic ecosystem services delivered by the coastal environment. Figure 23 captures the aesthetic cultural ecosystem services (CES) delivered by designated and protected areas. Figure 24 shows a heat map of geotagged photo density to identify hotspots around well-known aesthetically pleasing locations.

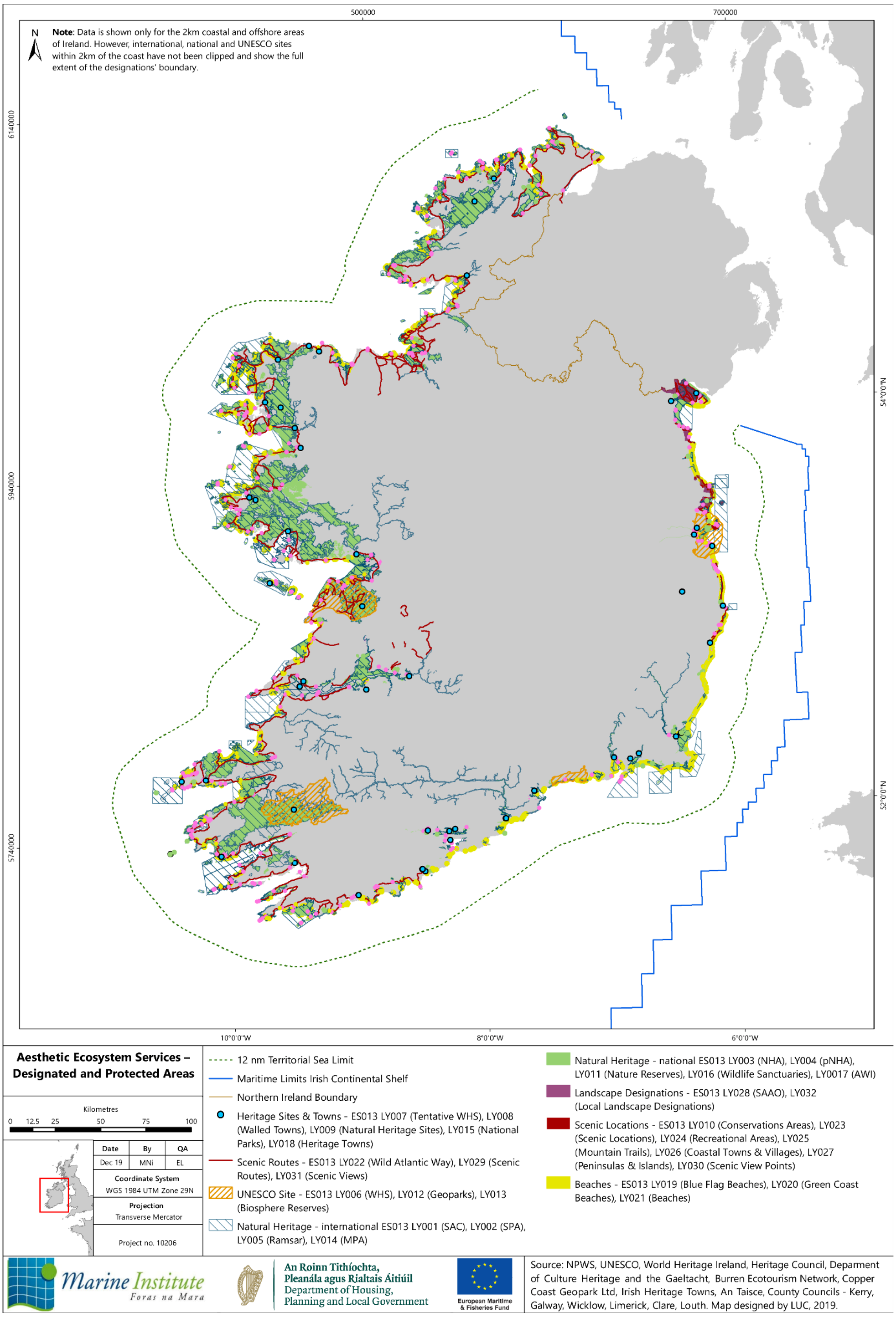


Figure 23. Cultural Services: Aesthetic - Designated and Protected Areas

What the service is

Aesthetic value from cultural ecosystem services is the interaction of people with the environment related to natural beauty based on human perceptions and judgments (Figueroa & Tang, 2015). Aesthetic ecosystem services represent the way that people experience, enjoy and value the coastal and marine environment.

Why is it important

In addition to underpinning many people's recreational experience, ecosystem services contribute to the local economy, influencing where people want to live and spend their leisure time.

Traditional approaches to mapping aesthetic CES generally include mapping designated and protected sites as proxy measures relating to environmental values (biodiversity, cultural heritage etc.). In recent years, several studies have adopted an alternative indicator for preferences on landscape/seascape aesthetics to overcome the limitations of traditional approaches for evaluating aesthetic value. Using social media databases of geotagged photos allows an understanding of socio-cultural usages of landscapes. As such, Flickr photos have been used for the landscape aesthetic assessment on the basis that people who take photos of landscapes (and upload them to the Flickr platform) consider those landscapes to be aesthetically pleasing.

How to interpret the maps

Figure 23 and Figure 24 illustrate the aesthetic ecosystem services delivered by the coastal environment. Two separate maps were created to capture the aesthetic cultural ecosystem services delivered by the coastal environment:

- Aesthetic Ecosystem Services – Designated and Protected Areas
- Aesthetic Ecosystem Services – Geotagged Photo Densities

Due to the large volume of data layers shown on the map, datasets are grouped into relevant topics, for example international, national and UNESCO designations, and identical symbology applied:

- SACs, SPAs, Ramsar and MPAs sites are grouped as international designations.
- Natural Heritage Areas proposed Natural Heritage Areas and Ancient & Long-Established Woodland are grouped as national designations.
- World Heritage Sites, Geoparks and Biosphere Reserves are grouped as UNESCO sites.
- Blue Flag beaches, Green Coast beaches and other beaches are grouped as 'Beaches'.
- Scenic Locations, Scenic Coastal Towns and Villages, Peninsulas and Islands, Scenic Mountain Trails, Recreational Areas, Local Authority Conservation Areas, Local Authority Scenic Views are grouped as Scenic Locations.
- The Wild Atlantic Way, Local Authority Scenic Routes, and Local Authority Scenic Views (polyline) are grouped as Scenic Routes.
- Tentative WHSs, OPW National Heritage Sites, Walled Towns of Ireland, Heritage Towns of Ireland and National Parks are grouped as Heritage Sites & Towns.
- Special Amenity Area Orders and Local Authority Scenic Landscapes are grouped as Landscape Designations.

Their layer IDs are noted in the legend. The data is shown only for the 2 km onshore and offshore areas of Ireland. However, international, national and UNESCO sites within 2 km of the coast have not been clipped and show the full extent of the designations' boundary.

For the Geotagged Photo Densities ES map (Figure 24), a colour ramp from red to blue to white indicates the most photographed to the least photographed locations. The heat map identifies hotspots around well-known aesthetically pleasing locations such as the Cliffs of Moher (Clare), Galway City, Clifden (Galway), the Arran Islands (Galway), Dingle Peninsula (Kerry), Iveragh Peninsula (Kerry), Mizen Head (Cork), Cape Clear Island (Cork), Cobh and Kinsale (Cork), Slieve League (Donegal), Inishowen (Donegal), Arranmore (Donegal), Fanad Peninsula (Donegal), Malin Head (Donegal), Lough Swilly and Inch Island (Donegal), Achill Island (Mayo), Louisburgh (Mayo), Kilmore and the Saltee Islands (Wexford).

The greatest concentration of photographs is taken in Dublin around Dublin Bay, Howth, Sutton, Dun Laoghaire, Dalkey, Killiney and extending to Bray and Greystones in Co. Wicklow. There is also a relatively high concentration of photographs taken at ferry ports such as Rosslare Harbour (Wexford) and Dublin Port which are not typical aesthetically revered locations themselves but may indicate concentrations of visitors to these locations at certain times.

How the maps were created

Multiple data sources were collated to create this map, including data layers created for Project 2 and new data layers prepared specifically for this ES map.

The study builds upon the more traditional approaches to mapping aesthetic ecosystem services (Peña *et al.*, 2018; Dales *et al.,* 2014; and LUC, 2013) and maps designated and protected areas, as well as scenic viewpoints, scenic coastal towns and villages, scenic mountains, and the peninsulas and islands as areas likely to be of high aesthetic value.

Data have been obtained from a variety of data sources. The following data layers were used to create the map:

- Special Areas of Conservation, Special Protection Areas, Natural Heritage Areas, Proposed Natural Heritage Areas, Ramsar Sites and World Heritage Sites, Marine Protected Areas, National Parks;
- Tentative World Heritage Sites - created from World Heritage Ireland website;
- Walled Towns of Ireland, Nature Reserves; Ancient Long-Established Woodland;
- Geopark Authorities - UNESCO Global Geoparks;
- Heritage Council – National Heritage Sites; Heritage Towns of Ireland
- Local Authorities – Local Authority Architectural Conservation Areas, UNESCO Biosphere Reserves; Local Authority Scenic Routes, Local Authority Scenic Views, Local Authority Scenic Landscapes;
- NPWS – Wildlife Sanctuaries;
- An Tasice – Blue Flag Beached 2019, Green Coast Beaches 2019;
- OSi – Beaches, Recreational Areas;
- MI – Wild Atlantic Way;
- Failte Ireland - Discovery Points, Signature Points, Historic Houses and Castles, Museums and Attractions, and National and Forest Parks;
- Scenic Mountain Trails; Scenic Coastal Towns and Villages, Peninsulas and Islands; and
- SAAO – Special Amenity Area Orders.

The data are shown only for the 2 km onshore and offshore areas of Ireland. However, international, national and UNESCO sites within 2 km of the coast have not been clipped and show the full extent of the designations' boundary.

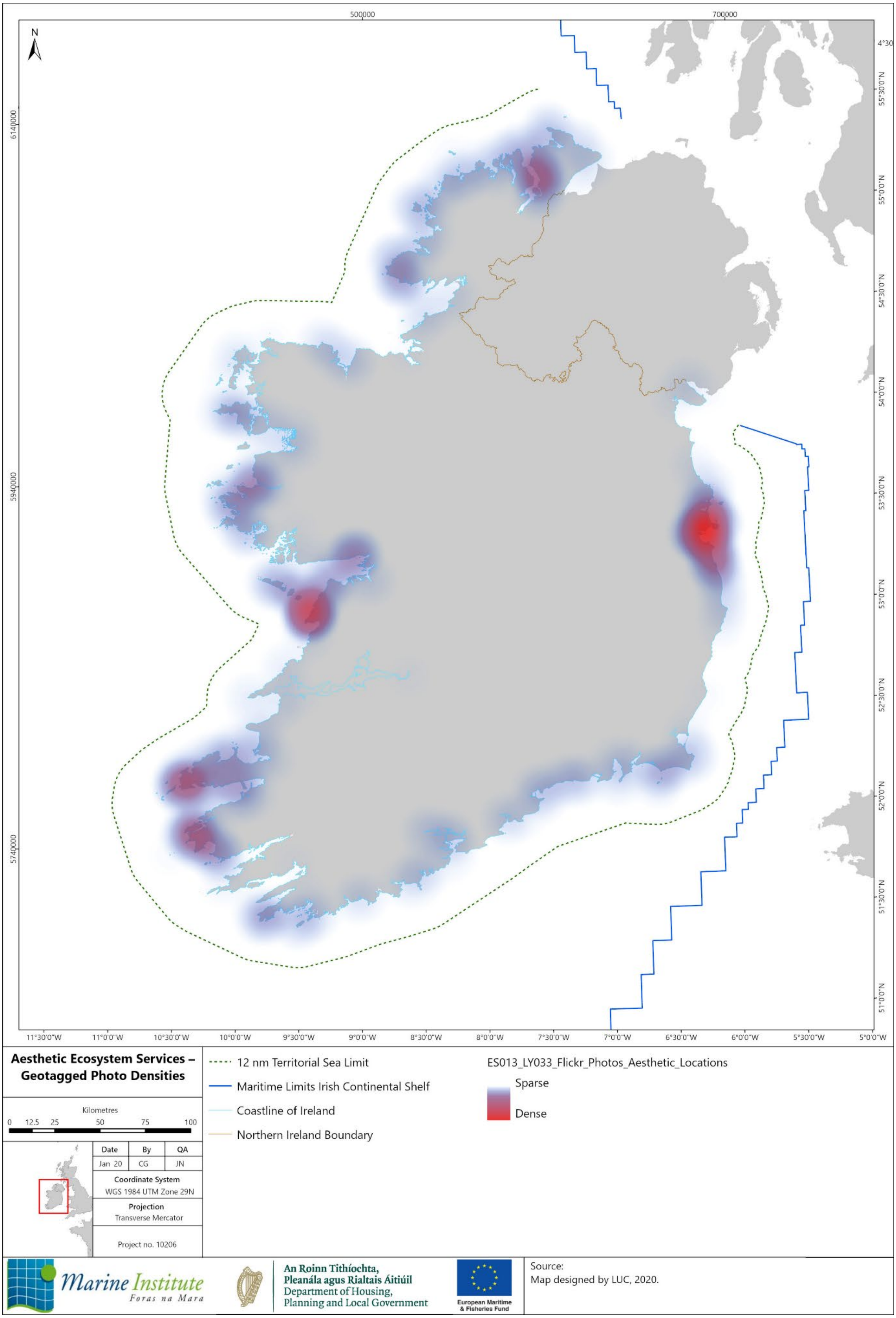


Figure 24. Geotagged Photo Densities

In line with the approach used by Langemeyer *et al.* (2018) and Lee *et al.* (2019a), the approach to mapping aesthetic ecosystem services also used geotagged photos uploaded to Flickr as a data source to identify landscape aesthetics. The following tags were used to capture aesthetic ecosystem services: "nature", "wildlife", "coast", "scenic", "seascapes", "waves", "sand", "shoreline", "sea", "ocean", "rugged", "beach", "cliff", "landmark", "sunset", "sunrise" and "wilderness". A 2 km buffer zone was used to capture photographs that are relevant to the coastal environment.

The geotagged photo points have been displayed as a heat map; a continuous surface showing the relative density of the points that comprise the layer. The colour scale chosen is intended to highlight the areas of highest density, without obscuring the detail of other areas that may have moderate density. This process was done using the 'Heat Map Symbology' option within ESRI ArcGIS Pro.

Data limitations

For the purposes of the study it is assumed that all designated and protected areas will provide aesthetic CES, although this cannot be verified.

There were several data layers which could not be sourced to feed into the assessment of aesthetic ES. Therefore, the maps may be under representative of all aesthetic services. Only data for two of the Special Amenity Area Orders was available. Data could not be sourced for Liffey Valley and North Bull Island. Additionally, only a small number of coastal local authorities provided data on locally designated landscape designations and scenic routes and views, with no local authority providing data on local nature designations, and scenic routes data was not available from Failte Ireland.

There was no OSi data on islands and peninsulas, an online search of the location of islands and peninsulas was undertaken. Only point data was obtainable. Therefore, the point data depicts a central point within each peninsula and island and is not indicative of its geographical extent. Similarly, point data has been used to identify areas such as National Parks, Nature Reserves, Tentative World Heritage Sites, Heritage Towns of Ireland, Walled Towns of Ireland and Wildlife Sanctuaries as no polygon data depicting the extent of the boundaries was available. This may result in these designations which are partially within the 2 km coastal buffer zone not being included as the centre points are not within the buffer zone.

For the production of Figure 24 of geotagged photo densities, the metadata for a significant number of photographs were required, due to the large size of the study area. As such metadata required considerable time to process. It should also be noted that automatic tagging in Flickr is prone to error. Incorrectly assigned tags can only be removed by the person who uploaded the photo, which may provide error in some assessment. Additionally, the photo-sharing community may not be representative of specific social groups: impacted by education, age, user's ability/willingness to correctly geotag the photos, biasing the assessment of aesthetic services. For this study only Flickr photos were analysed but there are also other more popular photo sharing websites (e.g. Instagram) which would yield more robust results, however, this platform restricts research availability.

Opportunities

Future studies may capture the aesthetic value of the coastal environment by creating viewsheds for photographs to identify aesthetically attractive photographed sites. The use of participatory GIS techniques to map aesthetic CES by either conducting in-depth interviews or issuing questionnaires among respondents asking how and why they appreciate a particular site or area for its aesthetic value, would also present a pathway to more robust insight of aesthetic CES in Ireland.

4.3.3 Scientific and educational

Figure 25 illustrates the scientific and educational ecosystem services delivered by the coastal environment.

What the service is

This map illustrates the scientific and educational ecosystem services delivered by the coastal environment.

Why is it important

Scientific and educational ecosystem services are important because they represent the way that the coastal and marine environment contributes to the sum of human knowledge, supporting technological advance, environmental management and sustainable development.

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 (Norton *et al*., 2018), as well as through course operators such as the Irish Sailing Association training centres. Ireland's role in marine research is also seen in projects such as SmartBay and Integrated Mapping for the Sustainable Development of Ireland's Marine Resource (INFOMAR) (Norton *et al*., 2018). Designated areas, locally important nature and landscapes, and woodlands/forests are also used as indicators of scientific and educational ecosystem services (Aalders & Stanik, 2016; Kenter *et al*., 2014; Plieninger *et al*., 2013).

How to interpret the map

Due to the large volume of data layers shown on the map, datasets are grouped into relevant topics, for example international, national and UNESCO designations, and identical symbology applied:

- SAC, SPA, Ramsar and MPA sites are grouped as international designations.
- Natural Heritage Areas, proposed Natural Heritage Areas and Ancient & Long-Established Woodland are grouped as national designations.
- World Heritage Sites, Geoparks and Biosphere Reserves are grouped as UNESCO sites.

Their layer IDs are noted in the legend. The remaining datasets are individually symbolised, and all datasets have been reordered to ensure that each data layer is visible on the final map.

The data are shown only for the 2 km coastal and offshore areas of Ireland. However, international, national and UNESCO sites within 2 km of the coast have not been clipped and show the full extent of the designations' boundary. Similarly, the INFOMAR Surveyed Areas have not been clipped to the 2 km coastal buffer.

How the map was created

Multiple data sources were collated to create this map, including data layers created for Project 2 and new data layers prepared specifically for this map.

The method for mapping scientific and educational CES built upon the method used by Aalders and Stanik (2016) who mapped designated areas, and Plieninger *et al.* (2013) who mapped woodland and

forests. A 2 km buffer zone was used to capture designated areas and woodlands/forests that are influenced by the coastal environment.
The following data layers were used to create the map:

- Special Areas of Conservation, Special Protection Areas, Natural Heritage Areas, Proposed Natural Heritage Areas, Ramsar Sites, UNESCO World Heritage Sites, Nature Reserves, National Parks, Marine Protected Areas;
- Geopark Authorities - UNESCO Global Geoparks;
- Local Authorities - UNESCO Biosphere Reserves, Local Authority Landscape Designations;
- NPWS – Wildlife Sanctuaries; and
- Ancient Long-Established Woodland;

In line with the examples provided by CICES for Scientific and Educational ecosystem services, which included "formal and informal education, including school nature walks and observation, woodland schools and other outdoor classroom activities", the following data layers were created and mapped as indicators of scientific and educational CES:

- Maritime Collections;
- Museums National Heritage Sites (merge of OPW data on Natural Heritage and Open Data on Museums Collections Archives); and
- National Parks Wildlife Service Education Centres (data from an online search of Education Centres – three Education Centres plotted – Ballycroy National Park, Connemara National Park and Wexford Wildfowl Reserve Education Centres)

Based on Norton *et al.* (2018), valuation of the marine scientific, education and training sector in Ireland, various education institutions offering courses relating to the marine environment including marine training centres (e.g. the Irish Sailing Association training centres), marine research centres and laboratories and marine research stations and test facility locations were also mapped:

- National Marine Organisations;
- Research Centres: MaREI – Centre for Marine and Renewable Energy (University of Cork), The Ryan Institute (NUI Galway), and the Marine and Freshwater Research Centre (GMIT);
- Education Institutions Marine Courses;
- Marine Research Stations Test Facilities, including SmartBay (Galway); Carna Research Station (Galway); Sherkin Island Marine Station (Cork); Mace Head Atmospheric Research Station (Galway); Bantry Marine Research Station (Cork); and, Abbotstown Laboratory Complex (Dublin);
- INFOMAR Surveyed Areas - Celtic Explorer and Celtic Voyager research vessels; and
- Irish Sailing Association Training Centres – Location of sailing clubs plotted from the 2018 Coastal Atlas of Recreational Boating.

Data limitations

For the purposes of the study it is assumed that all designated areas will provide scientific and educational CES, although this cannot be verified. Only a small number of coastal local authorities provided data on locally designated landscape designations, with no local authority providing data on local nature designations. Additionally, data on An Taisce's Greenschools and the Eco-UNESCO Marine Clubs were unavailable due to GDPR restrictions, therefore the extent of educational and scientific ecosystem services is underrepresented. Point data has been used to identify areas such as National Parks and Wildlife Sanctuaries as no polygon data depicting the extent of the boundaries was available. This may result in National Parks and Wildlife Sanctuaries which are partially within the 2 km coastal buffer zone not being included as the centre points are not within the buffer zone.

The INFOMAR data layer displays surveyed areas that are available to download only. A wider area has been surveyed however this data is not available to download.

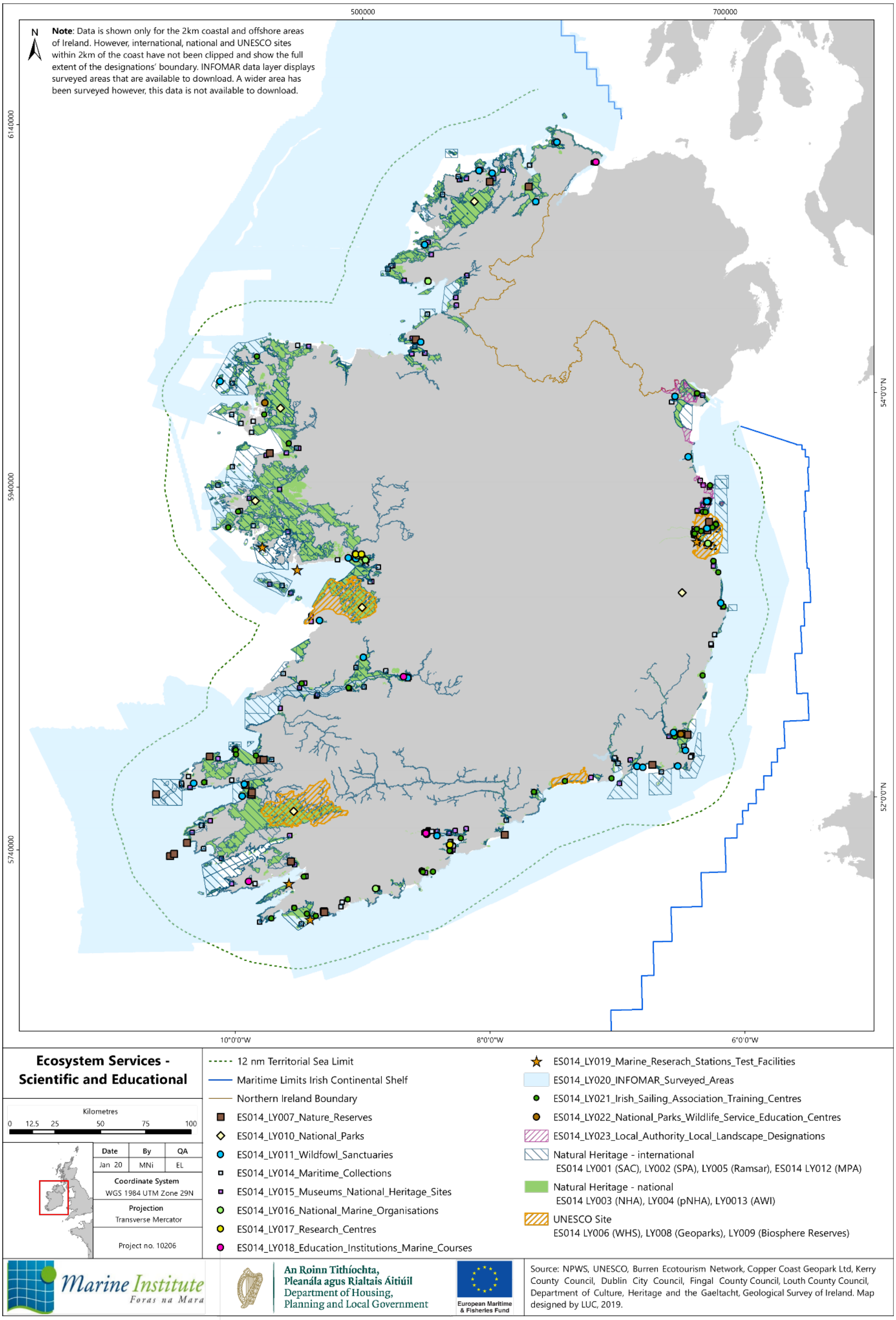


Figure 25. Cultural Service: Scientific and Educational

Opportunities

The citizen science project 'Capturing Our Coast' in the UK trained almost 3,000 members of the public nationwide to carry out transect surveys of marine species on UK rocky shores. A similar project in Ireland could be undertaken in the future to develop participants' understanding of the marine environment as well as encouraging participants' interest in science, which would further contribute towards our knowledge of educational and scientific CES.

To further define the value and extent of educational and scientific ecosystem services, a heat map could be prepared to indicate the areas which deliver a higher density of scientific and educational ecosystem services in Ireland. Heat mapping could provide an interpolated surface showing the density of occurrence of scientific and educational services. However, some more interpretation would be required as the datasets currently comprise a mix of point and polygon data.

4.3.4 Cultural heritage

Figure 26 and Figure 27 illustrate the cultural heritage ecosystem services delivered by the coastal environment.

What the service is

Cultural heritage value from CES can take two principal forms: that of the intrinsic and associated cultural importance of heritage assets themselves, and the experiential values (aesthetic, recreational, spiritual etc.) derived with people's visits to and interactions with heritage assets. The latter are more effectively and appropriately considered with wider aesthetic, recreational and spiritual benefits, and are therefore not considered further for cultural heritage.

Why is it important

Cultural heritage can provide a sense of unity and belonging and allows us to better understand previous generations and the history of where we come from. Understanding our cultural heritage can give a sense of personal identity.

Cultural heritage consists primarily of specific features in the physical landscape associated with cultural meanings and related to histories of human use. Cultural heritage CES has been generally identified by mapping the spatial distribution of designated and undesignated heritage assets such as World Heritage Sites (WHSs), Protected Monuments, and Conservation Areas.

How to interpret the maps

A map showing the location of cultural heritage assets is provided in Figure 26. Figure 27 shows the same data categorised into low/medium/high/very high value.

A diverse range of heritage assets survive on the land, on the foreshore and under the sea, providing insight into Ireland's recent past and distant millennia including:

- Skellig Michael WHS;
- Ceide Fields and North West Mayo Boglands, and the Western Stone Forts of Ireland Tentative WHSs;
- Over 21,000 National Monuments including early Christian monuments; medieval castles, abbeys and towers; and, late medieval, 18th and 19th Century monuments;
- Over 16,000 records from the National Inventory of Architectural Heritage;
- Over 21,000 records from the Archaeological Survey of Ireland; and,
- 286 hillforts from the Atlas of Hillforts.

A host of historically significant vessels are among the thousands of shipwrecks identified in Irish waters, particularly in the dangerous waters off Donegal and the southern coast of Ireland including six Spanish Armada wrecks; RMS Lusitania (Cork); RMS Leinster (Dublin); La Surveillante (Cork); HMS Audacious (Donegal); RMS Tayleur (Dublin); SS Empire Heritage (Donegal); and, SS Justicia (Donegal).

The following symbology was used to identify the different values assigned to each data layer:

- Very High – Dark green
- High – Light green
- Medium – Orange
- Low – Yellow

The data layer IDs are noted in the legend. The datasets are individually symbolised, and all datasets have been reordered to ensure that each data layer is visible on the final maps.

The data are shown only for the 2 km onshore and offshore areas of Ireland. However, the Wreck Extents are not clipped to 2 km offshore and all Wreck Extents within the Irish Continental Shelf boundary are included in the data. For the purposes of displaying the map in the report, it is zoomed in to capture detail within Ireland and the Wreck Extents closest to the coast.

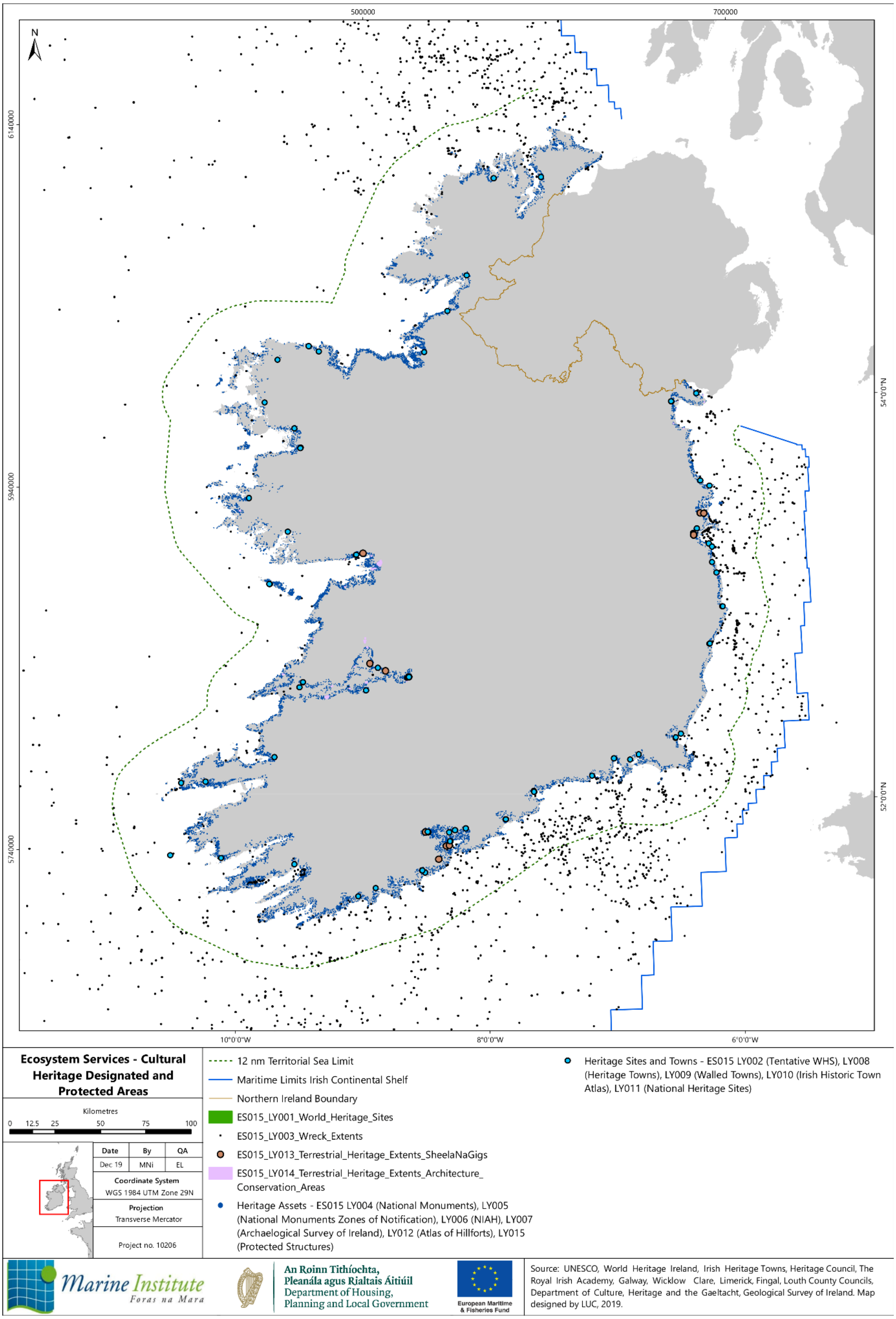


Figure 26. **Cultural Service: Cultural heritage**

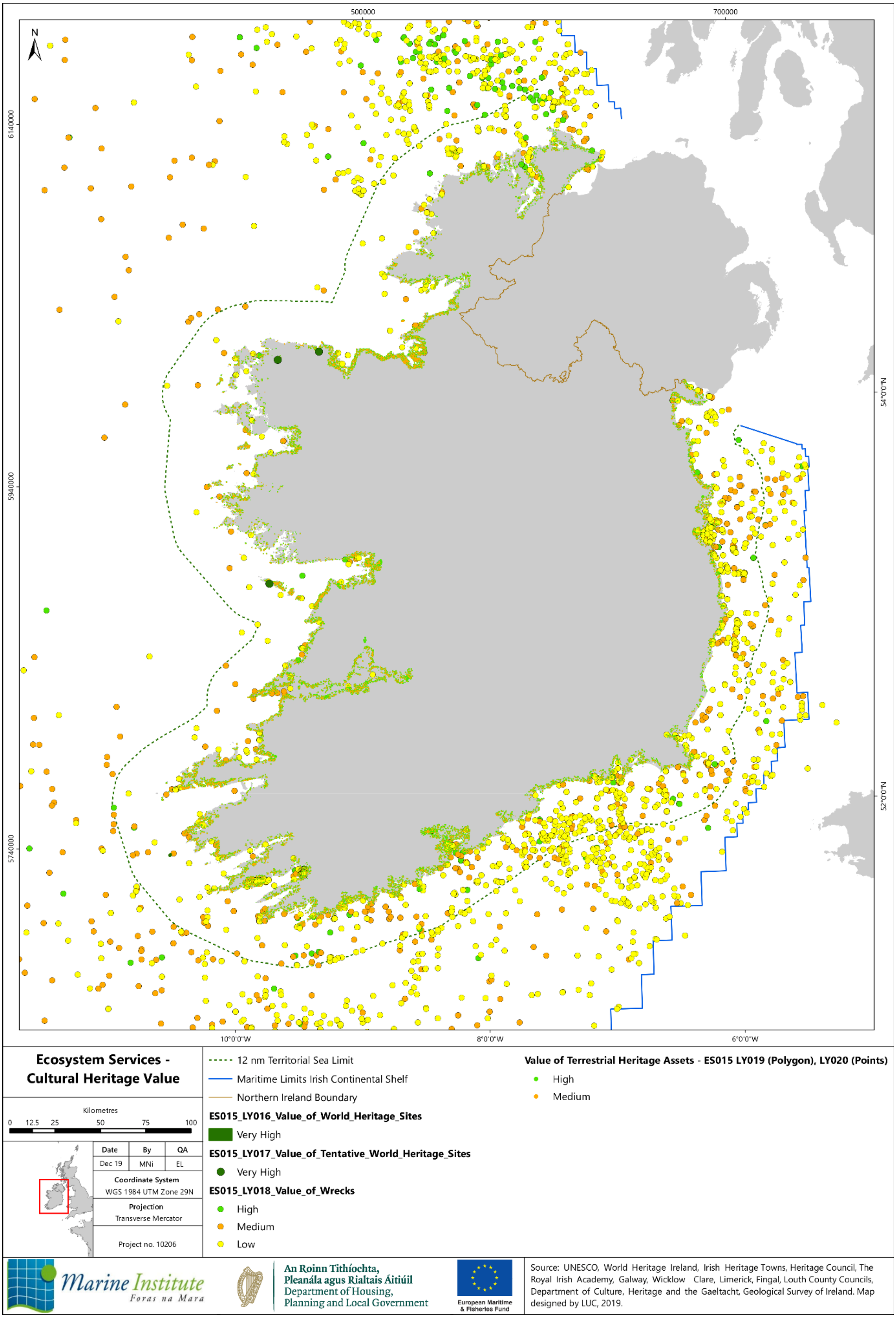


Figure 27. **Value of Cultural Heritage**

How the maps were created

Two separate maps were created to capture the spatial extent and value of cultural heritage ecosystem services delivered by the coastal environment. Multiple data sources were collated to create this map, including data layers created for Project 2.

