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Natural capital accounting for Clew Bay, Ireland

Clew Bay Natural Capital Profile

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1 Introduction

The Clew Bay Ocean Accounting Project (the Project) is part of the Natural capital program of work being completed by Bord Iascaigh Mhara. This project is the second phase of the program of work, with the initial phase in 2020 scoping the potential utility of natural capital accounting. This phase provides the opportunity for BIM to explore the utility of natural capital accounting and lead the extension and application of NCA to Irish marine and coastal areas. The project will complement existing projects that are being undertaken or that have been undertaken by the Environmental Protection Agency, Bord na Mona, Coillte and the Central Statistical Office.

The objectives of the project are to:

1. test and demonstrate the application of Natural Capital Accounting for the Irish Seafood sector, using the United Nations System of Environmental-Economic Accounting
2. improve the understanding of the complex relationship between seafood sector activities and the natural environment, and
3. contribute to the sustainable management of the seafood sector and the marine environment

Objective 1 and objective 2 aim at improving the quality of the environmental and economic information and drawing insights and knowledge from that information. Objective 3 is concerned with the use case, which in this context is to support the Irish seafood industry in the management of ocean resources sustainably, and to support seafood industry operators to create value. Four priority applications were chosen to evaluate how NCA contributes to sustainable management of the seafood sector and the marine environment:

1. preparing data and information for the Seafood sector to support their participation in Marine Spatial Planning
2. improving sustainability performance and communicating the results
3. reporting on sustainable development goals (SDG)
4. assessing the sustainability of the seafood sector in terms of
   a) natural capital
   b) produced, human and social capital

This case study focusses on Clew Bay, Ireland. The project will deliver a series of reports namely:

1. Use case assessment – framing natural capital from the perspective of a number of different users and potential applications of natural capital information
2. Clew Bay Natural Capital Profile – this report, which focusses on the provision of structured information on natural, produced, human and social capital in Clew Bay
3. Synthesis report – assessment of the information against the objectives of the project, and the priority applications, and recommendations for improvement in the future.

This report is structured as follows:

- Key features of Natural capital accounting
- Natural capital profile – focusses on describing the relationship between Natural Capital and the Seafood sector, with emphasis on the aquaculture sector (and the native oyster fishing sector). This sets the scene for the two case studies that follow in chapters 4 & 5.
- Case study 1 – Native Oyster Habitat restoration
- Case study 2 – The CLAMS program

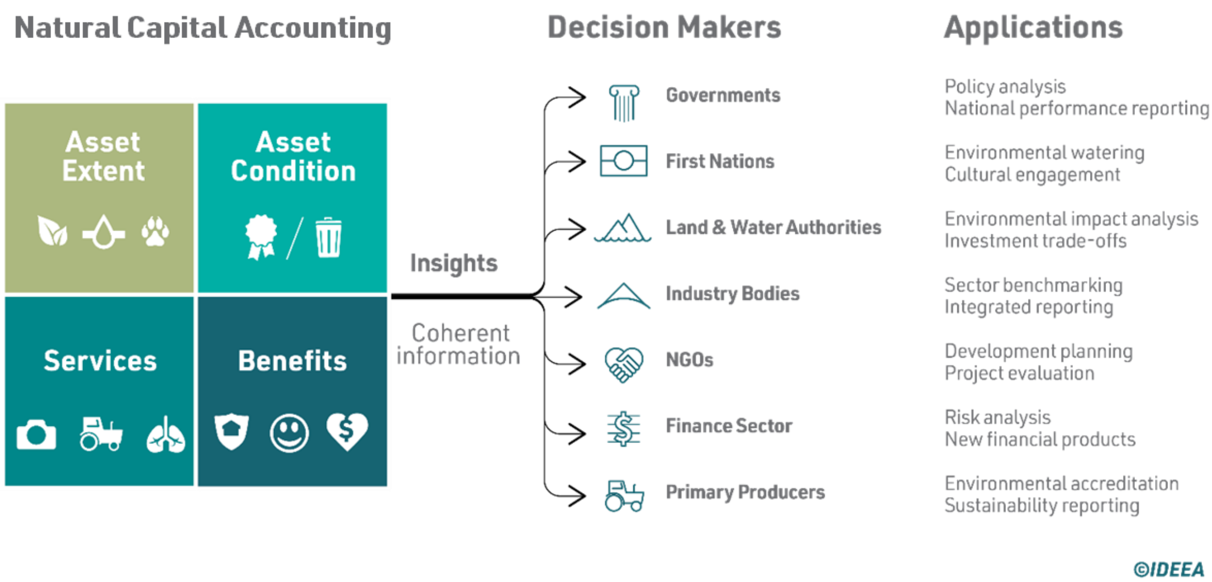
2 Key features of Natural Capital Accounting

2.1 Purpose

The environment's contribution to our prosperity and wellbeing are often overlooked in decision-making by governments, business and the community. While great progress has been made in monitoring and reporting on the environment, existing environmental information is sometimes piecemeal or inconsistent, doesn't provide sufficient insight into long-term environmental trends and, crucially, is not linked to socioeconomic data or the services and benefits the environment provides. As a result, many decisions by governments, businesses and individuals do not account for society's dependencies and impacts on the environment including changes in environmental assets over time, and the outcomes associated with these changes.

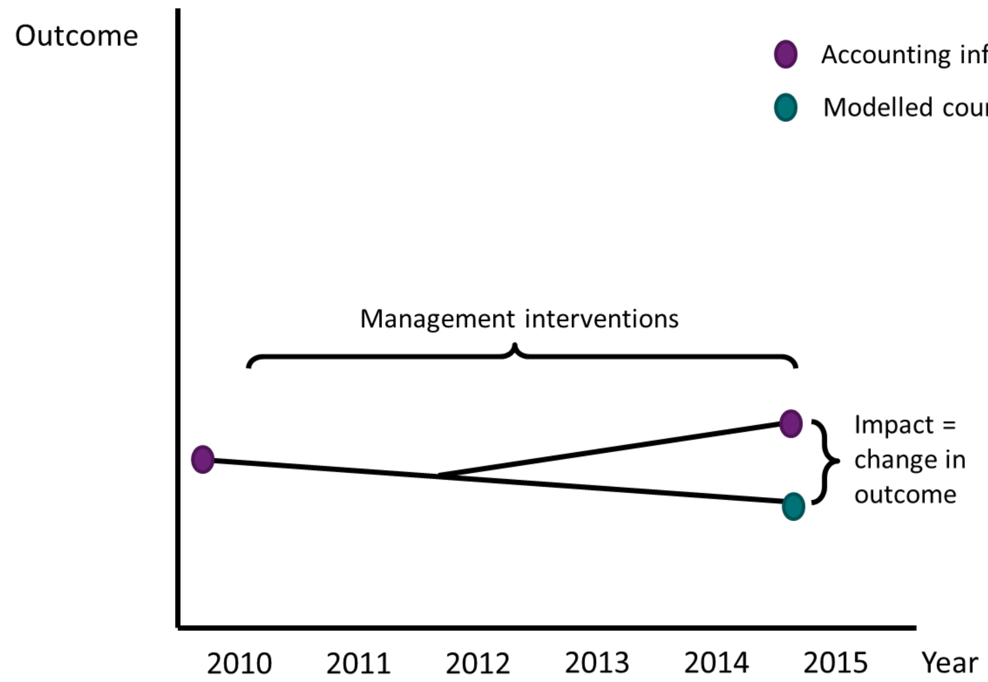
An emerging and powerful approach to overcoming these data and information challenges is the use of natural capital accounting (UN et al 2021). The process of applying the principles of natural capital accounting to environmental, economic and social data results in a set of coherent information that can be used to assist decision-making. Users can interpret and analyse coherent information from any of three entry points – environmental, economic and social – to support holistic and comprehensive decision making. Information produced in this nature can underpin a range of applications and be used by many stakeholders (see Figure 1).

Figure 1 Accounting underpins multiple applications



Environmental and economic data should be decision-centred and demand-led. The integrated information produced as part of this project is intended for use by the seafood sector (and other end users) in their management of Clew Bay, Co Mayo, Ireland. Applications of the information may include an evaluation of the effects of various management interventions (e.g., environmental management interventions such as alien species control and monitoring of water quality), broader environmental changes (for example, increased storm frequency as a result of climate change) and supporting the preparation of sustainability reports. Figure 2 provides a stylised view of how this information may be used to assess the outcomes of management interventions through consistent measurement of the state and changes in state (and associated services) in comparison to a modelled counterfactual.

Figure 2 Measuring change in outcomes resulting from management interventions

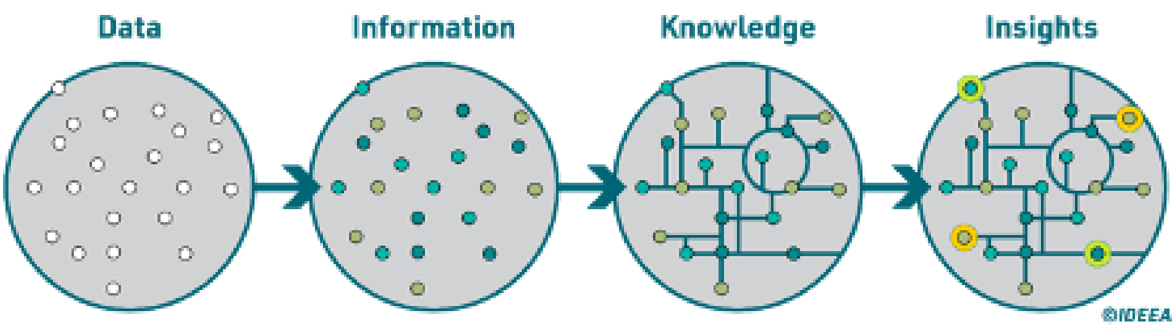


Note: Assumes counterfactual is consistent with trend before management intervention.

This report describes the accounting information for Clew Bay. It provides quantitative evidence on ecosystem extent, ecosystem condition and ecosystem services across a number of different years.

2.2 Why accounting?

Information is a key input into decision making. Quantitative information is part of the arsenal that is available to decision makers. However, it requires investment and tact to curate data into information, and ultimately knowledge and insights that decision makers can use.



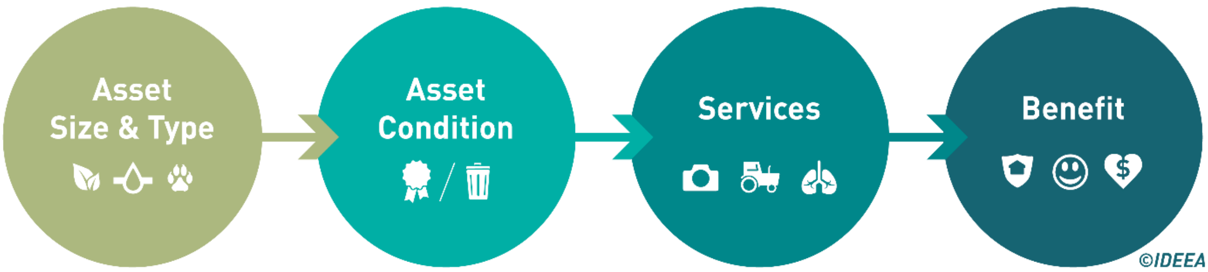
An accounting approach can improve the quality of information that is supplied to decision makers. A key feature of an accounting approach is the use of agreed concepts and definitions to support the integration of environmental and economic data. Application of an accounting approach supports the provision of coherent environmental and economic information, enables temporal and spatial comparisons, and aggregation over different geographies to provide a micro and a macro picture.

The accounting approach provides an organising framework for data across environmental and economic dimensions. The organising framework increases the benefits associated with otherwise ad hoc data collection and monitoring because the data can be integrated with other data. Accounting also generates an information set that is compatible with other sets of information, for example, standard economic data organised in countries' national accounts (UN et al., 2010). The information set in this report has been organised according to established natural capital principles (UN et al 2021).

2.3 The accounting framework

This project focuses on the application of ecosystem accounting using the international standard System of Natural capital Accounting - Ecosystem Accounting (SEEA EA) (UN et al 2021). The core ecosystem accounting framework (Figure 3) underpins the presentation of the information in this document. The framework presents an approach to bridging ecosystems and the economy by conceptualising ecosystems as an asset. These assets can be differentiated by their type (for example ecosystem type or further by their specific characteristics) and are then measured according to their quantity (extent or area) and quality (condition). Each ecosystem asset can supply multiple ecosystem services which are, in turn, used in the production of benefits. The flow of services from an ecosystem to a beneficiary (economic units such as households, governments and businesses) is treated as a transaction which can be recorded in physical and monetary units.

Figure 3 Core ecosystem accounting framework



Note: Pressures can also be integrated into the framework to provide another link between the economy/society and the environment.
Source: (Eigenraam and Obst 2018)

2.4 Accounting outputs

Several tables and maps have been produced as part of the project across a range of different ecological and economic concepts (see Table 1). Tables and maps include information on ecosystem extent, ecosystem condition and biodiversity, as well as ecosystem services, for example fish biomass provisioning services and climate regulation services. The use of services may be interpreted as a pressure if there are negative effects on ecosystems. For example, the extraction of wild oyster biomass greater than sustainable levels may result in a decline in condition of reefs and negatively impact the flow of other ecosystem services, such as water purification services.

Biodiversity is relevant across all areas of the core ecosystem accounting framework from ecosystem extent and condition, through to ecosystem services and benefits. Biodiversity can be analysed at different levels (for example, genetic, species and ecosystem diversity) and for different spatial scales. The challenge of conserving and restoring biodiversity is a topic that is currently being examined internationally including the development of indicators and metrics with a view to establishing net zero ambition and actions similar to that being adopted in relation to climate change. Direct field-based data on biodiversity can support the compilation of ecosystem condition accounts and may provide input to the measurement of ecosystem services. Further, the information on ecosystem extent and condition can be used to support a basic understanding of the status and trends in biodiversity, across large spatial extents, and support the derivation of habitat-based biodiversity indicators.

Tables for Clew Bay were developed based on the core ecosystem accounting framework (Figure 3). The tables represent an integrated assessment of the environment and the economy in Clew Bay. The ecosystem assets assessed in this project (in terms of their extent and condition) are within the boundary of Clew Bay. The scope of the services varies depending on the nature of the service and whether the beneficiaries are in situ (within Clew Bay) or outside (for example, global populations benefit from climate regulation services or downstream users benefit from water purification services).

Table 1 Overview of information produced as part of the accounting approach

Stock accounts, tables and maps: ecosystem assets	Flow accounts, tables and maps: ecosystem services
• Ecosystem extent • Ecosystem condition • Species	• Aquaculture provisioning services • Wild fish and other natural aquatic biomass provisioning services • Global climate regulation services • Nursery and habitat maintenance services • Recreation-related services

Notes: 1. While biodiversity can be considered a characteristic of ecosystem condition, it is also recognised in SEEA EA as a separate thematic account, therefore it is listed here as a separate set of information on the ecosystem assets.
2. Ecosystem and species appreciation are flows concerning non-use values and in SEEA EA are not treated as ecosystem services. They have been included here to recognise the relevance of non-use values in decision making.
3. Benefits are not shown in this table as their accounting was not the focus of this project. Benefits have in some cases been reported as they are used in the monetary valuation of ecosystem services. Benefits can be distinguished as being either SNA benefits (produced by economic units such as food, water, energy) or non-SNA benefits (not produced by economic units such as clean air, flood protection).

2.5 Interpretation of accounting outputs

The accounts and supplementary tables presented in this document are a mix of static information, time series information, and more conventional SEEA EA accounts such as asset accounts with opening and closing balances. Table 2 and Table 3 are examples of asset accounts and supply and use tables for ecosystem services, respectively.

Table 2 Asset account example

Extent	Ecosystem type A	Ecosystem type B	Total (ha)
Opening extent	100	200	300
Additions to extent			
Managed expansion	1	23	24
Unmanaged expansion	3	5	8
Unclassified expansion	–	–	–
Total additions	4	28	32
Reductions in extent			
Managed reduction	1	4	3
Unmanaged reduction	41	6	9
Unclassified reduction	–	–	–
Total reductions	42	10	12
Net change in extent	-38	18	20
Closing extent	62	218	320

Note: This is a stylised example based on Table 4.1 in the SEEA EA framework (UNCEEA 2021). '–' = 0

Table 3 Supply and use accounts example

Ecosystem service	Units	Industry	Household	Government	Tidal Mudflats and Sandflats	Large Shallow Inlets and Bays	Atlantic Salt Meadows
Supply							
Wild fish provisioning services	kg	No value	No value	No value	3,000	12,000	–
Carbon sequestration	Tn	No value	No value	No value	2,000	7,000	6,000
Use							
Wild fish provisioning services	kg	12,000	3,000	–	No value	No value	No value
Carbon sequestration	Tn	–	–	15,000	No value	No value	No value

Note: This is a stylised example based on Table 7.5 in the SEEA EA framework (UNCEEA 2021). '–' = 0. Tn = tonnes.

Table 4 links some of the policy and decision-making challenges to accounting information. There are many potential applications of coherent accounting information across the decision-making process including problem diagnosis, forecasting, target setting, scenario analysis, monitoring and reporting, and impact evaluation. The suitability of the accounting products to different applications will largely depend on the availability of fit-for-purpose data.

The accounts (stock and flow accounts, supply and use tables) are one of the outputs that can be used in decision making. In many cases, analyses can be performed on the account-ready data that underpins the accounts. Auxiliary information can also be used to further interpret the accounts. An understanding of the applications required to inform decision making, and the need for a set of coherent information (in the form of accounts, tables and account-ready data), can be used to direct the collection of data. This is referred to as demand pull for data rather than supply push for data. The latter generally lacks a clear connection to decision making and is motivated more by those producing data.

Table 4 Linking decision making to accounting information and data collection

Decision element	Description	Accounting information application
Problem diagnosis	Quantify trends in physical and environmental state and build business case for policy intervention	Interpret accounting information to assist with diagnosis
Problem diagnosis	Understand how a problem may manifest in the future, building additional evidence for action	Forecast based on accounting information: forecast outcomes associated with business-as-usual scenario
Design solution	Set target to help guide policy	Identify a practical target by considering accounting information
Design solution	Understand the influence of specific drivers in problems – e.g. to identify which policy levers will be most influential in solving the problem.	Use accounting information as inputs to scenario analysis to estimate outcomes associated with different actions (e.g. business as usual or interventions) Use accounting information to estimate the relative efficiency of alternative solutions e.g. trade-offs between economic benefits of planned urban development versus degradation of ecosystems or loss of biodiversity that may result
Design solution	Establish relationships between key variables	Use consistent accounting information combined with statistical techniques to establish relationships (e.g. increased temperature affects ecosystem health which affects yield)
Evaluate success of solution	For reporting purposes – e.g. to demonstrate progress in solving the problem along a time series	Use accounting information to monitor performance against projected outcomes Use accounting information for evaluation of performance against targets – e.g. to demonstrate progress against a target and/or attribute influence of policy
Evaluate success of solution	Understand the effectiveness and efficiency of different investments across the landscape	Use accounting information to demonstrate return on investment Use consistent accounting information to underpin quasi-experimental approaches to evaluate impacts

An example of the types of policy questions that can be explored using accounting information is provided in Table 5. There is a risk that Table 5 is interpreted as implying a one-to-one association between an accounting component and policy questions, whether they are basic or complex. However, in practice, individual elements of the accounting system are coherent, and they should be joined together to support integrated analysis. The return on investment in information increases when data can be used across multiple policy questions and decision-making applications (e.g. scenario analysis or impact evaluation). Thus, information needs to be appropriately designed and collected for it to be useful for this purpose. In this respect, data collection should consider multiple policy applications (where appropriate) and standards should be developed to ensure interoperability with future datasets. Also, data collection costs can be minimised by appropriately designing data collection for multiple uses.

From a policy point of view the coherence of data collection and accounting information allows a decision maker to link with other policies and coordinate policy responses. Often the information that supports a given policy can only be used for that policy. If there are other related polices it is very difficult to determine how each policy is contributing to the overall objectives. This is particularly true of policies aimed at natural resource sustainability. A simple example is the management of native forests. For many forests there will be a weeds and pests policy/program, a fire management policy/program, a timber harvesting policy/program and a recreation and tourism policy/program all of which have different definitions and conceptions of the native forest they are managing. Comparison of the data they collect is difficult and is a barrier to determining which policy/program is more effective and where investment could occur in the future to ensure sustainable outcomes.

Table 5 Linking accounts to policy questions

Account component	Basic policy questions, which can be answered by accounts alone	Complex policy questions, which can be answered by combining accounts with other information or methods
Species-level biodiversity	Have the average numbers of species declined or increased over the accounting period?	How will management actions that have focused on drivers of change impact future species diversity and distribution?
Ecosystem extent	Have key ecosystems expanded or contracted over the accounting period?	How will management actions that have focused on drivers of change impact future extent?
Ecosystem condition	Has the health (ecological integrity) of ecosystems improved or declined over the accounting period?	How will management actions that have focused on drivers of change impact condition?
Physical supply and use	Have ecosystem services to people improved or declined over the accounting period?	What management actions will improve individual ecosystem services?
Monetary supply and use	Has the value of the overall basket of ecosystem services to people improved or declined over the accounting period?	What management actions will optimise the benefits delivered by this ecosystem asset?
Monetary asset values	Has the value of the ecosystem improved or declined over the accounting period?	What is the cost/benefit to the economy and society of the degradation/enhancement of these ecosystem assets?

The approach to the collection of data and coherence supports a shift in the focus of policy / design from specific interventions to notions of integrated asset management. Asset management is a comprehensive approach to achieve sustainability and long-term productivity while also mitigating climate change risk. Asset management will be important as Ireland moves towards more integrated marine spatial planning within the National Marine Planning Framework. An asset-based approach to measurement enables the integration of data from the many entry points to asset management (specific interventions such as effluent management, fish quotas, biodiversity protection, oyster rehabilitation and their link to different assets).

3 Natural capital profile

3.1 Introduction

Ireland has a large, diverse, and complex seafood sector. The seafood sector consists of many operators all around the coast of Ireland. The seafood sector is a primary driver of rural economies around the coastline of Ireland and acts as an anchor in these locations around which other supporting service sectors develop. In 2020, the volume of seafood produced by the Irish seafood sector surpassed 220,000 tonnes with a value of €394m. While less than 20% of this volume was produced by the aquaculture sector it contributed 46% of the total value. Each seafood operator, from sole trader to large employers, must overcome their own challenges and grasp their own opportunities to earn a return and support livelihoods. Each seafood operator, by choosing to employ and invest in different types of capital, has a unique response to their specific challenges and opportunities. Each seafood operator formulates an optimal response to its unique environmental (for example, weather), economic (for example, existing levels of debt) and social conditions (for example, personal health and wellbeing). These responses may be organic, and developed by seafood operators themselves, or be mandated through regulation or market demand. An operator's response will also depend on the location's historical events and assumptions about future prospects.

Information is a key input in the formulation of a response by seafood operators. Both in identifying the challenges and opportunities that come before the response, and then in telling a story about the outcomes that result from that response. Yet, information about the environment that connects to the economy and society in a meaningful way, is lacking. Further, environmental information is rarely described within the context of a broader area, which is fundamental for providing context.

A natural capital profile describes the relationship between the economy (in this case seafood sector participants) and the environment in a particular geographic area, which in this case is Clew Bay. The relationship is described by identifying the dependencies and impacts on natural capital by considering the different economic actors in Clew Bay, and the stocks (the extent and condition of ecosystems and other environmental resources such as fish) and flows (physical and monetary denominations of ecosystem services) provided by natural capital that they are managing. A natural capital profile describes:

1. The geographic area of interest and key characteristics: this defines the geographic boundary for the purposes of the profile, and more explicitly the natural capital that is being managed.
2. Who are the economic actors managing natural capital and how is it managed? For example, what are the institutional arrangements that affect the management of natural capital by the public sector?
3. What natural capital is being managed by each of the economic actors and what is its condition? Are there other capitals that are being managed that affect natural capital and what are they?

4. What are the key dependencies between the economic actors and natural capital? This builds on an understanding of who is managing natural capital, and what is being managed. There may be multiple economic actors that depend on the natural capital.
5. What are the key pressures (negative) on natural capital in the area of interest? Pressures include the direct use of natural capital, and indirect or exogenous impacts from, for example, climate change or nutrient runoff, and pressures from use that may be impacting others.
6. What are the key environmental and socio-economic impacts in the area of interest? This includes both positive and negative impacts that have both a time and spatial dimension. Understanding impacts requires an understanding of how natural capital and ecosystem services are changing over time.

A natural capital profile consists of both qualitative and quantitative data and information. The natural capital profile is supported by a number of outputs, including but not limited to natural capital accounts, tables, graphs and maps.[1] The approach to compiling the natural capital profile in this project applies the UN System of Natural capital Accounting, a globally agreed set of concepts and definitions that describe the relationship between natural capital and the economy.

3.2 Clew Bay

Clew Bay is part of the Irish maritime area, which extends over 490,000km^2 (approximately 7 times its terrestrial landmass) (see Figure 4). Clew Bay is a sheltered bay on the west (Atlantic) coast of County Mayo, Ireland. The Bay is open to westerly swells off the Atlantic Ocean and is 25km long, 12.5km wide and covers an area of 31,250 hectares. The bay is bounded on both north and south by mountains—Croagh Patrick (795 metres) on the south and the Nephin Beg range on the north.

It has been said that the bay has 365 islands, one for every day of the year. A distinctive feature of the inner end of the bay is the archipelago of small islands formed by drumlins, or long oval mounds of glacial origin (Britannica, 2018). Achill Island and the Corraun Peninsula form western extensions of the northern shores and Clare Island, which is the biggest island, guards the entrance of the bay and is home to some 130 people.

[1] Natural capital accounts are an output (e.g. stock and flow account, balance sheet, supply and use table, environmental profit and loss), while natural capital accounting is the process of organising environmental, social and economic data into coherent information, which can be used for many purposes (of which natural capital accounts are included, but also extending to forecasting and scenario analysis).

Figure 4 Clew Bay, Ireland

The Bay's multitude of islands and complex series of interlocking bays provides both shelter and oxygen enriched waters, making Clew Bay an excellent location for the cultivation and capture of both shellfish (crustacean and bivalves) and finfish. The bay is highly productive, and the unique geomorphology provides shelter allowing for fishing activities to take place over extended periods throughout the year.

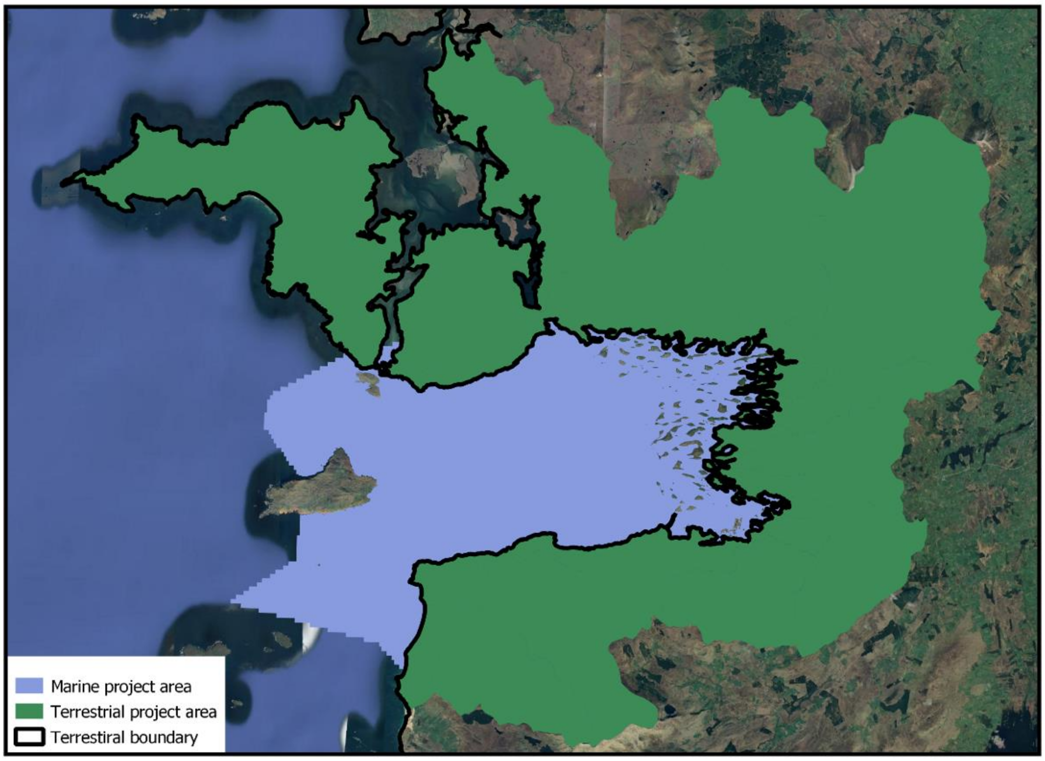
The main town adjacent to Clew Bay is Westport. Westport is designated as a heritage town and is one of only a few planned towns in Ireland. The population as of 2016 is approximately 6,198. Westport is County Mayo's premier tourist destination and is known for the scenery, the pubs and restaurants in the town, blue flag beaches, and Croagh Patrick. Westport's proximity to Connemara, Achill, Clew Bay and Croagh Patrick, and its hotels and guest houses, make it a base for holidaymakers to tour the region, which also forms part of the Wild Atlantic Way. The unique landscape with islands and mountains has attracted visitors and pilgrims for centuries, leaving many awestruck with its beauty and the harmonious interplay of land, sea and sky. Tracks and trails that cross the landscape offer visitors the opportunity to experience the wildness of the area, to hike and cycle off road for long distances, and to discover the stories of Clew Bay that stretch through time. The bay itself offers the adventure of sailing through islands and imagining the challenges that the legendary Granuaile faced in successfully defending these waters centuries back.

The area is the focus of a number of development plans. A new Mayo County Development Plan for the period 2021-2027, which includes Clew Bay, is due to be adopted by the end of 2021. County development plans cover a range of strategic planning issues including land zoning, housing, flood mapping, energy & renewable energy, infrastructure, economic development, sustainable development and protected structures (e.g., historical monuments). Fáilte Ireland has also developed a Destination and Experience Development Plan for Clew Bay (Failte Ireland 2021). The plan strives for improved development and promotion of the area's unique features to achieve increased international cut-through and further support the visitor experience. Finally, there is a strong link between tourism, local seafood produce in shops and restaurants, and the seafood sector primary producers, which is recognised in the Taste the Atlantic initiative.

3.2.1 Accounting

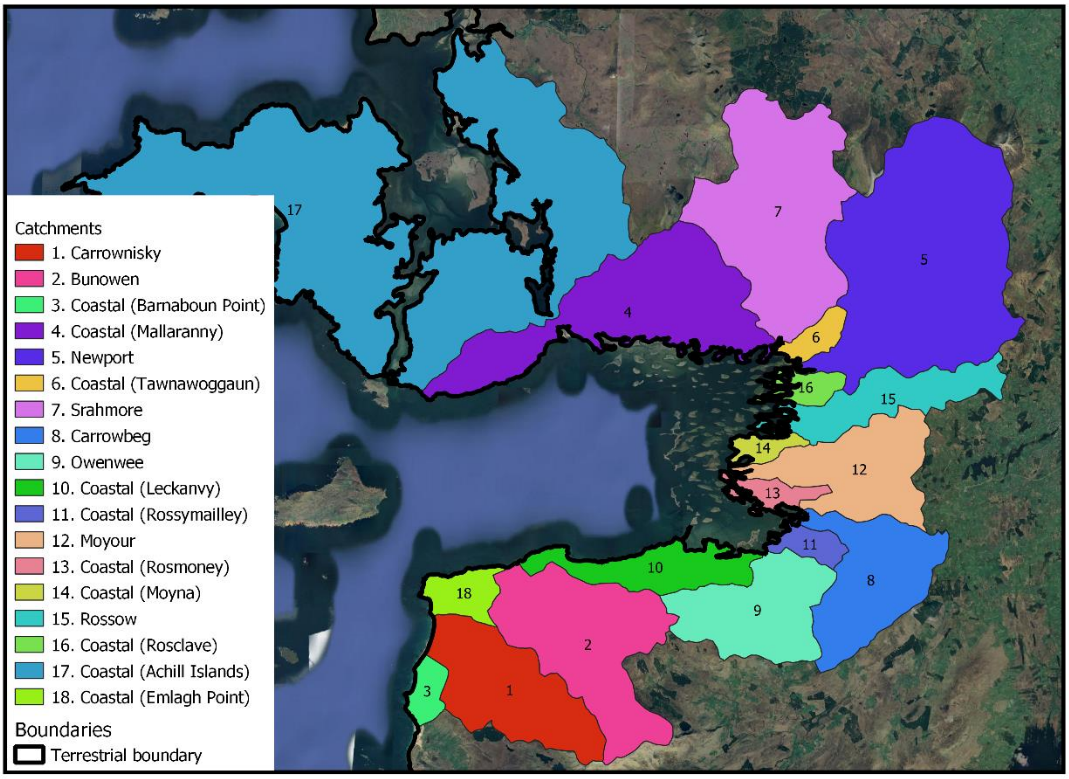
The Clew Bay accounting area consists of both marine and terrestrial areas (see Figure 5). The marine area is 38,786 hectares and the terrestrial area is 105,761 hectares (see Table 6). Terrestrial areas were included to capture the relationship between terrestrial and marine areas. For example, a potential pressure on marine ecosystems is water quality, which can be affected by runoff from agricultural activities. There are 19 sub catchments within the terrestrial area, the largest being the Achill Islands coastal area (see Table 6 and Figure 6).

Figure 5 Terrestrial and marine areas within the Clew Bay accounting area



Notes: the project area is delineated from multiple layers including: (i) habitats from the OA_002 MSFD Predominant habitat layer, (ii) adjacent subdivisions of the River basin to Clew Bay from OA_075, and (iii) Clare island from 0A_076.

Figure 6 Catchments within the project area



Notes: Data from OA_075

Table 6 Extent of marine and terrestrial areas, by catchment

Location	Sum of Area (ha)
Marine	38,786
Terrestrial	105,761
Catchments	
Bunowen	7,477
Carrowbeg	5,052
Carrownisky	5,441
Coastal (Achill Islands)	29,501
Coastal (Barnaboun Point)	768
Coastal (Emlagh Point)	1,246
Coastal (Leckanvy)	2,850
Coastal (Mallaranny)	9,089
Coastal (Moyna)	598
Coastal (Rosclave)	798
Coastal (Rosmoney)	829
Coastal (Rossymailley)	791
Coastal (Tawnawoggaun)	749
Moyour	4,801
Newport	14,884
Other	2,759
Owenwee	4,780
Rossow	3,325
Srahmore	10,025
Grand Total	144,546

Source: Area based measurements from OA_075 and OA_002

3.3 Natural capital managers

Clew Bay is a diverse area which presents many economic and social opportunities for businesses, households and visitors. These actors either manage natural capital for private benefits (for instance, trading of property rights through licensing provides exclusive access to natural capital) or on behalf of society.[2] These dependencies (reliance of an economic actor on natural capital for benefits) mean that managers often make changes (through actions) to the stock of capital. The focus of this section is on who is managing the marine ecosystems in Clew Bay (those ecosystems are described in more detail in section 3.4). This provides the starting point for an analysis of natural capital dependencies and impacts.

[2] Economic actors that have a negative impact on other economic actors assets are not deemed to be managers of those assets.

Both the public and private sector manage the natural capital in Clew Bay. The private sector includes the seafood sector, in which there are both aquaculture and fishery operators that have licenses to operate in specific areas of the bay. There are also marine leisure and tourism interests, including Mayo County Council who manage Blue Flag Beaches and piers and slipways, and a wide range of private businesses delivering recreational activities. Public sector organisations also support the management of Clew Bay, to ensure that the resource is managed effectively. These organisations include BIM, Mayo County Council, DAFM, DHLGH (and their agencies), and by extension, the EU.