To map the spatial extent of heritage assets in Ireland, the following data layers were used:

- World Heritage Sites;
- World Heritage Sites Tentative;
- Wreck Extents;
- Terrestrial Heritage Extents - National Monuments, National Monuments Zones of Notification,
- National Inventory of Architectural Heritage, Archaeological Survey of Ireland, Heritage Towns of Ireland, Walled Towns of Ireland, OPW National Heritage Sites, Atlas of Hillforts;
- Irish Historic Town Atlas;
- Sheela Na Gigs;
- Architecture Conservation Areas; and
- Record of Protected Structures.

Data layers were assigned a value rating based on their level of recognition within Ireland's statutory heritage protection framework (International>National>Regional>Local) (see Appendix D.1.4) and were further refined to reflect their importance to the coastal and marine environment.

The following data layers were used to identify the value of cultural heritage ecosystem services:

- Value of World Heritage Sites;
- Value of tentative World Heritage Sites;
- Value of Wrecks;
- Value of Terrestrial Heritage Assets.

Data limitations

Generally, point-based GIS data is the sole representation of cultural heritage assets which means that some heritage assets, regardless of their size and complexity are depicted by a single dot of a consistent size. It is therefore important to recognise the limitations in a 'point data-based' view of cultural heritage, which ensue from the geographical distribution of either spatially dispersed or clustered historic elements (Tengberg *et al.,* 2012).

There is currently no usable data available on the following:

- Submerged palaeolandscapes;
- Littoral and intertidal archaeology;
- Historic landscapes / historic landscape character; and,
- Aerial photography and other remote sensing techniques.

Only a small number of coastal authorities provided data on their Conservation Areas and Record of Protected Structures.

Opportunities

The future availability of information on submerged palaeolandscapes (underway as part of an international project in which MI is a key partner) is likely to transform the understanding of the cultural heritage and importance of the Irish Sea basin.

As historic landscape characterisation is rolled out across Ireland, ensuring national consistency of approach will be imperative to enable a stronger landscape focus in future iterations of CES mapping.

4.3.5 Spiritual and symbolic

Figure 28 to Figure 31 illustrate the spiritual and symbolic services delivered by the coastal environment.

These have been divided into religious services, sense of place, spiritual and wilderness services.

What the service is

Based on the literature review undertaken in relation to Spiritual and Symbolic services, there are four main facets associated with delivering 'spiritual and symbolic' services:

- *Religious* – Religious experiences may be linked to specific places, typically churches, cathedrals, cemeteries, religious monuments and trails (Winter & Gasson, 1996), and some of these form a bridge between Christian and pagan beliefs. Religious elements vary in size and importance, from sacred stones to large landscape features such as mountains which are recognised for their connections to religion (for example Croagh Patrick in Co. Mayo) (Aspinall *et al*., 2011). Pilgrimage routes offer opportunities for an experience of landscape that is marked out by religious elements such as holy wells and churchyards, while also offering opportunities for special-interest tourism (Aspinall *et al*., 2011).
- *Spiritual* – Spiritual experiences may also be linked to areas with religious associations, including holy places, sacred sites, religious monuments and trails. However, more frequently, spirituality as a cultural ecosystem service is associated with local places and landscapes through human attachment to place (Brown & Raymond, 2007). Natural England's (2009) study on cultural services and experiential qualities that landscapes provide identified the coast, the presence of water, mountains and hills, moorland, and, woodland and trees as being important for spirituality. Norton *et al*. (2018) identified that there is a spiritual connection between the marine environment and Gaeltacht areas.
- *Sense of Place* - Natural England's (2009) study on cultural services and experiential qualities that landscapes provide identified the coast, moorland, field systems, hedges, walls and lanes, and villages as providing a sense of place.
- *Wilderness/Solitude* - Natural England's (2009) study on cultural services and experiential qualities that landscapes provide identified the coast, the presence of water, mountains and hills, moorland, woodland and trees and field systems, as being important for escapism/solitude.

Why is it important

Spiritual and symbolic services are important because they represent less tangible aspects of the coastal and marine environment which nevertheless contribute to the way that people experience, enjoy and value it. The presence of such services is likely to underpin recreational visits to the coast and contribute to local economic activity.

How to interpret the maps

Four separate maps have been created to capture the spatial extent of the religious, spiritual, sense of place and wilderness/solitude cultural ecosystem services delivered by the coastal environment.

The data layers are individually symbolised, and all datasets have been reordered to ensure that each data layer is visible on the final maps.

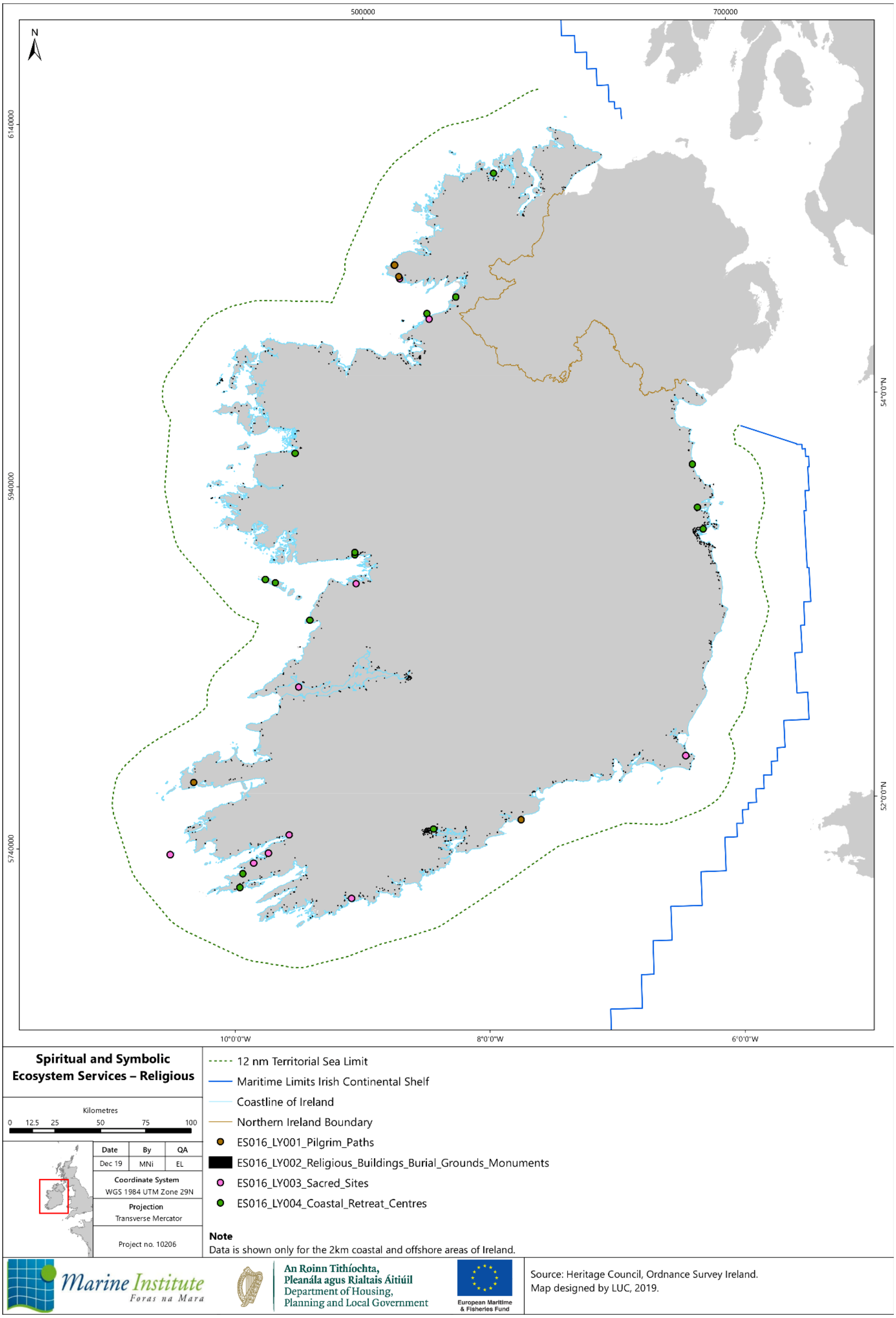


Figure 28. Cultural Service: Spiritual and Symbolic - Religious

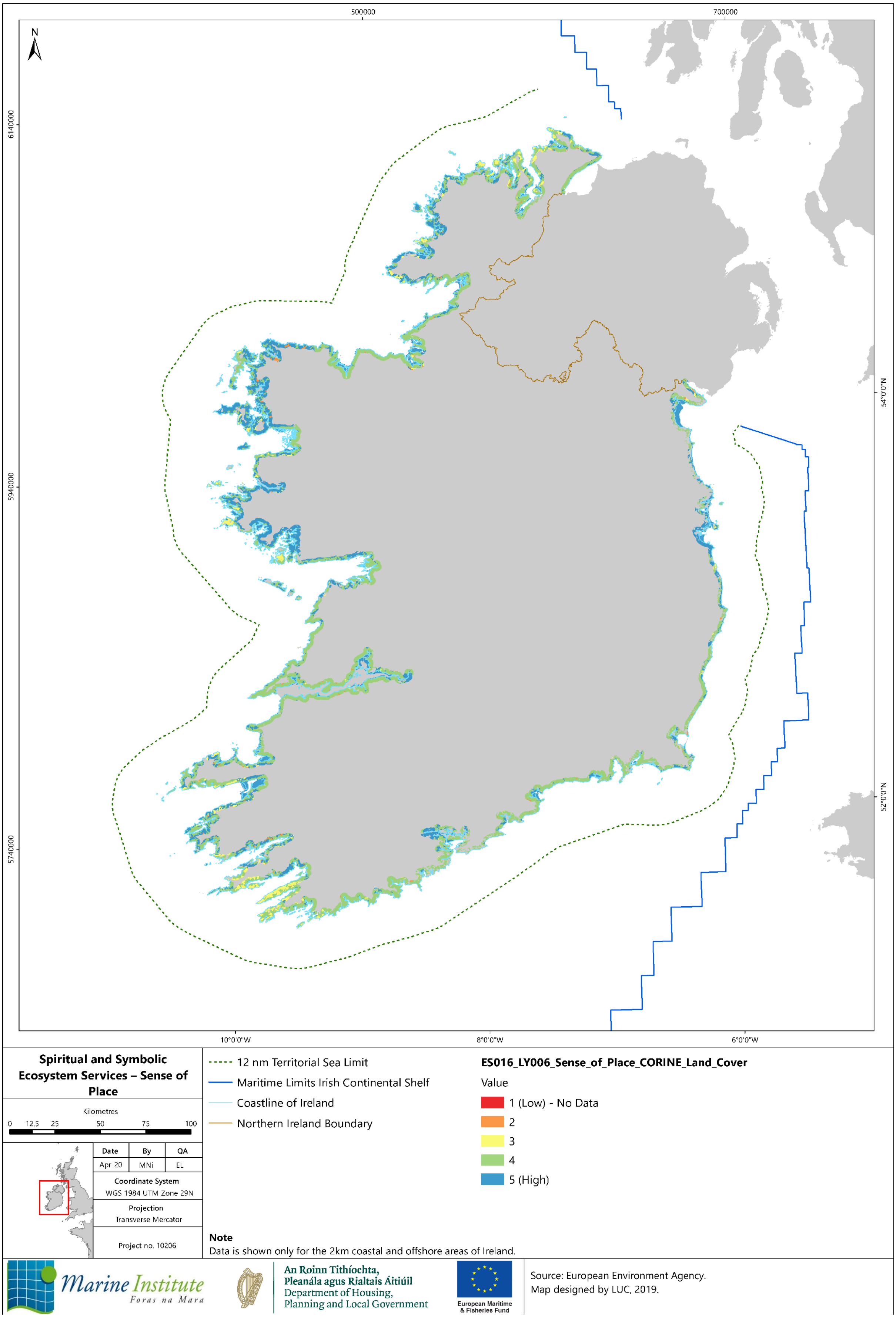


Figure 29. Cultural Service: Spiritual and Symbolic - Sense of Place

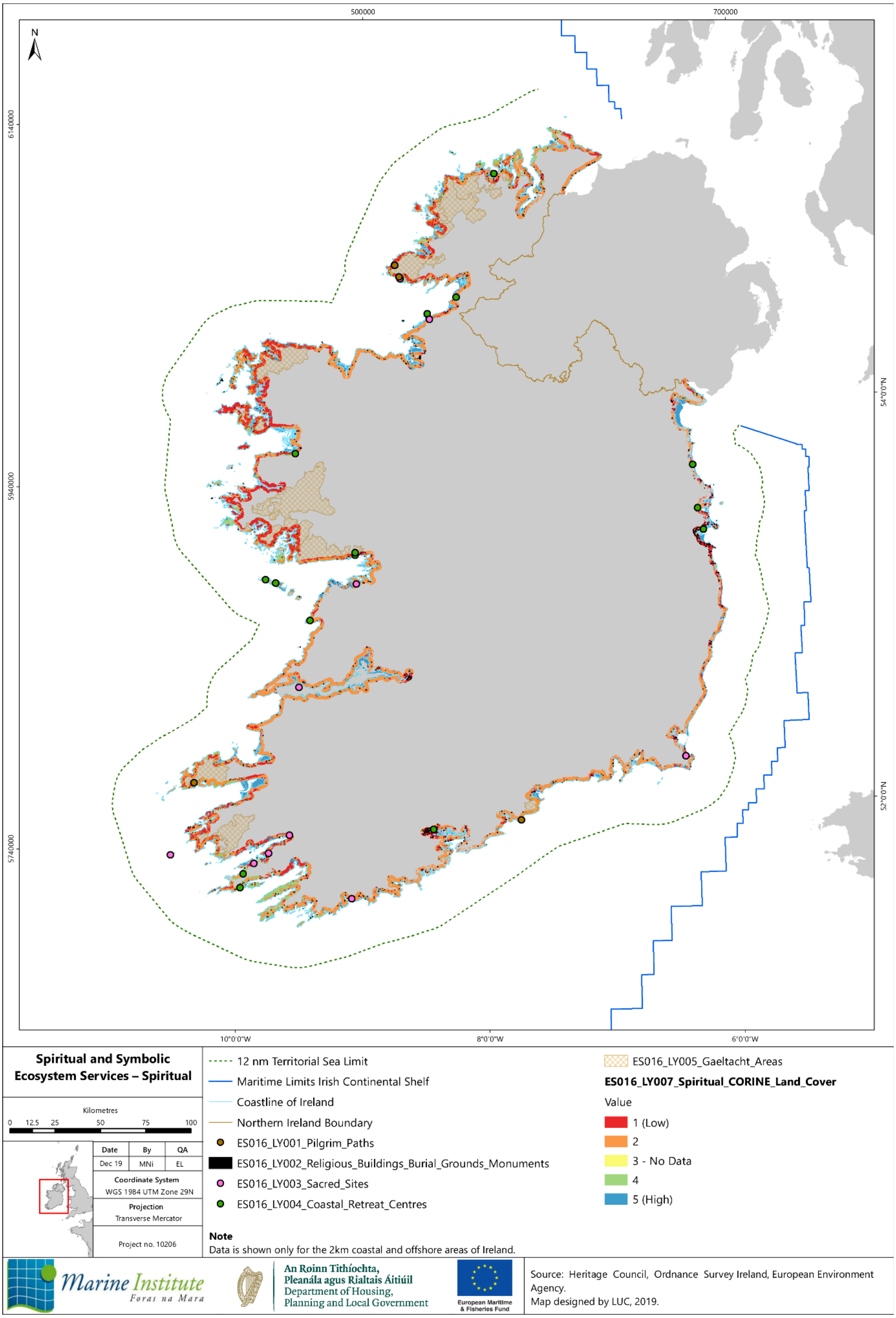


Figure 30. Cultural Service: Spiritual and Symbolic - Spiritual

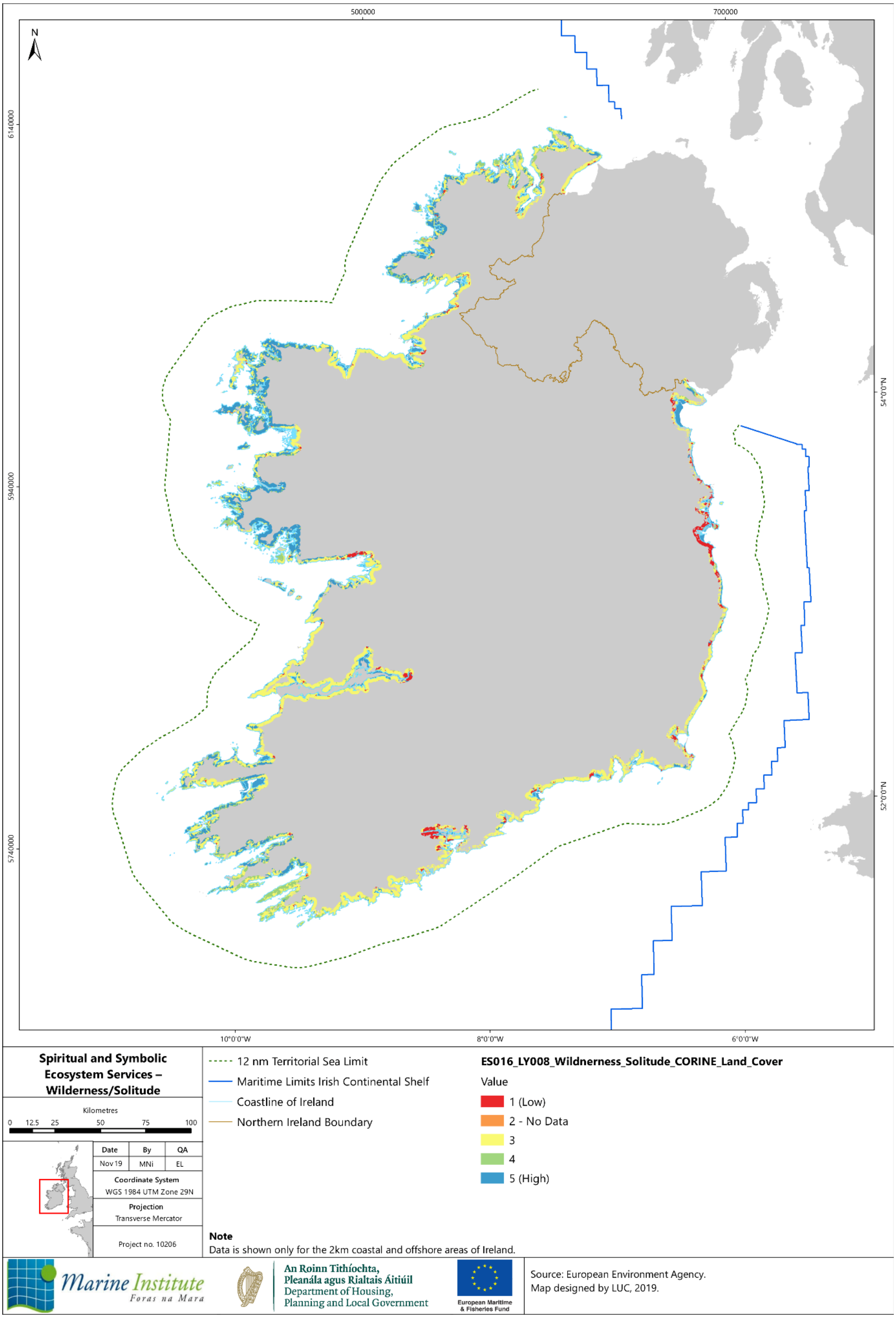


Figure 31. Cultural Service: Spiritual and Symbolic - Wilderness

Three data layers were prepared using the CORINE land cover dataset (2018):

- Sense of Place;
- Spiritual; and
- Wilderness and solitude.

Attribute values were assigned for each CORINE land cover class (2018) within 2 km of the coast to identity landscape characteristics/ features that correlate with spiritual enrichment, place identity, and wilderness/solitude. The principal land cover along the coastline and the values that have been assigned to each land cover class assumed to deliver spiritual and symbolic ecosystem services are detailed in Appendix Table D5. The values are based on the Natural England (2009) study but were refined to apply to the landscape features of the Irish coastline.

The following symbology was used to identify the different values assigned to each land cover class:

- Red – Value 1 - Low
- Orange – Value 2
- Yellow – Value 3
- Green – Value 4
- Blue – Value 5 – High.

Not all values are applicable for each map. For example, only values 2, 3, 4 and 5 are assigned for the Sense of Place ES map, with 'No Data' identified in the legend for value 1.

Religious ecosystem services are primarily concentrated in urban areas including Dublin City, Cork City, Limerick and Galway. Coastal retreat centres are concentrated in Galway, particularly the Arran Islands, and in Kerry, Dublin and Donegal. A number of sacred sites are identified in Kerry.

For the Spiritual ES map, Spiritual CORINE Land Cover classifies most of the coastline as being of low value in terms of delivering spiritual ecosystem services (values of 1 and 2). Although Mayo, Galway, Donegal and Kerry are primarily identified as not delivering spiritual ecosystem services in the CORINE land cover dataset, these counties include Gaeltacht areas and several retreat centres, sacred sites, Pilgrim paths, and other religious sites/buildings. Therefore, the CORINE land cover dataset and the other data layers depicting spiritual ecosystem services may present conflicting information and should be interpreted with caution.

As 'sense of place' is often associated with urban areas the counties delivering this ecosystem service are principally Dublin, Cork City, Limerick, Galway City and Waterford. As a sense of place may also be experienced at the coast and in boglands, counties Mayo, Donegal, Louth, Kerry and Sligo are also identified as locations where these ecosystem services may be delivered.

The counties delivering 'wilderness/solitude' ecosystem services are principally Mayo, Donegal, Kerry, and Louth. The main urban centres of Dublin, Cork City, Galway City and Limerick do not deliver wilderness/solitude benefits.

The data are shown only for the 2 km coastal and offshore areas of Ireland. However, the Gaeltacht areas within 2 km of the coast have not been clipped and show the full extent of the designations' boundaries.

How the maps were created

Multiple data sources were collated to create this map, including data layers created for Project 2 and new data layers prepared specifically for these ES maps.

In order to capture the religious element of this CES, the location of pilgrim paths, religious buildings, burial grounds, sacred sites, historic religious monuments and sites, and coastal retreat centres were mapped. A 2 km buffer zone was used to capture these assets that are influenced by the coastal environment. The following data layers were used to create the 'Spiritual and Symbolic Ecosystem Services - Religious' map:

- Pilgrim Paths;
- OSi Religious Buildings Burial Grounds Monuments - religious buildings, burial grounds, historic religious monuments and sites (e.g. cathedrals, churches, chapels, abbeys, cemeteries/graveyards, convents, monasteries, burial mounds, standing stones, holy wells;
- Sacred Sites including Skellig Islands, Croagh Patrick, Slieve League, Tobar Nalt, Kilmacduagh, Scattery Island, Brandon Mountain, Ardgroom, Drombohilly, Kenmare, Kealkil, Dromberg, Ardmore, Lough Derg, Lady's Island; and
- Coastal Retreat Centres including Ards Friary Retreat (Donegal), Arran Islands Retreat (Galway), Jesuit Centre of Spirituality and Culture (Galway), Ardfert Retreat Centre (Kerry), St. Dominic's Retreat House (Cork), Ballyvaloo Retreat Centre (Wexford), Manresa Jesuit Centre of Spirituality (Dublin), Stella Maris (Dublin).

Norton *et al.,* (2018) identified that the coastal Gaeltacht areas have a strong connection to the Irish language, traditions, songs and poetry and the spatialisation of these areas depicts the spiritual connection of the Gaeltacht areas to the marine environment. Therefore, the following data layer was prepared:

- Gaeltacht Areas.

For the 'Spiritual and Symbolic Ecosystem Services – Spiritual' map, the following data layers were used:

- Pilgrim Paths;
- OSi Religious Buildings Burial Grounds Monuments - religious buildings, burial grounds, historic religious monuments and sites (e.g. cathedrals, churches, chapels, abbeys, cemeteries/graveyards, convents, monasteries, burial mounds, standing stones, holy wells;
- Sacred Sites including Skellig Islands, Croagh Patrick, Slieve League, Tobar Nalt, Kilmacduagh, Scattery Island, Brandon Mountain, Ardgroom, Drombohilly, Kenmare, Kealkil, Dromberg, Ardmore, Lough Derg, Lady's Island;
- Coastal Retreat Centres including Ards Friary Retreat (Donegal), Arran Islands Retreat (Galway), Jesuit Centre of Spirituality and Culture (Galway), Ardfert Retreat Centre (Kerry), St. Dominic's Retreat House (Cork), Ballyvaloo Retreat Centre (Wexford), Manresa Jesuit Centre of Spirituality (Dublin), Stella Maris (Dublin);
- Gaeltacht Areas; and
- Spiritual CORINE Land Cover

For the 'Spiritual and Symbolic Ecosystem Services – Sense of Place' map, the following data layers were used:

- Sense of Place CORINE Land Cover

For the 'Spiritual and Symbolic Ecosystem Services – Wilderness/Solitude' map, the following data layers were used:

- Wilderness/ Solitude CORINE Land Cover

Data limitations

The Pilgrim Paths data is point data and not polyline data depicting the pilgrimage routes. It identifies the starting point of the Pilgrim Path. Therefore, where a Pilgrim Path does not begin in the 2 km coastal buffer zone, it is not identified even though the route may be along the coastline.

In the context of mapping religious and spiritual ecosystem services, religious experiences are more likely to be linked to specific places, typically churches, cathedrals, cemeteries, etc., and spirituality as a cultural ecosystem services is often associated with local places and landscapes. However, it was also assumed that assets with religious associations (i.e. Pilgrim Paths, religious buildings/burial grounds/monuments, sacred sites, and coastal retreat centres) could also deliver spiritual ecosystem services. For example, people may walk the Pilgrim Paths not as a religious experience but for their own spiritual benefit. However, this may not be the case and cannot be verified.

The approach to mapping symbolic and spiritual CES is based on assumptions and values which were identified for other studies and adapted to the context of the Irish coastal environment. The 'Spiritual' ES map combines the CORINE data layer (with assigned values) and other data layers relevant to delivering spiritual ecosystem services. However, these data layers are mutually exclusive and therefore may present contradictory information. This map should be interpreted with caution.

Knowledge gaps are particularly notable for mapping spiritual, religious, symbolic, and sense of place ecosystem services, for example there is a marked lack of evidence on the numbers of people who visit religious or spiritual sites, and the relative importance attributed to different landscape features should be investigated specifically for the features of Ireland and values of Irish society. Additionally, there is a lack of data which recognises who within society is benefitting from the flow of spiritual and symbolic cultural services, and where these people are located. Sense of place is also highly individual and as such the map might not fully represent all areas considered to provide sense of place cultural services. Additionally, land cover alone is likely insufficient to specialise sense of place as it is unlikely to capture areas of hedges, walls and lanes which were considered as significant in another study (Natural England, 2009). As such the current maps could be considered to be baseline maps which require further evidence and refinement.

Without undertaking participatory GIS techniques to map spiritual and symbolic and sense of place CES i.e. by involving the public in identifying key characteristics and valued areas, the study is limited as it can only be assumed that certain landscape features provide these ecosystem services.

Opportunities

Future studies should use participatory GIS techniques to map spiritual and symbolic CES by either conducting in-depth interviews or issuing questionnaires among respondents asking how and why they appreciate a particular site or area for its symbolic, religious or spiritual value, which would present a pathway to more robust insight of spiritual and symbolic CES in Ireland.

4.3.6 Existence and bequest

Figure 32 illustrates the existence and bequest services delivered by the coastal environment.

What the service is

This map illustrates the existence and bequest ecosystem services delivered by the coastal environment.

The CICES provides examples of existence and bequest cultural ecosystem services:

- *Existence* - Habitats, species and landscape elements which are regarded for their intrinsic value - this includes elements of biodiversity which people feel should be protected, or for which they are willing to pay for protection, as they constitute part of local and national identity, or are associated with sense of place and time. Nationally, these are demonstrated by National Parks, nature reserves and formal conservation designations (national and international), but locally it includes elements of biodiversity which form part of local aesthetic character.
- *Bequest* - Linked to the 'existence' class, but more specifically relates to the protection of habitats and landscape elements for the benefit of future generations (be it economic, social or cultural benefit). Potentially very extensive but demonstrated by National Parks, designated heritage sites, formal statutory designations for nature conservation and Protected and Recorded Monuments.

Without undertaking GIS participatory mapping techniques, it is not possible to assign existence and bequest values. Therefore, the approach to mapping existence and bequest CES is to identify international/national/local natural heritage, landscape and historic environment designations.

Why is it important

Existence and bequest ecosystem services are increasingly important aspects of the way that people experience and value the environment, including the importance of protecting the most important environmental resources and ensuring they are passed on to subsequent generations.

How to interpret the map

Due to the large volume of data layers to be shown on the map, datasets are grouped into relevant topics, for example international, national and UNESCO designations, and identical symbology applied:

- SAC, SPA, Ramsar and MPA sites are grouped as international designations;
- Natural Heritage Areas, proposed Natural Heritage Areas, Wildlife Sanctuaries and Nature Reserves are grouped as national designations;
- World Heritage Sites Tentative, OPW National Heritage Sites, Walled Towns of Ireland, Heritage Towns of Ireland, Irish Historic Town Atlas are grouped as Heritage Sites & Towns;
- Wreck Extents, National Monuments, National Monuments Zones of Notification, National Inventory of Architectural Heritage, Archaeological Survey of Ireland, Atlas of Hillforts, Record of Protected Structures, Sheela Na Gigs are grouped as Heritage Assets; and
- Special Amenity Area Orders, Local Landscape Designations, and Conservation Areas are grouped as Landscape Designations.

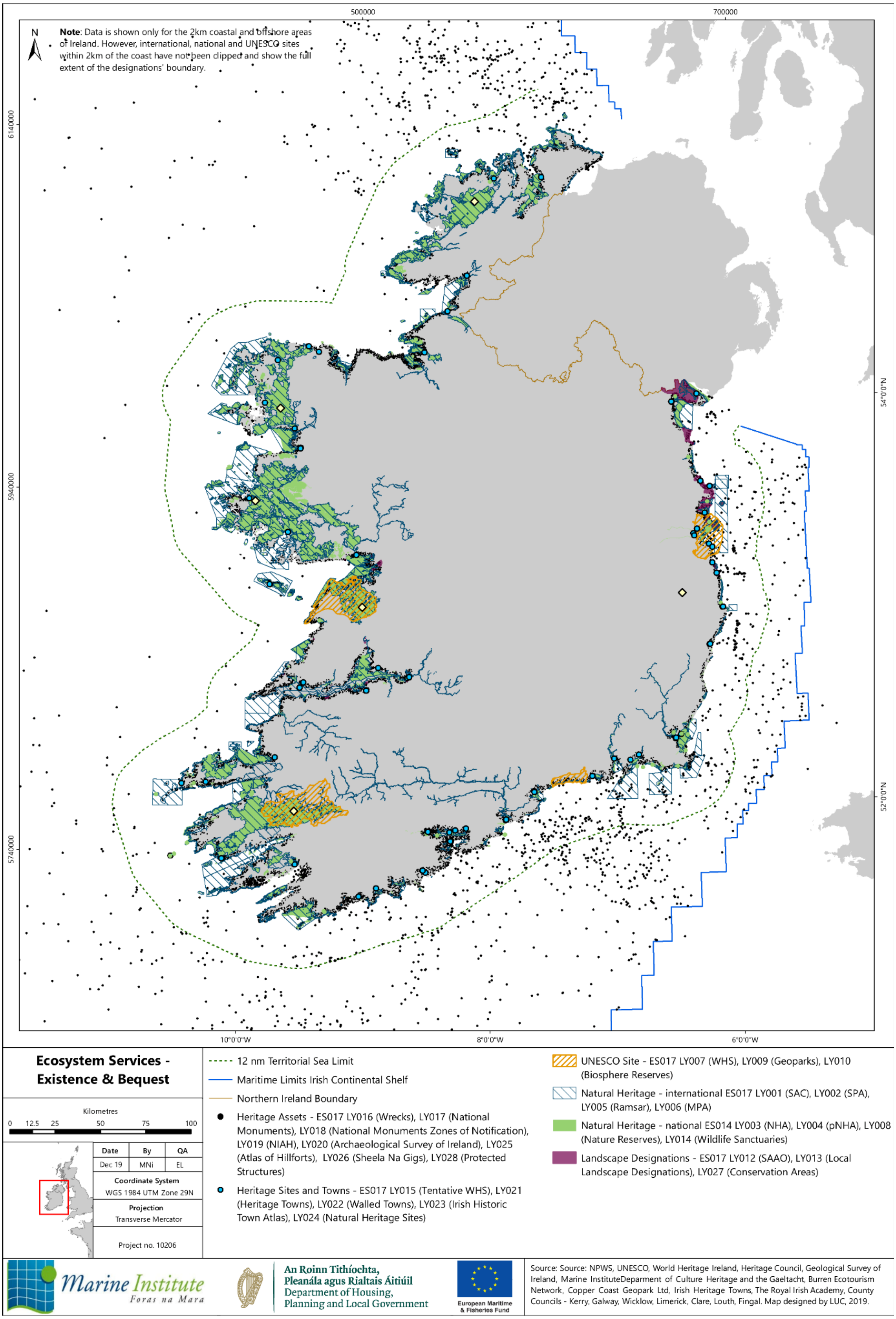


Figure 32. Cultural Service: Existence and bequest

Their layer IDs are noted in the legend. The remaining datasets are individually symbolised, and all datasets have been reordered to ensure that each data layer is visible on the final map.