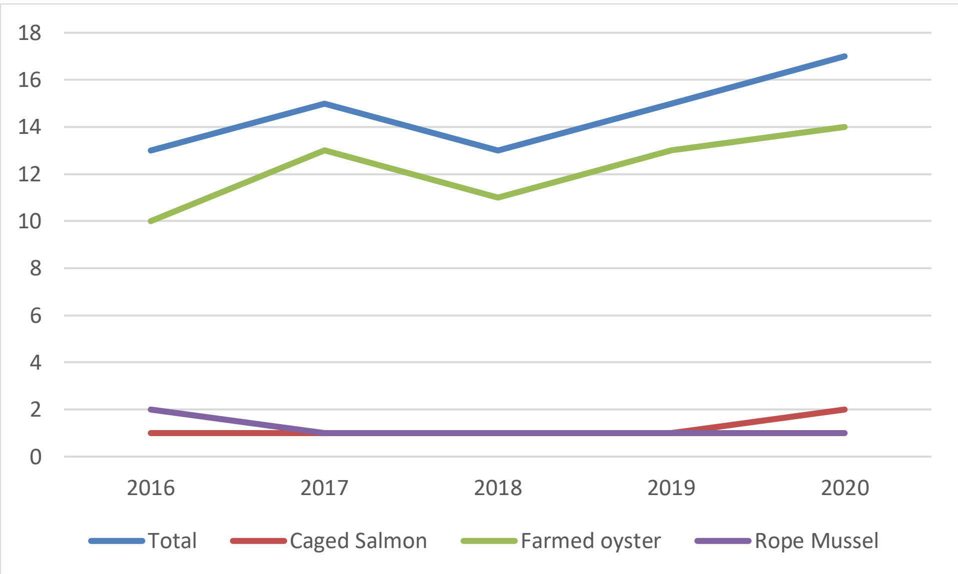
Wild Fisheries businesses

The commercial fishing industry provides an essential source of income for many people in communities along the coast of Mayo where there are few alternative employment opportunities. Further, fishing is one of the few activities that has sustained communities through periods of substantial emigration. Within a line from Roonah across the east of Clare Island to Achill there are approximately 20 licenced/Registered fishing vessels belonging to Clew Bay residents who are active in fishers. Another 15 vessels travel from other areas to fish in Clew Bay at different times of year. Fishing gear includes Pots, Gillnets, Trawls and Dredges. In addition there are approximately six others residing in the Clew Bay area who solely fish for native oysters.

Aquaculture businesses

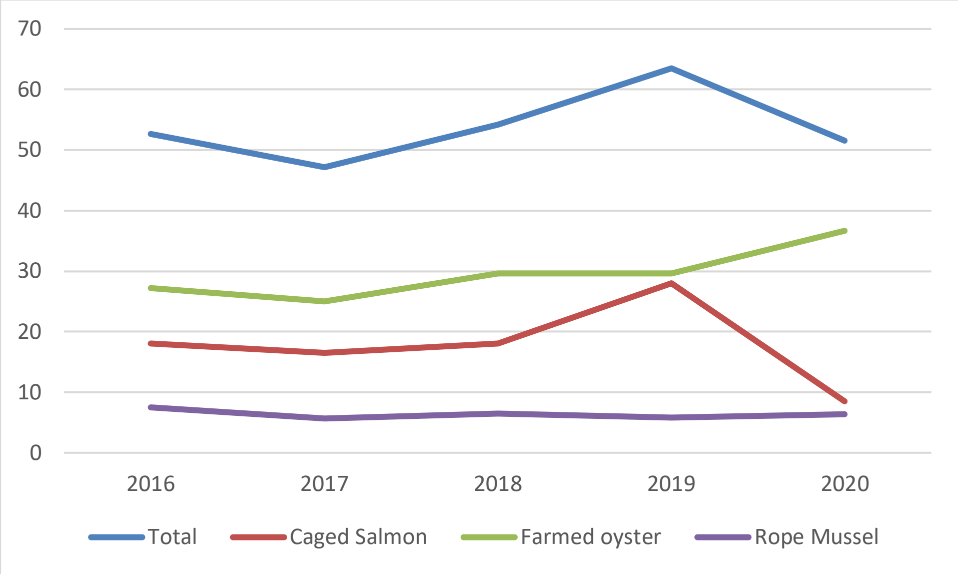
17 aquaculture businesses were in operation in Clew Bay in 2020. The total number of businesses has been growing steadily since 2016 (see Figure 7). There were 13 businesses in 2016 and 17 in 2020, with the change being driven by growth in farmed oyster businesses. The number of full-time employees varied from year to year but has remained relatively stable since 2016. There has been growth in the number of full-time employees in the farmed oyster business, but a decrease in the salmon aquaculture business. A large decrease in full time employees occurred between 2019 and 2020 in the salmon aquaculture sector (see Figure 8).

Figure 7 Number of businesses



Source: M_01

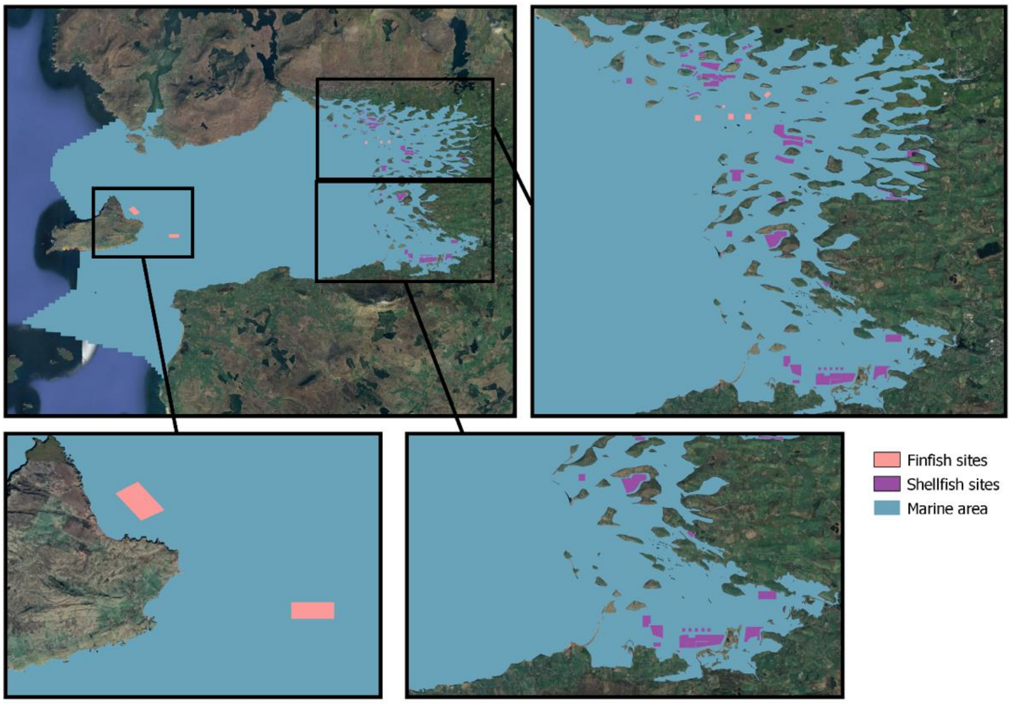
Figure 8 Number of Full Time Employees



Source: Mul_002

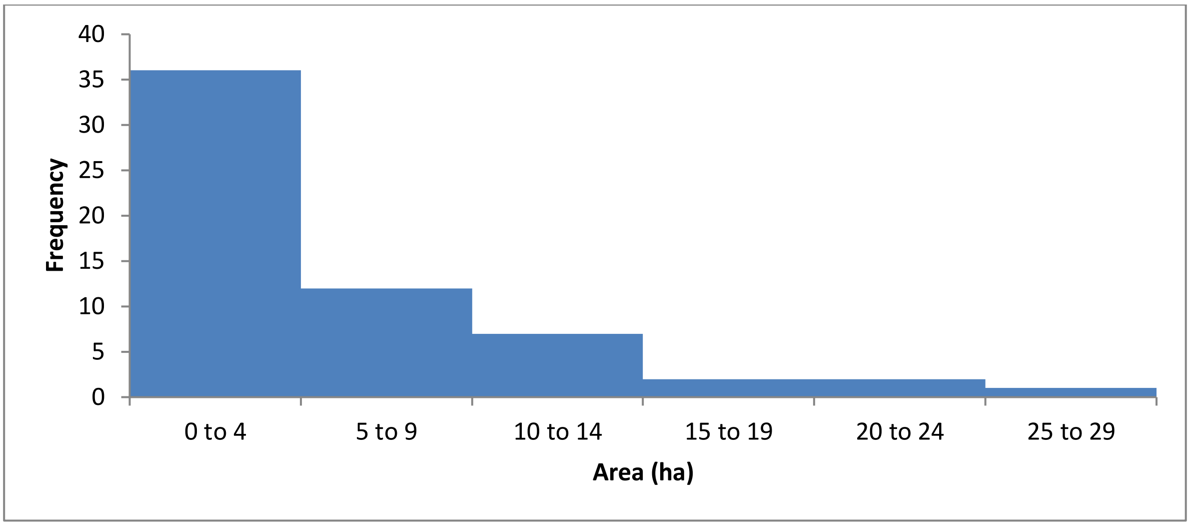
Figure 9 shows the aquaculture sites (finfish and shellfish) in Clew Bay. Currently, there are 58 aquaculture licences within Clew Bay. There are 41 farmed oyster sites (*Magallana gigas*), 5 farmed salmon sites, 4 rope mussel sites, 5 multi specie sites and 1 abalone site. There are 2 salmon farming sites at Clare Island. In Inner Clew Bay there are 2 Native Oyster Fishery Orders – the main one being the Clew Bay Oyster Fishery Order 1979 and a small Order at Cullenmore. The area of the aquaculture sites range from 0.5 hectares to 25.5 hectares and 60 per cent of the sites are between 0 and 4 hectares (see Figure 10).

Figure 9 Licensed Aquaculture sites



Source: Mul_003

Figure 10 Histogram of size of aquaculture sites



Source: Mul_003

Native Oyster Fishery

The Oyster fisheries in Clew Bay are managed by the Clew Bay Oyster Society Limited, under Fishery Order 1979. These fisheries have declined in recent years and stock biomass is low.

The spatial extent of the Clew Bay fishery is not definitely known but recent survey data indicates the probable distribution of areas which have commercial, albeit low densities, of oysters.

Licenses to fish for oyster are issued annually by Inland Fisheries Ireland (IFI). Six licenses were issued in 2013 for the Ballinakill area which includes the south side of Clew Bay. An additional 49 licenses were issued in the Bangor district which includes the north side of Clew Bay and Achill (Fisheries Natura Mitigation Plan – Mobile Gear Fisheries Clew Bay Complex, 2018).

Public sector organisations

There are a number of public sector organisations which manage or influence management in the bay, through different policies and programs. The organisations, which include BIM, Mayo County Council, DAFM, DHLGH (and their agencies), and by extension, the EU, can have a direct and indirect effect on the management of capital in Clew Bay.

With respect to public sector organisations, management may take the form of direct actions that change the stock or the condition of natural capital, or indirect actions which influence management. Generally indirect management actions are attempting to change the behaviour of those directly managing Natural Capital or regulating the economy in which Natural Capital managers operate. In many instances, the incentive to manage the stock and condition of Natural Capital is derived from indirect management actions in the form of public policy and regulation (for example, tourism development strategy and licensing). Indirect management can affect other capitals which are interdependent with the stock and condition of natural capital (e.g. educating human capital to improve natural capital). Table 7 lists the organisations and the mechanisms they use to influence Natural Capital managers.

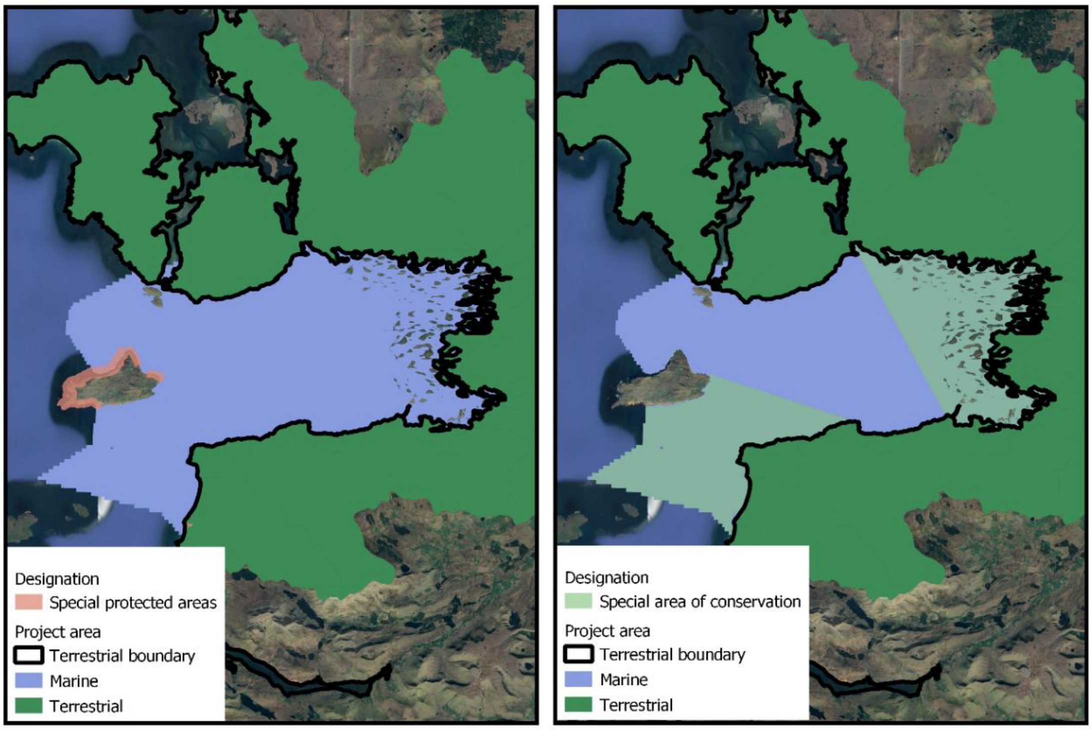
Table 7 Mechanisms used to influence the use of natural capital, by organisation

Organisation/Irish agency	Mechanism
Department of Agriculture Food and Marine (DAFM)	Aquaculture licensing (and associated foreshore licensing) Inshore Fisheries Management – vessel licensing, species linked Statutory Instruments, Fisheries Natura declarations.
BIM (agency of DAFM)	Development agency for the Irish seafood sector. CLAMS liaison officer
Marine Institute (agency of DAFM)	Scientific advisory services to DAFM & DHLGH CLAMS Liaison officer Prepare Natura Impact Statements for the Appropriate Assessments of fishing plans and Aquaculture licenses Fish Health - Shellfish movements
SFPA (agency of DAFM)	Aquaculture and Fishing regulation and enforcement Food Safety
Department of Housing Local Government and Heritage DHLGH	Foreshore licensing Marine Spatial Planning Marine Strategy Framework Directive. Water Framework Directive European Commission Natura 2000 EU Habitats and Birds Directives – Responsible for designation, management and reporting for Special Areas of Conservation (SACs) and Special Protected Areas (SPAs), (collectively known as Natura 2000 sites).
NPWS (unit of DHLGH)	Natura 2000 designation and management, (Management includes setting Conservation objectives, monitoring and reporting on condition e.g., monitoring of key species such as seagrass) Natural Heritage Areas National Biodiversity Action Plan
Mayo County Council	piers and slipways management and maintenance. Land Planning (including land-based aquaculture facilities) Water Framework Directive catchment management. Effluent discharge licensing Blue Flag Beaches County Development Plan
Others IFI	Licensing and Enforcement of Native Oyster fishing activity Management of inland fisheries.
Failte Ireland	Tourism development

Note: Authors interpretation

An example of a policy that affects the management of natural capital in Clew Bay is the Natura 2000 network. The protections of species and habitats is facilitated through the designation of Special Areas of Conservation (SACs) and bird through the designation of Special Protection Areas (SPAs), see Figure 11. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive.

Figure 11 Natura 2000 sites, Special protected areas and Special areas of conservation



Source: Boundaries consistent with Figure 5. SPA from OA_012 and SAC from OA_011.

Ireland does have a number of protected areas with Marine coverage, primarily Natura 2000 sites comprising SACs and SPAs. There are currently 159 marine SACs and 89 marine SPAs in Irish waters, covering around 2.4% of Ireland's exclusive economic zone (EEZ). There are also sites designated under OSPAR and Ramsar. Current Irish legislation does not define Marine Protected Areas (MPAs) but a programme of work is ongoing. There is an imperative for expanding Ireland's network of Marine Protected Areas. Ireland's current Programme for Government (2020) includes a commitment to expand Ireland's network of Marine Protected Areas (MPAs) to 10% of its maritime area as soon as is practical and to meeting a higher target of 30% by 2030 supporting the EU Biodiversity Strategy goal of protecting 30% of the EEZ by 2030 of which 10% will be strictly protected. The reality is that the seafood sector will need to maintain a good relationship and become actively involved with the public sector and other stakeholders to manage the transition to increased areas of MPAs and ensure the demands of environmental policies is not excessive .

Proposed definition for MPAs in Ireland

The following operational definition of an MPA is proposed for MPAs in Ireland

A geographically defined area of marine character or influence which is protected through legal means for the prupose of conservation of specified species, habitats or ecosystems and their associated ecosystem services and cultural values, and managed with thie intention of achieving stated objectives over the long term.

Note: Definition compiled by the MPA advisory group October 2020.

Source: Expanding Ireland's Marine Protected Area Network: A report by the MPA Advisory Group for Department of Housing Local Government and Heritage. October 2020.

Currently SACs cover approximately 52% of the marine area of Clew Bay and SPAs cover approximately 1%. Material areas of SACs and SPAs (i.e. those larger than 100 hectares) are:

- SACs:
  - Clew Bay Complex SAC [001482]
  - West coast Connaught coast SAC [002998]
  - Clare Island Cliffs SAC [002243] specific to Common Bottlenose Dolphin
- SPAs:
  - Clare Island SPA [004136] which is of special conservation interest for the following species: Chough, Fulmar, Shag, Kittiwake, Common Gull, Guillemot and Razorbill.

The SAC and SPA designations have direct relevance to aquaculture. Aquaculture and accompanying foreshore licences are issued for a ten-year period. In accordance with Article 6 of the Habitats Directive, activities not directly linked to the management of the site must undergo an appropriate assessment of their implications for the site in view of the site's conservation objectives. Since aquaculture activities pre-dated designations, in many cases the costs of these assessments have been borne by the state. However, the whole process has taken a long time and caused many delays to licence decisions nationally. The backlog for shellfish aquaculture licensing has now largely been cleared. Appropriate Assessment findings may impact licence size or activity if it is found to have a negative impact (alone or in-combination with other activities). Many of the current aquaculture licences in Clew Bay were issued in 2015 meaning that renewal will be required again in 2025.

3.4 Multiple capitals

This section builds on our understanding of who is managing natural capital in Clew Bay, to describe the natural capital that is being managed. A description of the other capitals (human, social and built capital) that are being managed in Clew Bay is also provided, as the management on natural capital is interdependent with the management of these capitals. For example, labour that is educated on the importance of the environment, may be more likely to embed nature positive actions into their business.

3.4.1 Natural capital

Natural capital is the stock of renewable and non-renewable resources (including plants, animals, water, soils and minerals) that combine to yield a flow of benefits to people (Natural Capital Coalition, 2018). In this section we focus on the type and size of the asset, and the condition of the asset (see Figure 12) that is being managed by the seafood sector. Ecosystems, natural resources such as fish, and other species that are not commercial are in scope. Information on accounting for these components is provided in Box 1.

Figure 12 Core ecosystem accounting framework

Source: (Eigenraam and Obst 2018)

Box 1 Key aspects in accounting for natural capital

Accounting for the different ecosystem assets involves recording the size and distribution of ecosystems in terms of spatial area (UNCEEA 2021). Extent accounting also records spatial information that is relevant to characterising ecosystems including land use, management areas and protected areas. Extent accounting highlights:

- the composition of different classes within the accounting area, including relative abundance and scarcity

- trends in extent, including changes in composition and substitution between different ecosystem types

Ecosystem condition accounting focusses on the measurement of the quality (ecological integrity) of ecosystems within the accounting area. Condition is assessed with respect to an ecosystem's composition, structure and function, which underpin the ecological integrity of the ecosystem. A reference condition approach is used where ecological integrity is assessed relative to a natural or anthropogenic state depending on the ecosystem. Here, we use a natural reference state. The reference condition is not based on a socially determined or desired state.

The approach to measuring condition in the SEEA EA can be aligned with the concept of intrinsic value. Intrinsic value focusses on measuring ecosystem condition as it relates to ecosystem integrity, independent of what ecosystem services it can provide to humanity.

While not the primary focus in measuring condition, an instrumental value perspective can be supported through the measurement of ecosystem capacity. This entails the reporting of condition variables that are important for key ecosystem services. Consistent reporting of condition and capacity supports an assessment of the characteristics that are important in delivering ecosystem services that meet the objectives (for example maximisation of societal welfare) of the asset manager as well as maintaining the ecological integrity of the ecosystem.

Fish stock accounting focusses on a biophysical quantity and an asset value of the commercial fish resource. Fish stock can be separated into wild fish and aquaculture.

Species accounting focusses on the stock of species, their status in terms of extinction risk, and their distribution. There are two approaches to compiling the information: the direct observation approach which is informed by large samples or survey stock assessments, and inferred approaches, for example a habitat-based approach which uses observations of changes in the spatial extent and configuration of habitat required by individual species or communities of species.

Source: adapted from the SEEA

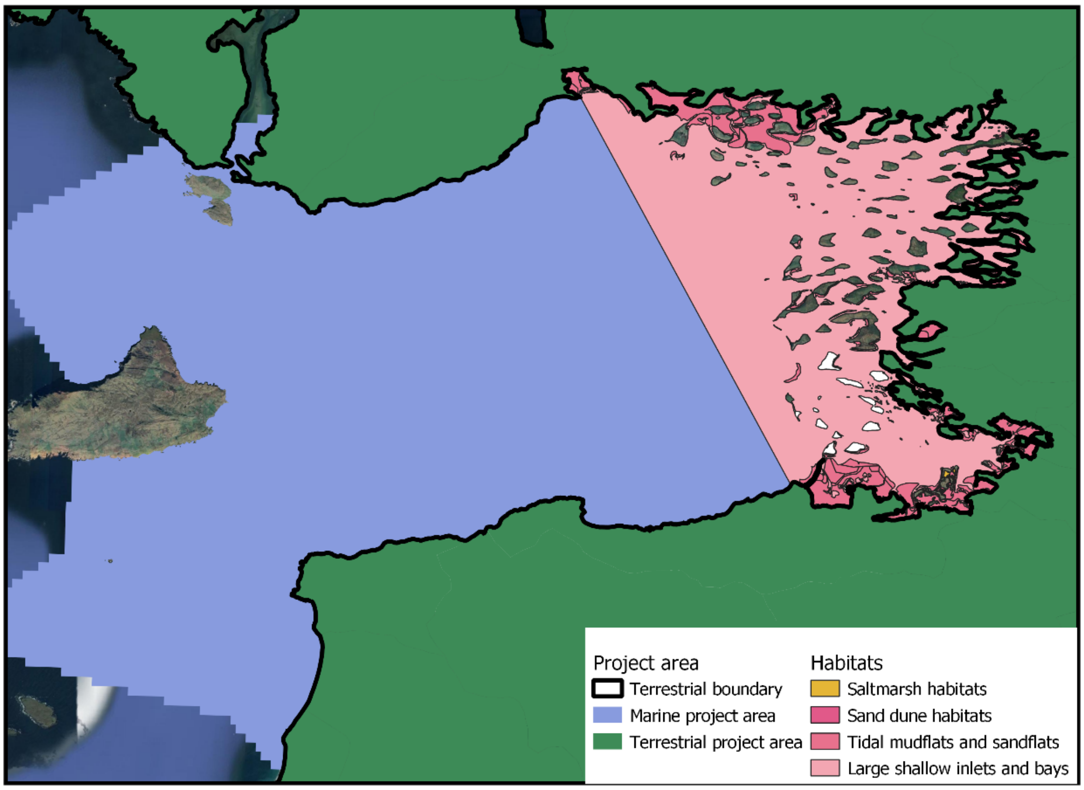
Ecosystem extent

There are several different ecosystems being managed in Clew Bay. There are a number of potential data sources which can be used to delineate ecosystems within the accounting area. Clew Bay contains a number of sites designated as a Special Area of Conservation (SAC). These SACs have been selected for the following habitats and/or species listed on Annex I / II of the E.U. Habitats Directive (numbers in brackets are Natura 2000 codes):

- [1140] Tidal Mudflats and Sandflats
- [1150] Coastal Lagoons*
- [1160] Large Shallow Inlets and Bays
- [1210] Annual Vegetation of Drift Lines
- [1220] Perennial Vegetation of Stony Banks
- [1330] Atlantic Salt Meadows
- [2110] Embryonic Shifting Dunes
- [2120] Marram Dunes (White Dunes)
- [21A0] Machairs (* in Ireland)
- [91A0] Old Oak Woodlands
- [1013] Geyer's Whorl Snail (Vertigo geyeri)
- [1355] Otter (Lutra lutra)
- [1365] Common (Harbour) Seal (Phoca vitulina)

Figure 13 shows that the Clew Bay SAC consists of large shallow inlets and bays, and tidal mudflats and sandflats. Large shallow inlets and bays is the dominant ecosystem type in the area, with tidal mudflats and sandflats the second most dominant ecosystem type.

Figure 13 Habitats protected within special areas of conservation



Source: SAC data from OA_011.

Aquaculture sites overlap several different habitats in Clew Bay Complex SAC. Table 8 presents the spatial extent (ha) of aquaculture activities overlapping with the qualifying interest (1140 - Mudflats and sandflats not covered by seawater at low tide and 1160-Large shallow inlets and bays) according to culture species, method of cultivation and license status.

Large shallow inlets and bays vary widely in habitat and species diversity depending on their location, exposure, geology and sediment composition, which determine their constituent habitat communities. Across Ireland, large areas of keystone species are found within the boundaries of Large shallow inlets and bays including 85% of mapped maërl (Lithothamnion corallioides and Phymatolithon calcareum) and 70% of mapped eelgrass beds (Zostera marina and Z. noltei).

Table 8 Area of habitat by aquaculture type

Species	Status	Location	1140 - Mudflats and sandflats not covered by seawater at low tide (1,277ha)		1160 - Large shallow inlets and Bays (10,198ha)	
			Area (ha)	*% Feature*	Area (ha)	*% Feature*
Oysters	Licensed	Intertidal	57.72	4.52	171.2	1.68
Oysters	Application	Intertidal	6.27	0.49	22.6	0.22
Mussels	Licensed	Subtidal	-	-	64.5	0.63
Mussels	Application	Subtidal	-	-	60.55	0.60
Finfish	Licensed	Subtidal	-	-	15.96	0.16
Scallops	Licensed	Subtidal	-	-	4	0.04
Lobster	Licensed	Subtidal	-	-	1.0	<0.001
Abalone	Licenced	Subtidal	-	-	2.64	0.03
Access Routes			6.71	0.53	10.09	0.1
Corrected Totals*			70.7	5.54	352.54	3.42

Notes *Corrected Totals refer to total spatial coverage of activity that will occur if certain licenced sites are surrendered on foot of successful new applications or realignment of sites (see Section 5.1) and do not reflect the sum of columns in the table.

Source: Report supporting Appropriate Assessment of Aquaculture and Risk Assessment of Fisheries in Clew Bay Complex SAC (Marine Institute, July 2019).

A detailed classification has been applied to the Clew Bay Special area of conservation. Constituent communities and community complexes recorded within the qualifying interest Annex 1 habitats (i.e. 1140 - Mudflats and sandflats not covered by seawater at low tide and 1160 - Large Shallow inlets and Bays) consist of:

- Zostera dominated community
- Maërl dominated communities
- Sandy mud with polychaetes and bivalves community complex
- Fine sand dominated by Nephtys cirrosa community
- Shingle
- Reef (Laminaria dominated community)
- Intertidal sandy mud with Tubificoides benedii and Pygospio elegans community complex

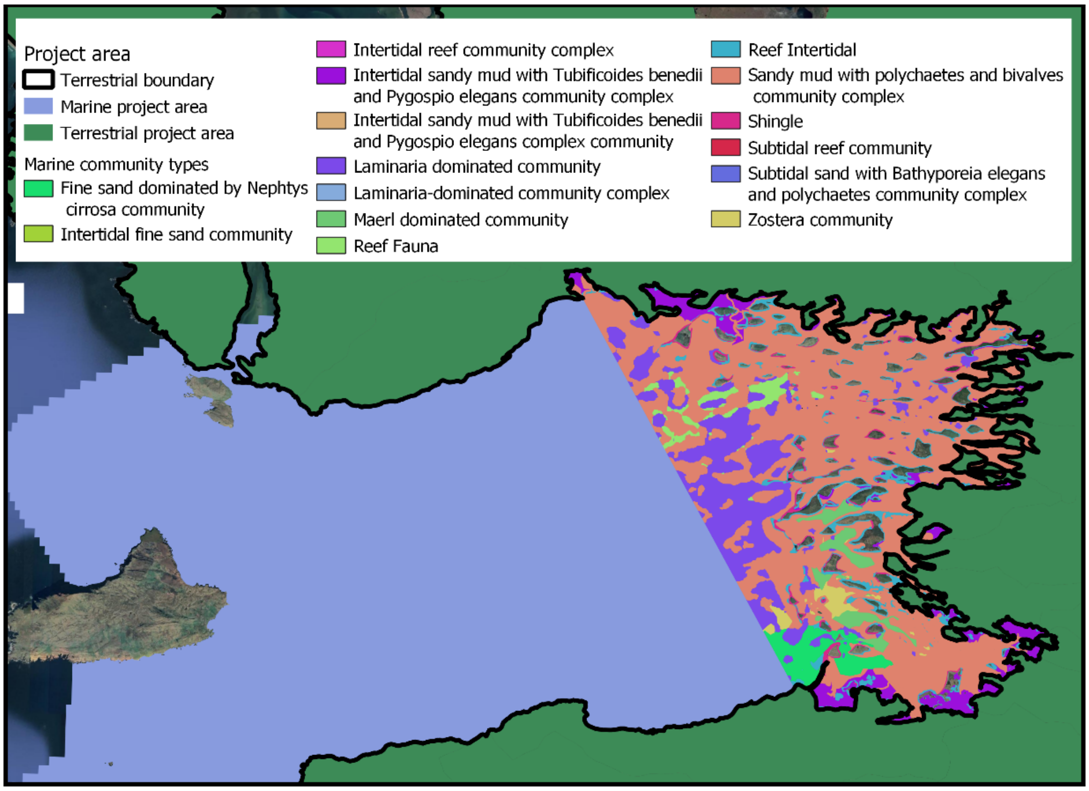
The dominant habitat type in the area covered by the SAC is the sandy mud with polychaetes and bivalves community complex (see Table 9). Laminaria dominated community, reef intertidal and intertidal sandy mud are other dominant types within the area. The spatial distribution of the habitat types are shown in Figure 14.

Table 9: Marine community extent in SAC

Marine community	Area (ha)	% of total
Fine sand dominated by Nephtys cirrosa community	297	0.77%
Intertidal sandy mud	791	2.04%
Laminaria dominated community	1,634	4.21%
Maerl dominated community	287	0.74%
Reef Fauna	215	0.55%
Reef Intertidal	832	2.14%
Sandy mud with polychaetes and bivalves community complex	5,788	14.92%
Shingle	145	0.37%
Zostera community	142	0.37%
Not covered by SAC	28,655	73.88%
Total	38,786	100.00%

Note: Intertidal sandy mud with Tubificoides benedii and Pygospio elegans complex community has been shortened to intertidal sandy mud.

Figure 14 Marine community types



Source: OA_010

Table 10 provides a table which shows the area of overlap between aquaculture operations and different marine communities. A large proportion of the aquaculture sites overlap with sandy mud with polychaetes and bivalves community complex. That might speak effectively to questions of capacity / suitability for aquaculture.

Table 10 Overlap of aquaculture sites and marine community

Marine community	Aquaculture			
	Finfish	Shellfish	Non-aquaculture	Total
Fine sand dominated by Nephtys cirrosa community		7	290	297
Intertidal sandy mud		13	779	792
Laminaria dominated community	1		1,634	1,635
Maerl dominated community		9	278	287
Other		3	134,405	134,407
Reef Fauna	5		210	215
Reef Intertidal		7	829	836
Sandy mud with polychaetes and bivalves community complex	11	239	5,538	5,788
Shingle			148	148
Subtidal reef community			0	0
Zostera community			142	142
Grand Total	16	278	144,252	144,546

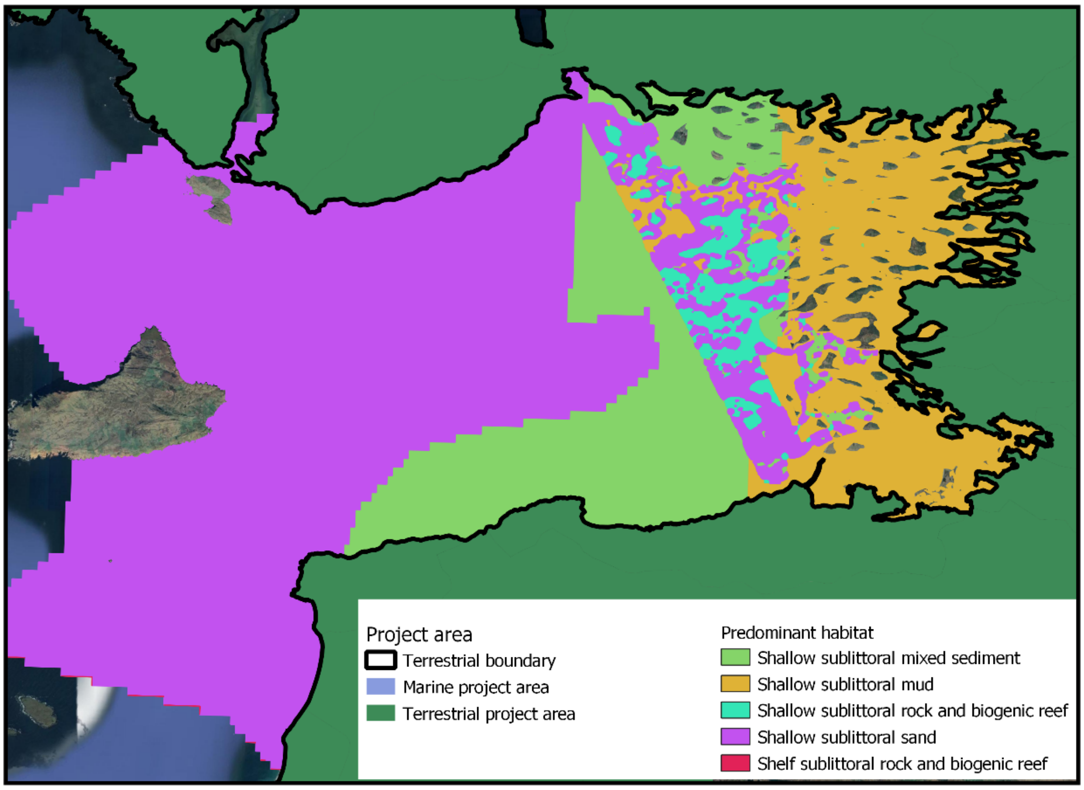
Note: Marine communities are from Clew Bay Special area of conservation
Source: OA_010 and Mul_003

There are other layers that are used to delineate the marine area in Clew Bay or have some coverage of the marine area. The marine strategy framework directive requires data on the predominant habitat type in Clew Bay (see Figure 15). The predominant habitat type layer provides some additional information in areas not covered by the special area of conservation. There is shallow sublittoral mixed sediment and shallow sublittoral sand in areas to the west of the Clew Bay special area of conservation. The Infomar seabed Substrate classification (see Figure 16) is another data layer, but it does not provide much additional information for Clew Bay.

Corine land cover is a data set that has some coverage of the marine area (see Figure 17). Corine was specified to standardize data collection related to land in Europe to support environmental policy development. The land cover data contribute to a wide range of studies and applications with European coverage, e.g.: ecosystem mapping, modelling the impacts of climate change, landscape fragmentation by roads, abandonment of farmland and major structural changes in agriculture.