The data is shown only for the 2 km coastal and offshore areas of Ireland. However, international, national and UNESCO sites within 2 km of the coast have not been clipped and show the full extent of the designations' boundary.

How the map was created

Multiple data sources were collated to create this map, including data layers created for Project 2 and new data layers prepared specifically for this ES map.

- Special Areas of Conservation; Special Protection Areas; Natural Heritage Areas; proposed Natural Heritage Areas; Ramsar Sites; Marine Protected Areas; UNESCO World Heritage Sites; Nature Reserves; National Parks;
- Special Amenity Areas Orders;
- Local Authority Local Landscape Designations;
- NPWS – Wildlife Sanctuaries;
- Tentative World Heritage Sites - created from World Heritage Ireland website;
- Geopark Authorities - UNESCO Global Geoparks;
- Wreck Extents;
- Local Authorities – Biosphere Reserves;
- Terrestrial Heritage Extents - National Monuments, National Monuments Zones of Notification,
- National Inventory of Architectural Heritage, Archaeological Survey of Ireland, Heritage Towns of Ireland, Walled Towns of Ireland, OPW National Heritage Sites, Atlas of Hillforts; Irish Historic Town Atlas;
- Sheela Na Gigs;
- Architecture Conservation Areas; and
- Record of Protected Structures.

Data limitations

- Point data has been used to identify areas such as National Parks, Nature Reserves, Tentative World Heritage Sites, Heritage Towns of Ireland, Walled Towns of Ireland and Wildlife Sanctuaries as no polygon data depicting the extent of the boundaries was available. This may result in these designations which are partially within the 2 km coastal buffer zone not being included as the centre points are not within the buffer zone.
- Only a small number of coastal local authorities provided data on locally designated landscape designations, with no local authority providing data on local nature designations.
- Data on Special Amenity Areas Orders is incomplete as we did not receive data on the Liffey Valley SAAO or the North Bull Island SAAO.
- Without undertaking participatory GIS techniques to value existence and bequest CES, the study is limited as it can only be assumed that designated nature, landscape and heritage assets provide these ecosystem services.

Opportunities

Future studies should use participatory GIS techniques to map existence and bequest CES which would present a pathway to more robust insight of existence and bequest CES in Ireland.

5 Spatialisation of the value of provisioning and regulating ES in Ireland

5.1 Valuation method

Building on the maps presented in Sections 4.1 and 4.2 for provisioning and regulating services, indicative economic values for these services have also been spatialised. A grid of consisting of individual 10 sq. km cells with unique identifiers was created covering the Irish EEZ. The value of each ecosystem service calculated using the methods described in sub-sections below was then assigned to each grid cell to create an overall value map for the provisioning and regulating services within the Irish EEZ.

The ecosystem services maps contain information as rasters, polygons, polylines or points. The approach differed for each. First, the overall value of the ecosystem service was apportioned spatially across the ecosystem services map. Some polygon/point data already had specific values associated with each polygon/point (e.g. mediation of wastes, carbon sequestration, water for non-drinking purposes). For others, the overall monetary value of the ecosystem service was pro-rated across the individual polygons based on area (e.g. wild seaweed harvesting, fish and shellfish aquaculture). Line data were given a monetary value based on the value per unit length (e.g. saltmarsh, sand dune, shingle). For raster data, the overall ecosystem value was apportioned across the grid based on intensity (e.g. carbon sequestration, wild capture fisheries and shellfisheries). Polygon and line data had their lengths/areas calculated prior to any manipulation.

The raster, polygon, polyline and point data were then intersected by the 10 sq. km grid, and for the polygons and polylines, a new value was calculated based on their new intersected area/length. For raster data, the values captured in each grid cell were summed. The monetary values for each ecosystem service were then summed for each grid cell to produce an overall value map of regulating and provisioning services.

It should be noted that monetary values cannot capture all values ascribed by human beings to natural capital and other services. Values for provisioning services, are largely appropriate and provide a guide even where services are realised without cost. Some regulating services can be anticipated to have a significant social or socio-cultural value but may in many cases can be poorly understood by the wider public. Regulating services are most easily measurable through monetary methods, but mainly as an indication of value. No monetary values were calculated for the provision of cultural services as currently there is large uncertainty with methods of valuing cultural ecosystem services. Although there may be some data on the value of tourism and recreational services, such as sailing, surfing, sea angling and eco-tourism (e.g. dolphin and whale watching), this does not capture a thorough picture of the value of cultural services.

5.1.1 Provisioning Services

Figure 33 illustrates the economic value of key provisioning services across the Irish EEZ. The value of each provisioning service was calculated using methods described in sub-sections below. These values were then linked to the direct and indirect Gross Added Value (GVA) for each sector in 2018 as presented in the SEMRU (2019) report. This allowed values to be standardised and equally weighted within the overall value heatmap.

The map shows higher values associated with wild fish capture offshore and with activities such as ports and aquaculture at the coast. The total GVA of the provisioning services mapped is £2.4 billion.

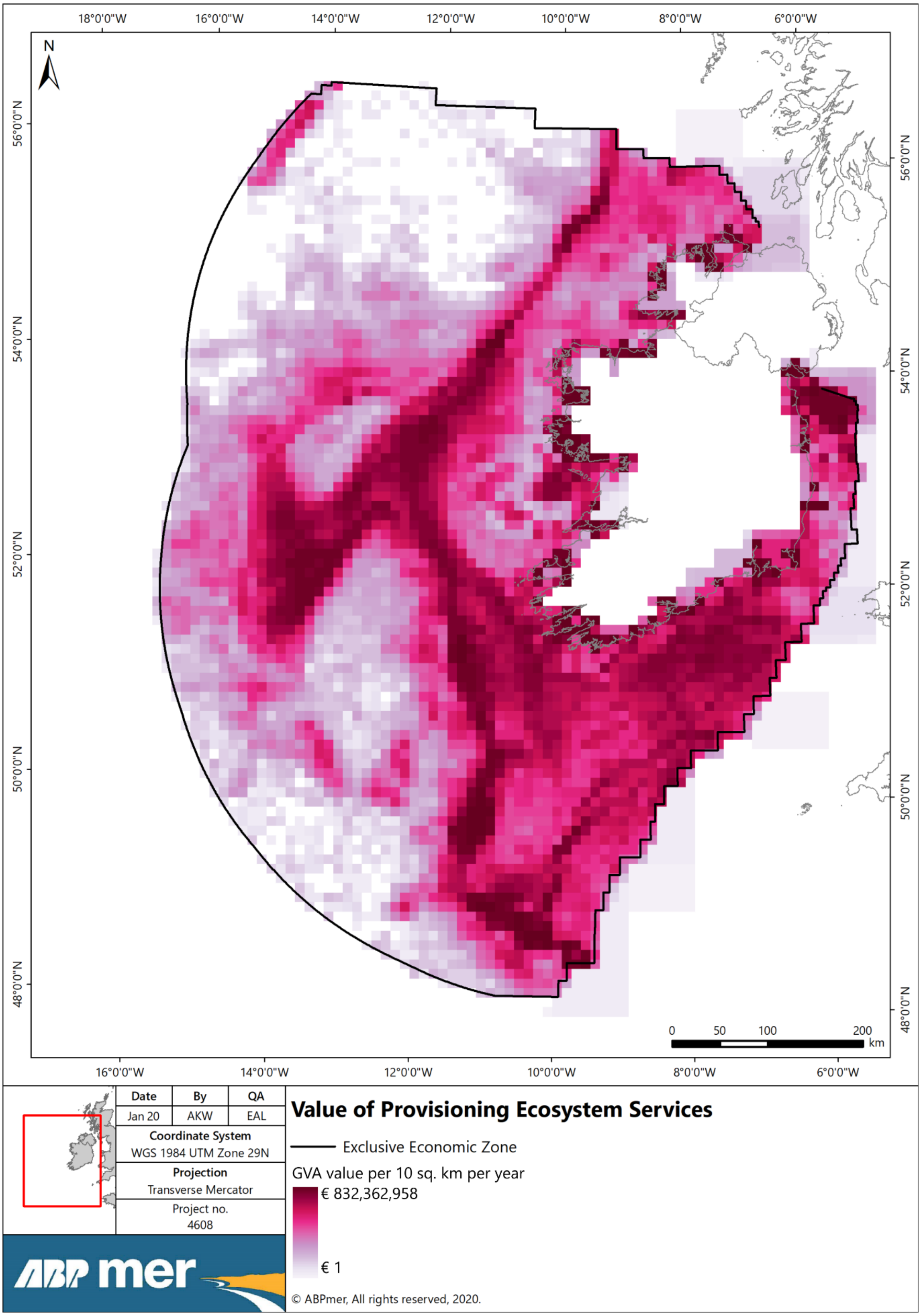


Figure 33. Value (GVA) of provisioning ecosystem services

Wild capture fish and shellfisheries

The annual average volume of catches of fish and shellfish from Irish waters were obtained from the STECF Fisheries Dependent Information – Classic (STECF-17-09), Deep Sea Annex, for all EU countries, for the period 2012-2016 (which were the latest years available). The data are available at the spatial scale of ICES statistical rectangles (0.5° latitude by 1.0° longitude). Data were extracted for the ICES rectangles that overlap Irish waters, and the volumes caught in each ICES rectangle were pro-rated according to the proportion of each ICES rectangle that lies within Irish waters using the 'ICES Statistical Rectangle Factors' dataset[3] provided by the UK Marine Management Organisation. To calculate value of catches, average values per tonne for each species were obtained from the Eurostat dataset 'Landings of fishery products - main data'[4] and applied to the volumes caught for each species.

To apportion the value between the inshore and the offshore fleet activity, the data were split into those for under-10 m and over-10 m vessels. The value for over-10 m vessels was applied to the distribution of effort from the VMS data. The value for under-10 m vessels was applied to the ICES rectangles where the catches were recorded[5]. The STECF data provided length categories for under 10 m, 10-15 m, and over-15 m. There was no length category split for over- and under-12 m vessels, which would have been more appropriate given that the VMS data applies to vessels over 12 m length. The data for 10-15 m vessels was mapped, and a large number of offshore ICES rectangles were present in the data. It was therefore considered appropriate to distribute the value from this length category to the VMS effort data. The data for under-10 m vessels were mapped and were mostly restricted to inshore ICES rectangles, which corresponded well with the inshore fishing areas mapped previously and shown on the ecosystem services map.

The value of fish and shellfish catches, from Irish waters, for each vessel category was:

- Offshore fishery: Vessels over 10 m: €626.6 million
- Inshore fishery: Vessels under 10 m: €15.5 million

The discrepancy in length categories means that the value attributed to the offshore fishery will be slightly over-estimated, and the value attributed to the inshore fishery will be slightly under-estimated. However, the total value is consistent with source data.

To calculate the added ES value provided by the provisioning of wild capture fisheries and shellfisheries, the value of the service was then standardised to GVA. The total direct and indirect GVA for the Irish Sea fisheries sector (€226,630,000) (SEMRU, 2019) was distributed across the inshore and offshore spatialised value data to calculate the contribution of each cell to the overall GVA value. These values were then incorporated into the Provisioning Value ES heatmap (Figure 33).

Seaweed wild harvest

The location of seaweed harvesting licence areas were digitised form DHPLG foreshore licensing applications.

3 https://www.gov.uk/government/statistics/uk-sea-fisheries-annual-statistics-report-2017. Downloaded 11 December 2019.

4 http://appsso.eurostat.ec.europa.eu/nui/setupDownloads.do. Downloaded 10 April 2019.

5 It was decided not to use the inshore fishing areas as previously mapped, since these are out-of-date, and do not necessarily reflect the current activity of the inshore fleet. However, the ICES rectangles included do correspond well with the inshore fishing areas.

Following the work by O'Toole and Hynes (2014) the value of wild harvested seaweed was calculated for the current volumes of seaweed harvested. In 2012 29,500 tonnes of seaweed were harvested in Ireland with an overall value of €3,914,000, yielding an average per tonne value of €133 of seaweed harvest.

The approximate volume of wild seaweed harvest in Ireland in 2018 was 36,000 tonnes. Using the average per tonne value of €133 the total value of wild harvest seaweed in Ireland in 2018 was €4,788,000 (based on 2012 values). This was then pro-rated according to the proportion of each licensing area.

The above value of wild seaweed harvest was then standardised to the total direct and indirect GVA as presented in SEMRU (2019). Within the SEMRU (2019) report seaweed harvesting is listed under the marine biotechnology and bio-products profile, with a total GVA of €60,427,000. This GVA value was used, although it is noted that it covers both the seaweed processing sub-sector in addition to harvesting. The spatial value of seaweed wild harvest was then standardised to the total GVA for the sector to provide the contribution of each cell to this GVA value. This was incorporated into the Provisioning Value ES heatmap (Figure 33).

Aquaculture: fish and shellfish

The spatial distribution of finfish and shellfish aquaculture sites was created from the original Aquaculture Licence GIS Data which contains currently licensed or operational aquaculture sites under Section 19A of the Fisheries (Amendment) Act 1997. Value data relating to currently licensed or operating aquaculture sites within Irish waters was sourced, for each county, from the Department of Agriculture, Food and the Marine.

Data sourced from DAFM were apportioned by county and aquaculture site to assign an average value of aquaculture production at each facility. These values were then normalised to total direct and indirect GVA value using the total GVA of marine aquaculture (€139,445,000) as a proxy (SEMRU, 2019).

Aquaculture: seaweed

Data sourced from DAFM were used to map current seaweed aquaculture licences in Ireland. There are currently 13 licensed aquaculture areas covering approximately 106 ha of licensed seaweed aquaculture. Based on best known performance, yield is 6 tonnes wet harvest / ha per hectare, therefore producing up to 636 tonnes of wet harvest per year (BIM, 2019).

In 2012 the UN Food and Agriculture Organisation calculated that globally, 25 million tonnes of seaweed were produced annually with a commercial value of $6.4 billion, with an approximate value of $256 per tonne (€230; December 2019 currency conversion) of seaweed. As such, the current Irish seaweed aquaculture industry is valued at €151,000 (2019 value).

To map the value of seaweed aquaculture it was assumed, based on best yield, that each hectare of aquaculture facility produced 6 tonnes of seaweed (wet harvest) with a value of €230 per hectare.

As there are no published GVA values for seaweed aquaculture, the GVA and turnover of marine aquaculture were used to calculate a proportionate GVA for seaweed aquaculture which could then be applied to normalise to sector value (SEMRU, 2019). Therefore, the Marine Aquaculture GVA (€139,445,000) was divided by the turnover for Marine Aquaculture (€176,000,000) and then multiplied by the calculated sector value (€151,000) to provide a Seaweed Aquaculture GVA of €119,638. The contribution of each cell to this GVA value was then calculated. These values were then incorporated into the Provisioning Value ES heatmap (Figure 33).

Mineral substances

The only current location of gas production in Ireland is the Corrib Gas field. This data was sources from the PAD. The Corrib Gas field produces around 56% on Ireland gas requirements, which equates to around 30 TWh/yr. Based on the wholesale gas price for January-June 2018 of €0.64/ therm (CRU, 2018), the supply of 30 TWh/yr from Corrib equates to a wholesale value for 2018 of €563 m.

To normalise the data the contribution of each cell was then proportioned to the total direct and indirect GVA for Oil and Gas Exploration and Production (€162,899,000; SEMRU, 2019).

Non-mineral substances

Arklow Bank is currently the only operating renewable energy facility within Irish waters. The current capacity of Arklow Bank is 25.2 MW.

Using data from BEIS (2019), we assumed a 40% load factor, which equates to an annual energy generation of 88 GWh.

Wholesale energy electricity prices were sourced for January-June 2018 from the Commission for Regulation of Utilities. The average wholesale price for electricity across the period was €58.33 per MWh. The average wholesale price was used to value to annual energy generated from Arklow Bank, which was calculated at €5.15 million. This value was assigned to the area of Arklow Bank.

To normalise the data the contribution of each cell was then proportioned to the total direct and indirect GVA for Marine Renewable Energy (€56,896,000; SEMRU, 2019).

Water for non-drinking purposes

Valuation of water for non-drinking purposes was calculated using two methods: 1) value of seawater used for cooling in coastal power stations, and 2) value of seawater for provision of waterborne transport.

Coastal power stations use water for cooling purposes. Data on the volume of water abstracted for cooling water purposes and the estimated energy output at each energy station was sourced from Norton *et al.* (2018). Stations using once through cooling systems are predicted to have a 2% increase in power efficiency compared to cooling tower systems (Turnpenny *et al.,* 2010).

Using the average efficiency of 40% (Turnpenny *et al.*, 2010) and the calculating a 2% increase in efficiency for coastal power stations, an additional energy production of 621 GWh was calculated for Irish coastal stations. Using the whole sale energy price of €58.33 per MWh (CRU, 2018) the additional energy produced by using seawater for cooling purposes equates to €36.2 million.

To value seawater for the provision of waterborne transport, data on the tonnage of goods handled across all Irish ports was sourced from the Central Statistics Office (2019). Data were sourced on tonnage and type of goods handled by each port and the number of passengers transported by cruise ships (Table 7).

Using the method developed by the Marine Management Organisation (2019), which aims to assigning value to shipping cargo flows, the average value of each type of cargo was calculated. By assigning a value to the total goods handled at each port, and/or the number of passengers on a cruise vessel, a value of waterborne transport was calculated.

The value of goods handled at each port (Table 7) was then assigned to each port location, to indicate where the ecosystem service value is realised. The total value of goods and passengers handled by all Irish ports in 2018 was €113.5 billion.

Normalising the value of water for non-drinking purposes involved the incorporation of multiple GVA values to cover the different sector contributions to the provisioning service. To convert the value of water used to for cooling purposes to GVA the turnover of renewable energy (€57,591,000) and the GVA for the marine renewable energy sector (€56,896,000) were used to calculate new a GVA based on the power station turnover (€36,186,949). The calculated GVA (€35,763,144) was then distributed based on power station value.

To convert the value of waterborne transport the direct and indirect GVA for shipping and maritime transport (€1,687,249,000) was distributed across ports based on the value of goods and passengers at each port (see Table 7). To then further incorporate the value of cruise ships utilising Irish ports, the international cruise direct and indirect GVA (€32,338,000) was used and distributed based on number of cruise ships (SEMRU, 2019).

5.1.2 Regulating services

Figure 34 shows the economic value of three key regulating services across the Irish EEZ. The value of each regulating service was calculated using methods described in sub-sections below. The map shows higher values at the coast associated with carbon sequestration (saltmarsh), regulation of flows (saltmarsh, shingle, sand dunes) and mediation of wastes (estuaries) and higher values offshore associated with carbon sequestration (sequestration of carbon within deep sea sediments). The total value of mapped regulating services is £14.9 billion.

Climate regulation

To map climate regulation services data from PML on modelled air-sea carbon flux estimates for marine waters (2008-2017) were utilised as a proxy for CO_2 exchanges with the water column and then converted to calculate the t CO_2 /ha/yr., for offshore, marine waters. For coastal water bodies NPWS data was used to map inshore sand dune, saltmarsh and estuary habitats. Data from Norton *et al.* (2018) were utilised to calculate the amount of carbon sequestered by each of the inshore habitats. The values use are as follows:

- Sand dunes: + 2.1 t CO_2 /ha/yr;
- Saltmarsh: + 5.2 t CO_2 /ha/yr;
- Estuaries: - 21.1 t CO_2 /ha/yr; and
- Coastal water bodies: + 0.4 t CO_2 /ha/yr.

The value (€) of CO_2 sequestration per hectare per year was then calculated for air-sea flux of CO_2 in offshore waters and for inshore habitats per hectare based on a carbon value of €20 per tonne of CO_2 (Department of Finance, 2011). The total net air-sea flux of CO_2 estimates the value of the climate regulation service provided by Irish waters to be €4.77 billion.

The per ha values for each habitat have been assigned to associated grid cell within the wider grid used to map to total value of provisioning and regulating services (Figure 35).

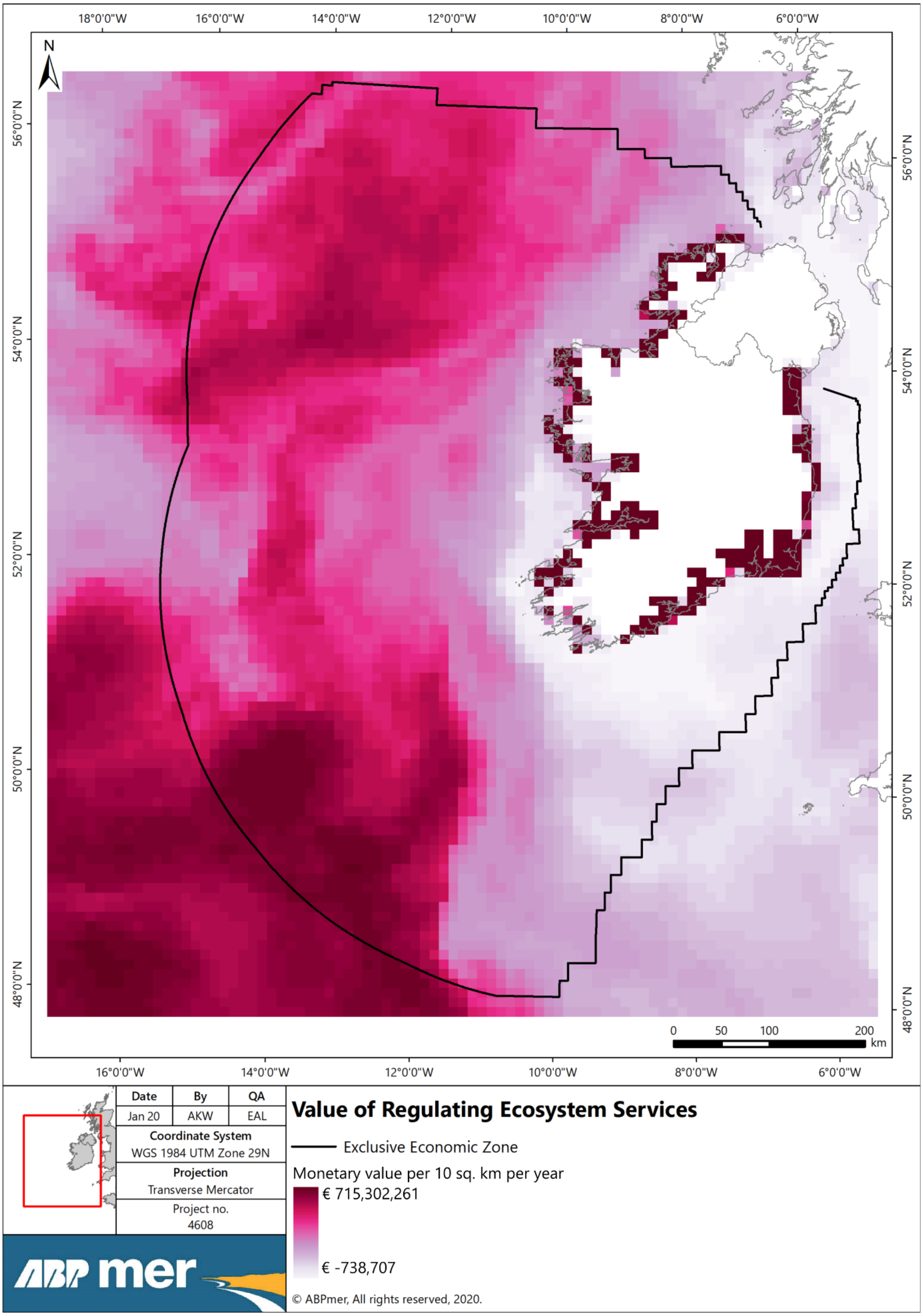


Figure 34. Economic value of regulating ecosystem services

Waste mediation

The value of waste mediation services was calculated using the cost avoided of treating water. The shadow price index (Hernandez-Sancho *et a*l. 2010) estimates the cost avoided by not having to bring discharged waste water from water treatment plants up to full re-use quality. The index calculates the cost (€) per kilogram of pollutant removed as:

- Biochemical Oxygen Demand: 0.07/kg
- Nitrogen: 30.93/ kg; and
- Phosphorous 93.63/ kg.

To identify the location of estuaries, WFD transitional waterbody data was utilised and the areas mapped. Riverine input data from the EPA was then used to assess the nitrogen and phosphorus inputs into transitional waterbodies. The shadow price index was then applied to the EPA riverine input values, to calculate what it would cost to treat the nitrogen and phosphorous input should waste water treatment plans be needed. The values (€) per sq. km per year were calculated for each transitional waterbody. This was apportioned across the polygon and assigned to the overlapping grid cell on the overall value map. The total value of waste mediation services is €8.22 billion p.a..

Regulation of flows

Habitat information was derived from NPWS data for saltmarsh, sand dunes, shingle. Coastal protection services were estimated by digitising the seaward extent of saltmarsh, sand dune and shingle habitats, indicating the protected length of coastline over which coastal protection services are being supplied. Habitats were only considered to provide coastal protection service in areas backed by agricultural or artificial land. This data was sourced from CORINE land cover data and was used to clip the extent of saltmarsh, shingle and sand dune habitats.

To calculate the value of regulation of flow services the saving of capital costs method was used (i.e. the value of putting in coastal defences if there was no saltmarsh). Using values from Norton *et al.* (2018) and ONS (2016) the natural sea defence value of dunes, shingle and saltmarsh habitats at €2063, €2037, and €4800 per meter of dune, shingle and saltmarsh respectively, were used to calculate the overall service value.

A total length of 583 km of coastline are protected by saltmarsh, sand dunes and shingle with an estimated ecosystem service value of €1.9 billion per year.

5.1.3 Valuation Results

The combined gridded heatmap of ecosystem service provision for provisioning and regulating services is provided in Figure 35. The map does not provide an absolute value of ecosystem services as it is a mixture of GVA and economic value methods. As such it provides an indication of areas which provide a higher ecosystem service function. Also, the map only includes values for provisioning and regulating services. No monetary values were calculated for the provision of cultural services as currently there is large uncertainty with methods of valuing cultural ecosystem services.

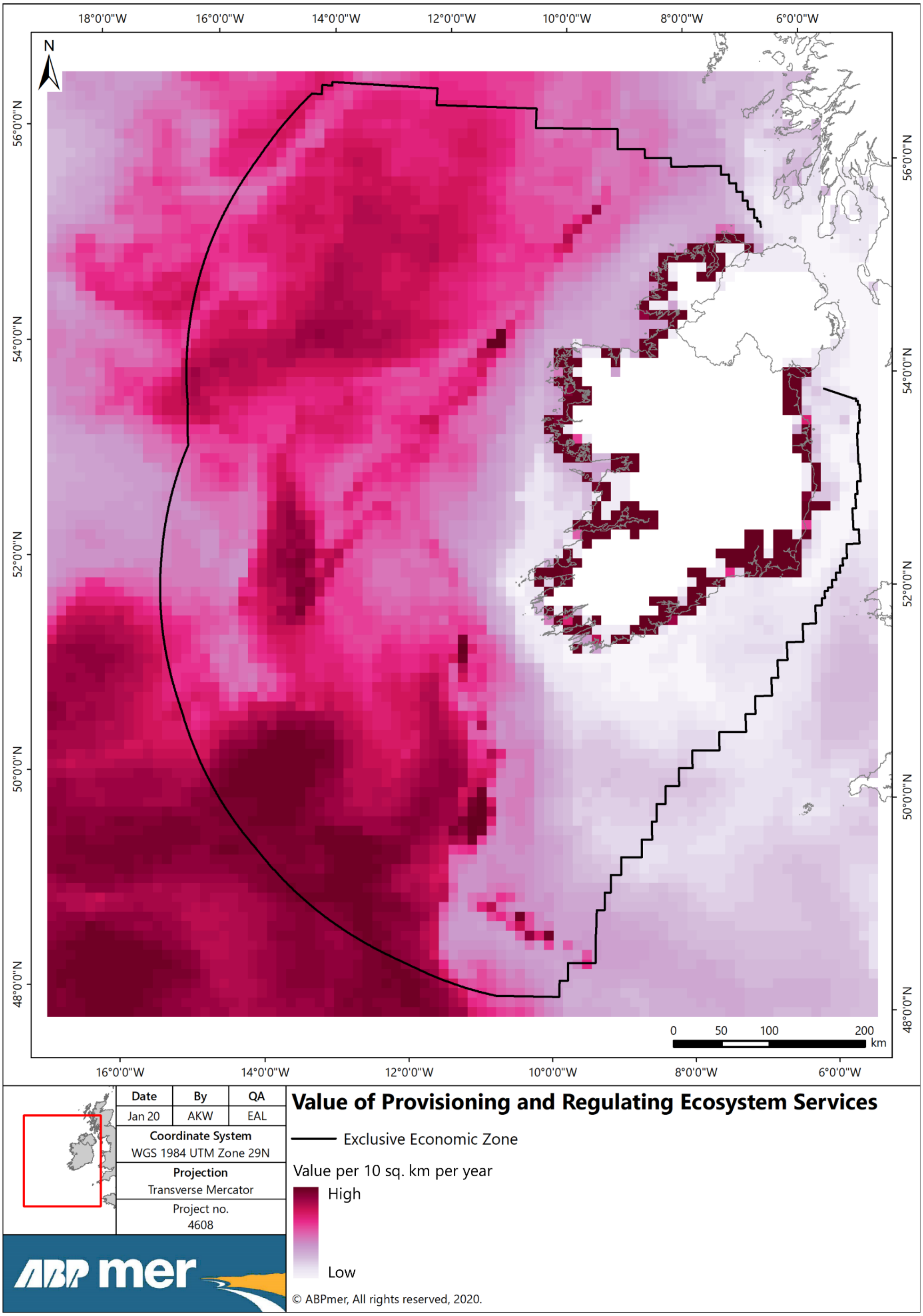


Figure 35. Value of provisioning and regulating ES in Ireland

6 Recommendations for further work

This section provides some high-level recommendations for future research which could further enhance the assessment, mapping and potential valuation of natural capital and ecosystem services. Such information could further enhance the MSP process by identifying aspects of the natural environment that contribute to human well-being and their relative importance and highlight areas for further opportunities.

6.1 Address underlying data gaps

Natural Capital asset maps and Ecosystem Services maps produced within this report (Sections 3 and 0) have been created using the most up-to-date, accessible data. However, several data gaps have been highlighted throughout the process, which if filled would greatly enhance the assessment of ES.

Some of the key gaps identified include:

- Wild capture fisheries: the resolution of data on the value and spatial extent of inshore fisheries. Increases in resolution of areas used by the inshore fishing fleet could enhance the spatial mapping of wild capture fisheries;
- Seaweed aquaculture: There is a lack of available information on the locations of harvesting carried out under private rights in intertidal areas, it is estimated that there are around 6,500 such private rights for which the Property Registration Authority holds information. However, currently this information is not readily available;
- Water for non-drinking purposes: recent work by the MMO (MMO, 2019) has used up-to-date AIS data to map the value of shipping. To replicate this process, raw AIS data which can be matched with individual MMSI numbers would be required to map vessel density by vessel type.
- Climate regulation: The current data on modelled air-sea carbon flux estimates are not well resolved in estuaries due to the resolution of the data model being too coarse to accurately capture estuaries and due to the reliability of data on organic carbon within estuaries to inform the wider model. Additionally, seagrass and kelp forest habitats have been identified as areas of significant carbon storage potential, although accurate mapping of kelp and seagrass distributions within Ireland are currently limited; and
- Cultural ecosystem services: There are some general limitations to mapping CES. Generally, spatialisation is challenging because data on the location and intensity of activities is often lacking.

6.2 Refine and improve methods for spatialising regulating services

6.2.1 Climate regulation

Obtaining robust information on greenhouse gas flux in marine systems is recognised as being very challenging and dependent on extensive monitoring of gas exchange over time. The current model is therefore focused on modelled carbon dioxide fluxes as this is the only greenhouse gas for which data is available. However, there is also limited information on air-sea carbon dioxide fluxes within Irish estuaries. The model therefore uses average flux values from across a number of European estuaries as a proxy.

As the model is largely based on fluxes, it does not incorporate specific habitats and species that play a more direct role in carbon storage and sequestration, however, these features can be mapped as natural capital assets which provide carbon storage and sequestration functions.

In the long-term, it may be possible to better integrate benthic habitat models within air-sea flux to better reflect the carbon storage and sequestration functions that specific habitats perform. Based on further developments in climate modelling, it may be possible in the future to incorporate information on fluxes of other greenhouse gases within the model, particularly methane and nitrous oxide.