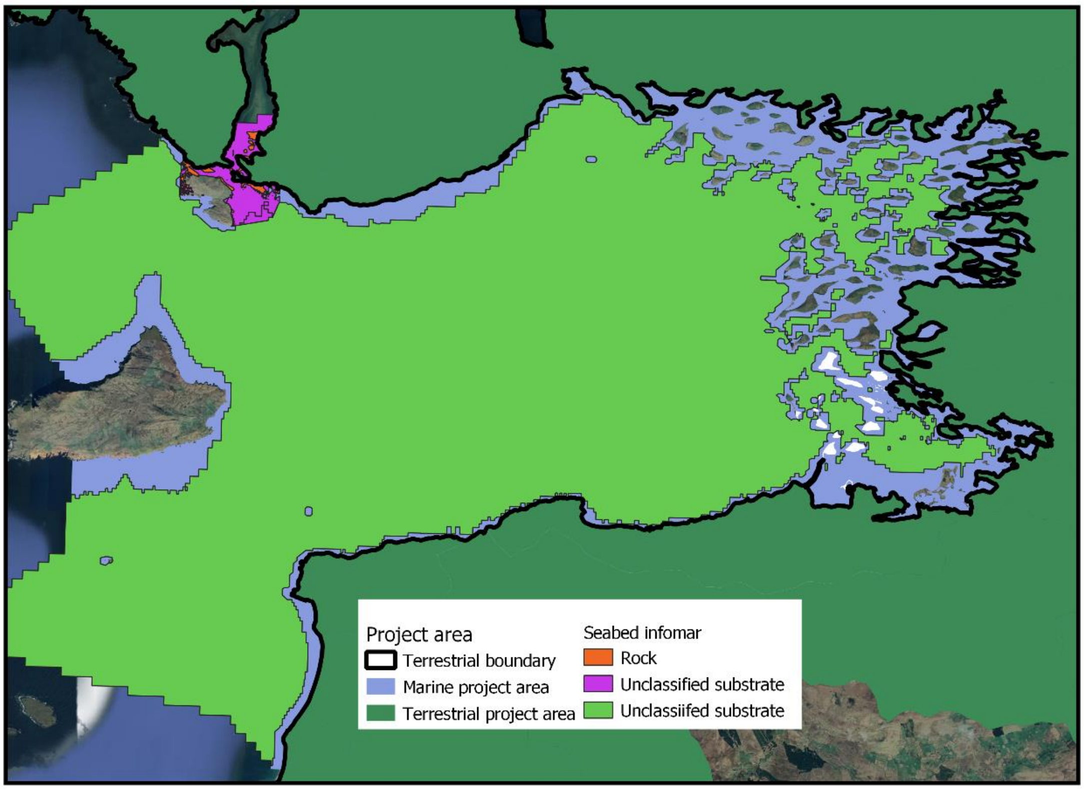
In the future, a coordinated effort at organising data for the marine area should be completed. Currently, there are many different datasets and combining them is difficult due to different classes and years of data collection. A standardised approach to data collection is required.

Figure 15 Marine strategy framework directive, predominant habitat type



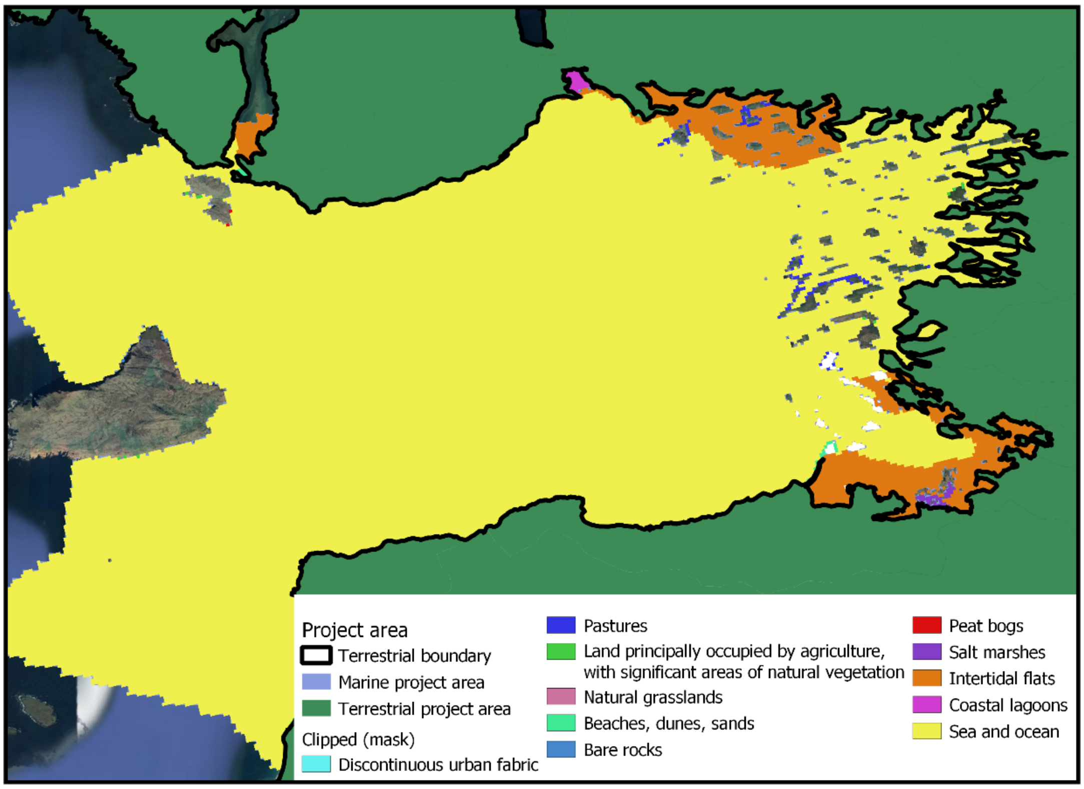
Source: OA_002

Figure 16 Infomar seabed classification



Source: OA_090

Figure 17 Land cover, Corinne 2018



Source: OA_091

Ecosystem condition

Approximately one third of large shallow inlets and bays within SACs around the coast of Ireland were surveyed to assess their structure and function between 2016 and 2018. The site-based conservation assessment was Unfavourable-Bad at eight sites, amounting to 52 per cent of the area surveyed. Clew Bay was assessed as unfavourable-bad.[3] The principal reason for the failure of the habitat to meet Favourable Conservation Status in the majority of SACs was the loss of eelgrass beds (Zostera marina in particular); this occurred in seven SACs (Kenmare River SAC, Valentia Harbour/Portmagee Channel SAC, Mulroy Bay SAC, Clew Bay Complex SAC, Broadhaven Bay SAC, Mullet/Blacksod Bay Complex SAC and Kingstown Bay SAC). This ranged from a gross negative change in abundance to a total loss of an area of eelgrass.

Ecosystem condition can be measured using other metrics such as water quality data and shellfish safety data.

Under the EU Water Framework Directive classification systems, coastal and transitional water bodies in Clew Bay are of good and high status respectively and are not considered to be at risk. Other measures of water quality such as trophic status assessment for the period 2018-2020 indicate that the bay is unpolluted, and designated bathing waters in the region are all of good to excellent quality.

The Sea-Fisheries Protection Authority (SFPA) classifies shellfish production areas for the commercial harvesting of bivalve shellfish, based on data obtained from a microbiological sampling programme for production areas in Ireland. EU regulations exist to control the public health risks associated with consumption of microbiologically contaminated shellfish. The risk of contamination of shellfish with bacterial and viral pathogens is evaluated by reference to (i) the sources and types of faecal contamination (human and animal) in the vicinity of the shellfish production areas and (ii) the results obtained, based on the indicator bacteria E. coli, from shellfish samples taken in these areas. The most probable number of E coli / gram shellfish flesh is used as a measure of seafood safety. Shellfish can be classified using these figures (see Table 11). The level of E coli is a proxy for water quality: poorer water quality may be associated with higher readings of E coli, e.g. from agricultural run off, and vice versa.

[3] (Kenmare River SAC, Valentia Harbour/Portmagee Channel SAC, Mulroy Bay SAC, Clew Bay Complex SAC, Broadhaven Bay SAC, Mullet/Blacksod Bay Complex SAC, Kingstown Bay SAC and Roaringwater Bay SAC)

Table 11 Shellfish classification based on E. coli monitoring

Classification	Standard per 100g of flesh and intervalvular fluid	Treatment required
A	80% of samples ≤ 230 E. coli/100g; all samples must be less than 700 E. coli/100g)	None - molluscs can be harvested for direct human consumption
B	Must not exceed the limits of a five-tube, three dilution Most Probable Number(MPN) test of 4,600 E. coli per 100 g of flesh and intervalvular liquid.2	Purification, relaying in class A area or cooking by an approved method
C	LBMs must not exceed the limits of a five-tube, three dilution MPN test of 46,000E. coli per 100 g of flesh and intervalvular liquid.	Relaying for a long period or cooking by an approved method
Prohibited	>46,000 E. coli per 100g of flesh and intervalvular fluid	Harvesting not permitted

Table 12 shows the list of classified Bivalve Mollusc Production Areas in Clew Bay. It shows that all production areas are of class A, for both mussels and oyster species. This indicates that water quality is good in Clew Bay.

Table 12 List of classified Bivalve Mollusc Production Areas in Ireland, 2020

Production Area	Bed name	Species	Class
Clew Bay Classified Production Areas	Tieranaur Bay	Oysters	A
	Inisquirk		
	Corrie Channel	Mussels	A
		Oysters	A
	Rosslaher	Mussels	A*
		Oysters	A
	Mynah	Oysters	A
	Inishlaughil	Mussels	A
	Carrowholly	Oysters	A*
	Murrisk	Oysters	A

Note * = Seasonal Classification 1 April to 01 Feb, Reverts to Class B at other times (Note 1).

In relation to shellfish (live bivalve mollusc) classification there are a number of classified production areas within Clew Bay (Table 12). Areas are classified following a full assessment of this risk and the classification given to an area determines whether shellfish harvested in that area require post-processing treatment and, where appropriate, the level of such treatment. In some instances a spike in ecoli can be traced back to a one-off event which happened to coincide with the sampling location and time. An example may be where the sample was collected following unusually heavy rainfall. In this instance, evidence of lower salinity, indicating higher freshwater influx, together with meterological records have helped the shellfish operators to make a case to the Molluscan Shellfish Safety Committee (MSSC) that the sample results were an outlier and hence justify a more representative classification for their production area.

In the future, information on ecosystem condition could be captured in an ecosystem condition account (see Table 13). The ecosystem condition account presents numerical data for a suite of ecosystem characteristics. A broad set of information on ecosystem characteristics and function is central to measuring and interpreting condition.

Key characteristics may include i) abiotic ecosystem characteristics, for example, physical and chemical, ii) biotic ecosystem characteristics, for example, characteristic biota, and iii) landscape/seascape level characteristics.

An example of seagrass meadows ecosystem characterisation is provided in see Table 13. It provides examples of ecosystem characteristics including a) abiotic ecosystem characteristics, b) biotic ecosystem characteristics and c) landscape/seascape characteristics.

The choice of a reference level (a benchmark of condition to assess current condition against) is central to the measurement of condition. Condition can be measured relative to its natural state, a modified state, or a target state within a framing of natural condition. In many instances it is argued that the ideal reference level is natural. However, in practice the reference level will relate to the time of ecosystem sampling which is spread across both time and space. Reference levels also vary across space because of endogenous and exogenous factors.

Table 13 Stylised example condition account, seagrass ecosystems

SEEA Ecosystem Condition Typology Class		Variable descriptor	Indicator values (0 - 1)		Weight in aggregate index	Index values		
			Opening	Closing		Opening	Closing	Change*
(1)	(2)	(3)	(9)	(10)	(12)	(13)	(14)	(15)
Abiotic characteristics	Physical state	Water clarity - turbidity	0.98	0.99	0.08	0.08	0.08	0.00
		Average patch size	0.23	0.00	0.08	0.02	0.00	-0.02
	Chemical state	Chlorophyll a concentration	0.13	0.08	0.17	0.02	0.01	-0.01
	Total abiotic				0.33	0.12	0.09	-0.03
Biotic characteristics	Compositional state	Fish species richness	0.30	0.20	0.17	0.05	0.03	-0.02
	Structural state	Seagrass shoot density	0.28	0.22	0.17	0.05	0.04	-0.01
	Functional state	Biological Oxygen Demand	0.85	0.85	0.17	0.14	0.14	0.00
	Total biotic				0.50	0.24	0.21	-0.03
Landscape/seascape characteristics		Seagrass meadow cover	0.50	0.38	0.17	0.08	0.06	-0.02
	Total landscape/seascape					0.08	0.06	-0.02
Total					1.00	0.45	0.37	-0.08

Source: (UN et al, 2021)

Fish stock

The size and health of the fish stock available in Clew Bay is crucial for the seafood sector. Wild fisheries depend on a healthy fish stock, which in turn depends on healthy ecosystems that provide nursery services. Wild fish can migrate, and therefore the health of ecosystems in other locations which those fish migrate from, is important.

Aquaculture also depends on a healthy fish stock, but there is less dependence on well-functioning ecosystems to support the stock of fish. For finfish aquaculture, inputs such as fish feed are used, and other produced capital, rather than a reliance on natural processes and functions. Shellfish aquaculture is wholly reliant on natural system providing phytoplankton and zooplankton for filter feeding. Humans have less of a role of managing the environmental conditions in these circumstances, but do need to focus on reducing and minimising the negative impacts of operations on the environment. Water quality, for example nitrogen and phosphorus levels in water, and water temperature are critical determinants of the health and size of the fish stock. The seafood sector can implement different techniques to manage water quality, and affect the stock of fish.

Recording the stock of fish, both for wild fisheries and aquaculture can inform management, for example the setting of catch limits with respect to wild fisheries, or the management of water quality when it comes to aquaculture. Table 14 provides an example of a stock account for a number of different species.

Table 14 Example asset account for fish

Stock	Species 1 (tonnes)	Species 2 (tonnes)	Species 3 (tonnes)	Total (tonnes)
Opening stock 2014	15	17	4	36
Managed expansion (a)				
Natural expansion (a)	1	3		4
Upwards reappraisals (a)				
Total additions to stock				
Managed regression (a)				
Natural regression (a)	3	1		4
Downward reappraisals (a)				
Total reductions in stock				
Closing stock 2019	13	19	4	36

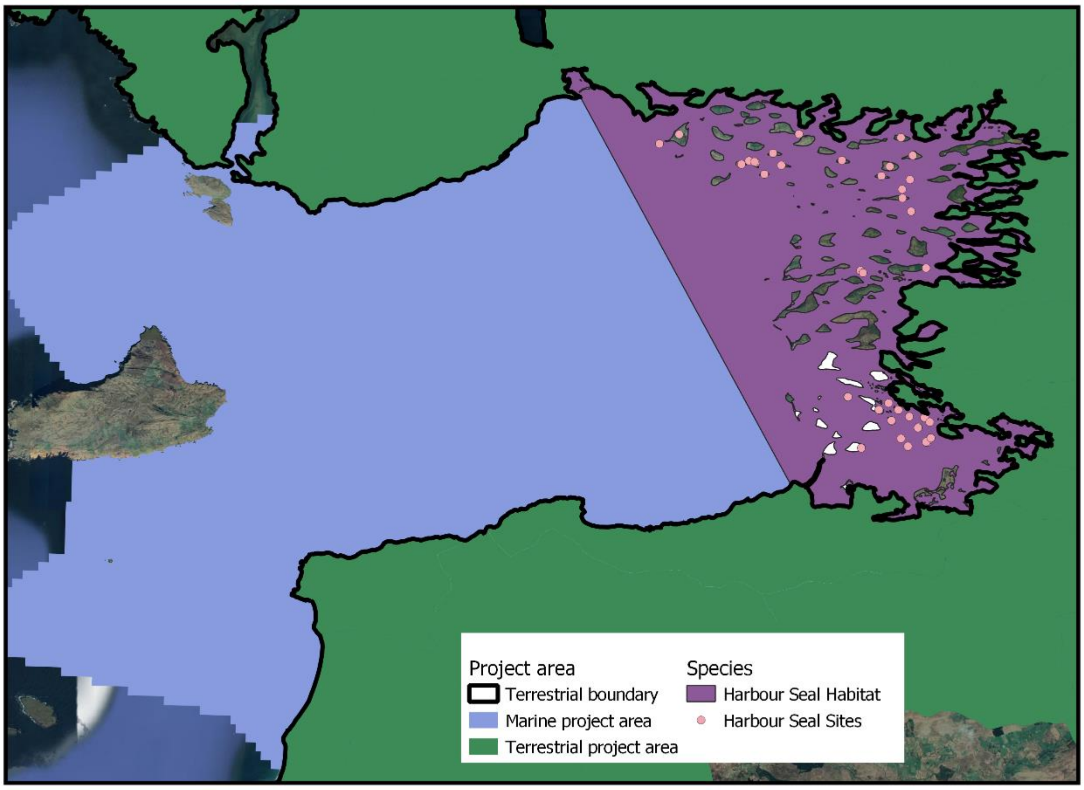
Note: individual accounts can be produced for different seafood producers, or accounts can have hierarchical heading labels, e.g. producer 1, species 1, 2, and 3, and then producer 2, species 1, 2, 3. Further, the rows can be modified depending on the business needs (e.g. Seed / juveniles (size, number, mass) Annual Growth (size, number, mass))

Species

Clew Bay is designated for and supports significant numbers of Harbour Seal (see Figure 18) and otter (see Figure 19) while salmon, designated in the Newport River which flows into the north east corner of the Bay, migrate through the Bay as smolts and as mature salmon returning from sea (Marine Institute, 2019).