6.2.2 Mediation of wastes

Developing on the current mapping outputs, quantities of waste assimilated can be expressed to identify locations where waste assimilation capacity might be exceeded, indicating nitrate sensitive areas. Additionally, incorporating relevant habitats into the assessment once their role in mediation is better defined, such as saltmarsh habitats and sub-tidal biogenic reef which provide a significant service in water purification. Recent research has also suggested the used of seaweed as a method of water purification and seaweed has a high capacity to absorb minerals and some toxic compounds (Arumugam *et al.,* 2018). However, there is currently limited data to support its use.

Other methods of valuing this ecosystem service could therefore include a calculation of the area of such habitats.

6.2.3 Regulation of flows

There is little information on the scale of benefits provided by habitats other than saltmarsh, sand dune and shingle. Therefore, there is potential to incorporate other coastal habitats, such as reefs, seagrasses and kelp beds/forests, which can also provide a significant role in mediation of flows. There is currently limited information on the scale of the benefit of these habitats, so future work to better assess their role in mediation of flows is required. Additionally, the spatial extent of these habitats is limited within Irish water, better understanding of distribution would be required.

6.3 Consider approaches to developing methods for 'hard to define' regulating services

Lifecycle maintenance and pest and disease control regulating services were omitted from the mapping process for the current project due to the uncertainly in methods and the lack of suitable data. However, to fully assess regulating services within the Irish EEZ these services need to be considered and methods developed for mapping and valuation of the services.

6.3.1 Lifecycle maintenance, habitat and gene pool protection

Multiple methods have been suggested for mapping of lifecycle maintenance, habitat and gene pool protection. For example, in Norton *et al.* (2018) species and habitats protected under the Habitats Directive in SACs were used as a proxy indicator for ES of lifecycles and habitats. Although SPAs and other protected areas were discussed they were not included within the assessment to avoid double counting of protected areas. The total extent of marine SACs was then reported.

However, there continues to be some debate about whether there is an element of double counting with other services, for example, the link between nursery populations and provisioning services such as wild capture fisheries and shellfisheries. Additionally, there is limited scientific understanding of how to represent or quantify this service.

A clear definition of this service is needed together with agreement on how the service might be reliably quantified.

6.3.2 Pest and disease control

Pests and diseases are regulated in ecosystems through the actions of predators and parasites as well as by the defence mechanisms of their prey. However, methods for assessing, mapping and valuing this service are poorly defined.

6.4 Develop quantitative methods for cultural services

The current cultural ecosystem service maps show the spatial distribution of areas considered important for the provision of cultural services. However, there is limited quantitative assessment of these services.

Taking account of the value of different recreational activities is important for planning in the marine and coastal environment. SEMRU (2016) estimated that recreation and tourism in marine and coastal areas is the second largest contributor to Ireland's ocean economy and the largest contributor in terms of employment. Recreation and tourism services have been valued by Norton *et al*. (2018) and SEMRU (2016) as contributing an estimate €1.68 billion p.a. and €1.3 billion p.a. to the Irish economy respectively.

As such a key area for future research is the mapping of marine and coastal cultural services and linking them to estimates of service value flows either through quantification of use e.g. number of trips per year or through overall service valuation. Failte Ireland holds data on bed nights and currently publishes this on a county basis but it is likely to be possible to analyse this data at more local levels to understand coastal stays. It may also be possible to spatialise information on the aggregate value of recreational activities such as sailing/marinas, sea angling, surfing, diving, eco-tourism using key locations for such activities.

6.5 Understanding how provision of ES varies with anthropogenic pressure

Increasing the understanding of how the provision of ecosystem services is impacted by anthropogenic pressures will help to define where pressures are limiting benefits from ES. For example, Parker *et al.,* (2016) not only considered ES provision but assessed areas where disbenefits occur. In their assessment of marine food provision, they assessed the presence of anthropogenic structures in the marine environment which will impact of marine provision if they impose fisheries restrictions. Areas which are heavily fished may provide a disbenefit for climate regulation services as disturbed sediments may have a reduced carbon storage and sequestration potential. Additionally, marine food provisioning services may be reduced with an increase in fishing pressure, in areas where overexploitation occurs, resulting in a loss on ES benefit due to anthropogenic pressure

To fully assess ecosystem services across the Irish EEZ the full impact of an activity needs to be considered to assess the level of service provided. Future work could then seek to incorporate the outputs into mapping.

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8 Abbreviations/Acronyms

AERs	Annual Environmental Reports
AIS	Automatic Identification System
AONB	Areas of Outstanding Natural Beauty
API	Application Programming Interface
BEIS	Department for Business, Energy & Industrial Strategy
BIM	Bord Iascaigh Mhara
BOD	Biochemical Oxygen Demand
BQI	Benthic Quality Index
CES	Cultural Ecosystem Services
CICES	Common International Classification of Ecosystem Services
CORINE	Coordination of Information on the Environment
CRU	Commission for Regulation of Utilities
CSO	Central Statistics Office
DAFM	Department of Agriculture, Food and the Marine
DCCAE	Department of Communications, Climate Action and Environment
DCF	Data Collection Framework
Defra	Department for Environment, Food and Rural Affairs
DHPLG	Department of Housing, Planning and Local Government.
DSM	Digital Surface Model
DTM	Digital Terrain Model
DUKES	Digest of UK Energy Statistics
EC	European Commission
EEA	Experimental Ecosystem Accounting
EEZ	Exclusive Economic Zone
EMODnet	European Marine Observation and Data Network
EPA	Environmental Protection Agency
ERSEM	European Regional Seas Ecosystem Model
ES	Ecosystem Services
EU	European Union
EUSeaMap	Physical Seabed Habitats in the UK - Dataset (JNCC)
GB	Great Britain
GDPR	General Data Protection Regulation
GIS	Geographic Information System
GMIT	Galway-Mayo Institute of Technology
GPS	Global Positioning System
GVA	Gross Value Added
HABs	Harmful Algal Blooms
HES	Historic Environment Scotland
HLC	historic landscape characterisation
HOOW	Harnessing Our Ocean Wealth
ICES	International Council for the Exploration of the Sea
ICOMOS	International Council on Monuments and Sites
ICS	Institute of Chartered Shipbrokers
IMAGIN	Irish Sea Marine Aggregate Initiative
INFOMAR	Integrated Mapping for the Sustainable Development of Ireland's Marine Resource
ISA	Irish Sailing Association
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee

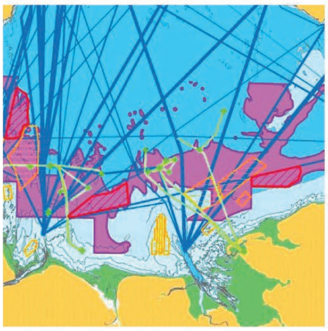
LUC	Land Use Consultants
MAES	Mapping European Seabed Habitats
MaREI	Centre for Marine and Renewable Energy (Ireland)
MEA	Millennium Ecosystem Assessment
MESH	Mapping European Seabed Habitats
MI	Marine Institute
MMO	Marine Management Organisation
MoEPRD	Ministry of Environmental Protection and Regional Development of the Republic of Latvia
MPA	Marine Protected Area
MSP	Marine Spatial Planning
MW	Mega Watt
NC	Natural Capital
NCC	Natural Capital Committee
NEA	National Ecosystem Assessment
NEMO	Nucleus for European Modelling of the Ocean
NERC	Natural Environment Research Council
NextMap	Elevation Data Suite (Intermap)
NHAs	National Heritage Areas
NIAH	National Inventory of Architectural Heritage
NMCI	National Maritime College of Ireland
NMPF	National Marine Planning Framework
NNS	Non-Native Species
NOAA	National Ocean and Atmospheric Association
NPWS	National Parks and Wildlife Service
NUI	National University of Ireland - Galway
O&M	Operation and Maintenance
ObSERVE	Survey of Seabirds and Cetaceans in Offshore Irish Waters
OGA	Oil and Gas Authority
ONS	Office of National Statistics
OPW	Office of Public Works (Ireland)
OREDP	Offshore Renewable Energy Development Plan
OS	Ordnance Survey
OS Mastermap	Ordnance Survey - Topography Viewer of GB Landscapes
OSI	Ordnance Survey Ireland
OSi	Open Systems Interconnection
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic (Oslo and Paris Commissions)
PAD	Petroleum Affairs Division
PMF	Priority Marine Feature
PML	Plymouth Marine Laboratory
pNHAs	proposed National Heritage Areas
POLCOMS	Proudman Oceanographic Laboratory Coastal Ocean Modelling System
PRA	Property Registration Authority (Ireland)
Ramsar	Wetlands of international importance, designated under The Convention on Wetlands (Ramsar, Iran, 1971)
RID	Riverine Inputs and Direct Discharges
RSPB	Royal Society for the Protection of Birds
RV	Research Vessel
SAAO	Special Amenity Area Orders
SAC	Special Areas of Conservation
SAMS	Scottish Association of Marine Science

SEAI	Sustainable Energy Authority of Ireland
SEMRU	Socio-Economic Marine Research Unit
SFPA	Sea Fisheries Protection Authority
SIMCelt	Supporting Implementation of Maritime Spatial Planning in the Celtic Sea
SMART	Support for Maritime Training
SMARTBay	Marine and Renewable Energy Test Site (Ireland)
SNH	Scottish Natural Heritage
SPA	Special Protection Area
SSE	Scottish and Southern Energy
SSSI	Site of Special Scientific Interest
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
STECF	Scientific, Technical and Economic Committee for Fisheries
TWh	Terawatt Hours
UK	United Kingdom
UN	United Nations
UNEP	UN Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
VALMER	Valuing Ecosystem Services in the Western Channel
VMS	Vessel Monitoring System
WCMC	World Conservation Monitoring Centre
WFD	Water Framework Directive
WHS	Word Heritage Site
WKCES	Workshop: Mapping Cultural Dimensions of Marine Ecosystem Services
WLA	Wild Land Areas
WWTP	Wastewater Treatment Plants

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

Appendices



Innovative Thinking - Sustainable Solutions

ABP mer

A CICES Framework

Table A1. CICES Ecosystem Service Framework and relation to ES mapping

CICES Ecosystem Service Framework	Specific Service
Provisioning	
1.1 Biomass	
1.1.2 Cultivated aquatic plants for nutrition, materials or energy 1.1.2.1 Plants cultivated by *in situ* aquaculture grown for nutritional purposes 1.1.2.2 Fibres and other materials from *in situ* aquaculture for direct use or processing (excluding genetic materials) 1.1.2.3 Plants cultivated by *in situ* aquaculture grown as an energy source	**Seaweed aquaculture**
1.1.4 Reared aquatic animals for nutrition, materials or energy 1.1.4.1 Animals reared by *in situ* aquaculture for nutritional purposes 1.1.4.2 Fibres and other materials from animals grown by *in situ* aquaculture for direct use or processing (excluding genetic materials) 1.1.4.3 Animals reared by *in situ* aquaculture as an energy source	**Fish and shellfish aquaculture**
1.1.5 Wild plants (terrestrial and aquatic) for nutrition, materials or energy 1.1.5.1 Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition 1.1.5.2 Fibres and other materials from wild plants for direct use or processing (excluding genetic materials) 1.1.5.3 Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy	**Wild seaweed harvesting**
1.1.6 Wild animals (terrestrial and aquatic) for nutrition, materials or energy 1.1.6.1 Wild animals (terrestrial and aquatic) used for nutritional purposes 1.1.6.2 Fibres and other materials from wild animals for direct use or processing (excluding genetic materials) 1.1.6.3 Wild animals (terrestrial and aquatic) used as a source of energy	**Wild capture fisheries and shellfisheries**
1.2 Genetic material from all biota (including seed, spore or gamete production)	
1.2.1 Genetic material from plants, algae or fungi 1.2.1.1 Seeds, spores and other plant materials collected for maintaining or establishing a population 1.2.1.2 Higher and lower plants (whole organisms) used to breed new strains or varieties 1.2.1.3 Individual genes extracted from higher and lower plants for the design and construction of new biological entities	**No data**
1.2.2 Genetic material from animals 1.2.2.1 Animal material collected for the purposes of maintaining or establishing a population 1.2.2.2 Wild animals (whole organisms) used to breed new strains or varieties 1.2.2.3 Individual genes extracted from organisms for the design and construction of new biological entities	**No data**
1.3 Water	
1.3.1 Surface water used for nutrition, materials or energy 1.3.1.1 Surface water for drinking	**Water for non-drinking purposes**

CICES Ecosystem Service Framework	Specific Service
1.3.1.2 Surface water used as a material (non-drinking purposes) 1.3.1.3 Freshwater surface water used as an energy source 1.3.1.4 Coastal and marine water used as energy source	Waterborne transport
1.3.2 Ground water for used for nutrition, materials or energy 1.3.2.1 Ground (and subsurface) water for drinking 1.3.2.2 Ground water (and subsurface) used as a material (non-drinking purposes) 1.3.2.3 Ground water (and subsurface) used as an energy source	
1.4 Non-aqueous natural abiotic ecosystem outputs	
1.4.1 Mineral substances used for nutritional purposes 1.4.1.1 Mineral substances used for nutritional purposes 1.4.1.2 Mineral substances used for material purposes 1.4.1.3 Mineral substances used for as an energy source	Marine aggregates Oil and gas
1.4.2 Non-mineral substances or ecosystem properties used for nutrition, materials or energy 1.4.2.1 Non-mineral substances or ecosystem properties used for nutritional purposes 1.4.2.2 Non-mineral substances used for materials 1.4.2.3 Wind energy 1.4.2.4 Solar energy 1.4.2.5 Geothermal 1.4.2.6 Other	 Offshore wind. Wave and tidal energy
Regulation & Maintenance	
2.1 Transformation of biochemical or physical inputs to ecosystems	
2.1.1 Mediation of wastes or toxic substances of anthropogenic origin by living processes 2.1.1.1 Bio-remediation by micro-organisms, algae, plants, and animals 2.1.1.2 Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	**Mediation of wastes** BOD, nutrients – could also add bacteria
2.1.2 Mediation of waste, toxics and other nuisances by non-living processes 2.1.2.1 Dilution by freshwater and marine ecosystems 2.1.2.2 Dilution by atmosphere 2.1.2.3 Mediation by other chemical or physical means (e.g. via Filtration, sequestration, storage or accumulation)	**Mediation of wastes** Power station cooling water
2.1.3 Mediation of nuisances of anthropogenic origin 2.1.3.1 Smell reduction 2.1.3.3 Visual screening 2.1.3.1 Mediation of nuisances by abiotic structures or processes	

CICES Ecosystem Service Framework	Specific Service
2.2 Regulation of physical, chemical, biological conditions	
2.2.1 Regulation of baseline flows and extreme events 2.2.1.1 Control of erosion rates 2.2.1.2 Buffering and attenuation of mass movement 2.2.1.3 Hydrological cycle and water flow regulation (Including flood control, and coastal protection) 2.2.1.4 Mass flows 2.2.1.5 Liquid flows 2.2.1.6 Gaseous flows	**Regulation of flows** Coastal erosion and flood protection Non-erodible shorelines, rocks/cliffs?
2.2.2 Lifecycle maintenance, habitat and gene pool protection 2.2.2.1 Pollination (or 'gamete' dispersal in a marine context) 2.2.2.2 Seed dispersal 2.2.2.3 Maintaining nursery populations and habitats (Including gene pool protection)	**Lifecycle maintenance** No current robust marine method, however some have used biodiversity as a proxy
2.2.3 Pest and disease control 2.2.3.1 Pest control (including invasive species) 2.2.3.2 Disease control	**Pest and disease control** No method for mapping
2.2.4 Regulation of soil quality 2.2.4.2 Decomposition and fixing processes and their effect on soil quality	
2.2.5 Water conditions 2.2.5.2 Regulation of the chemical condition of salt waters by living processes	
2.2.6 Atmospheric composition and conditions 2.2.6.1 Regulation of chemical composition of atmosphere and oceans	**Climate regulation and carbon sequestration** Carbon fluxes plus carbon storage
2.2.7 Maintenance of physical, chemical, abiotic conditions 2.2.7.1 Maintenance and regulation by inorganic natural chemical and physical processes	
Cultural	
3.1 Direct, *in situ* and outdoor interactions with living systems and natural physical systems that depend on presence in the environmental setting	
3.1.1 Physical and experiential interactions with natural environment 3.1.1.1 Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions 3.1.1.2 Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	**Recreation and tourism** Ecotourism

CICES Ecosystem Service Framework	Specific Service
3.3.2 Physical and experiential interactions with natural abiotic components of the environment 3.3.2.1 Natural, abiotic characteristics of nature that enable active or passive physical and experiential interactions	**Recreation and tourism** Beaches, seawater for recreational activities plus cultural heritage (part e.g. paleolandscapes), coastal footpaths and other landside infrastructure
3.1.3 Intellectual and representative interactions with natural environment 3.1.3.1 Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge 3.1.3.2 Characteristics of living systems that enable education and training 3.1.3.3 Characteristics of living systems that are resonant in terms of culture or heritage 3.1.3.4 Characteristics of living systems that enable aesthetic experiences 3.1.3.5 Natural, abiotic characteristics of nature that enable intellectual interactions	**Scientific and educational** Part of **cultural heritage** **Aesthetic services** –potentially double counting due to overlap with tourism and recreation Part of **cultural heritage**
3.2 Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	
3.2.1 Spiritual, symbolic and other interactions with natural environment 3.2.1.1 Elements of living systems that have symbolic meaning 3.2.1.2 Elements of living systems that have sacred or religious meaning 3.2.1.3 Elements of living systems used for entertainment or representation **3.2.2 Spiritual, symbolic and other interactions with the abiotic components of the natural environment** 3.2.1.1 Natural, abiotic characteristics of nature that enable spiritual, symbolic and other interactions	**Spiritual and emblematic**
3.2.3 Other characteristics that have a non-use value 3.2.3.1 Characteristics or features of living systems that have an existence value 3.2.3.2 Characteristics or features of living systems that have an option or bequest value 3.2.3.1 Natural, abiotic characteristics or features of nature that have either an existence, option or bequest value	**Existence and bequest** Some overlap with spiritual and emblematic

B Provisioning Ecosystem Service Mapping

This appendix discusses previous methods and options which have been utilised for mapping ecosystem services, it details the method used in this project following review of mapping methods and discusses data availability.

Each section also discusses gaps and limitations in the current data and suggests future developments.

B.1 Provisioning services

B.1.1 Wild capture fisheries and shellfisheries

This ecosystem service refers to the production of biomass from wild capture fisheries for human consumption. Food provisioning from fisheries and shellfisheries is one of the ecosystem services that has been more widely assessed. The main method to calculate the value of the ecosystem service provided by fish provision has generally been to use commercial landings data and available market price data.

The economic benefit from food provisioning can be estimated from landing or market statistics that are published annually for fisheries. The value of food can be spatially allocated based on where it was sourced from. For fisheries this assessment can be made using spatial effort data based on Vessel Monitoring System (VMS) data for vessels over 12 m long and reported ICES rectangle positions for non-VMS vessels under 12 m long, and catch value by rectangle. It can be more challenging to obtain spatial and landings data from non-Irish vessels fishing in Irish waters, because they report to their flag state and not necessarily to the Irish authorities. Capture of marine species is also undertaken for personal consumption, but there is usually a strong recreational element to this activity and the value is best considered under the recreation category (Saunders *et al.*, 2010).

Provisioning services are often produced and consumed or used in different places. This is particularly relevant for wild capture fisheries and shellfisheries. They are generally transported from the place of production (i.e. supply) to the place of consumption (i.e. demand). It is possible to map the supply, as described above, and this is generally more relevant in relation to marine spatial planning (knowing which areas are important for food production). Demand is a function of socio-economic drivers and is more difficult to map (Burkhard & Maes, 2017), and may derive from both national, as well as international (export) markets.

The location of where the fish and shellfish are landed can be mapped from statistics of landings to ports. It may be possible to trace some of the derivation of benefits from the food provision through the location of fish and shellfish processing businesses, but generally there is little information available to trace the onward flow of fish and shellfish once it has been landed (and it may end up being exported from Ireland for consumption in other countries). The Marine Institute is developing a spatial marine industries database, which will include some value chain businesses, and in the future this could be used to map the location of processing businesses.

The production of food provisioning ecosystem services from wild capture fisheries and shellfisheries is location-specific but is also dynamic over time. This includes seasonal patterns in the relative importance of different locations (for different fisheries at different times of year) as well as annual or decadal shifts in the relative importance of different fishing grounds, which may be exacerbated by climate-induced shifts in fish distribution.

Seasonal patterns are relevant when considering project-level and local developments, but for the purposes of marine spatial planning and a national marine spatial plan, it is more relevant to know the areas that are important at some point in the year, so that they can be given due consideration in policy decisions. Specific seasonal constraints and considerations can be taken into account separately in project-level decisions.

Annual variability is important to recognise. This can be done by taking into account several years of data in the generation of an ES map, rather than a single year. Five years' data is generally used, for example for the assessment of socio-economic impacts of developments or marine protected areas (Marine Scotland, 2019a; 2019b), although other timeframes could be considered.

Decadal shifts mean it is relevant to map food provisioning ES periodically (e.g. on an annual basis, and/or with an update every five years) to capture these long-term changes in the importance of different areas for food provisioning.

Options for mapping

Norton *et al.* (2018) split this service into offshore capture fisheries and inshore capture fisheries. Offshore capture fisheries were valued using data from the Scientific, Technical and Economic Committee for Fisheries (STECF), collected through the Data Collection Framework (DCF) under the Common Fisheries Policy. This covers landings from EU member states at the spatial resolution of ICES rectangles. Data from 2014, and from vessels over 15 m length, were used. Non-EU fisheries were considered using data from the ICES Official Nominal Catches 2006-2013 dataset, but not mapped spatially. Values were mapped by ICES rectangle overall (Figure B1) and for individual species. The advantage of using data at ICES rectangle scale is that it covers all European vessels, the disadvantage is that it is a very coarse spatial scale – it shows the general distribution of areas that are more or less important, but is too coarse to be of use to marine spatial planning.

Inshore capture fisheries, of boats less than 15 m length, were based on the Shellfish Stocks and Fisheries Review 2014 (MI & BIM, 2015), using 2013 data. The shellfish and crustacean stocks within the 12-nautical mile limit are nearly all targeted by vessels less than 15 m. However, the analysis under-represents the total value of the inshore fishery as it does not include any finfish capture. The inshore fishery was only discussed in relation to its value and was not mapped spatially.

Parker *et al.* (2016) mapped 'marine food (provision)' through the provision of algae, fish and shellfish (Figure B2). The service is defined as including provision from both wild harvest and from aquaculture, but the data sources used only related to wild capture fisheries and did not include aquaculture. Some habitats[6] and protected areas were also included. The fisheries data used were those layers available for 'offshore' (over-15 m vessels with vessel monitoring systems (VMS)) and 'inshore' (non-VMS vessels) fisheries, by gear type, and periwinkle harvesting access points. The offshore layers relate to the time period 2007–2011, and the inshore layers relate to 2010-2013.

6 The map highlights the inclusion of 'terrestrial habitats … where they are of direct relevance, such as saltmarshes, which form nursery areas and support marine fisheries', however the data sources and scoring provided in Appendix L indicate that only estuaries and coastal lagoons were included.

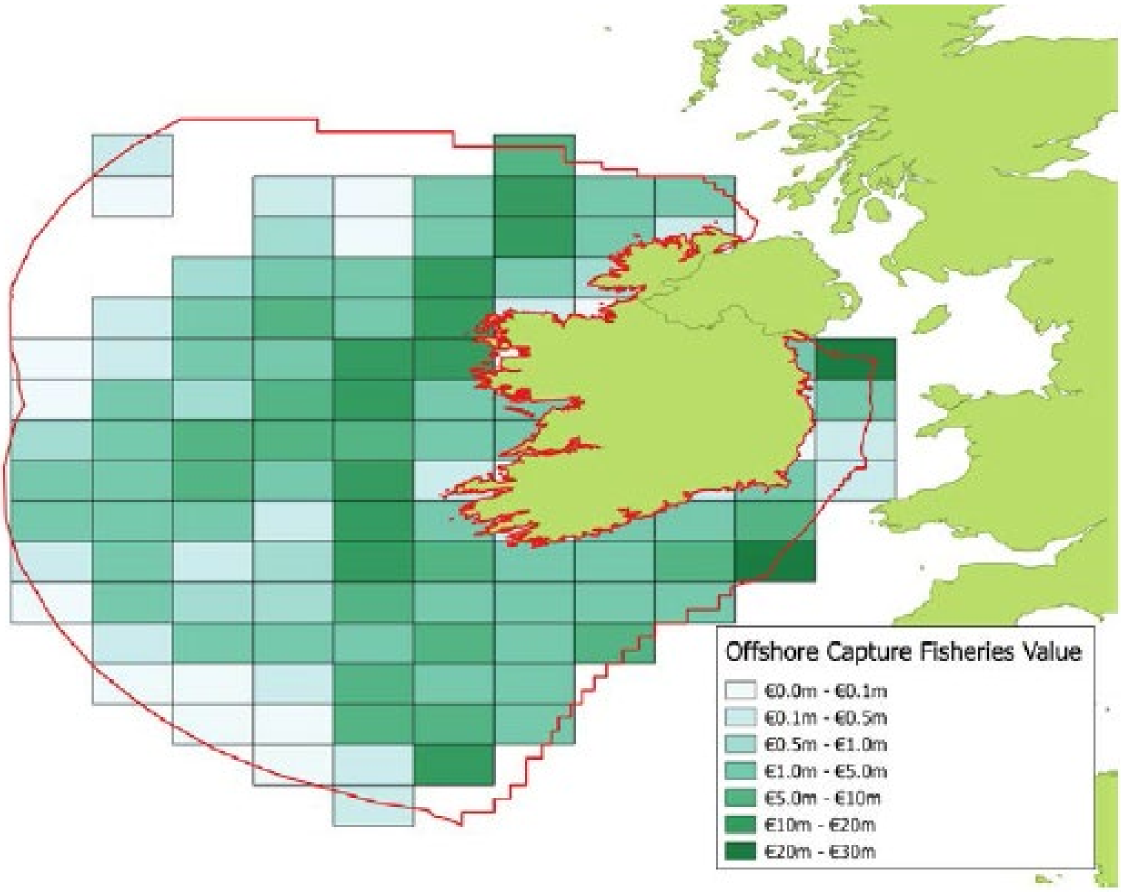


Figure B1. Offshore capture fisheries value ecosystem service (in millions of Euros) mapped in Norton et al., 2018.

Aspects that negatively affect the ability of the environment to provide ecosystem services, leading to a loss of ES benefit, were also included, such as ferry ports (where fishing activity is unlikely to take place) and dumping at sea boundaries. These layers were combined through a scoring system (e.g. low, medium, high) for various attributes, based on expert judgement of their contribution to the provision of the ecosystem service.

Marine habitats were not included, due to the lack of understanding of the linkages between habitat types and individual species fished. The benefit of this approach is that it allows a range of layers showing different features and variables (protected areas, habitats, different gear types and parameters) to be combined into a single layer. The disadvantage is that the scoring is subjective and may under- or over-represent the importance of some features, and the interpretation of the map is more complicated as users/viewers may want to understand why a particular area is of high or low importance, but this becomes hidden in the scoring system and the individual layers.

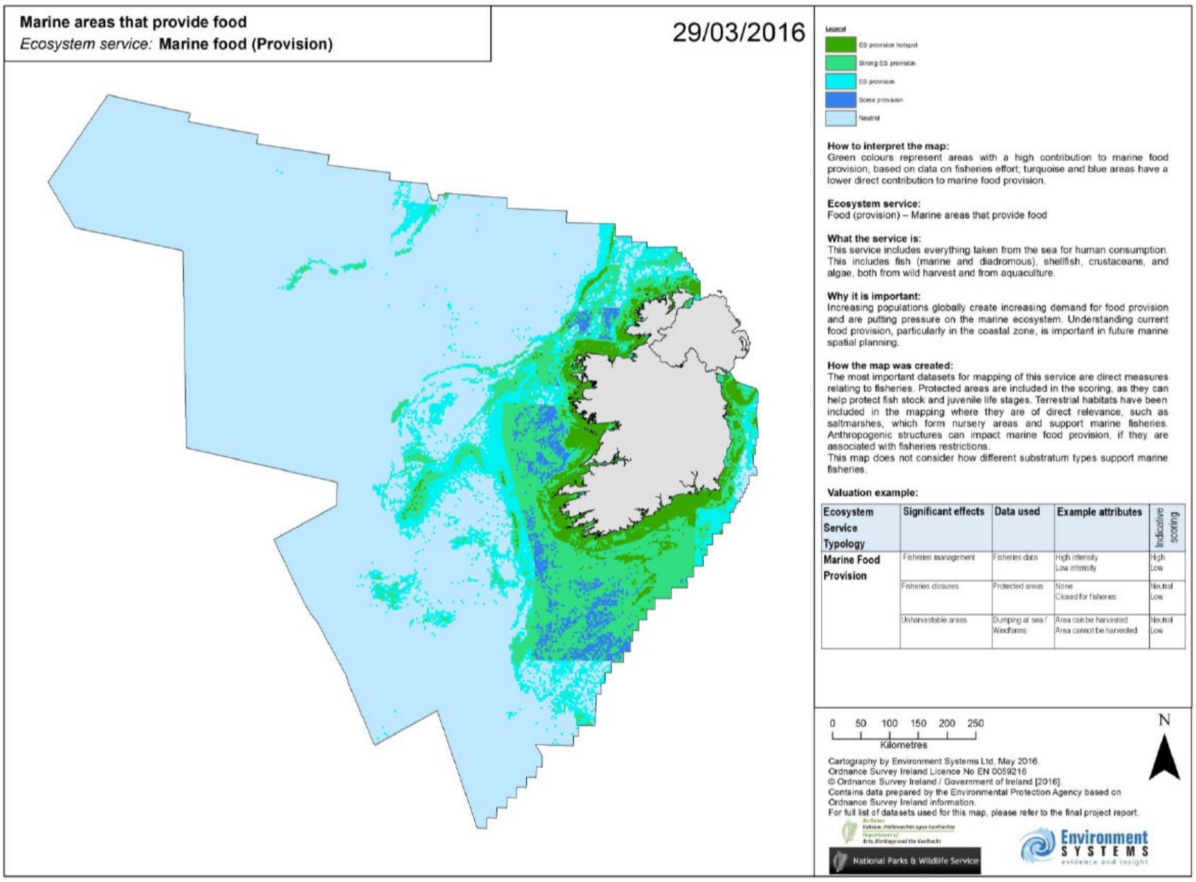


Figure B2. Marine areas that provide food, as mapped by Parker et al., 2016

Hasler *et al* (2016) suggest two options for assessing the 'wild fish for food' ecosystem service: (i) use of fish stock assessment information to reflect the potential capacity (supply) of the ecosystem service; and (ii) use of information on the amount of harvested fish, ('demand-driven approach') to assess the actual flow of the ecosystem service. In relation to the former, they note the lack of comprehensive information on the status of all harvested fish stocks. It is also relevant that ecosystem services are framed around their benefits to humans, therefore the benefit is only realised when the fish are harvested and consumed. Stock status could therefore be used as an indication of the potential sustainability of the ecosystem service – if a stock is not being harvested sustainably then the benefits for supply from wild capture fisheries and shellfisheries will be temporary.

Hasler *et al*. also highlight the connection of contaminants in seafood to the potential for food provisioning (i.e. if fish/shellfish are contaminated with hazardous substances, they lose the potential to contribute to food supply). Contaminants in seafood could therefore be used as an additional indicator of the quality of the ecosystem service provision.

Temporal aspects of food provision from wild fisheries and shellfisheries are generally difficult to integrate on a map but several maps can be used to show the change of the supply or demand of the provisioning service over time (e.g. seasonal maps, or maps of sequential time periods) (Burkhard & Maes, 2017).

Method

Based on the discussion above, the method adopted was to map the ecosystem service based on the location of harvesting (i.e. fishing activity) rather than stock status. In addition, the location of where benefits are realised was added based on the volume of landings to ports in Ireland.

The Marine Institute has recently produced a new set of fisheries layers showing activity of larger vessels that have vessel monitoring systems (VMS) installed (Gerritsen and Kelly, 2019). These represent the activity of over-12 m vessels. A number of different layers are available, showing fishing effort by gear type, for Irish vessels, and international effort (all vessel nationalities).

Fishing effort layers present a good representation of the most important areas in relation to fisheries, although fishing effort itself does not necessarily correlate to the most productive areas in terms of volume of fish and shellfish harvested (contributing to food supply) or value harvested (contributing to supply chains and business turnover). Additionally, the location where processing takes place, and the final market, is important in terms of indirect GVA and induced GVA.

Areas of importance to inshore fisheries were added from the inshore fishing layers on the Marine Institute's Atlas. These areas were mapped in support of the Natura 2000 risk assessment in 2013. Therefore, they do not necessarily represent the current distribution of effort of the inshore fleet, and there is no consistent measure of intensity for these layers. The polygons were combined to reflect the area of interest to the inshore fleet. In addition, periwinkle harvesting locations were added.

Landings data by port was presented using pie charts scaled to the volume of landings at each port, split into demersal/pelagic/shellfish/deep-sea species groups. These data were obtained from the Sea Fisheries Protection Authority of the Department for Agriculture, Fisheries and the Marine.

Consideration was given to the addition of supporting habitats (e.g. saltmarsh, estuaries, seagrass beds) and spawning and nursery grounds for various species to the map . However, the large number of separate layers would make the resulting product difficult to interpret and therefore these were not included.

Data availability

Updated VMS fishing layers have been prepared by MI for 2014-2018. Inshore fishing layers and periwinkle harvesting locations were obtained from the Marine Institute's Atlas. Landings by port are available from SFPA which show the landings by Irish vessels. Fisheries data on volume of landings by species by ICES rectangle was sourced from STECF which provides data on fish catches from Irish waters by all EU vessels (i.e. excludes non-EU states such as Norway and Faroes). Value was derived by applying an average value per tonne, for each species, derived from Eurostat.

Gaps and limitations

Supporting habitats for fish provision – food webs, spawning and nursery grounds, contribution of MPAs to fisheries productivity – were not included in the ecosystem service map, but maps of these natural capital assets were provided in the layers for food provisioning where available.
Production and the importance of different areas will vary from year to year and over time with climate change-related shifts in species distribution.

Future developments

The map can be updated periodically to incorporate changes to the distribution of fishing effort.

B.1.2 Algae/ Seaweed harvesting

CICES recognises the provision of nutrition, materials and energy ecosystem services from algae. This section refers to algae and seaweed harvesting for all uses as data is limiting and it is difficult to differentiate individual uses of the seaweed harvested. Such uses include food source provision, pharmaceutical or biochemical and alginate production.

In Ireland, seaweeds are predominantly harvested on the west coast, in the counties of Donegal, Sligo, Mayo, Galway, Clare and Cork. Most of this seaweed is harvested intertidally under existing land rights for which no licence is required. It is estimated that there are around 6,500 such private rights. The Property Registration Authority (PRA) holds information on private rights, but this information is not readily available, and it is understood to be incomplete. There is currently one foreshore licence for seaweed harvesting. This relates to kelp harvesting from a number of areas within Bantry Bay.

Options for mapping

There is currently a lack of data to enable mapping of seaweed harvesting activity apart from the foreshore licence relating to Bantry Bay. There is no published information on the amount of kelp harvested under this licence.

It would be possible to map rocky intertidal areas around the west coast of Ireland as locations of potential harvesting activity under private rights, but this would provide only a very crude spatialisation of the activity. Norton *et al*. (2018) and sources therein estimated that around 30,000 tonnes of seaweed is harvested annually under private rights with an estimated value of around €4 million.

Method

In the absence of data on the location of private rights for seaweed harvesting, it is not possible to create an accurate map for this ecosystem service. However, a map of currently licenced harvesting areas can be produced to indicate areas of interest.

Data availability

Data is available on the location of the foreshore licence for kelp harvesting in Bantry Bay. There is no published information on the volumes extracted.

There is a lack of available data on private rights for harvesting seaweed from the foreshore. Norton *et al*. (2018) summarise available data on the estimated volumes of seaweed harvested under private rights and their value.

Gaps and limitations

The key gaps are:

- There is a lack of available information on the locations of harvesting carried out under private rights in intertidal areas. There is uncertainty concerning the volumes of seaweed harvested under these rights. There is a lack of information on tonnages/value harvested from Bantry Bay.
- There is a lack of information on where the benefits from seaweed harvesting are experienced on land.
- There is a lack of information on the different uses made of harvested seaweed.

Future developments

Information on existing harvesting rights in the intertidal from PRA could be used to identify key areas for intertidal harvesting and to seek to spatialise volumes/values using assumptions.

Information on volumes of kelp harvested from Bantry Bay from the operator would enable quantification of this ES.

B.1.3 Aquaculture – finfish and shellfish

This ecosystem service refers to the production of biomass from aquaculture for fish and shellfish. Most of the aquaculture outputs in Ireland relate to salmon, oyster and mussel farming and are based on the west coast of Ireland.

Harvesting farmed products produced through aquaculture is an important component of food provisioning ecosystem services from the marine environment.

For valuation of the food provisioning service from aquaculture, annual market turnover can be spatially allocated based on the location of farms, and where such information are available, their biomass output and the species farmed (Saunders *et al*., 2010).

Options for mapping

Burkhard & Maes (2017) indicate that infrastructure from aquaculture, such as cages, basins, ropes, is visible in the field and can be used to identify the extent of the provisioning area. However, a preferable approach where spatial data are available, is to use the licensed production areas for aquaculture, by species type.

Norton *et al*. (2018) showed the value of aquaculture production by county, broken down into species (oysters, mussels, salmon and other). This was based on 2015 data from the BIM Annual Aquaculture Survey 2016 which includes both production and market price data.

Parker *et al.* (2016) mapped 'marine food (provision)' through the provision of algae, fish and shellfish. The service is defined as including provision from both wild harvest and from aquaculture, but the data sources used only related to wild capture fisheries and did not include aquaculture.

Method

Map the location of licensed aquaculture sites for finfish and shellfish (these can be identified separately in the legend), based on information in the DAFM database.

In addition, the overall value of production for each county can be shown using pie charts, scaled to the value, broken down by species type. This preserves the anonymity and any sensitive information relating to individual producers, whilst showing which areas (at county level) are more important in relation to production value.

Data availability

Licensed aquaculture production areas are available from the DAFM database which MI holds. Data on production quantities by volume and value, for finfish (freshwater trout and salmon) and shellfish (bottom cultured mussel, rope-grown mussel, Gigas oyster, native oyster), smolt/parr/ova and 'other spps' are available from BIM's annual aquaculture survey (latest year shows 2017 data – BIM, 2018).

Gaps and limitations

Due to confidentiality, volume and value of production at an individual site level cannot be published.

Future developments

The map can be updated periodically (ideally annually) to reflect any new licensed sites, and updates to production values. The data on value of production by species type could be presented at a finer spatial resolution, such as for specific bays, depending on data confidentiality.

B.1.4 Aquaculture – Seaweed

This ecosystem service refers to the production of biomass from seaweed aquaculture.

Options for mapping

Burkhard & Maes (2017) indicate that infrastructure from aquaculture, such as cages, basins, ropes, is visible in the field and can be used to identify the extent of the provisioning area. However, a preferable approach where spatial data are available, is to use the licensed production areas for aquaculture, by species type.

Parker *et al.* (2016) mapped 'marine food (provision)' through the provision of algae, fish and shellfish. The service is defined as including provision from both wild harvest and from aquaculture, but the data sources used only related to wild capture fisheries, and did not include aquaculture.

Method

Licensed aquaculture production areas for seaweed were mapped.

Data availability

Licensed aquaculture production areas are available from the DAFM database which MI holds.

Gaps and limitations

Data on the volume and value of seaweed production is not available in BIM's annual aquaculture survey (BIM, 2018).

Future developments

The map can be updated periodically (ideally annually) to reflect any new licensed sites. It may be possible to incorporate information on production values or volumes at an aggregated level if these data are not confidential or commercially sensitive.

B.1.5 Mineral substances

This service refers to a variety of raw materials which can be collected in the marine environment for uses such as energy/pharmaceuticals and construction materials. It includes extraction of oil and gas and marine aggregates.

Currently there is some gas production from within Irish waters but no oil production. There is no licensed marine aggregate extraction. Some material form navigation dredging is used for fill and construction purposes, but this isn't the primary purpose of the activity so has not been considered here.

Options for mapping

The locations of gas production are known from the location of commercial gas fields and gas infrastructure. Information is also available on gas production and wholesale gas prices.

Method

The only significant production facility currently is the Corrib field. The location of this field was mapped together with information on estimated gas production. The gas is brought ashore and processed at a plant near Bellanaboy Bridge (which was also mapped) before being distributed via the national grid network. Although currently operational, the Kinsale Head gas field is due to be decommissioned in 2020 and has been excluded from the mapping process.

Monetary estimates of oil and gas production in Scotland were based on the 'residual value' resource rent methodology published by ONS in June 2013. Production statistics were combined with oil and gas price data supplied by the Oil and Gas Authority (OGA) to calculate income. Deductions were then made for operating expenditure, sourced from Scottish Government and user costs of produced assets, apportioned from ONS UK capital stocks data (ONS, 2018).

Data availability

Data on the location of the Corrib gas field is available from Petroleum Affairs Division.

In 2016/17, this field was estimated to produce around 56% of Ireland's total gas demand of around 53 TWh/yr. (Gas Networks Ireland, 2017). This equates to a supply of around 30 TWh/yr., equivalent to around 2,925 million m^3 of gas. Based on a wholesale gas price for 2016 of around €0.45/ therm (CRU, 2018), this equates to a wholesale value for 2016/17 of around €465m.

Gaps and limitations

Precise production figures for the Corrib field are not publicly available. Production will vary from year to year.

Future development

The map can be updated to take account of declines in production over time at the Corrib field and to incorporate any additional fields that come into production.

B.1.6 Non-mineral substances

A wide range of renewable energy technologies can be used to make use of energy resources in the sea for which Irish waters have significant potential. These include wind, wave, tidal, thermal and geothermal energy. Currently only demonstration projects exist in Irish waters for wind and wave energy and there are no known tidal, thermal or geothermal projects in Irish waters.

Options for mapping

Spatialisation of renewable energy ecosystem services can be undertaken using information on the location of renewable energy developments and their average energy production. The location of construction and O&M facilities can also be mapped.

Method

The only significant offshore renewable energy development currently supplying electricity is the Arklow Bank offshore wind farm. Devices operating at the Galway Test site do not export electricity to the grid. The location of the Arklow Bank offshore wind farm was mapped together with information on electricity generation. The location of existing Arklow Bank O&M facilities was also mapped.

Data availability

Data on the location of Arklow Bank offshore wind farm is available from DHPLG. Data on the location of existing Arklow Bank O&M facilities was obtained from SSE.

Information on potential annual electricity generation was estimated based on installed capacity. The current installed capacity of Arklow Bank offshore wind farm is 25.2 MW. Assuming a load factor of 40%, this would equate to annual electricity generation of around 85 GWh. Information on wholesale electricity prices from the Commission for Regulation of Utilities (CRU, 2018) was used.

Gaps and limitations

Information on actual electricity generation from Arklow Bank offshore wind farm is not publicly available.

Future developments

The map can be updated to take account of other renewable energy development projects once they become operational.

B.1.7 Genetic resources

This service relates to genetic material from plants, algae, fungi or animals collected for the purpose of maintaining or establishing a population, or gene extraction for design or construction of new biological entities. The scale of benefit currently derived from this service in Ireland's marine environment is understood to be very small.

Options for mapping

There is currently no data available for mapping or quantifying this service.

Method

Due to a lack of data, this service was not mapped.

Data availability

Data on use of genetic resources not available

Gaps and limitations

No data to inform assessment.

Future developments

Dependent on availability of data.

B.1.8 Water for non-drinking purposes

Seawater is used for once-through cooling in some coastal power stations. It also plays a vital role in waterborne transport (transport of good and people). This is a particularly valuable service which provides significant environmental social and economic benefits compared to other forms of transport.

Options for mapping

Norton *et al*. (2018) calculated volume of water used for cooling electricity generating systems. Six power plants were identified as using cooling water in estuaries in Ireland. Data for each were based on Annual Environmental Reports (AERs) from the EPA, inspector reports by the EPA. Mapping the location of these six power plants and the volumes abstracted is an initial step to assessing the use of water for non-drinking purposes. Turnpenny *et al.* (2010) indicate that there is a 2% increase in power plant energy efficiency for once through cooling water systems compared to cooling towers. This can be used to estimate the net benefit in additional electricity generated from power stations with once through cooling water systems based on the estimates of electricity generated by each power station.

Few if any studies have captured the benefits of waterborne transport within ecosystem services assessments. Information on shipping density (for example, number of vessels per grid cell or number of vessel hours per grid cell) can be used to spatially map the importance of sea space for waterborne transport. Port statistics identify the flows of good and people through ports. No studies have yet sought to combine vessel movements and the flows of goods and people, although a current research project for the Marine Management Organisation (MMO) is exploring the feasibility of doing this.

Method

For power station cooling water abstractions, the method of Norton *et al.* (2018) was followed. Locations of the cooling water abstractions was obtained from the DHPLG Foreshore Licensing Database and volumes were based on those obtained by Norton *et al.* (2018) from the EPA. The value of the benefit was estimated assuming a 2% efficiency for energy generation based on Turnpenny *et al.* (2010).
For waterborne transport, initial maps of shipping density and port throughput statistics can be used to illustrate important locations for this service. A current project by the MMO is exploring the feasibility of assigning monetary values to the flows of goods and people. The method has assessed the average value of cargos and has assigned these to individual vessel AIS data to show the value of flows of goods. The volume of different cargos handled by Irish ports is shown in Table B1 below. The average value for each cargo type for freight handled by Irish ports in 2018 is also shown. Ports are a key location on land where the benefits of shipping are realised. The scale of benefits at individual ports can be represented by information from port throughput statistics.

The MMO project also aims to develop a method to value the number of cruise ship calls, by assigning a value to the number of passengers on a cruise vessel (MMO, 2019). In 2018, 300 cruise ships, transporting 398,505 passengers, arrived at Irish ports (Central Statistics Office, 2019). These data were used to calculate the value of cruise ships providing further assessment of the value of waterborne transport.

Table B1. Tonnage of goods handled classified by category of traffic for 2018 and average value of goods

Category of Traffic	Total Goods Handled (000's T)[1]	Average Value (£ per T)[2]
Liquid bulk		
Liquefied gas	120	
Crude oil	3,576	
Oil products	7,668	
Other liquid bulk goods	807	
Total	12,170	270.96
Dry bulk		
Ores	4,368	
Coal	1,273	
Agricultural products	5,836	
Other dry bulk goods	6,276	
Total	17,754	143.62
Lift-on/lift-off traffic		
20 ft containers	1,104	
40 ft containers	5,780	
Other containers	745	
Total	7,629	5,585.38
Roll-on/roll-off traffic		
Road goods vehicles	6,197	
Trade vehicles	174	
Unaccompanied trailers	9,666	
Total	16,037	2,566.73
Break bulk and other goods		
Forestry products	419	
Iron and steel products	617	
Other general cargo	459	
Total	1,495	381.54
Total	**55,086**	

1: Tonnages from Central Statistics Office, 2019; 2: Average values from MMO, 2019

Data availability

Data is available on the location of coastal power stations that abstract seawater and abstraction volumes from DHPLG and EPA respectively.

Data is available on shipping density (EMODnet, Irish Coastguard) and on port statistics (CSO). Tonnage of goods handled classified by category of traffic for 2018 and average value of goods (MMO, 2019).Gaps and limitations

The abstraction volumes are estimates based on EPA data cited in Norton *et al.* (2018) The value of once-through cooling water is based on an estimate provided in Turnpenny *et al.* (2010).

The distribution of shipping is based on the number of vessels/ numbers of vessel hours per grid cell rather than on trade flows.

Future developments

It may be possible to improve the representation of the waterborne transport ecosystem service in the future through the integration of trade flows with shipping density, by utilising AIS data.

C Regulating Ecosystem Service Mapping

C.1 Regulating services mapping methods

C.1.1 Climate regulation

Climate regulation includes a number of elements relating to greenhouse gases such as cycling, storage and/or sequestration. Much of the focus in previous assessments has been on quantification of carbon sequestration and monetisation based on carbon pricing. However, the service also relates to other greenhouse gases such as methane and nitrous oxide.

For the purposes of this assessment, carbon cycling and short-term storage are considered to be ecosystem processes which contribute to providing a final benefit in terms of carbon sequestration. The method developed below therefore focuses on carbon sequestration. While there is no formal definition of carbon sequestration, for the purposes of this assessment it has been considered to be long-term storage (on at least decadal scales).

Options for mapping

Spatialisation of climate regulation services has been undertaken in a variety of studies including; Burrows *et al.* (2017), eftec & ABPmer (2013, 2017a; b) and Parker *et al*. (2016). These approaches have largely been based on mapping the distribution of habitats indicated to provide climate regulation services, such as saltmarsh, sand dunes, mudflats and offshore sediments. Data from sources such as MESH Atlantic Habitat Maps, EUSeaMap and collated seabed substrates can provide valuable data for habitat mapping. These approaches do not take account of the importance of ocean circulation patterns in removing fixed carbon from active exchange between the water column and atmosphere. For example, Wakelin *et al.* (2012) demonstrate the importance of net transport off the North West European Shelf as a means of trapping fixed carbon in deeper oceanic waters, and Legge *et al*. (2020) found off-shelf transport and burial in the sediments account for 60–100 % of carbon outputs from the north-west European continental shelf seas. Studies on air-sea fluxes of carbon in estuaries also demonstrate estuaries to be net sources of atmospheric CO_2, largely as a result of their role in processing allochthonous carbon (Borges *et al.*, 2006).

Most work hitherto has focused on carbon, particularly carbon dioxide, with limited work done on other greenhouse gases such as methane and nitrous oxide. Methane has a global warming potential 28-36 times greater than carbon dioxide and nitrous oxide has a global warming potential 265-298 times greater than carbon dioxide over 100 years. In order to fully understand the role of marine ecosystems in climate regulation it would be necessary to understand fluxes of methane and nitrous oxide as well as carbon dioxide. For example, these gases are included in verification assessments for the contribution of coastal wetland creation projects to climate regulation (Verified Carbon Standard, 2014). However, such information is generally not available at a broad scale and therefore only a partial assessment of the climate regulation service is possible.

Norton *et al*. (2018), in seeking to quantify marine ecosystem services in Irish waters, estimated carbon sequestration services provided by saltmarsh habitat and sand dunes from CORINE data (Lydon and Smith, 2014). Additionally, overall carbon sequestration contribution from estuaries, coastal and offshore waters was calculated based on carbon flux estimates. The area of estuaries is based on that reported for transitional waters minus coastal lagoons for the WFD. In offshore waters carbon flux was generated for two grid cells of the National Ocean and Atmospheric Association (NOAA) model of oceanic carbon flux (NOAA, 2016). The quantities of sequestered carbon were monetised based on the Irish carbon tax.

Burrows *et al*. (2017) sought to spatialise carbon storage and sequestration processes within Scottish Nature Conservation MPAs. This included consideration of a range of biological (kelp forest, intertidal macroalgae, subcanopy algae, maerl beds, seagrass beds, saltmarshes, horse mussel (*Modiolus modiolus*), blue mussel (*Mytilus edulis*), flame shell (*Limaria hians*), cold water coral (*Lophelia pertusa*), tubeworm (*Serpula vermicularis*), *Sabellaria* reefs and brittlestar beds) and geological features (rock, coarse grained sediments, fine grained sediment and sea loch mud).

Parker *et al*. (2016) sought to provide an assessment of the cumulative impacts on different habitats to estimate (high, medium, low) areas of contribution to carbon sequestration. Substrate and management were the two main indicators used to map this ecosystem service. EUSeaMap and MESH data were used for substrate mapping and bathymetry data were included to indicate potential levels of carbon sequestration. Dumping at sea boundaries were included as input of organic material adds to carbon on the seabed, dredging activities were also included within the assessment as they can disturb sediment and release stored carbon back into the water column.

SIMCelt similarly modelled marine sediment carbon storage based on EMODnet seabed habitat layers however, the outputs did not consider coastal habitats such as saltmarsh and seagrass beds, which are known to be some of the most effective carbon sinks, it is therefore likely to be an underestimate or carbon sequestration services.

Hull *et al.* (2014) modelled carbon sequestration for UK seas based on Thomas *et al.* (2005) estimates in relation to the North Sea carbon pump and shallow water sequestration, Nellemann *et al.* (2009) for deep ocean sequestration and International Union for Conservation of Nature (IUCN) (2009) for saltmarsh sequestration. The quantities of sequestered carbon were monetised using non-traded carbon prices.

Method

The method built upon Norton *et al*. (2018) in terms of assessing the carbon sequestration potential of Irish waters (e.g. estuaries, coastal areas, offshore) as opposed to individual species assets such as the method proposed by SAMS (Burrows *et al*., 2017).

Norton *et al*. (2018) had limited information on offshore potential for carbon capture and storage, but provide an order of magnitude method which can be utilised to map this service. Data from Wakelin *et al.* (2012) POLCOMS-ERSEM modelling study was used to refine the spatial resolution of air-sea carbon flux estimates. Otherwise the methodology and data sources used in Norton *et al.* (2018) were used. It is noted that the Wakelin *et al.* (2012) model is not well-refined in estuaries. Data from Borges *et al.* (2006) was used to estimate carbon fluxes within estuaries (defined as WFD transitional water bodies).

Supralittoral habitats were also incorporated within the assessment, similar to Norton *et al.* (2018). This included sand dunes and saltmarsh, both of which were subtracted from the estuary areas to remove any double counting where overlap occurred. Norton *et al*. (2018) rely on CORINE landcover data to provide the spatial extent of sand dunes and saltmarsh which has an area resolution of 25 ha. To accurately represent the area of sand dunes and saltmarsh, both CORINE and NPWS data were combined, the latter of which contains higher resolution data but lacks the spatial extent of the former. The rate of carbon sequestration for dunes used the same data sources used by Norton *et al.* (2018).

Data availability

The following data sources were used:

- CORINE and NPWS data for sand dune and saltmarsh distribution;
- WFD boundaries for transitional waters;
- Average air-sea carbon flux estimates for estuaries (Borges *et al.,* 2006);
- Modelled air-sea carbon flux estimates for marine waters (Wakelin *et al.,* 2012).

Gaps and limitations

There is significant uncertainty concerning carbon cycling, storage and sequestration in Irish waters. The method adopted for offshore waters using net air-sea flux is a proxy for sequestration although the values are consistent with general understanding of carbon cycling in shelf and offshore waters.

Obtaining robust information on greenhouse gas flux in marine systems is recognised as being very challenging and dependent on extensive monitoring of gas exchange over time (Verified Carbon Standard, 2014). The assessment is therefore focused on modelled carbon dioxide fluxes as this is the only greenhouse gas for which data is available.

There is limited information on air-sea carbon dioxide fluxes within Irish estuaries. The model therefore uses average flux values from across a number of European estuaries as a proxy.

The Wakelin *et al.* (2012) model identifies average net air-sea carbon dioxide fluxes for the period 1989-2004. Annual net fluxes may vary significantly from these average values. While there is a net flux from air to sea over much of the North West European Continental Shelf, the principal mechanism by which carbon is sequestered is through transport of carbon which is fixed in the water column on the shelf and then subsequently transported off the shelf into deeper waters. While the model broadly identifies where the carbon is fixed, it does not represent the oceanographic processes which subsequently result in the carbon being sequestered.

As the model is largely based on fluxes, it does not incorporate specific habitats and species that play a more direct role in carbon storage and sequestration, the approach pursued by Burrows *et al.* (2017). However, these features can be mapped as natural capital assets which provide carbon storage and sequestration functions.

The estimated value is sensitive to assumptions on carbon values. This analysis has used €20 per tonne of CO_2-equivalent (Department of Finance, 2011) but other higher values are in use elsewhere, for example, for Ireland's Emissions Trading Scheme, Motherway & Walker (2009) used a value of €39 per tonne of CO_2-equivalent.

Future developments

In the long-term, it may be possible to better integrate benthic habitat models within ERSEM to better reflect the carbon storage and sequestration functions that specific habitats perform. There is an on-going Science Foundation Ireland project investigating the processes and mechanisms controlling carbon sequestration and storage in 'blue carbon habitats' which may help integrate habitat function into climate regulation ES assessment.

Based on further developments in climate modelling, it may be possible in the future to incorporate information on fluxes in other greenhouse gases within the model, particularly methane and nitrous oxide.

C.1.2 Mediation of wastes

Mediation of wastes and toxins is an ecosystem service whose function is based on the ability of biota and habitats to remove pollutants e.g. filtration, storage or accumulation of harmful substances in soil or groundwater. There is limited evidence concerning the ability of different habitats to mediate wastes. Much of the mediation is achieved through water column processes including dilution, adsorption onto sediments, sedimentation, chemical transformation and biological transformation/uptake. The use of the service is dependent on there being a source of waste to mediate.

Options for mapping

There are two broad options for mapping this service. The first is to map the sources of waste. The second is to map habitats that perform a mediation function.

Norton *et al.* (2018) valued waste ecosystem services by assessing the volume of wastewater discharged from urban wastewater treatment plants (WWTPs). The location of WWTP around Ireland were mapped along with their level of wastewater treatment. The data for wastewater treatment were based mainly on AERs for 2015 and, where there was not enough data from the AERs, EPA inspectors' reports and applications for wastewater discharge licences were used.

VALMER (2015) considered bioturbation (how much the species present rework the sediment, and hence the potential for waste to be oxygenated, buried and otherwise neutralised) using empirical data. They assessed coarse sands/ gravel to have medium potential to supply waste processing services, whereas subtidal sands, muds and muddy sands, and unstable cobbles and gravels to have low waste processing services.

Depellegrin *et al.* (2017) looked at nutrient modelling, using dispersion as a proxy for water regulation. They considered the regulation of water flows (e.g. water purification and mass transport of water), waste treatment and assimilation due to dilution of toxicants through hydrodynamic processes, and through the coupling of biogeochemical models, model indicators for microbial reduction and cycling of excess nutrients can be generated.

Method

Given that the use of the service is dependent on there being a source of waste to mediate, the methodology was based on information relation to the sources of waste in the marine environment.

The methodology builds on the work of Norton *et al.* (2018) in relation to point source discharges but also seeks to include riverine inputs into estuaries. A 1 km x 1 km grid was produced for the entire coastline and all estuaries to display the quantities of waste being produced spatially at these locations. The physical processes of dilution and dispersion are key mechanisms for mediating wastes and will occur in close proximity to input sources. Given the important role of estuaries in mediating riverine waste inputs, all transitional water bodies were identified as important areas for mediation of wastes and all riverine inputs into these waterbodies were distributed equally across their 1 km grid footprint area. For coastal discharges, the immediate 1 km grid cell around each outfall location was identified as the main location of waste mediation. Together, these data produce a 1 km grid of waste discharges around the coastline and in estuaries.

The intensity of the mediation function is based on the quantity of waste in each 1 km grid cell. The value of this mediation service is quantified using the cost associated with removing those pollutants based on values in Norton *et al.* (2018).

Data availability

Annual environmental reports, wastewater treatment inspections and applications for wastewater discharge licences all provide data for the number of plants directly discharging into coastal and estuarine waters. From this the calculation of effluent flows and estimated BOD_5 (5-day BOD), total nitrogen and phosphorus entering transitional and coastal waterbodies can be assessed.

Riverine Inputs and Direct Discharges (RID) data collated by OSPAR provides information on major riverine inputs to Irish waters.

Gaps and limitations

Not all wastewater treatment plants have data associated with them and therefore there are limitations in the assessment of nitrogen and phosphorous inputs into the waterbody. Additionally, not all rivers have data associated with them so total N and P input might not be accounted for.

There is uncertainty concerning where mediation of wastes occurs. The data presented represent a simplistic assumption that mediation occurs within estuaries and at coastal point source discharges.

Future developments

Developing on mapping outputs quantities of waste assimilated can be expressed to identify locations where waste assimilation capacity might be exceeded, indicating nitrate sensitive areas.

Seek to incorporate relevant habitats into the assessment once their role in mediation is better defined. Saltmarsh habitats, sub-tidal biogenic reef and kelp provide a significant service in water purification. Other methods of valuing this ecosystem service could therefore include a calculation of the area of such habitats (eftec, 2015).

C.1.3 Regulation of flows/ Natural hazard protection

Natural hazard protection is the service of coastal defence, the preventative or moderating effect that certain ecosystems can have in infrequent natural hazards thereby reducing the level of harm imposed on life, health or property. This can include protection from erosion and form flooding.

Options for mapping

Topography and geology are important factors influencing the risk associated with marine natural hazards from erosion and flooding. Elevated ground and hard geology will not be susceptible to erosion or flooding even in the long term. The focus of mapping has therefore tended to be on low-lying coastal environments with soft geology where there are risks of erosion and flooding. Within these areas, attention has focused on physical and biological habitats that can reduce risks of erosion and/or reduce wave energy reaching the shoreline. For example, coastal habitats such as reefs, seagrasses, kelp beds/forests, dunes, shingle and saltmarshes, can provide a significant role in reducing wave energy reaching the shoreline.

Apart from saltmarsh, shingle and dunes, there is very little information on the scale of benefit provided by these habitats either in terms of reduced erosion or wave attenuation. Mapping of the natural hazard protection service has therefore tended to focus on these features. Where saltmarsh is present, the greatest benefit is provided where there is a significant width (>80 m) of saltmarsh in more open coastal locations, where wave energy is likely to be greatest. Moller (2006) estimated that saltmarsh can attenuate 87% of waves at low inundation depths, and can still provide up to 72% wave attenuation at greater depths. They estimated that saltmarsh provides a dissipating role at depths under 3.7 m. Dunes and shingle are likely to provide a significant benefit where they protect low-lying hinterland.

Beaumont *et al.* (2010) used several different methods to estimate the potential natural hazard protection benefits of these features.

For saltmarsh, the main method applied estimated a 'replacement cost', based on the estimated cost of replacing saltmarsh with sea defences (based on King & Lester, 1995) – different metrics were used both for area of saltmarsh and linear length of saltmarsh. This method may overstate the value because it assumes that the saltmarsh would be replaced. Shepherd *et al.* (2007) estimated that fronting saltmarsh provided a net saving of £4,950 km^{-1} yr^{-1} (at 2007 prices) in flood defence expenditure on the Blackwater Estuary. This measure may provide a better estimate of the benefit provided by saltmarsh where that saltmarsh persists.

For sand dunes and shingle, the 'replacement cost' method was also used. For sand dunes, the estimate of replacement cost was refined by taking account only of areas where sand dunes were protecting low lying hinterland.

The study also considered methods based on 'avoidance cost' which could assess the costs of flooding that would be avoided based on the level of protection provided by the saltmarsh. It also considered the use of value transfer based on willingness to pay studies. However, it was concluded that there was insufficient data to allow application of these methods at that time.

The Office for National Statistics (2016) applied similar methods to Beaumont *et al.* (2010) in estimating the benefits of natural hazard protection from UK coastal habitats. An additional valuation was made for saltmarsh using value transfer based on the work of Morris & Camino (2011) and Brander *et al.* (2008) which assessed the flood protection benefits of saltmarsh as £4,030 per hectare per year (at 2015 prices).

Norton *et al*. (2018) assessed the natural hazard protection service of saltmarsh based on the methods of Beaumont *et al*. (2010) using replacement cost methods based on data from King and Lester (1995). For assessing distribution of saltmarsh, Coordination of Information on the Environment (CORINE) data was utilised to maps saltmarsh area larger than 25 ha.

Method

The method used by Norton *et al.* (2018) was built upon using the best available data layer on saltmarsh, shingle and sand dune distribution, based on CORINE landcover and NPWS data. Together, these datasets combine spatial extent and resolution to provide the best indication of habitat extent. The length of coastline protected by significant widths of saltmarsh (>80 m) was digitised along with the length protected by sand dunes and shingle. It was assumed that there is a net saving in flood defence expenditure of €4,800 m^{-1} with maintenance costs of €64 m^{-1} where saltmarsh protection occurs Norton *et al.* (2018). The ONS (2016) method was applied to shingle and sand dunes using the replacement cost method at £1,712 m^{-1} of shingle and £1,734 m^{-1} of sand dune. The protected lengths of coastline were compared to the distribution of urban and agricultural areas from CORINE landcover data, and only habitats which protect such areas were included in the cost analysis.

Data availability

- Saltmarsh, shingle and sand dune layers were derived from NPWS and CORINE data, providing a combination of extensive and high-resolution data.
- Agricultural and urban areas were identified from CORINE landcover data.

Gaps and limitations

There is little information on the scale of benefits provided by habitats other than saltmarsh, sand dune and shingle.

Benefits for saltmarsh are likely to be site-specific – the greatest benefit is in open coastal locations where saltmarsh backed by flood defences protecting low-lying areas.

Future developments

There is potential to incorporate other habitats. Coastal habitats, such as reefs, seagrasses and kelp beds/forests, can also provide a significant role in mediation of flows but there is currently limited information on the scale of their benefit. There is also potential to develop a better understanding of where saltmarsh provides benefits.

C.1.4 Lifecycle maintenance, habitat and gene pool protection

CICES defines lifecycle maintenance, habitat and gene pool protection as including (in the marine environment), gamete and seed dispersal and maintaining nursery populations and habitats (including gene pool protection).

There continues to be some debate about whether there is an element of double counting with other services, for example, the link between nursery populations and provisioning services such as wild capture fisheries and shellfisheries.

Options for mapping

Various different approaches have been adopted to the spatialisation of this service. These include methods that have sought to focus solely on mapping some aspect of marine biodiversity through to approaches that also seek to take account of the sensitivity of marine biodiversity and current human activity pressures affecting marine biodiversity. All of the approaches used have significant methodological challenges and limitations.

In Norton *et al.* (2018) species and habitats protected under the Habitats Directive in SACs were used as a proxy indicator for ES of lifecycles and habitats. Although SPAs and other protected areas were discussed they were not included within the assessment to avoid double counting of protected areas. The total extent of marine SACs was reported but not mapped.

MoEPRD (2016) also considered the extent of marine protected areas in their assessment of biodiversity as an ecosystem service. They further considered the conservation status of protected habitat types and Benthic Quality Index (BQI) within their assessment.

Parker *et al,* (2016) aimed to map marine biodiversity and pressures acting upon it. The main indicator utilised for mapping was substrate type the highest values being where biogenic (formed by living organisms, e.g. corals or mussels) habitats have been recorded. High energy environments with a lot of tide, current and wave action have quite a low value, as movement of currents in these areas can cause crushing of benthic organisms, with exposure also being an influencing factor. Other indicators include anthropogenic structures, as these offer additional habitat complexity, and which therefore potentially increase biodiversity in the immediate vicinity by creating additional ecological niches. The approach necessarily required a lot of judgements to be made about relative biodiversity importance. Species data were not incorporated in the model due to the difficulty of mapping such mobile species with incomplete data, however this highlights a limitation to the maps produced. The method also sought to incorporate negative impacts on marine biodiversity from human activity pressures. Again, this required subjective judgements to be made about the spatial extent of such pressures.

More broadly, various other methodologies exist for seeking to map general marine biodiversity. These include methods such as species diversity indices and biotope diversity indices (Jackson *et al.,* 2010), but the application of such methods tends to be limited by available data, particularly when seeking to work at national scales.

Method

The scope for developing meaningful data layers for the lifecycle maintenance, habitat and gene pool protection ecosystem service is significantly constrained by a lack of scientific consensus on what this service represents, how it may be mapped and a lack of suitable data. Most previous studies have sought to map some aspect of marine biodiversity and a few studies have also sought to incorporate aspects of human activity pressure (as a negative impact on marine biodiversity).

A possible starting point is to seek to map the distribution of marine habitats and associated benthic species that are recognised at international level as being of nature conservation importance. This might include features for which SACs are designated and features on the OSPAR list of threatened and declining habitats and species. It may also be appropriate to include key hotspots for some mobile species including marine mammals, basking shark and seabirds (seabird colonies).