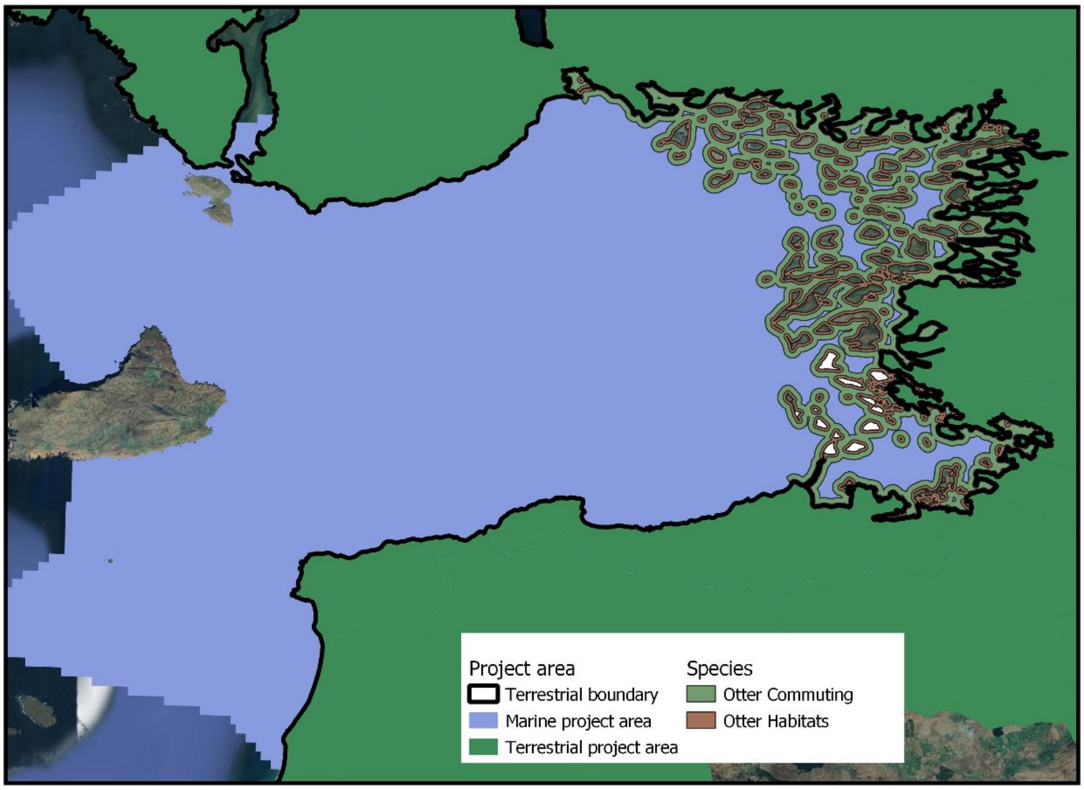
Important populations of Otter and Common (Harbour) Seal are found in Clew Bay. A total of 95 Common Seals were recorded ashore within Clew Bay Complex SAC in August 2003 during a national aerial survey for the species. Continued land-based monitoring within the site recorded 121 seals of all ages ashore in August 2009 and 118 in August 2010. The Clew Bay Complex supports a good diversity of wintering waterfowl, with nationally important numbers of Red-breasted Merganser (average maximum of 70 in the winters 1995/96-1999/00) and Ringed Plover (average maximum of 142 in the winters 1995/96-1999/00). A population of Barnacle Goose (100-200 birds) frequents the islands during winter. Other species which occur in significant numbers include Great Northern Diver (14), Brent Goose (118), Shelduck (74), Wigeon (112), Teal (127), Mallard (64), Oystercatcher (250), Dunlin (450), Bar-tailed Godwit (73), Curlew (373), Redshank (172), Greenshank (10) and Turnstone (27) (all figures are average maxima for the winters 1995/95-1999/00). Species which breed in important numbers include Cormorant (115 pairs in 1985), Common Tern (20+ pairs in 2000/01), Arctic Tern (100+ pairs in 2000/01) and Little Tern (9 pairs in 2000). The various tern species, as well as Barnacle Goose, Great Northern Diver and Bar-tailed Godwit, are listed on Annex I of the E.U. Birds Directive. (SY001482)

Figure 18 Harbour seal habitat and sites within the Clew Bay SAC



Source: OA_092

Figure 19 Otter habitat and commuting areas



Source: OA_093

Accounting for species can be linked to accounting for condition. Higher species counts and diversity may be associated with higher quality ecosystems. Data on species can be recorded in their own right, or included in the condition account (see stylised table in Table 13).

3.4.2 Produced capital

Seafood operators in Clew Bay use many different produced assets in the catching and farming of fish. Vessels are predominantly under 10m with 4-5 being under 16m (see Table 15). Sixteen of the vessels have polyvalent licences which allow operators to access all commercial species fished in the bay other than oysters which require a secondary licence which is issued by Inland Fisheries Ireland (IFI). Seven of the vessels are restricted to using pots only (so called P licences) and 3 vessels are licenced in the Aquaculture segment of the fleet. Aquaculture vessels may dredge for oysters provided they have an IFI oyster permit.

Shrimp, prawn, crayfish, and whelk are the main fisheries with drift netting and gill netting providing small seasonal catches. There are a few boats dredging scallop in the bay on a seasonal basis. Although most pot fishermen purchase bait (frozen pelagic) ashore some fishermen use trammel nets to fish for wrasse, pollack and dogfish which are used as bait in pots. The fishery is likely to occur at the edges of reef areas and may be localised. Cloughmore and Raigh are the busiest ports.

Oyster farming sites are typically accessed at low tide using tractors and quads. Access is mainly from public roads and land and crosses the foreshore to the licensed sites using designated routes. These routes, which are delineated by markings, are typically maintained by the private aquaculture businesses utilising them.

Seafood businesses utilise a range of produced capital from vehicles and vessels to gear specific to the fishing or culture method. In Clew Bay Oysters are grown in the intertidal environment using the bag and trestle method and mussels are grown sub-tidally on a rope culture system. Salmon are grown in a pen system. Oysters are fished from vessels under 10m in length using blade or fixed toothed dredges. One dredge, measuring approximately 1.2m in width, is used by each vessel.[4]

Table 15 Commercial Licenced/Registered Vessels by Size

Size in Meters	Number of Vessels	Number of days
4-6	5	Seasonal
6-8	13	Up to 100 days
8-10	10	100-120 days
10-12	1	120- 150 days
12 and over	1	Less than 50 days

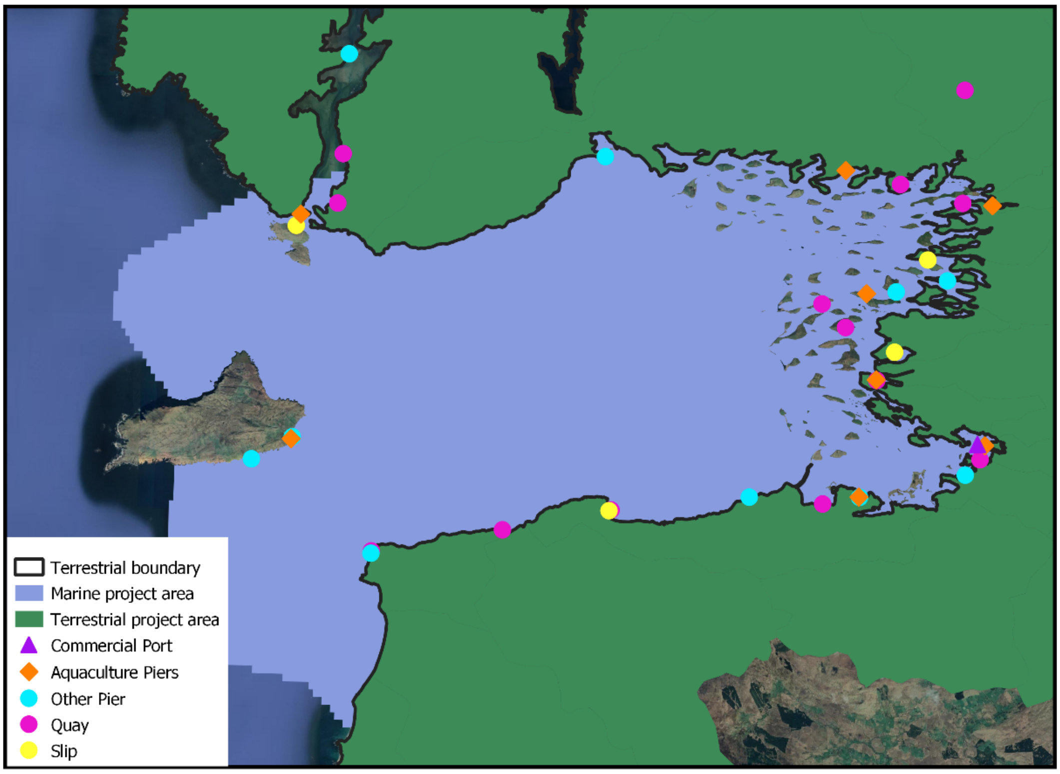
Note: Figures exclude Native Oyster Vessels

There are a number of public produced assets located and managed in Clew Bay (see Figure 20). Public built assets such as piers, quays and slips provide marine vessel access to the natural capital in the bay. This includes access to aquaculture sites, (mussels, salmon and seaweed),

[4] The scope of this study did not extend to a comprehensive assessment of private capital holdings. However, the type of private capital used may impact on the businesses productive and natural capital.

inshore fishing including native oysters, and leisure craft. Aquaculture piers are predominately located in the inner Clew Bay area. There is one commercial port, Westport Quay, located in inner clew bay too.

Figure 20 Public infrastructure, Clew Bay



Source: OA_069

3.4.3 Human capital

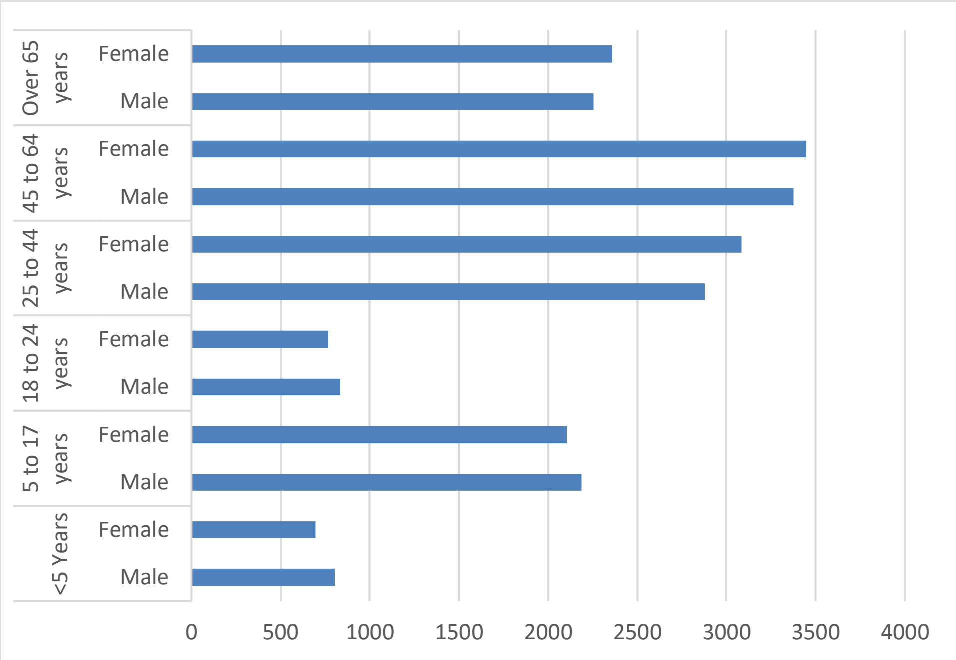
Investments in produced and human capital, and the efficient use of labour and produced capital inputs are central to fishing operations. In this section we present some information on human capital. The information can be extended in the future to better describe the links between human and natural capital.

Human capital is the importance of people – their abilities, their knowledge, and their competencies (Keeley, 2007). The quantity and quality of human capital is linked to the management and use of both natural and built capital. For example, staff that have received training may be better equipped to use new technology that improves environmental performance.

The quantity and quality of human capital is managed by households, industry, and government. Household heads choose the number of children they have and make choices about factors such as education and nutrition for both themselves and their children. Employers also manage human capital by investing in training and ensuring their staff's mental health. Government also has a role to play, by providing incentives and subsidies for different training programs and degrees.

The information provided in Figure 21 to Figure 23 give a sense of the capacity of human capital in the project area. Figure 21 provides an overview of the number of people, by age and sex. The human capital is distributed across a number of age categories. The category with the largest number of people is the 45 to 64 years old category. The older population (aged 25 years and older) have a larger number of people than the young population (25 years and younger) Females are more prominent in categories 25 years and over, and males are more prominent in the categories of 24 years and younger.

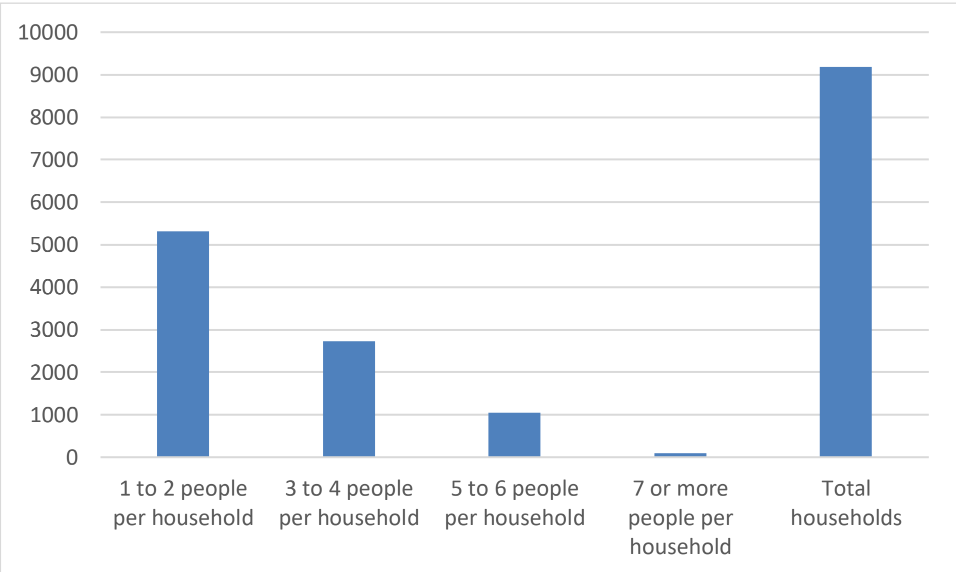
Figure 21 Number of people, by age and sex, accounting area



Note: contains data from small areas that are within the accounting area. Not all small areas are perfectly inside the area.
Source: Census 2016 Small Area Population Statistics.

Figure 22 shows that most households have 1-2 people, or 3-4 people per household in the accounting area. This demonstrates that the size of a household is quite small.

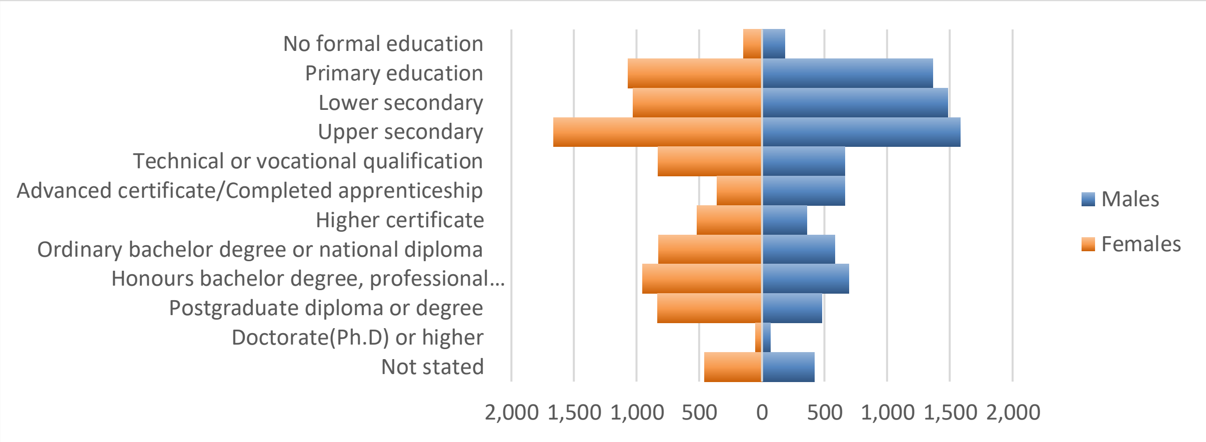
Figure 22 Number of households, by size of household, accounting area



Note: contains data from small areas that are within the accounting area. Not all small areas are perfectly inside the area. Source: Census 2016 Small Area Population Statistics.

Figure 23 shows the population in the accounting area aged 15 years and over by sex and highest level of education completed. Females seem to be represented higher than males in university degrees.

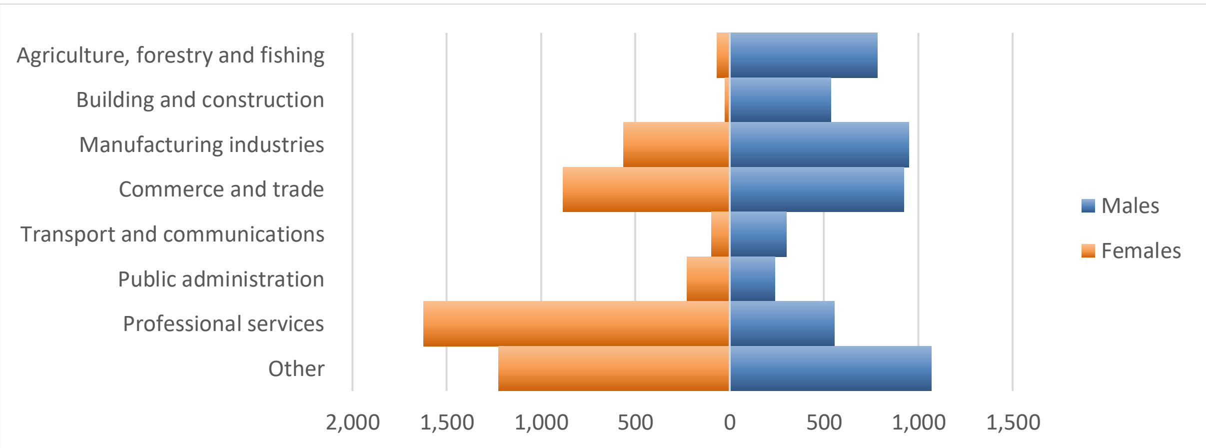
Figure 23 Population aged 15 years and over by sex and highest level of education completed



Note: contains data from small areas that are within the accounting area. Not all small areas are perfectly inside the area. Source: Census 2016 Small Area Population Statistics.

Figure 24 shows persons at work by industry and sex. Males appear to dominate the agriculture, forest and fisheries sector, while Females appear to dominate the professional services sector. As many seafood businesses are small family operations, females (wives, sisters) may not be recorded as official employees despite taking on responsibility for many of the key administrative activities of the business.

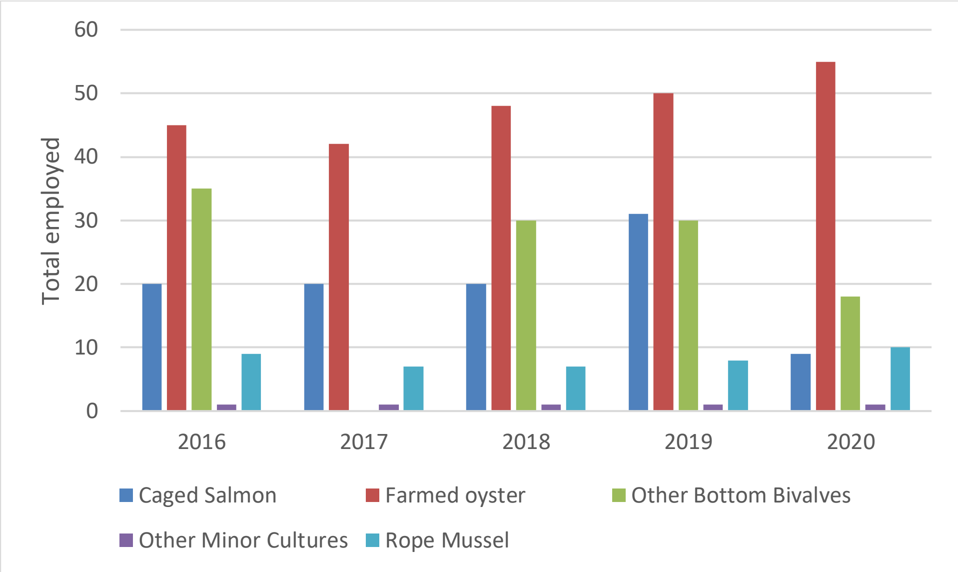
Figure 24 Persons at work by industry and sex



Note: contains data from small areas that are within the accounting area. Not all small areas are perfectly inside the area. Source: Census 2016 Small Area Population Statistics.