Negative pressures on these areas of biodiversity could be represented based on the location of human activity. Such maps could usefully identify where there are areas of human activity overlapping with areas of high biodiversity importance.

There are no agreed methods for quantifying this ecosystem service and given the limited understanding of the service, no quantification has been attempted in this study. Some data exists concerning the value that society attaches to protecting marine biodiversity based on Willingness to Pay studies e.g. McVittie & Moran (2008). However, such studies relate to the benefits of marine nature conservation as a whole and thus extend beyond just the lifecycle maintenance, habitat and gene pool protection ecosystem service. The use of value transfer is therefore not appropriate.

Data availability

- Maps of the distribution of SAC features, OSPAR threatened and declining species and mobile species are available and/or to be created under Project 2;
- Maps of the location of human activity are available/to be created under Project 2;
- A map of demersal fishing pressure is available from ICES; maps for other human activities would need to be created based on assumptions concerning the spatial footprint of such pressures.

Gaps and limitations

There is limited scientific understanding of how to represent or quantify this service.

Future developments

A clear definition of this service is needed together with agreement on how the service might be reliably quantified.

D Cultural Ecosystem Services Mapping

D.1 Cultural services mapping methods

The Millennium Ecosystem Assessment (2005) (MEA) defined cultural ecosystem services (CES) as "non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences" (MEA, 2005). These benefits include cultural diversity, spiritual/religious values, recreation/tourism, social relations, educational values as well as aesthetic values, sense of place and cultural heritage.

However, research on cultural services has been relatively neglected (Baveye, 2017; Boerema *et al.,* 2016). A review about ES mapping papers (Crossman *et al*., 2013) concluded that CES were mapped in only 18% of the papers. Moreover, Hernandez-Morcillo *et al*. (2013) found that only 23% of studies about CES included an explicit spatial representation. This may be because CES are widely considered to be inherently difficult to quantify (Daniel *et al*., 2012; Dickinson & Hobbs, 2017; Willcock, *et al*., 2017). While many ecosystem services relate to easily measured biophysical processes or changes (Bagstad, Semmens, Ancona & Sherrouse, 2017; Satz *et al*., 2013), cultural services include intangible concepts such as aesthetic value (Daniel *et al*., 2012; Milcu *et al*., 2013). Furthermore, people value cultural services in different ways, and these values can change over time (Gould *et al*., 2018; Plieninger *et al*., 2015). Therefore, despite recognition of their importance (Guerry, *et al*., 2012; Daniel *et al*., 2012), CES are often considered difficult to quantify and as such are sometimes omitted from valuation exercises (Small *et al*., 2017).

The table overleaf provides a summary of the CES defined in the 2018 version of the CICES and examples for each CES category.

Table D1 Cultural ecosystem service in the Common International Classification of Ecosystem Services

Division	Group	Class	V4.3 Equivalent	Class in Project 3	Examples
Direct, *in situ* and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions	Experiential use of plants, animals and land-/seascapes in different environmental	**Recreation and tourism**	*In situ* bird and wildlife watching, snorkelling, diving and other experiential enjoyment of nature. Walking, cycling, climbing, boating, angling, surfing, and other physical activities in nature.
		Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	Physical use of land-/seascapes in different environmental settings		
	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	Scientific	**Scientific and Educational**	Subject matter for research both on location and via other media.
		Characteristics of living systems that enable education and training	Educational		Specifically, formal and informal education, including school nature walks and observation, woodland schools and other outdoor classroom activities.
		Characteristics of living systems that are resonant in terms of culture or heritage	Heritage, cultural	**Cultural Heritage**	Historic records, cultural heritage e.g. preserved in water bodies and soils, interplay of nature and culture, traditional uses of nature, cultural identity. Many species are important motifs in Irish art, music and literature, and in folklore and mythology (e.g. the blackbird, oak, ash, yew, salmon, golden eagle). Several habitats also have similar associations, especially woodlands, peatlands and rivers (symbolism associated with the Liffey, Barrow, Nore, Suir, Shannon etc.). Habitats and landscapes associated with traditional agricultural practices such as low-intensity and traditional grazing practices and commonage, often linked with high nature value farmland (machairs, limestone pavements, upland heaths etc.). Habitats and species associated with traditional crafts and arts include reedbeds associated with thatching, willow-coppice associated with weaving, small plots managed for flax growing associated with linen production, and agricultural lands associated with traditional wool production.

Division	Group	Class	V4.3 Equivalent	Class in Project 3	Examples
		Characteristics of living systems that enable aesthetic experiences	Aesthetic	**Aesthetic**	Areas of particularly unique or valued scenic character, including those valued for artistic inspiration. Whilst the AONB designation is limited to Northern Ireland (not used officially in the Republic), there are many scenic routes and beauty spots recognised or designated by local authorities and highlighted on tourist maps and trails. Examples include the Cliffs of Moher, the Sally Gap in Wicklow, Ring of Kerry, the Wild Atlantic Way, Ireland's Ancient East etc. Several iconic mountain, coast and lake landscapes are associated with Irish artists or art movements.
Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems that have symbolic meaning	Symbolic	**Spiritual and Symbolic**	Sense of place, place identity
		Elements of living systems that have sacred or religious meaning	Sacred and/or religious		Specifically relates to areas that are largely or primarily of interest due to spiritual / religious associations, including holy places, sacred sites, religious monuments and trails. Examples include the Skellig Islands, Clonmacnoise and Glendalough, and Croagh Patrick.
		Characteristics or features of living systems that have an existence value	Existence	**Existence and Bequest**	Habitats, species and landscape elements which are regarded for their intrinsic value - this includes elements of biodiversity which people feel should be protected, or for which they are willing to pay for protection, as they constitute part of local and national identity, or are associated with sense of place and time. Nationally, these are demonstrated by National Parks, botanic gardens & arboreta, nature reserves and formal conservation designations (national and international), but locally it includes elements of biodiversity which form part of local aesthetic character.
		Other biotic characteristics that have a non-use value	Bequest		Linked to the 'existence' class, but more specifically relates to the protection of habitats and landscape elements for the benefit of future generations (be it economic, social or cultural benefit). Potentially very extensive but demonstrated by National Parks and Gardens, designated heritage sites, formal statutory designations for nature conservation and Protected and Recorded monuments.

D.1.1 Recreation and Tourism

Tourism and recreation CES represent an important way that people derive benefit from the natural environment and are particularly relevant to the marine and coastal environment. Tourism and recreation is a category of the CES, which is conceptually easier to identify and measure (Kopperoninen *et al*., 2017) and is consequently investigated more than other CES (Milcu *et al*. 2013; Martin *et al*. 2016; Kulczyk *et al*., 2018). Despite this, within Ireland, data relating to visitor numbers to even well-known sites or trails are relatively poor, however, where there are examples these can be indicative of visitor numbers elsewhere.

Options for mapping

Recent years have seen a number of studies designed to improve understanding of the way that the natural environment provides benefits for tourism and recreation CES (Parachhini *et al.,* 2014; Ruskule *et al.,* 2018). It is suggested that mapping of ecosystem services in marine and coastal areas can be challenging due to difficulties in establishing a link between the biophysical features of coastal ecosystems and the supply of recreation 'services.

Following the ecosystem service concept, which emphasises the natural environment as a provider of benefits to society, the recreational potential of land has often been mapped based on physical attributes e.g. land cover and access (Martinez-Harms & Balvanera, 2012; Scholte *et al*., 2018). Taking an early ecosystem service-based approach, Natural England (2009) analysed the recreation, enjoyment and understanding of upland landscapes. Key criteria used to identify areas judged to provide important recreation services included national landscape designations (National Parks and Areas of Outstanding Natural Beauty), upland areas with open access, tranquillity, geology, historic assets, areas known to be popular for walking and proximity to population. For the most part, this considered supply side factors as a proxy for recreation activity and public preferences.

Casado-Arzuaga *et al*. (2013) identified two components for mapping recreation services: the recreation potential and the recreation opportunity. The recreation potential was mapped with the assumption that it was positively correlated to a limited list of territorial features associated with attractiveness for recreational activities, i.e. the degree of naturalness, the presence of protected areas, the presence of coastal lines (sea) and the quality of the bathing water. The recreation opportunity took into account the infrastructure that was in place to host or guide the visitors and included information regarding the density of mountain summits and the location of recreational areas, climbing sites, cycling paths and routes of geological interest. The recreation provision service was calculated aggregating these two components with the values of the resulting map classified by Jenks Natural Breaks.

This type of approach, based solely on assumptions of certain physical attributes having higher recreational potential or proximity to infrastructure/accessibility from roads, has been criticised as being overly mechanical (Ruskule *et al*., 2018). Pena *et al*. (2015) argue that analysis based solely on recreational potential (supply side) can over-estimate recreation activity and that it is necessary to consider factors influencing demand too. Scholte *et al*. (2018) argues that such a mechanistic approach fails to incorporate the experiences and perceptions of the public and recommend that participatory mapping methods are used to study the spatial distribution of recreational experiences.

Participatory methods are commonly used in order to capture people's perception on plurality of the CES values (Martin *et al*., 2016). This approach has also been followed by several studies addressing marine and coastal ecosystems (e.g. LUC, 2016; Panter *et al*., 2016), who undertook visitor surveys generating information about where coastal recreation takes place, the activities that are undertaken, the reasons for selecting particular designations and the local economic benefit. These types of surveys can remove the need for analysis of factors such as accessibility and proximity to population, providing a definitive and spatially specific indication of where recreation and tourism CES are provided.

All activities combined

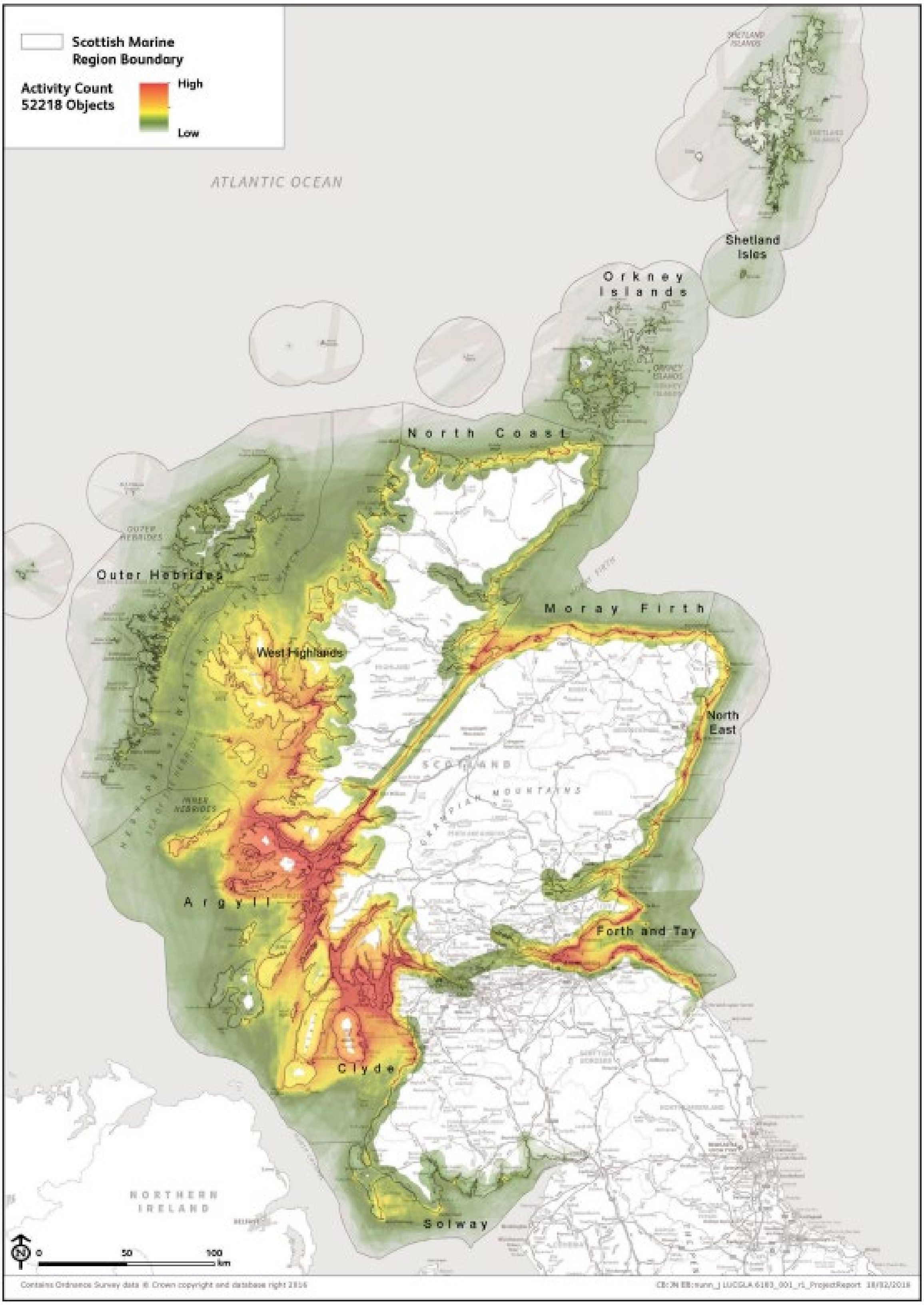


Figure D1 **Recreation activities along the Scottish coastline identified through visitor and participatory surveys**

CES mapping approaches are often trans-disciplinary, covering bio-physical, sociocultural as well as economic dimensions (Paracchini *et al.*, 2014). Working at an EU level, Paracchini *et al.* (2014) developed a model which integrates biophysical attributes (e.g. natural value and accessibility) representing recreational potential with behavioural data derived from surveys and population, characterising recreational demand. Ruskule *et al.* (2018), in assessing the cultural services provided by coastal areas in Latvia, developed this approach at a more local level. They identified four principal factors influencing the flow of recreation and tourism CES: (i) accessibility; (ii) proximity to population; (iii) suitability of an area for recreation and tourism; and, (iv) recreational use (see Table D2).

Table D2. Multi-criteria assessment of recreation ES

Criteria	Definition of criteria	Variables	Scoring
Accessibility	Infrastructure in the coast areas providing access to recreation locations	Public access to the beach Road infrastructure Availability of public transport Availability of car parking	Well managed access for different transport modes Limited public transport access but within 1 km of public road Limited access (more than 1 km from public road) No public access
Proximity to population	Potential recreational demand based on proximity to settlements, including holiday accommodation	Settlement size and distance Population density Concentration of recreation services	Developed resort areas Close to dense settlement More than 5 km from dense settlement
Suitability of an area for recreation and tourism	The most favourable physical and social conditions for recreation types (including niche activities)	Natural features Abiotic features such as wind, wave height Specific supporting infrastructure and amenities	High quality and specific nature resources supported by appropriate visitor infrastructure High quality nature resources supported by general infrastructure Variable nature resources, fragmented or no infrastructure
Recreational use	Intensity of recreation activity at particular locations	Number of tourism and recreation benefits in a given time period	Intense visitor activity Moderate visitor activity Low visitor activity

In the absence of undertaking participatory mapping methods, there are a number of potential ways of addressing the lack of good information on recreation activity. Recent research by LUC for Natural Resources Wales (2019) explored ways of developing information on the intensity of visitor activity in the intertidal zone. This included an assessment of the potential use of 'big data' to map spatial activity at the coast.

Sources included:

- Mobile phone network data which can provide information on the number of people visiting different areas based on the presence of phones in mobile phone cells (Figure D2). These tend to be small in urban areas and much larger in remote rural areas (including large parts of the coastline) meaning that spatial accuracy may be poor. The data can however distinguish between residents and visitors and by time of day or day of the week. Data are costly, at over €50k for the entire coastline.

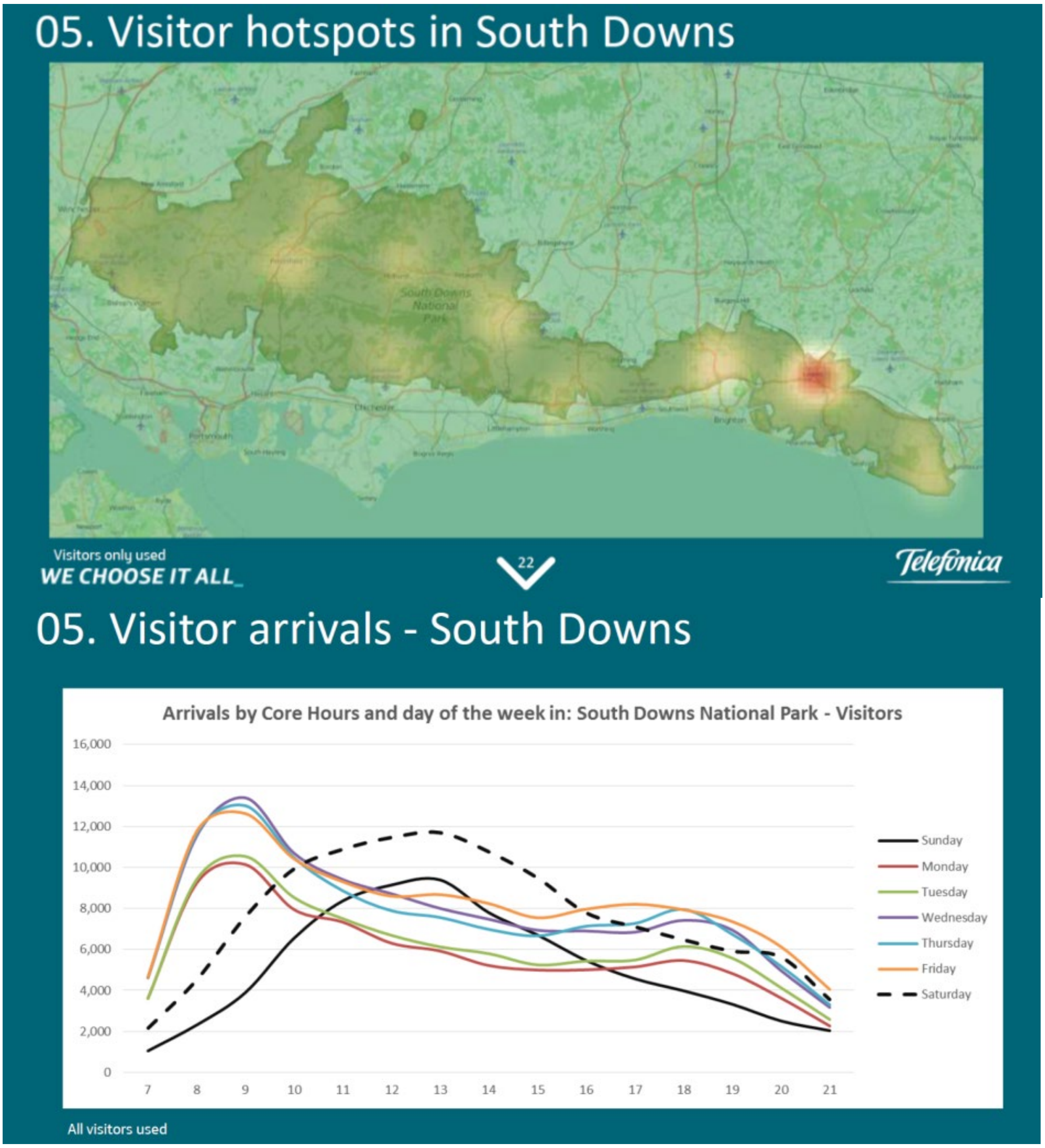


Figure D2. Visitor data for the South Downs National Park identified through mobile phone network data

- Activity apps, such as Strava, are used by people engaged in sport and active recreation to record and track their activity (Figure D3). The app uses GPS to record the route followed by runners, cyclists, walkers and people undertaking water sports, for example. Subject to privacy settings, Strava aggregate individuals' data and publish composite activity maps. These maps are available to purchase but is also free to view online on Strava heat maps (https://www.strava.com/heatmap). The heat maps show combined data in the following categories: cycling, running, water and winter activities. Online heat maps are also continuously updated to reflect new activities and data. Again, data are costly and could be in the region of €50k for the entire coastline.

Figure D3. Strava data identifying running and walking routes

In recent years, several studies have used social media databases of geotagged photos that have been uploaded to crowdsourcing photo repositories (e.g. Flickr) to identify the location and number of visits to an area for various recreational activities. As explained under the Aesthetic CES method statement, photograph metadata can be downloaded from Flickr through a publicly available Application Programming Interface (API). Apart from the photos' geographical references (a geotag describing latitude and longitude), other metadata added by users was also obtained (e.g. photo tag and descriptions, pictured date). Using the automatic tags assigned by Flickr (e.g. 'sailing', 'surfing', canoeing'), the density of photographs within the study area can be mapped using the point density tool in ArcMap to identify where the various recreational activities take place along the coastline. This is particularly useful for mapping less popular activities (e.g. kite buggying, kite landboarding, sand yachting, or wakeboarding/waterskiing) as there is little data available on where these activities take place.

Lee *et al*. (2019a) calculated photo-user-days as the total annual days that a photographer took at least one photo within a cell in the study area (Sharp *et al*., 2016). By using the photo-user-days instead of the total number of photos, one avoids a bias caused by an exceptionally high number of photos by a single photographer in a single day. Thus, this metric gives a good indication of the number of visitors to the area (Wood *et al*., 2013) in the study region during the analysed time period. Despite the limitations of using geotagged photos, such as a biased user population and behaviour (Yoshimura & Hiura, 2017), previous studies using geotagged photos from the Flickr database have shown that the visitation rate extracted from Flickr photos and user information matched well with the one calculated from the empirical visitor data (Ruths & Pfeffer, 2014; Sonter *et al*., 2016). This highlights the reliability of the indicator to assess the demand for recreational activities. This is a relatively low-cost option and is also being proposed as a means of measuring the aesthetic CES so could provide an additional layer in the tourism and recreation CES analysis.

A limited set of cultural values can be reflected by economic indication and measured in market terms to a large extent, like recreation or ecotourism, due to willingness to pay for ES or travel cost pricing (Milcu *et al*., 2013). Norton *et al*. (2018) used secondary sources of information, primarily a survey by SEMRU of the Irish population's coastal and marine-based recreational activities and previous research on marine activity participation rates carried out by the ESRI in 1996 and 2003, to estimate the value of recreational services. The study estimated that 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. Although this process is useful for valuation it did not map the spatial provision of recreational ecosystem services.

Method

The method for mapping recreation and tourism CES was to create individual layers for each activity, and then combine them into four heat maps to represent activities on the water, on the beach/intertidal zone, on the land, and all activities combined.

A number of data layers were produced as part of Project 2 which are of relevance to mapping recreation and tourism CES:

- Location and intensity of recreational angling (DPT128)
- Location and intensity of kite surfing (DPT129)
- Location and intensity of windsurfing (DPT130)
- Location and intensity of surfing (DPT131)
- Location and intensity of climbing/coasteering/bouldering (DPT132)
- Location and intensity of diving/snorkelling (DPT133)
- Location and intensity of recreational drone use (DPT134)
- Location and intensity of general beach leisure (DPT135)
- Location and intensity of general tourism (DPT136)
- Location and intensity of hovercrafting (DPT137)
- Location and intensity of coastal cycling (DPT138)
- Location and intensity of coastal quad biking/scrambling (DPT139)
- Location and intensity of sand-yachting/land sailing/land-yachting (DPT140)
- Location and intensity of kite buggying (DPT141)
- Location and intensity of kite landboarding (DPT142)
- Location and intensity of coastal recreational light aircraft (DPT143)
- Location and intensity of motor/power boating (DPT144)
- Location and intensity of motorised sailing (DPT145)
- Location and intensity of wakeboarding/waterskiing (DPT146)
- Location and intensity of parascending (DPT147)
- Location and intensity of unmotorised sailing (DPT148)
- Location and intensity of kayaking (DPT149)
- Location and intensity of Canadian canoeing (DPT150)
- Location and intensity of stand-up paddleboarding (DPT151)
- Location and intensity of rowing/sculling (DPT152)
- Location and intensity of dinghy/dayboat/small keelboat sailing (DPT153)
- Location and intensity of personal watercraft use (DPT154)

- Location and intensity of visitor attractions (DPT155)
- Location and intensity of coastal walking (DPT156)
- Location and intensity of wildlife/bird watching/wildfowling (DPT157)
- Location of marine recreational infrastructure (DPT158)
- Location of coastal tourism infrastructure (DPT159)
- Value of tourism & recreation activity (DPT160)

Flickr data is publicly available through the Application Programming Interface (API).

In addition, the following layer was produced to indicate recreation and tourism CES in Ireland:

- CORINE Land Cover 2018.

A range of data layers were used to create the four individual heat maps. To create the 'On the Water' map the following data layers were used (54 data layers in total). Note that these are the same data layers prepared for Project 2 but are renamed using the prefix ES012 for the purposes of creating the ES maps:

- ES012_LY001_Location_And_Intensity_Of_**Recreational_Angling_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'angling', 'shore+angling', 'sea+angling', 'fishing'.
- ES012_LY002_Location_And_Intensity_Of_**Recreational_Angling** – Data created by LUC showing sea angling locations using data from the Sea Angling Ireland website.
- ES012_LY003_Location_And_Intensity_Of_**Recreational_Angling_ClubsCentresOperatorsSchools** – Data created by LUC from club information available on the Irish Federation of Sea Anglers website and from angling clubs/operators coordinates provided by Failte Ireland in 2018.
- ES012_LY004_Location_And_Intensity_Of_**Kitesurfing_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'kitesurfing' and 'kite+surfing'.
- ES012_LY005_Location_And_Intensity_Of_**Kitesurfing** – Data was created by LUC using KiteSurfIreland.ie and Local Kite Sports website to identify popular kitesurfing locations.
- ES012_LY006_Location_And_Intensity_Of_**Kitesurfing_ClubsCentresOperatorsSchools** – Data was created using club information available on the Irish Kitesurfing Association website.
- ES012_LY007_Location_And_Intensity_Of_**Windsurfing** – Data was created using the Irish Windsurfing Association website to identify popular kitesurfing locations.
- ES012_LY008_Location_And_Intensity_Of_**Windsurfing_ClubsCentresOperatorsSchools** – Data on clubs was provided by the Irish Windsurfing Association.
- ES012_LY009_Location_And_Intensity_Of_**Windsurfing_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'windsurfing' and 'windsurfer'.
- ES012_LY010_Location_And_Intensity_Of_**Surfing_ClubsCentresOperatorsSchools** – Data was created by LUC using coordinates and facility names provided by Irish Surfing.
- ES012_LY011_Location_And_Intensity_Of_**Surfing_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'surfing', 'surfer' and 'surf+board'.
- ES012_LY015_Location_And_Intensity_Of_**Diving_Snorkelling** – Data created by LUC using locations identified on the Irish Underwater Council website.
- ES012_LY016_Location_And_Intensity_Of_**Diving_Snorkelling_ClubsCentresOperatorsSchools** – Data created by LUC using diving/snorkelling club information identified on the Irish Underwater Council website.

- ES012_LY017_Location_And_Intensity_Of_**Diving_Snorkelling_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'snorkel' and 'snorkelling'.
- ES012_LY027_Location_And_Intensity_Of_**General_Coastal_Tourism_Activities_Ferry_Routes** – Data received from ABPMer who extracted recreational ferry routes from Ordnance Survey Ireland database.
- ES012_LY040_Location_And_Intensity_Of_**Motor_Power_Boating_ClubsCentresOperatorsSchools** – Data created by LUC with permission from Irish Sailing to plot clubs identified on their website.
- ES012_LY041_Location_And_Intensity_Of_**Motor_Power_Boating_Recreational_Routes** – Data created by LUC using the routes illustrated in The Coastal Atlas of Recreational Boating of Ireland (provided by Irish Sailing).
- ES012_LY042_Location_And_Intensity_Of_**Motor_Power_Boating_Racing_Areas** – Data created by LUC using the racing areas illustrated in The Coastal Atlas of Recreational Boating of Ireland (provided by Irish Sailing).
- ES012_LY043_Location_And_Intensity_Of_**Motor_Power_Boating_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'motor+cruiser', 'powerboat', 'power+boat' and 'cabin+cruiser'.
- ES012_LY044_Location_And_Intensity_Of_**Motorised_Sailing_ClubsCentresOperatorsSchools** – Data created by LUC with permission from Irish Sailing to plot clubs identified on their website.
- ES012_LY045_Location_And_Intensity_Of_**Motorised_Sailing_Recreational_Routes** – Data created by LUC using the routes illustrated in The Coastal Atlas of Recreational Boating of Ireland (provided by Irish Sailing).
- ES012_LY046_Location_And_Intensity_Of_**Motorised_Sailing_Racing_Areas** – Data created by LUC using the racing areas illustrated in The Coastal Atlas of Recreational Boating of Ireland (provided by Irish Sailing).
- ES012_LY047_Location_And_Intensity_Of_**Motorised_Sailing_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'yacht', 'yachting', 'cruising', 'yacht+race' and 'yacht+racing'.
- ES012_LY048_Location_And_Intensity_Of_**Wakeboarding_Waterskiing_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'waterskiing', 'wakeboarding', 'wakeboard' and 'waterski'.
- ES012_LY049_Location_And_Intensity_Of_**Parascending_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'parascending', 'parasailing' and 'parakiting'.
- ES012_LY050_Location_And_Intensity_Of_**Unmotorised_Sailing_ClubsCentresOperatorsSchools** – Data created by LUC with permission from Irish Sailing to plot clubs identified on their website.
- ES012_LY051_Location_And_Intensity_Of_**Unmotorised_Sailing_Recreational_Routes** – Data created by LUC using the routes illustrated in The Coastal Atlas of Recreational Boating of Ireland (provided by Irish Sailing).
- ES012_LY052_Location_And_Intensity_Of_**Unmotorised_Sailing_General_Sailing_Areas** – Data created by LUC using the sailing areas illustrated in The Coastal Atlas of Recreational Boating of Ireland (provided by Irish Sailing).
- ES012_LY053_Location_And_Intensity_Of_**Unmotorised_Sailing_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'sailing' and 'sail+boat'.
- ES012_LY054_Location_And_Intensity_Of_**Kayaking_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'kayaking', 'sea+kayaking', 'kayak' and 'sea+kayak'.

- ES012_LY055_Location_And_Intensity_Of_**Kayaking_ClubsCentresOperatorsSchools** – Data created by LUC using the Canoeing Ireland website to identify kayaking clubs.
- ES012_LY0056_Location_And_Intensity_Of_**Canadian_Canoeing_ClubsCentresOperatorsSchools**– Data created by LUC using the Canoeing Ireland website to identify canoeing clubs.
- ES012_LY057_Location_And_Intensity_Of_**Canadian_Canoeing_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'canoeing' and 'canoe'.
- ES012_LY058_Location_And_Intensity_Of_**Stand_Up_Paddleboarding_ClubsCentresOperatorsSchools** – Data was created by LUC using coordinates and facility names provided by Irish Surfing.
- ES012_LY059_Location_And_Intensity_Of_**Stand_Up_Paddleboarding_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'stand+up+paddleboarding', 'paddleboarding' and 'paddleboard'
- ES012_LY060_Location_And_Intensity_Of_**Rowing_Sculling_ClubsCentresOperatorsSchools** – Data created by LUC using club information on Rowing Ireland websites.
- ES012_LY061_Location_And_Intensity_Of_**Rowing_Sculling_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'rowing', 'sculling', 'rowing+boat' and 'row+boat'.
- ES012_LY062_Location_And_Intensity_Of_**Dinghy_Dayboat_Small_Keelboat_Sailing_Recreational_Routes** – Data created by LUC using the routes illustrated in The Coastal Atlas of Recreational Boating of Ireland (provided by Irish Sailing).
- ES012_LY063_Location_And_Intensity_Of_**Dinghy_Dayboat_Small_Keelboat_Sailing_General_Racing_Areas** – Data created by LUC using the sailing areas illustrated in The Coastal Atlas of Recreational Boating of Ireland (provided by Irish Sailing).
- ES012_LY064_Location_And_Intensity_Of_**Dinghy_Dayboat_Small_Keelboat_Sailing_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'dinghy' and 'keelboat'.
- ES012_LY065_Location_And_Intensity_Of_**Dinghy_Dayboat_Small_Keelboat_Sailing_ClubsCentresOperatorsSchools** – Data created by LUC with permission from Irish Sailing to plot clubs identified on their website.
- ES012_LY066_Location_And_Intensity_Of_**Personal_Watercraft_Use_Recreational_Routes** – Data created by LUC using the routes illustrated in The Coastal Atlas of Recreational Boating of Ireland (provided by Irish Sailing).
- ES012_LY067_Location_And_Intensity_Of_**Personal_Watercraft_Use_General_Sailing_Areas** – Data created by LUC using the sailing areas illustrated in The Coastal Atlas of Recreational Boating of Ireland (provided by Irish Sailing).
- ES012_LY068_Location_And_Intensity_Of_**Personal_Watercraft_Use_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'jet+ski' and 'jetski'.
- ES012_LY069_Location_And_Intensity_Of_**Personal_Watercraft_Use_ClubsCentresOperatorsSchools** – Data created by LUC using club information on Rowing Ireland websites.
- ES012_LY074_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_SAC**- Open Data available under Creative Commons Attribution 4.0.
- ES012_LY075_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_SPA** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY076_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_NHA** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY077_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_pNHA** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY078_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_Marine_Protected_Area** - Open Data available under Creative Commons Attribution 4.0.

- ES012_LY079_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_UNESCO_Global_Geopark** - Polygon data obtained from Geopark Authorities.
- ES012_LY080_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_UNESCO_Biosphere_Reserves** - Polygon data obtained from Local Authorities.
- ES012_LY081_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_Wildfowl_Sanctuaries** - Data plotted from spreadsheet available on National Parks and Wildlife Service website.
- ES012_LY082_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_Nature_Reserves** - Open Data available under Creative Commons Attribution 4.0.

Data layers ES012_LY074 to ES012_LY0082 were clipped to only show the offshore elements of the SACs, SPAs, NHAs, pNHAs, MPAs, Geoparks, Biosphere Reserves, Wildfowl Sanctuaries, and Nature Reserves, to depict bird and wildlife watching 'on the water'.

Weighting was applied to the recreational routes for motor boating, sailing, unmotorised sailing, personal watercraft and small keelboat/dinghy sailing to denote heavy, medium and light traffic routes.

The following data layers were used to create the 'On the Beach/Intertidal Zone' map (25 data layers in total):

- ES012_LY001_Location_And_Intensity_Of_**Recreational_Angling_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'angling', 'shore+angling', 'sea+angling', 'fishing'.
- ES012_LY002_Location_And_Intensity_Of_**Recreational_Angling** – Data created by LUC showing sea angling locations using data from the Sea Angling Ireland website.
- ES012_LY003_Location_And_Intensity_Of_**Recreational_Angling_ClubsCentresOperatorsSchools** – Data created by LUC from club information available on the Irish Federation of Sea Anglers website and from angling clubs/operators coordinates provided by Failte Ireland in 2018.
- ES012_LY012_Location_And_Intensity_Of_**Climbing_Coasteering_Bouldering_Mountaineering_ScenicMountainTrails** – Data was created by LUC using IB4UD website to identify most scenic mountain trails in Ireland.
- ES012_LY013_Location_And_Intensity_Of_**Climbing_Coasteering_Bouldering_Mountaineering_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'climbing', 'coasteering' and 'bouldering'.
- ES012_LY014_Location_And_Intensity_Of_**Climbing_Coasteering_Bouldering_Mountaineering_ClubsCentresOperatorsSchools** – Data was created by LUC using Outsider website to identify clubs and adventure centres offering climbing, coasteering, bouldering and mountaineering.
- ES012_LY019_Location_And_Intensity_Of_**General_Beach_Leisure_BlueFlagAwardBeaches_2019** – Data provided by An Tasice.
- ES012_LY020_Location_And_Intensity_Of_**General_Beach_Leisure_GreenCoastAwardBeaches_2019** – Data provided by An Tasice.
- ES012_LY021_Location_And_Intensity_Of_**General_Beach_Leisure_Beaches** – Data received from ABPMer who extracted 'beaches' from Ordnance Survey Ireland database.
- ES012_LY022_Location_And_Intensity_Of_**General_Beach_Leisure_DesignatedBathingWaterLocations** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY023_Location_And_Intensity_Of_**General_Beach_Leisure_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search term 'beach'.

- ES012_LY032_Location_And_Intensity_Of_**Coastal_Quad_Biking_Scrambling_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'quad+biking', 'scrambling' and 'motocross'.
- ES012_LY033_Location_And_Intensity_Of_**Sand_Yachting_Land_Sailing_Land_Yachting_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'sand+yachting', 'sand+yacht' and 'landsailing'.
- ES012_LY034_Location_And_Intensity_Of_**Sand_Yachting_Land_Sailing_Land_Yachting** – Data created by LUC using Mini Land Yachts website to identify locations for sand yachting, land sailing and land yachting.
- ES012_LY035_Location_And_Intensity_Of_**Kite_Buggying_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'kite+buggying' and 'kite+buggy'.
- ES012_LY074_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_SAC**- Open Data available under Creative Commons Attribution 4.0.
- ES012_LY075_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_SPA** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY076_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_NHA** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY077_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_pNHA** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY078_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_Marine_Protected_Area** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY079_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_UNESCO_Global_Geopark -** Polygon data obtained from Geopark Authorities.
- ES012_LY080_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_UNESCO_Biosphere_Reserves** - Polygon data obtained from Local Authorities.
- ES012_LY081_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_Wildfowl_Sanctuaries** - Data plotted from spreadsheet available on National Parks and Wildlife Service website.
- ES012_LY082_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_Nature_Reserves** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY083_Location_Of_**Marine_Recreation_Infrastructure** – Data created from three sources: Marine Institute's piers/quays/slipways; Marine Institute's marinas; and, Ordnance Survey's harbours.

Data layers ES012_LY074 to ES012_LY0082 were clipped to only show elements of the SACs, SPAs, NHAs, pNHAs, MPAs, Geoparks, Biosphere Reserves, Wildfowl Sanctuaries, and Nature Reserves within 500 m of the coastline to depict bird and wildlife watching 'on the beach/intertidal zone'. A 500 m buffer was used as an approximate indication of the beach/intertidal zone as there was no dataset available which identified high and low tide marks.

The following data layers were used to create the 'On the Land' map (31 data layers in total):

- ES012_LY012_Location_And_Intensity_Of_**Climbing_Coasteering_Bouldering_Mountaineering_ScenicMountainTrails** – Data was created by LUC using IB4UD website to identify most scenic mountain trails in Ireland.
- ES012_LY013_Location_And_Intensity_Of_**Climbing_Coasteering_Bouldering_Mountaineering_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'climbing', 'coasteering' and 'bouldering'.
- ES012_LY014_Location_And_Intensity_Of_**Climbing_Coasteering_Bouldering_Mountaineering_ClubsCentresOperatorsSchools** – Data was created by LUC using Outsider website to

identify clubs and adventure centres offering climbing, coasteering, bouldering and mountaineering.

- ES012_LY018_Location_And_Intensity_Of_**Recreational_Drone_Use** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'drone' and 'uav'.
- ES012_LY024_Location_And_Intensity_Of_**General_Coastal_Tourism_Activities_Flickr_Locations** - - Data created by LUC showing recorded locations of photos from Flickr using search terms 'scenic+drives', 'coastal+drive', 'coastal+view', 'sea+view', 'scenic+view', 'viewpoint' and 'boat+tour'.
- ES012_LY025_Location_And_Intensity_Of_**General_Coastal_Tourism_Activities_ScenicCoastalTownsVillages** – Data created from various web sources identifying scenic coastal towns and villages.
- ES012_LY026_**Location_And_Intensity_Of_General_Coastal_Tourism_Activities** – Failte Ireland 2018 data identifying discovery points, signature points, historic houses and castles, museums, national/forest parks.
- ES012_LY028_Location_And_Intensity_Of_**General_Coastal_Tourism_Activities_Wild_Atlantic_Way** – Data provided by the Marine Institute.
- ES012_LY029_Location_And_Intensity_Of_**Coastal_Cycling_Routes** – Data received from Sports Ireland.
- ES012_LY030_Location_And_Intensity_Of_**Coastal_Cycling_Clubs_Bike_Rental_Locations** – Data created by LUC using information provided by Cycling Ireland and bike rental locations from Failte Ireland 2018 data.
- ES012_LY031_Location_And_Intensity_Of_**Coastal_Cycling_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search term 'cycling'.
- ES012_LY036_Location_And_Intensity_Of_**Coastal_Recreational_Light_Aircraft_Small_Airports** – Data created using two sources – Ordnance Survey Ireland airport data and coordinates obtained from Our Airports website.
- ES012_LY037_Location_And_Intensity_Of_**Coastal_Recreational_Light_Aircraft_Airfields** – Data received from ABPMer who extracted 'airfields' from Ordnance Survey Ireland database.
- ES012_LY038_Location_And_Intensity_Of_**Coastal_Recreational_Light_Aircraft_Handgliding_Paragliding_Sites** – Data received from Irish Hang Gliding and Paragliding Association.
- ES012_LY039_Location_And_Intensity_Of_**Coastal_Recreational_Light_Aircraft_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'hang+gliding', 'hanggliding' and 'paragliding'.
- ES012_LY070_Location_And_Intensity_Of_**Visitor_Attractions** – Data created from four sources – Heritage Council's Natural Heritage Sites; Failte Ireland's churches, abbeys, monasteries; DCHG museums, collections, visitor centres; and, Ordnance Survey data on museums.
- ES012_LY071_Location_And_Intensity_Of_**Coastal_Walking_PilgrimPaths** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY072_Location_And_Intensity_Of_**Coastal_Walking_Trails** – Data received from Sports Ireland.
- ES012_LY073_Location_And_Intensity_Of_**Coastal_Walking_Flickr_Locations** - Data created by LUC showing recorded locations of photos from Flickr using search terms 'coastal+walking', 'coastal+walk', 'cliff+walk', 'beach+walk'.
- ES012_LY074_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_SAC**- Open Data available under Creative Commons Attribution 4.0.
- ES012_LY075_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_SPA** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY076_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_NHA** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY077_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_pNHA** - Open Data available under Creative Commons Attribution 4.0.

- ES012_LY078_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_Marine_Protected_Area** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY079_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_UNESCO_Global_Geopark** - Polygon data obtained from Geopark Authorities.
- ES012_LY080_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_UNESCO_Biosphere_Reserves** - Polygon data obtained from Local Authorities.
- ES012_LY081_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_Wildfowl_Sanctuaries** - Data plotted from spreadsheet available on National Parks and Wildlife Service website.
- ES012_LY082_Location_And_Intensity_Of_**Wildlife_Bird_Watching_Wildfowling_Nature_Reserves** - Open Data available under Creative Commons Attribution 4.0.
- ES012_LY084_Location_Of_**Coastal_Tourism_Infrastructure_Accommodation** – Data provided by Failte Ireland in 2018.
- ES012_LY085_Location_Of_**Coastal_Tourism_Infrastructure_Food_and_Drink_Providers** – Data provided by Failte Ireland in 2018.
- ES012_LY086_Location_Of_**Coastal_Tourism_Infrastructure_Arts_Crafts_Souvenirs** – Data provided by Failte Ireland in 2018.

Data layers ES012_LY074 to ES012_LY0082 were clipped to only show elements of the SACs, SPAs, NHAs, pNHAs, MPAs, Geoparks, Biosphere Reserves, Wildfowl Sanctuaries, and Nature Reserves within 2km of the coastline to depict bird and wildlife watching 'on land' (excluding offshore elements). The designations within 2km inshore have not been clipped and show the full extent of the designations' boundary.

The 'All Activities' ES map was created using all 86 data layers.

As the heat maps were generated using three different types of spatial geometry (points, lines and polygons), it was necessary to perform multiple types of analysis and combine the results into one summary dataset. For the points, a kernel density estimation was applied in order to generate a continuous surface extrapolating the density based on the number of points present across the study area. For the lines, a simple line density calculation was performed, which calculates the units of length within set distance of each pixel in the output raster. A weighting was applied to those with relevant attributes (e.g. level of traffic in the Irish Sailing recreational routes), in order to pull out variations in the importance of the features. These two datasets were then normalised to remove any difference in scale between them, and then combined to give a single pixel value for each location. Due to the spatial nature of polygonal data, it is not possible to create a meaningful density map from that type of features. Instead, a heavy transparency (80%) was applied to them and they were overlaid onto the density map. This has the effect of darkening the areas with multiple overlapping polygons to show their prominence, without affecting the accuracy of the overall density map.

Gaps and limitations

The following are general data limitations:

- Spatialisation is challenging because data on the location and intensity of some activities is often lacking. Additionally, some ecosystem services are more easily mapped than other therefore some services may be under-appreciated.
- Temporal change is a key issue when mapping CES – the frequency of an activity, e.g. the seasonality of recreational activities, is not recorded.
- Due to the large study area, the metadata for a significant number of photographs was required which required considerable time to process.

- Automatic tagging in Flickr is prone to error. Incorrectly assigned tags can only be removed by the person who uploaded the photo.
- The photo-sharing community may not be representative of specific social groups: impacted by education, age, user's ability/willingness to correctly geotag the photos.
- Wang *et al*. (2013) showed that Flickr photos have positional errors from tens to hundreds of meters.

The following list identifies more specific limitations and gaps associated with the data layers:

- ES012_LY002_Location_And_Intensity_Of_Recreational_Angling.shp – Data from Fisheries Ireland and Angling Council of Ireland was unavailable and therefore there may be additional recreational angling locations that are not plotted in this data layer.
- ES012_LY003_Location_And_Intensity_Of_Recreational_Angling_ClubsCentresOperatorsSchools.shp – Data from Failte Ireland on angling operators/guides was unavailable and therefore there may be additional recreational angling clubs that are not plotted in this data layer.
- ES012_LY005_Location_And_Intensity_Of_Kitesurfing.shp – Data from Maps.ie was unavailable and therefore there may be additional kitesurfing locations that are not plotted in this data layer.
- ES012_LY006_Location_And_Intensity_Of_Kitesurfing_ClubsCentresOperatorsSchools.shp - Data from Failte Ireland on kitesurfing operators was unavailable and therefore there may be additional kitesurfing clubs/centres that are not plotted in this data layer.
- ES012_LY007_Location_And_Intensity_Of_Windsurfing.shp - Data from Maps.ie was unavailable and therefore there may be additional windsurfing locations that are not plotted in this data layer.
- ES012_LY008_Location_And_Intensity_Of_Windsurfing_ClubsCentresOperatorsSchools.shp - Data from Failte Ireland on windsurfing operators was unavailable and therefore there may be additional windsurfing clubs/centres that are not plotted in this data layer.
- ES012_LY010_Location_And_Intensity_Of_Surfing_ClubsCentresOperatorsSchools.shp - Data from Maps.ie and Magic Seaweed was unavailable and therefore there may be additional surfing locations that are not plotted in this data layer. Data from Failte Ireland on surfing operators was unavailable and therefore there may be additional surfing clubs/centres that are not plotted in this data layer.
- ES012_LY014_Location_And_Intensity_Of_Climbing_Coasteering_Bouldering_Mountaineering_ClubsCentresOperatorsSchools.shp - Data from Maps.ie and UK Climbing was unavailable and therefore there may be additional climbing/coasteering locations that are not plotted in this data layer. Data from Failte Ireland on climbing/coasteering operators was unavailable and therefore there may be additional climbing/coasteering clubs/centres that are not plotted in this data layer.
- ES012_LY016_Location_And_Intensity_Of_Diving_Snorkelling_ClubsCentresOperatorsSchools.shp - Data from Failte Ireland on diving/snorkelling operators was unavailable and therefore there may be additional diving/snorkelling clubs/centres that are not plotted in this data layer.
- ES012_LY018_Location_And_Intensity_Of_Recreational_Drone_Use.shp – No official data source on recreational drone use and therefore only data source available is Flickr data.
- ES012_LY026_Location_And_Intensity_Of_General_Coastal_Tourism_Activities.shp – Data from Failte Ireland on scenic driving routes was unavailable and therefore scenic driving routes are not plotted in this data layer.
- ES012_LY032_Location_And_Intensity_Of_Coastal_Quad_Biking_Scrambling_Flickr_Locations.shp - Data from Failte Ireland on quad biking/scrambling was unavailable and therefore there may be quad biking/scrambling clubs/centres/operators that are not plotted in this data layer. Only data source available is Flickr data.

- ES012_LY034_Location_And_Intensity_Of_Sand_Yachting_Land_Sailing_Land_Yachting - Data from Failte Ireland on sand yachting/land sailing/land yachting was unavailable and therefore there may be additional sand yachting/land sailing/land yachting clubs/centres/operators that are not plotted in this data layer.
- ES012_LY035_Location_And_Intensity_Of_Kite_Buggying_Flickr_Locations.shp - Data from Failte Ireland on kite buggying was unavailable and therefore there may be kite buggying clubs/centres/operators that are not plotted in this data layer. Only data source available is Flickr data.
- ES012_LY038_Location_And_Intensity_Of_Coastal_Recreational_Light_Aircraft_Handgliding_Paragliding_Sites.shp – Data from Irish Powered Paragliding and Hang Gliding Association, the Irish Light Aviation Society and Failte Ireland was unavailable and therefore there may be additional light aircraft, hanggliding and paragliding sites and clubs/centres that are not plotted in this data layer.
- ES012_LY044_Location_And_Intensity_Of_Motor_Power_Boating_ClubsCentresOperatorsSchools.shp – Data from Failte Ireland on motor and power boating was unavailable and therefore there may be additional motor and power boating clubs/centres/schools that are not plotted in this data layer.
- ES012_LY044_Location_And_Intensity_Of_Motorised_Sailing_ClubsCentresOperatorsSchools.shp – Data from Failte Ireland on motorised sailing was unavailable and therefore there may be additional motorised sailing clubs/centres/schools that are not plotted in this data layer.
- ES012_LY048_Location_And_Intensity_Of_Wakeboarding_Waterskiing_Flickr_Locations.shp - Data from Failte Ireland on wakeboarding and waterskiing was unavailable and therefore there may be wakeboarding and waterskiing clubs/centres/operators that are not plotted in this data layer. Only data source available is Flickr data.
- ES012_LY049_Location_And_Intensity_Of_Parascending_Flickr_Locations.shp - Data from Failte Ireland on parascending was unavailable and therefore there may be parascending clubs/centres/operators that are not plotted in this data layer. Only data source available is Flickr data.
- ES012_LY050_Location_And_Intensity_Of_Unmotorised_Sailing_ClubsCentresOperatorsSchools.shp - Data from Failte Ireland on unmotorised sailing was unavailable and therefore there may be additional unmotorised sailing clubs/centres/schools that are not plotted in this data layer.
- ES012_LY055_Location_And_Intensity_Of_Kayaking_ClubsCentresOperatorsSchools.shp - Data from Failte Ireland on kayaking was unavailable and therefore there may be additional kayaking clubs/centres/schools that are not plotted in this data layer.
- ES012_LY0056_Location_And_Intensity_Of_Canadian_Canoeing_ClubsCentresOperatorsSchools.shp - Data from Failte Ireland on canoeing was unavailable and therefore there may be additional canoeing clubs/centres/schools that are not plotted in this data layer.
- ES012_LY058_Location_And_Intensity_Of_Stand_Up_Paddleboarding_ClubsCentresOperatorsSchools.shp - Data from Failte Ireland on SUP was unavailable and therefore there may be additional SUP clubs/centres/schools that are not plotted in this data layer.
- ES012_LY060_Location_And_Intensity_Of_Rowing_Sculling_ClubsCentresOperatorsSchools.shp - Data from Failte Ireland on rowing and sculling was unavailable and therefore there may be additional rowing and sculling clubs/centres/schools that are not plotted in this data layer.
- ES012_LY065_Location_And_Intensity_Of_Dinghy_Dayboat_Small_Keelboat_Sailing_ClubsCentresOperatorsSchools - Data from Failte Ireland on dinghy/dayboat/small keelboat sailing was unavailable and therefore there may be additional dinghy/dayboat/small keelboat sailing clubs/centres/schools that are not plotted in this data layer.
- ES012_LY069_Location_And_Intensity_Of_Personal_Watercraft_Use_ClubsCentresOperatorsSchools.shp - Data from Failte Ireland on personal watercraft was unavailable and therefore there may be additional personal watercraft clubs/centres/schools that are not plotted in this data layer.

- ES012_LY071_Location_And_Intensity_Of_Coastal_Walking_PilgrimPaths.shp – Data identifies the starting point of Pilgrim Paths and not polyline data depicting the routes.
- ES012_LY081_Location_And_Intensity_Of_Wildlife_Bird_Watching_Wildfowling_Wildfowl_Sanctuaries.shp – It is important to note that the point data depicts the known approximate centre of the record and is not indicative of its geographic extent.
- ES012_LY082_Location_And_Intensity_Of_Wildlife_Bird_Watching_Wildfowling_Nature_Reserves.shp - It is important to note that the point data depicts the known approximate centre of the record and is not indicative of its geographic extent.

In addition to the data limitations, there are gaps in the process of assessing recreation and tourism ecosystem service. For example, recreational activity does not necessarily relate to the perceived value of a destination. Everybody has their favourite natural destinations, which may often be places that are relatively free of visitors or in areas of wilderness. This may link to areas of sense of place or of landscape value. These places will not have the value of popular destinations but can contribute more to leisure/ tourism experiences and repeat visits. The same might be true of iconic landscapes, but these might be captured by the geotagged photos.

Future developments

Participatory methods are commonly used in order to capture people's perception on plurality of the CES values (Martin *et al.*, 2016) and are recommended for any future studies on recreation and tourism CES. This approach has also been followed by several studies addressing marine and coastal ecosystems, which demonstrate the multiple values of CES based on interviews and participatory mapping (e.g. Gee & Burkhard, 2010; Klain & Chan, 2012; Brown & Hausner, 2017). Examples of benefits include the generation of trust between policy makers and knowledge holders and strengthening management plans through the inclusion of community held knowledge.

D.1.2 Aesthetic

Aesthetic value from CES is the interaction of people with the environment related to natural beauty based on human perceptions and judgments (Figueroa & Tang, 2015).

Options for mapping

Traditional approaches to mapping aesthetic CES generally include mapping (1) the type of relief; (2) the diversity of landscape; (3) the presence of water bodies; (4) the influence of landmarks; and (5) the influence of negative elements in the landscapes (Peña *et al.*, 2018). In general, the presence of waterbodies and/or landmarks in landscape, a higher diversity of landscapes, and a higher difference in relief were related to a higher aesthetic value. However, the influence of negative elements in the landscapes as wind farms, active quarries, landfills, roads, and railways were related to a lower aesthetic value (Peña *et al.*, 2018). On behalf of Natural England, Dales, Brown and Lusardi's (2014) approach to mapping aesthetic CES involved mapping designated and protected sites including National Parks, AONBs, SSSIs, Local Nature Reserves, National Nature Reserves, Country Parks, World Heritage Sites, Registered Parks and Gardens, RSPB Reserves, Countryside Rights of Way, Coastal Access, Accessible Woodland, and Woodland Trust Sites. Similarly, the study 'Cultural Ecosystem Services delivered by the Water Environment' (LUC, 2013) mapped aesthetic CES by identifying National Scenic Areas, Local Landscape Designations, Heritage Areas, World Heritage Sites, and, Scheduled Monuments.

This type of approach relies on professional judgements about the aesthetic importance of designated landscapes or proxy measures relating to other environmental values (biodiversity, cultural heritage etc.). The disadvantages of relying on these designations include a tendency, until quite recently, for environmental designations to focus on terrestrial environments rather than coastal or marine environments, and the failure to capture evidence on patterns of visitation (people 'voting with their feet') or people's perceptions of aesthetic value.

Mapping the aesthetic value of landscapes has been mainly based on the results of questionnaire surveys (Casado-Arzuaga *et al*., 2013; Peña *et al*., 2015) or interviews on preferences (van Zanten *et al*., 2016) gained by empirical methods, and by participatory approaches combined with environmental factors that represent attractiveness such as naturalness (Crossman *et al*., 2013; de Vries *et al*., 2007). However, such surveys are often costly and time-consuming. In recent years, several studies have adopted an alternative indicator for preferences on landscape/seascape aesthetics to overcome the limitations of traditional approaches for evaluating aesthetic value. Social media databases of geotagged photos that have been uploaded to crowdsourcing photo repositories (e.g. Flickr) have been used to understand socio-cultural usages of landscapes (Gliozzo *et al*., 2016; and, van Zanten *et al*., 2016).

Langemeyer, Calcagni and Baro (2018) used Flickr as a data source to identify landscape aesthetics rather than other photo-sharing platforms as, although Panoramio and Instagram provide a similar coverage (van Zanten *et al*, 2016b) and could be valid sources, Instagram restricts research availability and Panoramio ceased operation after 2016. Flickr data is also the main data source for previous CES assessments (Dunkel, 2015; Gliozzo *et al*., 2016; Tenerelli *et al*., 2016; Yoshimura & Hiura, 2017).

Lee *et al*. (2019a) identified that previous studies using geotagged photos in CES analyses can be grouped into three categories.

- The first group focuses on the spatial and temporal information of photos (Casalegno *et al*., 2013; Gliozzo *et al*., 2016; Tieskens *et al*., 2017). The focus of these studies has been on the location and the users by whom the photos were taken and uploaded.
- A second group of the studies aims at relating landscape context and biophysical settings with the locations of geotagged photos (Pastur *et al*., 2016; Tenerelli *et al*., 2016; van Zanten *et al*., 2016; Oteros-Rozas *et al*., 2017). Pastur *et al*. (2016), for example, related the location of the photos representing the aesthetic value of the landscape of Southern Patagonia to biophysical characteristics such as the presence of water bodies and vegetation types.
- A third group analyses the content of the photos. The focus of the analysis has been not only on the spatial and temporal information of the photos but also on the thematic information such as 'what' users have taken and uploaded (Di Minin *et al*., 2015).

Langemeyer, Calcagni and Baro (2018) used Flickr photos for the landscape aesthetic assessment and hypothesised that people who take photos of landscapes (and upload them to the Flickr platform) consider those landscapes to be aesthetically pleasing. In other words, the landscape photo location is assumed to meet the photographer's aesthetic preferences (Langemeyer, Calcagni & Baro, 2018). For this study, photograph metadata was downloaded from Flickr through a publicly available Application Programming Interface (API). Apart from the photo's geographical references (a geotag describing latitude and longitude), other metadata added by users was also obtained (e.g. photo tag and descriptions, pictured date). As the Flicker API returns data on a maximum of 250 geotagged photographs within a given bounding box, Retka *et al*. (2019) divided their study area (a Marine Protected Area) into 1 km^2 cell grids and the bounding box of each cell was used for sampling. In this study, spatial analysis involved estimating the density of photographs within the study area using the point density tool in ArcMap and mapping the total number of photographs per square kilometre. Due to the small number of photographs in the study area, the content of each photograph was visualised, analysed and classified using an objective coding approach based on previous studies of CES (Richards & Friess, 2015).

Since the manual labelling of photos is a labour-intensive task, it is only applicable for a relatively small number of photos (Di Minin *et al*., 2015). Lee *et al*. (2019a) suggested a new approach allowing the interpretation of large volumes of photos based on their content within a feasible time frame using automated tags. Tagging allows users to manage and to share their online resources through keywords (Cattuto *et al*., 2007; Anderson *et al*., 2008; Tisselli, 2010). While Flickr provides users with tag suggestions, tagging is not mandatory and strictly guided in Flickr, thus often leading to photos with no user-provided tags (Sigurbjornsson & van Zwol, 2008; Tisselli, 2010). Different languages used in tagging is another source of data inconsistency. Lee *et al*. (2019a) sought to overcome some of these difficulties by using an image annotation engine developed by Clarifai which uses machine-learning to recognise visual patterns of images and assigns tags automatically. Another option would be to use the automatic tag suggestion algorithm provided by Flickr. Lee at al. (2019b) decided to use the well-specified image annotation algorithm provided by Clarifai as, at the time of their analysis, no sufficient information on the image recognition algorithm used by Flickr was provided. According to Lee *et al*. (2019a), by using the tags provided from Flickr, 20.2% of the photos would have been ignored because the users did not add tags to their photos. Furthermore, the unrestricted and non-standard characteristics of Flickr tagging potentially hinders interpretation of tags (Anderson *et al*., 2008; Tisselli, 2010). Therefore, Lee *et al*. (2019a) used a pre-trained model (general-v1.3) provided by Clarifai to assign 20 tags per photo together with the associated probability of each tag. However, the study concluded that during their manual validation of tags, 19.6% of automatic tags were incorrect.

To identify themes of photos, Lee *et al*. (2019a) investigated networks of assigned tags based on tag occurrence assuming that photos with similar themes share similar semantic tags. Tag co-occurrence is therefore regarded as an indicator to determine the contents of the photos and allows for the development of CES clusters such as “aesthetics” or “existence”. The “aesthetics” cluster included tags representing scenery, whereas the “existence” cluster included tags for specific species such as “butterflies” or “flowers”. Figueroa and Tang (2015) identified tags to capture aesthetic CES including “nature”, “wildlife”, “coast”, “scenic”, “landscapes”, “landmark”, and “wilderness”. In total, Lee *et al*. (2019a) identified nine clusters consisting of CES (aesthetic and existence) and non-CES activities in their study and therefore the approach of geotagging photos could be applied for other CES such as recreation. However, it is noted in the study that photo taking is limited in some recreation activities and also other types of CES such as religious activities.

Lee *et al*. (2019a) also calculated photo-user-days as the total annual days that a photographer took at least one photo within a cell in the study area (Sharp *et al*., 2016). By using the photo-user-days instead of the total number of photos, one avoids a bias caused by an exceptionally high number of photos by a single photographer in a single day. Thus, this metric gives a good indication of the number of visitors to the area (Wood *et al*., 2013) in the study region during the analysed time period. Despite the limitations of using geotagged photos, such as a biased user population and behaviour (Yoshimura & Hiura, 2017), previous studies using geotagged photos from the Flickr database have shown that the visitation rate extracted from Flickr photos and user information matched well with the one calculated from the empirical visitor data (Ruths & Pfeffer, 2014; Sonter *et al*., 2016). This highlights the reliability of the indicator to assess the demand for landscape/seascape aesthetics.

Kopperoinen *et al*. (2017) identified that geotagged photographs, which can be used to locate aesthetically attractive areas and derive frequentation rates, can be combined with biophysical and built-up characteristics of the landscape to allow for analysis of complex visual landscapes which are perceived by beneficiaries at specific locations. In open areas, as scenic beauty is especially related to panoramic view, photographs capturing panoramas can therefore be used as spatially explicit data of actual service provision. This data can be related with biophysical factors of the landscapes seen from the respective viewpoints. The visible area and the respective visual indicators can be calculated for each theoretic viewshed, derived from a Digital Elevation Model, corresponding to the photograph location. The viewshed is thus considered as a Service Providing Area from the perspective of the beneficiary (a spatial unit within which a CES is provided) (Kopperoinen *et al*., 2017). To further evaluate the spatial information of the Flickr-photo-based indicator, Kopperoinen *et al*. (2017) compared the distribution of photos with six different components of the landscape (i.e. depth, relief, landcover, landform, geology and habitat) while Lee *et al*. (2019a) used aggregated information on the location of special protection areas, special areas of conservation, nature reserves, protected landscapes and nature conservation parks. The use of viewsheds is more appropriate for smaller, more discrete areas, rather than for large geographical areas.

Content analysis of crowdsourced photos has a high potential to improve our understanding of the socio-cultural usage of the landscape (Lee *et al*, 2019a). Despite this high potential, concerns remain regarding the representativeness of populations who uploaded photos in social media databases (Ruths & Pfeffer, 2014). However, given the limitations of geotagged real-time data collection within a limited time at a large scale (e.g., surveys and interviews) (Ford *et al*., 2016), the use of photo repositories offers an important opportunity to derive additional information on CES hotspots and detailed contents of those hotspots.

Norton *et al*. (2018) used a proxy for valuing aesthetic ecosystem services based on estimating the proportion of house values attributable to being located near the coast. For house prices, Daft.ie prices (Daft, 2012) were used, which detail house price by urban and rural markets and by number of bedrooms in a house for the year 2012. This represents a proxy of the value of the aesthetic view but does not include the total economic value of aesthetics, as it measures only the value of living near the coast and does not take into account the economic value of an aesthetic view from visitors to the coast. Furthermore, assigning monetary value to such services is challenging and there is potential for double counting with other recreational measures.

Method

The method to map aesthetic CES used geotagged photos uploaded to Flickr photo as a data source to identify landscape aesthetics. The photos' metadata was accessed through the publicly-available Application Programming Interface (API). Similar to the method adopted by Figueroa and Tang (2015), tags to capture aesthetic CES will include "nature", "wildlife", "coast", "scenic", "seascapes", "waves", "sand", "shoreline", "Atlantic", "sea", "ocean", "rugged", "beach", "cliff", "landmark", "sunset", "sunrise" and "wilderness". Rather than using an image annotation engine (e.g. Clarifai) which uses machine-learning to recognise visual patterns of images and assigns tags automatically (Lee *et al*., 2019a), our approach used the automatic tag suggestion algorithm provided by Flickr. A 2 km buffer zone was used to capture photographs that are relevant to the coastal environment. The density of photographs within this area was analysed using the point density tool in ArcMap and the total number of photographs per square kilometre was mapped.

The study also builds upon the more traditional approaches (Peña *et al*., 2018; Dales *et al*., 2014; and LUC, 2013) and mapped designated and protected areas, as well as scenic viewpoints, scenic driving/touring routes, scenic coastal towns and villages, scenic mountains, and the peninsulas and islands as areas likely to be of high aesthetic value.

Data availability

Several data layers are available on the MI Atlas that are relevant to mapping aesthetic CES:

- Special Areas of Conservation;
- Special Protection Areas;
- Natural Heritage Areas;
- Sites of Special Scientific Interest;
- Proposed Natural Heritage Areas.

Several data layers are being produced as part of Project 2 which are of relevance to mapping aesthetic CES:

- Ramsar Site Boundaries
- World Heritage Sites
- Nature Reserves
- UNESCO Global Geoparks
- National Parks
- Biosphere Reserves
- Ancient and Long-Established Woodland
- Special Amenity Order areas
- Local nature and landscape designations for coastal counties
- Irish Heritage Towns
- Terrestrial heritage assets
- Green Coast/Blue Flag beaches and 'Beaches' in Failte Ireland data
- Wild Atlantic Way
- Coastal touring/scenic routes ('Discovery Points' and 'Signature Points' in Failte Ireland data; 'Viewing Areas' and 'Scenic Areas' in Osi data; scenic touring routes in Failte Ireland data.)
- Scenic mountain trails[7] (Slieve Foy [Louth]; Diamond Hill Loop [Galway]; Torc Mountain [Kerry]; Mount Brandon [Kerry]; Slieve League [Donegal]; Croaghaun [Mayo]; Benbulbin [Sligo]; Mount Errigal [Donegal]; Croagh Patrick [Mayo])
- Scenic coastal towns and villages[8] (Kinsale [Cork]; Valentia [Kerry]; Strandhill [Sligo]; Carlingford [Louth]; Gweedore [Donegal]; Westport [Mayo]; Skerries [Dublin]; Tramore [Waterford]; Rosslare [Wexford]; Youghal [Cork]; Lahinch [Clare]; Enniscrone [Sligo]; Ballybunion [Kerry]; Donegal Town [Donegal]; Bundoran [Donegal]; Clonakilty [Cork]; Clifden [Galway]; Dungarven [Waterford]; Curracloe [Wexford]; Dingle [Kerry]; Brittas Bay [Wicklow]; Malahide [Dublin]; Roundstone [Galway]; Howth [Dublin]; Dunmore East [Waterford]; Ballyvaughan [Clare]; Portmagee [Kerry]; Arthurstown [Wexford]; Caherdaniel [Kerry]; Eyeries, Beara Peninsula [Cork]; Ardara [Donegal]; Cobh [Cork]; Dalkey [Dublin]; Kenmare [Kerry]).
- Peninsulas and islands - Cape Clear [Cork]; Arran Islands [Galway]; Inishturk Island [Mayo]; Holy Island [Clare]; The Skellig Islands [Kerry]; Arranmore [Donegal]; Sherkin Island [Cork]; Tory Island [Donegal]; Clare Island [Mayo]; Great Blasket Island [Kerry]; Spike Island [Cork]; Bere Island [Cork]; Dursey Island [Cork]; Achill Island [Mayo]; Beara Peninsula [Cork]; Dingle Peninsula [Kerry]; Iveragh Peninsula [Kerry]; Corraun Peninsula [Mayo]; Mullet Peninsula [Mayo]; Sheeps's Head [Cork]; Mizen Head [Cork]; Fanad Peninsula [Donegal]; Horn Head {Donegal]; Muckross Head [Donegal]; Inishowen [Donegal]; Isle of Doagh [Donegal]; Rosguill [Donegal]; Cooley Peninsula [Louth]; Hook Peninsula [Wexford]).