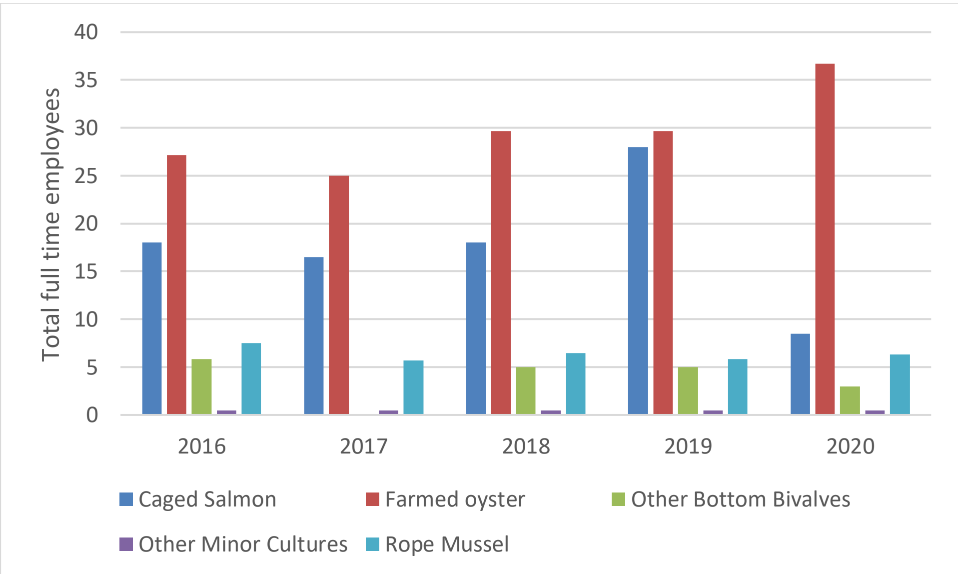
Figure 25 and Figure 26 show the number of full-time employees by aquaculture type. Farmed oyster businesses have a total of 37 FTE, compared to salmon aquaculture, which has 9 FTE, and rope mussel, which has 6 FTE. While some fishers are part time, up to 60% are full time fishers. An analysis of aquaculture employment as a proportion of all employment in the area shows that aquaculture is quite small as a component of agriculture, forestry and fishery (approximately 900 FTE).

Figure 25 Employees by type of aquaculture, Clew Bay



Source: Mul_002

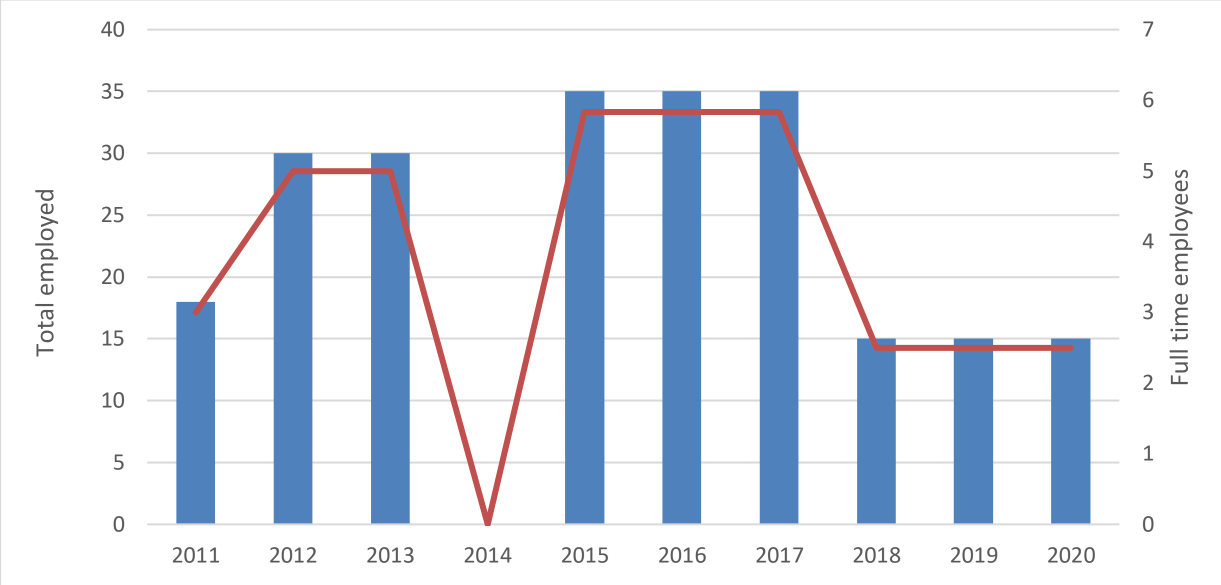
Figure 26 Full time employees by type of aquaculture, Clew Bay



Source: Mul_002

Figure 27 show the number of full-time employees and the total people employed for the native oyster fishery between 2011 and 2020. There were a maximum of 6 FTE in each of 2015, 2016 and 2017. In 2020, there were 3 full time employees and 15 people employed.

Figure 27 Total employed and full-time employees, the native oyster fishery, 2011 to 2020



3.4.4 Social capital

Investments in social capital are perhaps less obvious than investments in produced and human capital, but they can have a positive effect on natural capital. Social capital consists of any networks of individuals, households, businesses, not for profit or government, that have shared beliefs (see Box 3 for a description of social capital).

Box 2 Defining Social capital

The social capital of a society includes the institutions, the relationships, the attitudes and values that govern interactions among people and contribute to economic and social development. Social capital, however, is not simply the sum of institutions which underpin society, it is also the glue that holds them together. It includes the shared values and rules for social conduct expressed in personal relationships, trust, and a common sense of 'civic' responsibility, that makes society more than just a collection of individuals (World Bank 1998).

Social capital encompasses "networks, including institutions, together with shared norms, values and understandings that facilitate cooperation within or among groups" (OECD 2007, p.103). Social capital may be reflected in both formal and informal arrangements and can be considered as the "glue" that binds individuals in communities. More broadly, it is the form of capital that "enables" the production and allocation of other forms of capital (UNU-IHDP and UNEP 2014).

Social capital is typically formed in response to social preferences. Legislation and regulation are the embodiment (a reflection) of social preferences and thus represent the preferences of a majority network (at least in democracies). Groups of individuals may come together in different geographic areas to deliver on the intent of the legislation and those groups are forms of social capital with aligned objectives. There are also many other forms of social preferences that are not embodied in legislation and regulation. This includes caring for local natural capital and the benefits it provides.

The stock of social capital is the size of the network within a geographic area and the condition of that network can be measured by qualitative characteristics such as trust between network members or the speed in which information is transmitted across the network. Services provided by social capital include information sharing, coordination and or collaboration services, which ultimately reduce the transaction costs associated with working together.

Social capital has a number of features:

- investments are made by each node in the network (seafood operators, government members, etc) in the form of time and effort
- there are complementarities and efficiencies for individuals that invest time, effort, and money in social capital simultaneously. That is, an individual will get more benefit from the network if all other individuals put in effort simultaneously.
- complementarities across individuals result in social multipliers (see Becker and Murphy 2001). Social multipliers mean that small changes in fundamentals can lead to large changes in aggregate behaviour.
- Social capital will have its own norms, values etc, which are embodied in a set of rules. These rules, which are formally represented in protocols and legislation, are legitimized by getting consensus from the network. Agreed rules can promote cooperation and minimize conflict with other resource users.
- Social capital acts as a networking infrastructure for the sharing of information.
- Members depend on the bargaining power of social capital to collectively address social and environmental issues (the idea of strength in numbers)

There are many forms of social capital in Ireland. The Coordinated Local Aquaculture Management Systems (CLAMS) group is an example of social capital in Clew Bay. CLAMS is a nationwide initiative to manage the development of aquaculture in bays and inshore waters throughout Ireland at a local level. The Clew Bay CLAMS group has developed a plan which fully integrates aquaculture interests with relevant national policies, and which clearly lays out what finfish and shellfish farmers are currently doing in the bay, how they operate and what their future plans are. Section 5 provides a case study of social capital in Clew Bay, with a focus on the CLAMS group.

3.5 Dependencies

Asset managers depend on their own assets together with assets managed elsewhere, to derive benefits (for example, some livelihoods depend on the commons that are managed by public institutions). An asset manager should consider two things when focussing on dependencies:

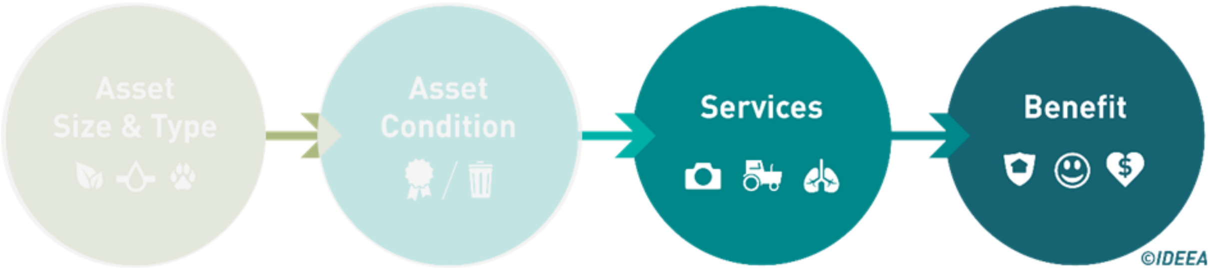
- the quantity and quality of their own assets and
- the role of assets that they do not control that they are dependent on.

The seafood sector depends on a healthy environment for the sustainable production of fish. They depend on functioning ecosystems that purify the water and ensure high water quality and provide nursery services for fish, and productive waters that support the food webs that enable fish and shellfish to grow.

This section builds on the description of who is managing natural capital in Clew Bay, and what natural capital is being managed, to describe the dependencies of each economic actor on natural capital. These dependencies are best understood by describing both the supply and use of ecosystem services. The focus on this section will be on the aquaculture sector within Clew Bay, and where possible, the native oyster industry.

Accounting for ecosystem services involves recording the flows of services provided by an ecosystem, and the use of those services by economic units, that is,. households, governments and businesses. The measurement of ecosystem services can be undertaken in physical and monetary terms and can be used to reveal how the health of the ecosystem is related to the flows of ecosystem services, and how human activity may be influencing the level of services. Further, ecosystem services can be measured over time to understand trends in the relationship between different economic units and ecosystems and the relative contribution of ecosystems to different social and economic benefits. Priority areas for management interventions can be identified by comparing ecosystem services across spatial areas.

Figure 28 Core ecosystem accounting framework



Source: (Eigenraam and Obst 2018)

Flows of ecosystem services are connected to the extent and condition of ecosystem assets and thus it is best practice for the methods which are used to classify and record both extent and condition to underpin the measurement of ecosystem services. Coherence across the different components of the four-box model enable policy makers to link changes in assets to changes in services.

The ecosystem services provided by Clew Bay ecosystems fall into three broad categories: provisioning services; regulating and maintenance services; and cultural services. Flows related to non-use values can also be considered, although they are not included in this report. Examples of these services are provided in Table 16. Each ecosystem service will contribute to a benefit. In some cases, the benefits are goods and services already recorded as monetary transactions, for example, sales of fish and seafood. In other cases, the benefits concerning improvements in, for example, health, are not recorded as monetary transactions. In all cases ecosystem services accounting focuses on recording the flows of ecosystem services but, as relevant, data on the related benefits can also be presented.

Table 16 Examples of ecosystem services

Service type	Example
Provisioning services	Fish biomass provisioning services
Regulating and maintenance services	Global climate regulation
Cultural services	Spiritual, artistic and symbolic services (via cultural heritage connection) and recreation-related services

The ecosystem services (following the SEEA EA ecosystem services reference list) supplied by Clew Bay to different economic actors is presented in Table 17. The provisioning services identified include aquaculture provisioning services, and wild fish and other natural aquatic biomass provisioning services. Both of these services are provided to both household and industry. Regulating services include global climate regulating services, water purification services, nursery population and habitat maintenance services, and flood control services. Cultural services include recreation related services, visual amenity services, education, scientific and research services, and spiritual, artistic and symbolic services. No systematic link between the actor and the ecosystem type is made in this table, but it is true that each ecosystem service is provided by an ecosystem type, to an actor.

Table 17 Ecosystem services supplied by Clew Bay to different economic actors

Ecosystem Service	Household	Industry	Government
Provisioning services			
Aquaculture provisioning services	Yes	Yes	No
Wild fish and other natural aquatic biomass provisioning services	Yes	Yes	No
Regulating and maintenance services			
Global climate regulation services	No*	No*	Yes
Water purification services	No	Yes	No
Nursery population and habitat maintenance services	Yes (intermediate)	Yes (intermediate)	No*
Flood control services	Yes	Yes	No
Cultural services			
Recreation related services	Yes	No	No
Visual amenity services	Yes	No	No
Education, scientific and research services	Yes	Yes	Yes
Spiritual, artistic and symbolic services	Yes	No	No
Flows related to non-use values			
Ecosystem and species appreciation	Yes	No	No

Note: Ecosystem services are from the first column of table 6.3 in the SEEA EA. The second column of table 6.3 further breaks down ecosystem services where possible. For example, water purification services are composed of both retention and breakdown of nutrients, and retention and breakdown of other pollutants. Flood control services include coastal protection services and river flood mitigation services. *This table serves as an example and focusses on the use of accounting conventions under the UN SEEA. Other interpretations may suggest that all economic actors benefit from all ecosystem services, for example, that household and industry benefit from global climate regulation services.

In the following section, we link the service to the ecosystem and provide a quantitative estimate of ecosystem services where possible. The estimates are tier 1, in that they are basic calculations using available data from other projects and research.

3.5.1 Provisioning services

The Clew Bay marine ecosystems provide aquaculture provisioning services. Aquaculture provisioning services are the ecosystem contributions to the growth of animals and plants (e.g., fish, shellfish, seaweed) in aquaculture facilities that are harvested by economic units for various uses. This service is quantified as the volume and quality of fish harvested from the aquaculture sites in Clew Bay. The direct users of this ecosystem service are the seafood operators.

Ecosystem contributions to aquaculture provisioning services are complex. Depending on the type of species, various processes can be exhibited before marine ecosystems contribute to their biomass growth. For example, fish can be incubated and hatched in breeding farms before being transported to a marine on-growing facility. The ecosystem contribution is therefore likely to be less than the quantity of biomass farmed, and produced capital and human capital are very important in the farming process. Concerning the contribution of the ecosystem, the quantity and quality of fish biomass harvested is also function of water quality in the marine environment, which can be regulated by marine ecosystems. Access rights to use this biomass are allocated by the government (in the form of quotas and licenses).

The Aquaculture sector depends on the natural environment to produce fish and shellfish. 2,903 tonnes of finfish and shellfish were produced in Clew Bay in 2020, down from 4,218 tonnes in 2016. The total value also decreased between 2020 and 2016, from 18,787,517 Euros to 15,705,661 Euros. Salmon has had the largest share of the total tonnage and value in each of the years since 2016, although the aggregate quantity is lower in 2019 and 2020 compared to the quantity in 2016, 2017 and 2018. The quantity of farmed oyster has increased in recent years, from 578 tonnes in 2017 to 706 tonnes in 2020.

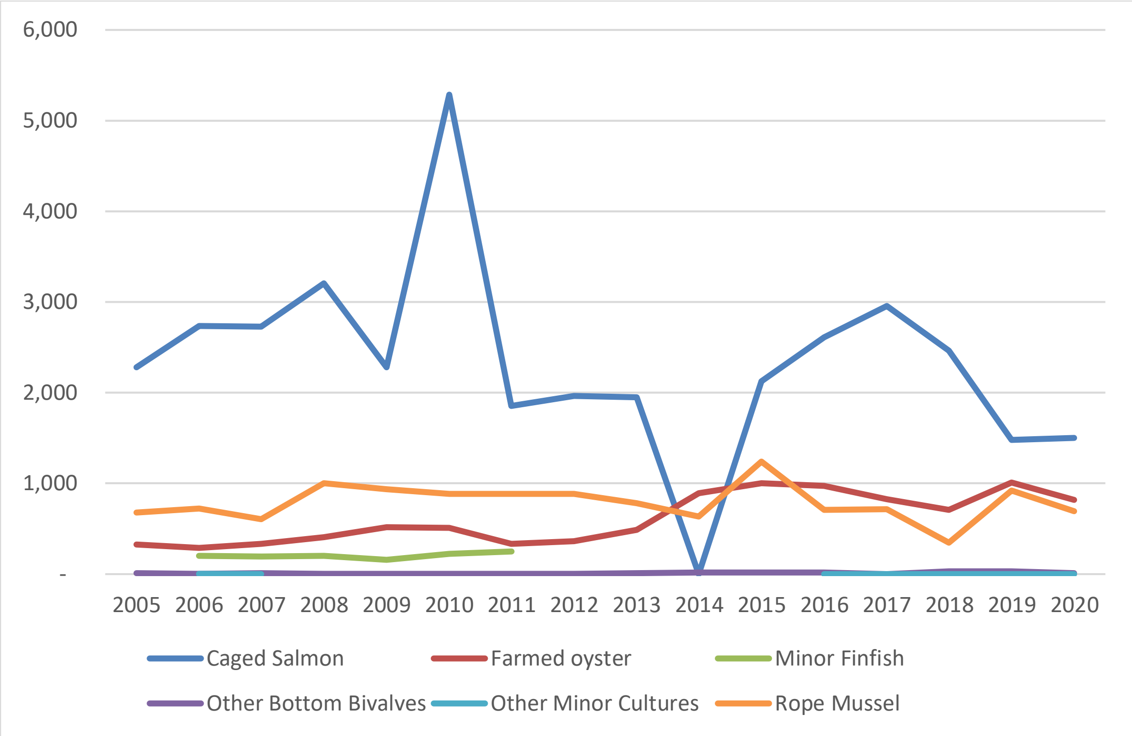
Gross value added by seafood type is provided in Table 18. Gross value added is defined as output (at basic prices) minus intermediate consumption (at purchaser prices). Once again, the salmon industry contributes most heavily to GVA. Figure 29 and Figure 30 show trends in tonnage and value since 2005, respectively. Salmon tonnage and value has exhibited the most variation between years, while farmed oysters has shown an increasing trend in production and value since 2005.