Flickr data is publicly available through the Application Programming Interface (API).

Gaps and limitations

- Creating viewsheds for each photograph to identify the photographed sites rather than mapping the density of photos by using the photography positions would yield more robust results, however, due to the scale of the study area and the number of viewsheds that would need to be created for each photograph this is not a feasible approach for this study.

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7 Top 10 scenic mountain trails of Ireland https://www.irelandbeforeyoudie.com/top-10-scenic-mountain-trails-ireland/

8 Top 10 most beautiful seaside towns in Ireland: https://www.irelandbeforeyoudie.com/top-10-most-beautiful-seaside-towns-in-ireland/ Ireland's top seaside towns, villages and beaches https://www.irishcentral.com/travel/best-of-ireland/ireland-seaside-vacation-villages-beaches The 19 prettiest villages and small towns in Ireland 2019 https://www.skyscanner.ie/news/inspiration/10-of-the-most-beautiful-historic-villages-in-ireland The 20 most charming towns in Ireland https://www.travelmag.com/articles/most-charming-towns-ireland/

- Automatic tagging in Flickr is prone to error. Incorrectly assigned tags can only be removed by the person who uploaded the photo.
- The photo-sharing community may not be representative of specific social groups: impacted by education, age, user's ability/willingness to correctly geotag the photos.
- Wang *et al*. (2013) showed that Flickr photos have positional errors from tens to hundreds of meters.

Future developments

Future studies may capture the aesthetic value of the coastal environment by creating viewsheds for photographs to identify aesthetically attractive photographed sites.

D.1.3 Scientific and Educational

The CICES provides examples of educational and scientific cultural ecosystem services:

- *Educational* – Specifically formal and informal education, including school nature walks and observation, woodland schools and other outdoor classroom activities. Nature as a location for education.
- *Scientific* – Subject matter for research both on location and via other media.

Options for mapping

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 (Norton *et al*., 2018). The State also has purpose-built research vessels:

- The RV Celtic Explorer which is a 65.5 m multipurpose research vessel suitable for fisheries acoustic research, oceanographic, hydrographic and geological research; and,
- The smaller RV Celtic Voyager which is 31.4 m 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 Integrated Mapping for the Sustainable Development of Ireland's Marine Resource (INFOMAR) (Norton *et al*., 2018). 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 (located 4.5 km east of Spiddal, Galway, approximately 1.5 km offshore and in water depths of 23 m; SmartBay Ireland also manages Ireland's ¼ scale marine test site which is within the confines of Galway Bay). The INFOMAR programme is a joint venture between the Marine Institute and Geological Survey of Ireland that is aimed at mapping the remaining un-surveyed coastal and continental shelf areas in Ireland's Exclusive Economic Zone (EEZ) (200 nautical miles from the State's coastline). 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) identified six fully marine undergraduate courses, two 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 four fully marine postgraduate courses, two 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) 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 seagoing 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.

Aalders and Stanik (2016) identified that scientific and educational CES are difficult to distinguish as those areas that have scientific interest often also provide an educational role. They also highlighted the difficulty in identifying clear education roles without duplication with those provided by, for example, visitor centres in National Parks that provide physical interaction with ecosystems. Aalders and Stanik (2016) list available data sources which are linked to CICES classes based on interpretation of current literature. For scientific and educational CES, the following data sources were identified: designated areas; geological reserves; RSPB nature reserves; visits to woodlands; and, World Heritage Sites. Kenter *et al*. (2014) identified that locally important nature and landscapes are important indicators for educational CES. Plieninger *et al*. (2013) identified educational values of a Biosphere Reserve as areas which widen knowledge about plant and animal species. They identified that waterbodies and forests were 'hotspots' for delivering educational CES.

Retka *et al*. (2019) mapped geotagged photographs for various CES categories and, while most CES categories were represented, no photographs depicting educational engagements or scientific research were identified (i.e. photographs showing research or education activities or equipment). Therefore, this approach is not proposed for mapping educational or scientific CES.

Method

The proposed method to mapping scientific and educational CES built upon the method used by Aalders and Stanik (2016) and mapped designated areas (UNESCO World Heritage Sites; UNESCO Global Geoparks; Natural Heritage Areas; Special Areas of Conservation; Special Protection Areas; Wildfowl Sanctuaries; OSPAR Marine Protected Areas; National Parks; Biosphere Reserves; and, Nature Reserves); local nature and landscape designations (Kenter *et al*. 2014); and, woodlands/forests (Plieninger *et al*. 2013). A 2 km buffer zone was used to capture designated areas and woodlands/forests that are influenced by the coastal environment. For those areas that overlapped the 2km buffer, the whole area was included in the map.

In line with the examples provided by CICES, the National Parks and Wildlife Service Education Centres near the coast, as well as the Open Data on Maritime Collections and coastal museums, were mapped as indicators of educational CES.

Based on Norton *et al*. (2018) valuation of the marine scientific, education and training sector in Ireland, the various education institutions offering courses relating to the marine environment were mapped: marine training centres (e.g. the Irish Sailing Association training centres); marine research centres and laboratories; marine research stations and test facility locations; the INFOMAR surveyed seabed; research vessels observation/measurement points;, research vessels cruise stations; and, research vessels weather stations.

Data availability

Several data layers are available on the MI Atlas that are relevant to mapping scientific and educational CES:

- Special Areas of Conservation;
- Special Protection Areas;
- Sites of Special Scientific Interest;
- Ramsar Sites;
- Natural Heritage Areas;
- Proposed Natural Heritage Areas.

Several data layers are being produced as part of Project 2 which are of relevance to mapping scientific and educational CES:

- UNESCO World Heritage Sites.
- UNESCO Global Geoparks.
- Wildfowl Sanctuaries.
- OSPAR Marine Protected Areas.
- National Parks.
- Nature Reserves.
- Biosphere Reserves.
- Locally designated nature and landscape areas.
- Museums, collections and archives.
- Maritime collections.

In addition, several layers were produced to indicate scientific and educational CES in Ireland:

- Marine Institute (Galway); Irish Maritime Development Office (Dublin); MI Catchment Research Facility (Mayo); Bord Iascaigh Mhara (offices in Dun Laoghaire, Clonakilty, Killybegs, Galway).
- Research Centres - MaREI – Centre for Marine and Renewable Energy (University College Cork); The Ryan Institute (NUI Galway); GMIT (Marine and Freshwater Research Centre).
- Education institutions offering courses relating to the marine environment: National Maritime College of Ireland (Cork); University College Cork (Cork); Cork Institute of Technology (Cork); NUI Galway (Galway); Galway Mayo Institute of Technology (Galway); Galway Mayo Institute of Technology (Mayo); Dublin Institute of Technology (Dublin); National Fisheries College of Ireland (Donegal); National Fisheries College of Ireland (Cork); Institute of Chartered Shipbrokers Ireland (Dublin); Strategic Marine Alliance for Research and Training (Smart) (Galway).
- Marine research stations and test facility locations – SmartBay (Galway); Carna Research Station (Galway); Sherkin Island Marine Station (Cork); Mace Head Atmospheric Research Station (Galway); Bantry Marine Research Station (Cork); Abbotstown Laboratory Complex (Dublin).
- INFOMAR Surveyed Areas (represent where the Celtic Explorer and Celtic Voyager research vessels have mapped the seabed).
- Celtic Voyager observation/measurement points; Celtic Voyager cruise stations; Celtic Voyager weather stations; Celtic Explorer observation/measurement points; Celtic Explorer cruise stations; Celtic Explorer weather stations; Deepwater survey stations.
- Irish Sailing Association training centres.

- National Parks and Wildlife Service Education Centres (near the coast): (Ballycroy National Park Education Centre (Mayo); Connemara National Park Education Centre (Galway); Wexford Wildfowl Reserve Education Centre (Wexford).
- Eco-UNESCO clubs near the coast that teach and run activities to protect and enhance the marine environment.
- Greenschools near the coast that offer training to primary and secondary schools on protecting and enhancing the marine environment.

Gaps and limitations

For the purposes of the study it is assumed that all designated areas will provide scientific and educational CES and that Eco-UNESCO clubs and Greenschools near the coast will offer training and run activities on protecting and enhancing the marine environment, which may not be the case and cannot be verified.

Data on Eco-UNESCO clubs, and Greenschools near the coast are not available and as such do not capture the full service of educational CES in coastal environments.

Future developments

The citizen science project 'Capturing Our Coast' in the UK trained almost 3,000 members of the public nationwide to carry out transect surveys of marine species on UK rocky shores. A similar project in Ireland could be undertaken in the future to develop participants' understanding of the marine environment as well as encouraging participants' interest in science, which would further contribute towards our knowledge of educational and scientific CES.

D.1.4 Cultural heritage

Cultural heritage value from CES can take two principal forms: that of the intrinsic and associated cultural importance of heritage assets themselves (hereinafter 'cultural significance'); and, the experiential values (aesthetic, recreational, spiritual etc.) derived with people's visits to and interactions with heritage assets. The latter are more effectively and appropriately – in this context – considered in the round with wider aesthetic, recreational and spiritual benefits, and are not considered further for cultural heritage.

The concept of cultural significance, agreed internationally in 1979 through the Burra Charter and periodically refreshed, is broadly taken to refer to the architectural, historical, associative, communal or evidential value derived from a place or asset for past, present and future generations. This significance is embodied in the place itself, its fabric, setting, use, associations, meaning, records, related places, objects and works of art (Australia ICOMOS, 2013).

Options for mapping

It is widely recognised that, since the adoption of the ES approach of the Millennium Ecosystem Assessment (MEA, 2005), while cultural ecosystem services have been accepted as one pillar of the Common International Classification of Ecosystem Services (CICES) (Haines-Young & Potschin, 2013), the levels of understanding of CES in general and cultural heritage in particular has lagged significantly behind (La Rosa *et al.*, 2016; Stanik *et al.*, 2019). Nevertheless, the need to develop indicators that can be objectively assessed is critical to the ability to understand the spatial distribution, value and relative importance of cultural heritage at a range of scales (Hernández-Morcillo *et al.*, 2013).

The development of indicators for cultural heritage within the CES context requires an understanding of how cultural heritage values arise in a distinct spatial context (Scholte *et al*., 2015). Cultural heritage consists primarily of specific features in the physical landscape associated with cultural meanings and related to histories of human use (MEA, 2005; UNESCO, 2017).

For the vast majority of countries, including Ireland, point-based GIS data is the sole representation of cultural heritage assets. This means that, in general, heritage assets regardless of their size and complexity are depicted by a single dot of a consistent size. Cultural heritage CES has therefore been widely assessed using the number of recognisably 'historic' places, sites or monuments (e.g. castles, churches, forts or other heritage assets) recorded in such datasets as a single proxy for complex historic values of a whole landscape (Bieling and Plieninger, 2013). It is therefore important to recognise the limitations in a 'point data-based' view of cultural heritage, which ensue from the geographical distribution of either spatially dispersed or clustered historic elements (Tengberg *et al*., 2012).

More recent approaches have recognised the inherent connection between heritage assets and the wider landscape, and the indivisibility of the CES delivered by both. However, the ability to assess the cultural value and 'richness' of landscapes is dependent on the availability of good quality, systematic and complete coverage historic landscape characterisation (HLC) information. While such an approach has been piloted in Scotland (Stanik *et al*., 2019), this is possibly only because of national Historic Land-use Assessment dataset produced by Historic Environment Scotland and associated publications (Watson & Dixon, 2018; HES, 2019). Limited HLC work has been undertaken in Ireland, but the lack of consistent national coverage prevents the application of such a landscape-focused approach (Lambrick, Hind & Wain, 2013).

Arguably however, in the context of marine planning this is potentially less significant. The heritage assets in question for this study are principally within the marine environment and are not, therefore, as closely linked to either their landscape setting as terrestrial assets, being mainly shipwrecks. While this may play a role with regard to the formation processes of the asset – for example, a ship being driven against rocks during a storm – it is not a deliberate design- or symbolism-driven relationship and is therefore far less strongly related to its cultural significance.

In terms of placing a value on individual heritage assets, this has generally followed the approach of assigning greater cultural value to designated/protected assets – in recognition of their appraisal by experts against a (nationally) agreed suite of metrics to warrant legal protection (e.g. Albert *et al*., 2016; Aalders & Stanik, 2016). While other approaches could be considered and may assist in understanding how people relate to heritage assets for example, the geo-tagged photography approach (e.g. Casado-Arzuaga *et al*., 2013; Langmeyer *et al*., 2018), this is considered to relate to experiential and recreational value than 'communal value' (in heritage terms) or a meaningful reflection of cultural significance. For example, the potential for easily-accessible and promoted/managed assets to skew perceptions of value based on accessibility, rather than a true reflection of cultural importance. An example that cautions against such an approach is embodied in Gliozzo *et al*. (2016), where the findings in relation to cultural heritage are considered to be somewhat illusory for these reasons.

Based on the available data and tried-and-trusted methods of assessing cultural heritage value, the option proposed below is held to be robust.

Method

The approach draws on data produced by a number of stakeholders that depicts both the location and relative value of Ireland's heritage assets.

The method assigned a value rating (International>National>Regional>Local) importance to heritage asset data, based on their level of recognition within Ireland's statutory heritage protection framework (Table D3). For wreck sites, there is inevitably a greater degree of uncertainty where the identity or location of vessels is less well-established. Nevertheless, a precautionary approach was applied, based on the assumption that all wreck sites have historical and evidential value. Those with more closely-understood histories and associations (for example, World War I and II combat losses, or relatively recent wrecks of local vessels) were afforded a greater degree of importance.

Table D3. Assigned value rating for Cultural Heritage ES

	Very High	High	Medium	Low
World Heritage Sites	X			
Tentative World Heritage Sites	X			
Wreck Extents - Classification - Unknown				X
Wreck Extents – Classification – Wreck/Object				X
Wreck Extents – Vessel Type – Anti-Aircraft Cruiser; Armed Auxiliary Cruiser; Armed Merchant Cruiser; Cargo Vessel; Battleship; Cruiser; Gun Frigate; Ocean Liner; Passenger Liner; Passenger Ship; Poss. Armada Ship; Submarine; Submarine (deadlight); Submarine (possibly); Submarine (Type VII)		X		
Wreck Extents – Vessel Type – All others			X	
Wreck Extents – Classification – Admiralty/Decoy Ship; Airplane; Anti-Submarine Drifter; Battleship; Corvette; Cruiser; Destroyer; Dreadnought; East Indiaman; Frigate; Galleon; Ironclad Battleship; Liner; Logboat; Man O' War; Mine-sweeper; Screw Gunboat; Submarine		X		
Wreck Extents – Classification – All others			X	
National Monuments		X		
National Monuments Zones of Notification		X		
National Inventory of Architectural Heritage		X		
Archaeological Survey of Ireland			X	
Heritage Towns of Ireland			X	
Walled Towns of Ireland		X		
Irish Historic Town Atlas		X		
OPW National Heritage Sites		X		
Atlas of Hillforts			X	
Local Authority Conservation Areas		X		
Local Authority Records of Protected Structures		X		
Sheela Na Gigs		X		

This enabled the generation of data layers depicting the location of cultural heritage CES and their relative value.

Data availability

Data layers available on the MI Atlas relevant to mapping cultural heritage CES are:

- INFOMAR Surveyed Shipwrecks.

Several data layers are being produced as part of Project 2 which are of relevance to mapping cultural heritage CES:

- UNESCO World Heritage Sites.
- UNESCO World Heritage Site buffer zones.
- National Monuments Service: wreck extents.
- National Monuments Service: National Monuments.
- National Monuments Service: zones of notification.
- National Monuments Service: National Inventory of Architectural Heritage.
- Archaeological Survey of Ireland: Record of Monuments and Places.
- Archaeological Survey of Ireland: Record of Protected Structures.
- Heritage Council: Irish Historic Towns Atlas.
- Heritage Council: Atlas of Hillforts.
- Heritage Council: Architectural Conservation Areas.
- National Museum of Ireland: Finds database (for context only).

Gaps and limitations

There is currently no usable data available on the following:

- submerged palaeolandscapes;
- littoral and intertidal archaeology;
- historic landscapes / historic landscape character; and,
- aerial photography and other remote sensing techniques.

Data are inherently proxy, in that it depicts the asset location rather than the extent of CES delivery/benefit. This is not considered to be a significant issue and is well-understood from a range of previous studies.

The following list identifies more specific limitations and gaps associated with the data layers:

- ES015_LY002_World_Heritage_Sites_Tentative.shp – Point not polygon data used which does not reflect the spatial extent of the Tentative WHS boundaries.
- ES015_LY003_Wreck_Extents.shp – Only a small proportion of records on the NMS Wreck Viewer have coordinate data. Therefore, only 3,802 out of 17,000 records are plotted in this data layer.
- ES015_LY004_Terrestrial_Heritage_Extents_ NationalMonuments.shp - It is important to note that the point data depicts the known approximate centre of the record and is not indicative of its geographic extent.
- ES015_LY005_Terrestrial_Heritage_Extents_NationalMonuments_ZonesOfNotification.shp – The zones do not define the exact extent of the monuments but rather are intended to identify them for the purposes of notification under Section 12 of the National Monuments Act (1930-2004): each is referred to as a "zone of notification".
- ES015_LY006_Terrestrial_Heritage_Extents_NationalInventoryOfArchitecturalHeritage.shp - It is important to note that the point data depicts the known approximate centre of the record and is not indicative of its geographic extent.
- ES015_LY007_Terrestrial_Heritage_Extents_Archaeological_Survey_Of_Ireland.shp - It is important to note that the point data depicts the known approximate centre of the record and is not indicative of its geographic extent.
- ES015_LY008_Terrestrial_Heritage_Extents_HeritageTownsofIreland.shp - It is important to note that the point data depicts a central point within each featured town.
- ES015_LY009_Terrestrial_Heritage_Extents_WalledTownsofIreland.shp - It is important to note that the point data depicts a central point within each featured town.

- ES015_LY010_Terrestrial_Heritage_Extents_Irish_Historic_Town_Atlas.shp - It is important to note that the point data depicts a central point within each featured town.
- ES015_LY011_Terrestrial_Heritage_Extents_OPW_National_Heritage_Sites.shp - It is important to note that the point data depicts the known approximate centre of the record and is not indicative of its geographic extent.
- ES015_LY012_Terrestrial_Heritage_Extents_Atlas_Of_Hillforts.shp - The data presented in the atlas is a snapshot taken between 2012 and October 2016 and at the moment there is no provision for updating.
- ES015_LY014_Terrestrial_Heritage_Extents_Architecture_Conservation_Areas.shp – Only data from Galway City Council, Galway County Council, Wicklow County Council, Limerick City and County Council, Louth County Council, and Clare County Council was received. Data is missing for Donegal, Wexford, Sligo, Waterford, Mayo, Dublin City, Dublin – Fingal, Dublin – Dun Laoghaire, Leitrim, Meath, and Kilkenny.
- ES015_LY015_Terrestrial_Heritage_Extents_Record_Of_Protected_Structures.shp – Only data from Leitrim County Council, Wicklow County Council, Galway City Council, Galway County Council, Louth County Council, Limerick City and County Council, Clare County Council, and Sligo County Council was received. Data is missing for Donegal, Wexford, Waterford, Mayo, Dublin City, Dublin – Fingal, Dublin – Dun Laoghaire, Meath, and Kilkenny.

Future developments

- The future availability of information on submerged palaeolandscapes (underway as part of an international project in which MI is a key partner) is likely to transform the understanding of the cultural heritage and importance of the Irish Sea basin.
- As HLC is rolled out across Ireland, ensuring national consistency of approach will be imperative to enable a stronger landscape focus in future iterations of CES mapping.

D.1.5 Spiritual and Symbolic

The CICES provides examples of symbolic and spiritual cultural ecosystem services:

- *Spiritual* - Specifically relates to areas that are largely or primarily of interest due to spiritual / religious associations, including holy places, sacred sites, religious monuments and trails.
- *Symbolic* - Sense of place, place identity.

Options for mapping

Very few studies have focused on mapping the demand, supply or the flow of benefits from intangible services. Based on the examples provided in the CICES, there are three main facets associated with delivering ‘spiritual and symbolic’ CES: spiritual, religious, and sense of place.

In the context of mapping ‘spiritual’ ecosystem services, it is important to note that, although religion and spirituality are two separate themes, both will be considered in this project. Religious experiences may be linked to specific places, typically churches, cathedrals, cemeteries, religious monuments and trails (Winter & Gasson, 1996), and some of these form a bridge between Christian and pagan beliefs. Religious elements vary in size and importance, from sacred stones to large landscape features such as mountains which are recognised for their connections to religion (for example Croagh Patrick in Co. Mayo) (Aspinall *et al.*, 2011). Pilgrimage routes offer opportunities for an experience of landscape that is marked out by religious elements such as holy wells and churchyards, while also offering opportunities for special-interest tourism (Aspinall *et al.*, 2011).

More frequently, spirituality as a cultural ecosystem service is associated with local places and landscapes through human attachment to place (Brown & Raymond, 2007). Pike *et al*. (2011) identified spirituality as encompassing many elements which included tranquillity, relaxation, the experience of nature, beaches and coastal towns as part of a recreational experience, and peacefulness. Pike *et al*. (2011) undertook interviews with Marine Protected Area (MPA) practitioners and visitors to MPAs. The study identified that spirituality is not highly recognised and was thus assigned the lowest value compared to other ecosystem services valued as part of the study. The research emphasised the 'sense of place' and emotive connection people have with the coast which is principally focused on the coast, coastal views and landscape, and not specifically on marine elements.

Natural England (2009) undertook a study on the cultural services and experiential qualities that landscapes provide to society in the UK. The research was aimed at understanding whether cultural ecosystem services including, for example, spiritual enrichment, correlate to particular landscape characteristics or particular landscape features. The use of land cover as a proxy indicator for the presence of various ecosystem services is a common technique used in ecosystem valuation (e.g. Naidoo *et al*., 2008; and Troy & Wilson, 2006). The study focused on eight cultural services, including spiritual values; sense of place; relaxation/tranquillity/peace and quiet; and escapism. The study found that the presence of water, including still lakes or slow-moving streams and rivers, deliver many of the cultural benefits, including calm/tranquillity, escapism and spiritual feelings. The coast, as a key facet of an island nation, provides a sense of place as well as being important for tranquillity/spirituality/escapism. Woodlands were also identified as delivering many cultural services, being most important for calmness/tranquillity/peace/spiritualism (mainly broadleaved). Escapism was also thought to be high in woodland areas. Moorlands were also identified as important for spiritualism, escapism and providing a sense of place. Villages were identified as places providing a sense of place and important for escapism/calmness but had less of a capacity to be spiritual. The table below identifies the different landscape features delivering spiritual, sense of place, calmness and escapism services.

Table D4. The delivery of cultural services by different landscape features

Feature	Sense of Place	Calmness	Spiritual	Escapism
Water, rivers, streams	Medium	High	High	High
Bogs and marshes			Low	
Coast	High	Medium	High	High
Mountains and hills	Low	Medium	High	High
Moorland	High	Low	High	High
Grassland			Low	
Woodland and trees	Medium	High	High	High
Field systems	High	High	Low	High
Hedges, walls and lanes	High	High	Medium	
Villages	High	Medium	Low	Medium

Pike *et al*. (2011) indirectly identified as spiritual the 'outdoors experience' which takes people out of their homes and offices and *"away from modern life"* allowing them to connect with nature. Similarly, Habron (1999) identified that people associate spirituality with notions of wilderness. The Scottish Natural Heritage (SNH) identified 42 'Wild Land Areas' (WLA) in 2014 following a detailed analysis of where wildness can be found across all of Scotland's landscapes (SNH, 2014). WLAs have the following physical attributes (only relevant attributes to ES mapping of spiritual services from the WLAs are identified):

- A high degree of perceived naturalness – Different land classes identified in the Land Cover Map 2007, the Native Woodland Survey of Scotland and the National Forest Inventory datasets were analysed at 25 m cell resolution with each land class assigned a 'naturalness score' from 1 (low perceived naturalness) to 5 (high perceived naturalness).
- The lack of modern human artefacts or structures – The theoretical visibility of buildings and structures such as roads, railways, pylons, masts and wind turbines, was established using a voxel viewshed analysis using OS Mastermap together with a Digital Surface Model (DSM).
- Remoteness - The theoretical time it would take to walk or cycle, taking account of distance, relative slope, ground cover and barrier features such as open water and very steep ground, from the nearest public road, ferry landing or railway station was calculated at 25 m cell resolution using the NextMap DTM.

As stated by Norton *et al*. (2018), there is generally insufficient information to place monetary values on spiritual and emblematic marine ecosystem service benefits and no method is likely to succeed in picking up on the complete spiritual value that connection with marine ecosystems holds for individuals and society. 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 (Norton *et al*., 2018).

Several studies (Canedoli *et al*., 2017; Bryce *et al*., 2016; Brown, 2013) have used participatory GIS techniques to map spiritual and symbolic CES by either conducting in-depth interviews or issuing questionnaires among respondents asking how and why they appreciate a particular site or area for its symbolic, religious or spiritual value. Participants were generally not instructed to contemplate the structure and function of landscapes, but rather to reflect on the values and benefits they perceive or have experienced in the study areas. In line with the studies which used land cover as a proxy for identifying CES, spiritual values were most closely associated with the coast, water bodies and forested land cover.

Method

Four different data layers were created to map the spatial extent of religious, spiritual, sense of place, and wilderness/solitude cultural ecosystem services.

In order to capture the religious element of this CES, the locations of pilgrim paths, religious buildings, burial grounds, sacred sites such as Skellig Islands and Croagh Patrick, historic religious monuments and sites, and coastal retreat centres such as the Arran Islands Retreat Centre in Galway were mapped.

Similar to the approach adopted by Natural England (2009) and SNH (2014), three data layers were created which attribute values to each CORINE land cover class (2018) within 2 km of the coast to identity landscape characteristics/features that correlate with spiritual enrichment, place identity, wilderness/solitude. The values that were assigned to each land cover class assumed to deliver spiritual and symbolic ecosystem services are identified in Table D5.

Finally, in line with Norton *et al*. (2018), the coastal Gaeltacht areas have a strong connection to the Irish language, traditions, songs and poetry and the spatialisation of these areas depict the spiritual connection of the Gaeltacht areas to the marine environment.

Table D5. Approach to identifying the delivery of cultural services by different landscape features along the coastline in Ireland

Feature	Sense of Place	Spiritual	Wilderness/ Solitude
Coastal lagoons; beaches, dunes, sand; bare rocks; intertidal flats	5	5	5
Broadleaved forests	4	5	4
Coniferous forests	2	5	4
Mixed woodlands	3	5	4
Peat bogs; inland marshes; salt marshes	5	1	5
Urban fabric	5	1	1
Land principally occupied by agriculture; pastures; complex cultivation patterns	4	2	3
Moors and heaths	3	4	4

Data availability

Several data layers were produced as part of Project 2 which are of relevance to mapping spiritual and symbolic CES:

- Pilgrim Paths.

In addition, several layers were produced to indicate spiritual and symbolic CES in Ireland:

- Religious buildings and burial grounds (e.g. cathedrals, churches, chapels, abbeys, cemeteries/graveyards, convents, monasteries) (OSi data).
- Sacred sites, for example Skellig Islands, Croagh Patrick, Slieve League, Tobar Nalt, Kilmacduagh, Scattery Island, Brandon Mountain, Ardgroom, Drombohilly, Kenmare, Kealkil, Dromberg, Ardmore, Lough Derg, Lady's Island, etc.
- Historic religious monuments and sites (e.g. burial mounds, standing stones, holy wells, etc.).
- Coastal retreat centres[9], for example Ards Friary Retreat [Donegal];, Star of the Sea Centre [Sligo]; The Spiritual Life Institute [Sligo]; Arran Islands Retreat [Galway]; La Retraite Hermitage [Galway]; Jesuit Centre of Spirituality and Culture [Galway); Ardfert Retreat Centre [Kerry]; St. Dominic's Retreat House [Cork]; Dzogchen Beara Retreat Centre [Cork]; Ballyvaloo Retreat Centre [Wexford]; Manresa Jesuit Centre of Spirituality [Dublin]; Stella Maris [Dublin]; Anam Aras [Meath].
- Gaeltacht areas.
- CORINE Land Cover 2018.

Gaps and limitations

- The approach for mapping symbolic and spiritual CES is based on assumptions and values which were identified for other studies and have been adapted to the context of the Irish coastal environment.
- Knowledge gaps are particularly notable for mapping spiritual, religious, symbolic, and sense of place ecosystem services, for example there is a marked lack of evidence on the numbers of people who visit religious or spiritual sites.

[9] Retreat Centers in Ireland https://www.retreatsireland.ie/category/county/

- There is a lack of data which recognises who within society is benefitting from the flow of spiritual and symbolic cultural services, and where these people are located.
- Without undertaking participatory GIS techniques to map spiritual and symbolic CES i.e. by involving the public in identifying key characteristics and valued areas, the study is limited as it can only be assumed that certain landscape features provide these ecosystem services.

Future developments

Future studies should use participatory GIS techniques to map spiritual and symbolic CES by either conducting in-depth interviews or issuing questionnaires among respondents asking how and why they appreciate a particular site or area for its symbolic, religious or spiritual value, which would present a pathway to more robust insight of spiritual and symbolic CES in Ireland. Ground-truthing of scores for different habitat types would enable the importance of different landscape features to be adjusted for the specific cultural context and values for Ireland.

D.1.6 Existence and Bequest

CICES provides examples of existence and bequest cultural ecosystem services:

- *Existence* - Habitats, species and landscape elements which are regarded for their intrinsic value - this includes elements of biodiversity which people feel should be protected, or for which they are willing to pay for protection, as they constitute part of local and national identity, or are associated with sense of place and time. Nationally, these are demonstrated by National Parks, botanic gardens & arboreta, nature reserves and formal conservation designations (national and international), but locally it includes elements of biodiversity which form part of local aesthetic character.

- *Bequest* - Linked to the 'existence' class, but more specifically relates to the protection of habitats and landscape elements for the benefit of future generations (be it economic, social or cultural benefit). Potentially very extensive but demonstrated by National Parks, designated heritage sites, formal statutory designations for nature conservation and Protected and Recorded Monuments.

Options for mapping

Very few studies have focused on mapping the demand, supply or the flow of benefits from intangible services. Generally, research studies acknowledge the difficulty in valuing and mapping these CES and do not incorporate them into their wider studies of ES. The ICES Report (2013) acknowledges that it is challenging to identify spatially the areas associated with existence and bequest values as, for example the preferences of future generations can only be assumed. On the flip side, determining the people who value a place for existence or bequest value may prove challenging as many live far away and have no contact with the actual place (ICES 2013).

Ashley (2014) identified that surveys of public and local communities are of use in establishing not only willingness to pay (existence) but also bequest values (value of evidence of the past and past cultures to future generations). Raymond *et al.* (2009) undertook in-depth interviews and a mapping task with 56 natural resource management decision makers and community representatives who quantified and mapped values of natural capital assets and ecosystem services. They found that the most highly valued ecosystem services were, aside from recreation and tourism, bequest and existence.

Method

Without undertaking GIS participatory mapping techniques, it is not possible to assign existence and bequest values. Therefore, the approach to mapping existence and bequest CES was to identify international/national/local natural heritage, landscape and historic environment designations.

Data availability

Several data layers are available on the MI Atlas that are relevant to mapping existence and bequest CES:

- Special Areas of Conservation;
- Special Protection Areas;
- Sites of Special Scientific Interest;
- Ramsar Sites;
- Natural Heritage Areas;
- Proposed Natural Heritage Areas.
- INFOMAR Surveyed Shipwrecks.

A number of data layers were produced as part of Project 2 which are of relevance to mapping existence and bequest CES:

- UNESCO World Heritage Sites.
- UNESCO World Heritage Site buffer zones.
- UNESCO Global Geoparks.
- Wildfowl Sanctuaries.
- OSPAR Marine Protected Areas.
- National Parks.
- Nature Reserves.
- Biosphere Reserves.
- Special Amenity Order Areas.
- Locally designated nature and landscape areas.
- National Monuments Service: wreck extents.
- National Monuments Service: National Monuments.
- National Monuments Service: zones of notification.
- National Monuments Service: National Inventory of Architectural Heritage.
- Archaeological Survey of Ireland: Record of Monuments and Places.
- Archaeological Survey of Ireland: Record of Protected Structures.
- Heritage Council: Irish Historic Towns Atlas.
- Heritage Council: Atlas of Hillforts.
- Heritage Council: Architectural Conservation Areas.

Gaps and limitations

Without undertaking participatory GIS techniques to value existence and bequest CES, the study is limited as it can only be assumed that designated nature, landscape and heritage assets provide these ecosystem services.

Future developments

Future studies should use participatory GIS techniques to map existence and bequest CES which would present a pathway to more robust insight of existence and bequest CES in Ireland.

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This project or operation is part supported by the Irish government and the European Maritime & Fisheries Fund
as part of the EMFF Operational Programme for 2014-2020

Ireland's EU Structural and Investment Funds Programmes 2014 - 2020
Co-funded by the Irish Government and the European Union

An Roinn Talmhaíochta, Bia agus Mara
Department of Agriculture, Food and the Marine

EUROPEAN UNION
This measure is part-financed by the European Maritime and Fisheries Fund

Marine Institute
Foras na Mara