Table 18 Gross value added by seafood type

Aquaculture type	Gross value added
Caged Salmon	17,354,838
Farmed oyster	4,766,014
Other Bottom Bivalves	710,664
Other Minor Cultures	-
Rope Mussel	244,578

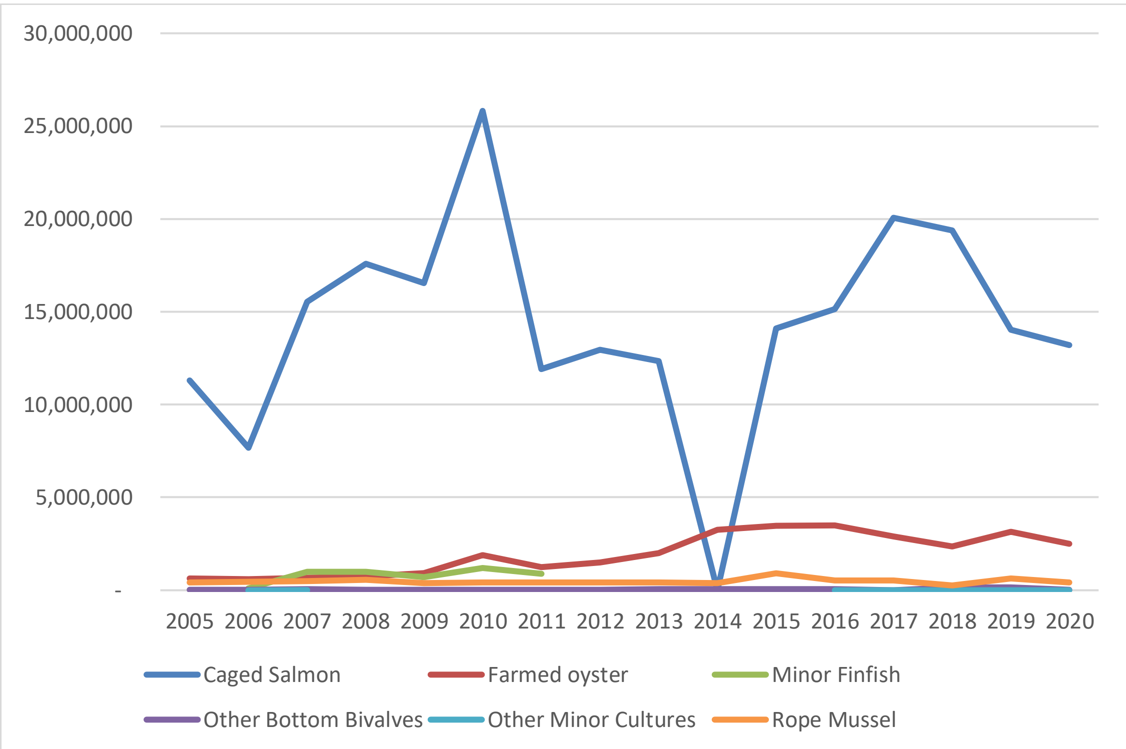
Note: Calculations assume GVA of Clew Bay is directly proportional to GVA of National aquaculture
Source: Mul_002

Figure 29 Tonnage harvested by aquaculture type, 2005 to 2020



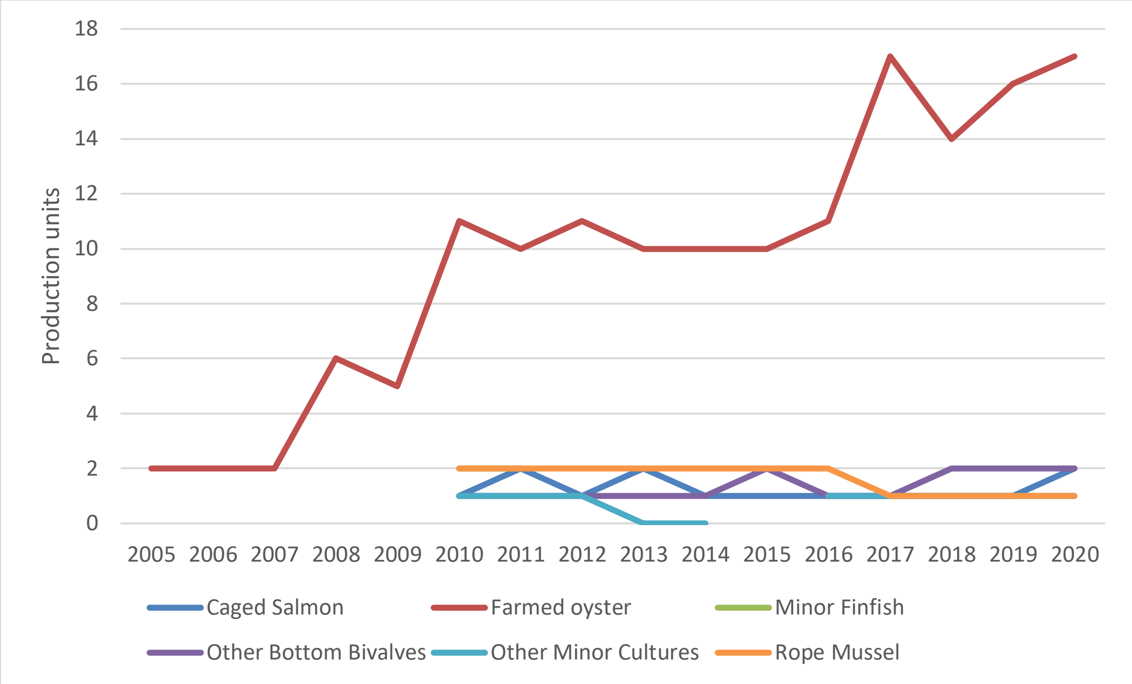
Source: Mul_004

Figure 30 Value of fish production harvested by aquaculture type, 2005 to 2020



Source: Mul_004

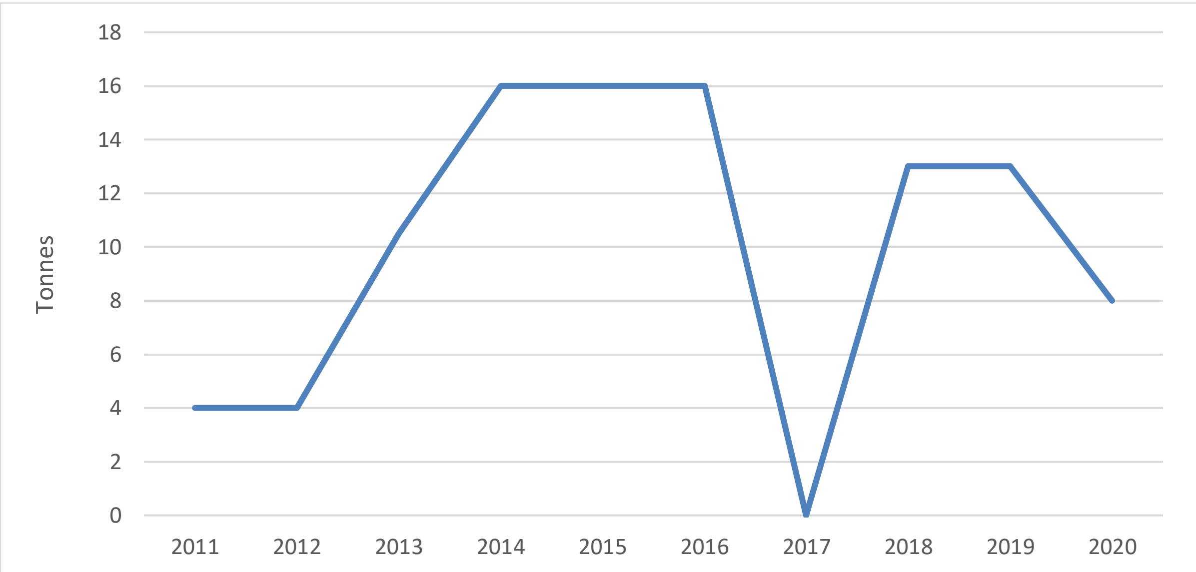
Figure 31 Production units by aquaculture type, 2005 to 2020



Source: Mul_004

Wild fisheries are also an established component of the Clew Bay seafood sector. The Native Oyster Fishery produced 8 tonnes of native oyster in 2020 (see Figure 32). This is half of the tonnage produced in each of the years between 2014 and 2016. In recent years the season has lasted a maximum of 16 days per annum Oct – Feb/March (9am-4pm fishing). In 2017 no oyster fishing was permitted.

Figure 32 Tonnes of native oyster harvested in Clew Bay, 2011 to 2020



Source: Mul_005

3.5.2 Regulating and maintenance services

Regulating and maintenance services are those ecosystem services resulting from the ability of ecosystems to regulate biological processes and to influence climate, hydrological and biochemical cycles, and thereby maintain environmental conditions beneficial to individuals and society.

Global climate regulation services

Some of the ecosystems in Clew Bay provide global climate regulation services through carbon sequestration by soil and biomass. This service can be quantified in terms of the tonnes of carbon sequestered per year. Following the SEEA EA, the user of global climate regulation services is the national government, who are treated as using the service on behalf of the Irish and global communities who benefit from the reduced impacts of climate change (Table 16).

Using the area of the marine communities in the SAC that partially cover Clew Bay, a lower bound estimate of carbon sequestered in Clew Bay is 1,972 tonnes per year (see Table 19). The Maerl dominated community has the highest sequestration rate per hectare, followed by the Zostera community, and then the laminaria dominated community. The estimates can be improved with local carbon sampling and further delineation of ecosystem types within Clew Bay, but are a reasonable first estimate.

Table 19 Carbon sequestered by habitat type

Marine community	Area (ha)	Carbon sequestered (Tonnes per ha per year)	Total carbon sequestered (Tonnes per year)
Fine sand dominated by Nephtys cirrosa community	297	-	-
Intertidal sandy mud	791	-	-
Laminaria dominated community	1,634	0.49	801
Maerl dominated community	287	3.4	976
Reef Fauna	215	-	-
Reef Intertidal	832	-	-
Sandy mud with polychaetes and bivalves community complex	5,788	-	-
Shingle	145	-	-
Zostera community	142	1.38	196
Not covered by SAC	28,655	-	-
Total	38,786	-	1,972

Note: see Table 20 for figures used

Table 20 Calculating tonnes of carbon sequestered per hectare per year

Ecosystem type	Biomass / primary production	Soil	Tonnes C per ha per year
Maerl dominated	On average, live maerl sequesters 330 g C m-2 yr-1 through primary production	an average of 0.1 Mg OC Ha-1 is sequestered	3.4 Tonnes of carbon per ha per year
Laminaria dominated	NA	NA	0.494285714 Tonnes of Carbon per ha per year
Zostera community	NA	1.38	1.38 Tonnes of Carbon per ha per year

Source: Maerl: (Scottish Government Riaghaltas na h-Alba, 2020), Zostera: (Fourqurean et al., 2012), Laminaria:(Krause-Jensen and Duarte, 2016)
Note: to calculate Laminaria tonnes per ha per year divide carbon sequestered (173,000,000 tonnes per year) by macroalgae area (350,000,000 ha)

Water purification and nutrient sequestration services

Water purification services are the ecosystem contributions to the restoration and maintenance of the chemical condition of surface water and groundwater bodies through the breakdown or removal of nutrients and other pollutants by ecosystem components that mitigate the harmful effects of the pollutants on human use or health. This may be recorded as a final or intermediate ecosystem service.

Studies in bivalve ecology have emphasized that phytoplankton dynamics in coastal regions may be strongly coupled with bivalve filter-feeding activity to the extent that the bivalve community plays a major ecological role in controlling phytoplankton biomass and trophic structure. Cultured shellfish rather than being a source of eutrophication can mitigate its effects in coastal waters by being highly effective circuit breakers between the primary symptoms of eutrophication (decreased light availability, increased organic decomposition and algal dominance changes) and secondary symptoms (loss of Submerged Aquatic Vegetation, low dissolved oxygen and an increase in harmful algal blooms) (Duncan, 2018).

Shellfish perform several important roles which serve to increase water and habitat quality in coastal waters: Nutrients are removed when shellfish are harvested; shellfish feeding enhances bacterial denitrification; shellfish enhance sedimentation rates and accelerate the sequestration of nutrients; and feeding reduces turbidity, increasing light penetration which in turn deepens the oxic zone.

Suspended culture operations provide the greatest potential for maximizing the water clarification services of bivalve filter-feeders owing to the direct access of dense populations to particulate matter throughout the water column. Direct measurements of the water clarification capacity of mussel farms have revealed up to 80% particle depletion inside some sections of the farm. When averaged across the total farm volume, some the most intensive suspended mussel aquaculture operations currently in production have been observed to reduce suspended particle concentrations by 13–31%. The spatial extent and magnitude of this control on the phytoplankton is always site- and time-specific as a result of factors controlling food consumption (e.g. intensity of culture, food availability and composition, and temperature) and food resupply processes such as tidal flushing and primary production (Duncan, 2018).

Nutrient extraction in the bivalve harvest represents one of the most promising measures for controlling the consequences of anthropogenic nutrient supply to coastal waters (Petersen et al. 2016). Attempts to also maximize the ecological services from water clarification should consider possible interactions with nutrient extraction. This aligns with the concept of production carrying capacity in which aquaculture farm production (i.e. nutrient extraction) is maximized by preventing excessive food depletion (water clarification).

Accurate measurement of water purification and nutrient sequestration services requires context specific measurements of Nitrogen, Phosphorus and Carbon loadings. Ecosystems in Clew Bay will have capacity to supply the service, but the supply of the service will depend on the flow of residuals into Clew Bay, and there being users of the services, for example aquaculture producers. Further work is needed to provide a basic estimate of this service.

Nursery and habitat maintenance services

Nursery population and habitat maintenance services are the ecosystem contributions necessary for sustaining populations of species that economic units ultimately use or enjoy either through the maintenance of habitats (e.g., for nurseries or migration) or the protection of natural gene pools. This service is an intermediate service and may input to a number of different final ecosystem services including biomass provision and recreation-related services.

In particular, shellfish as filter feeders are reliant on the productivity of the areas in which they grow. Shellfish aquaculture operators do not feed their stocks, but rely on the natural environment for stock growth.

Clew Bay's unique geography has long supported an abundance of fish species, which in turn support the fishing community with the most commonly fished commercial species shown in Table 21. The shelter provided by the islands support an abundance of ideal juvenile nursery areas with reefs and seagrass, allowing fish and shellfish species to flourish. Furthermore, the shelter provided by the many islands offers more days annually for safe fishing.

Table 21 Most Common species Commercially Fished

Species	Months	Importance 1-10	Local sales	Other Markets
Lobster	All year	1	20%	80%
Shrimp	Aug -Jan inclusive	2	0	100%
Brown Crab	All year	4	10%	90%
Velvet Crab	All year	7	0	100%
Pollack	April - Nov	8	25%	75%
Mackeral (line caught)	April to Sept	9	50%	50%
Whitefish (see below)	All year	10	30%	70%
Scallop	All year	5	30%	70%
Prawns	All year	6	25%	75%
Whelk	May to Dec	11	0	100%
PeriWinkles (hand Picked)	Sept to May	3	0	100%
Cockles (hand Picked	Sept to May	14	0	100%
Wild Salmon (TAC)	May-July	16	80%	20%
Native Oysters	Nov-Feb (20 days)	12	10%	90%
Herring	Nov - Feb	15	30%	70%
Sprat	Nov - Feb	Occasional	0	100%
Crayfish	unknown	unknown	unknown	
Spidercrab	All year	13	0	100%

Source: Informal data table compiled on the basis of internal BIM knowledge of the area. The first official census of Inshore fishing activities in Ireland is being conducted in 2022. The fishing vessel register and Sales notes (where available) are the only formal data sources on inshore fishing (<15m vessels) activities to date.

3.5.3 Cultural services

The seafood sector is embedded in an area which provides cultural services. The landscapes, ecosystems, species, and their quality, are characteristics of the area that make it attractive and facilitate a connection for both locals and visitors. Cultural services in Clew Bay include recreation related services, visual amenity services, education, scientific and research services, and spiritual, artistic and symbolic services.

Recreation-related services are of major interest in Clew Bay. Recreation-related services are used by households and the characteristics and condition of ecosystems may impact the quantity of services that households demand. The link between the ecosystem (quantity and quality) and the recreation activity (visitors and visit days) are key components of the narrative. The quantity and quality of Clew Bay ecosystems can affect the quantity of all recreation transactions now and into the future.

Recreation demand is determined by factors such as the type and quality of accommodation, and services provided in towns surrounding Clew Bay. For people undertaking multi-destination and multi-purpose trips, the location and proximity of these other destinations and purposes will also play a part in determining how often and how long people visit the region.

Households can engage with the tourism & leisure industry to participate in recreation activities in Clew Bay, or they can consume them directly (household consumption), for example in the case of recreation-based fishing. A complete information set will capture each recreational activity or transaction, estimate the potential value of the recreation transactions, and link them to one or more ecosystem assets to understand how the attributes and condition of the ecosystem affects the transaction.

Information is available for recreation ecosystem services in County Mayo in 2019. This information is not at the level of Clew Bay, but is still useful in building a narrative:

- There were just over 303,000 overseas visitors in 2019 – representing 9% of overseas visitors to the Wild Atlantic Way. Clew Bay is a destination on the Wild Atlantic Way. There were 658,000 domestic trips – representing 13% of domestic trips to the Wild Atlantic Way.
- Total expenditure from tourists amounted to €240 million. €103 million expenditure from overseas visitors – representing 5% of overseas spend along the Wild Atlantic Way. €137 million from domestic visitors – representing 13% of domestic spend along the Wild Atlantic Way.
- Spend per overseas visitor in Co. Mayo is estimated to be €340 – which is below the average spend per overseas visitor for the West region.
- Spend per domestic visitor to Co. Mayo is estimated to be €208 – a higher level of spend than the average domestic visitor for the West region.
- Overseas spending per 10,000 population in Co. Mayo – €5.98 m (10th/26 counties) (IBEC Local Economic Indicators 2018).
- Selected attraction visits – 2019: Westport Estate – 123,975; Croagh Patrick 113,540; Achill Experience – 32,000; Glen Keen Farm – 31,000; Wild Nephin National Park – 23,743; Clew Bay Heritage Centre – 4,000.
- Fáilte Ireland has undertaken significant research on the country's key consumer segments, including their travel motivations, lifestyle, values, interests, and travel information sources.

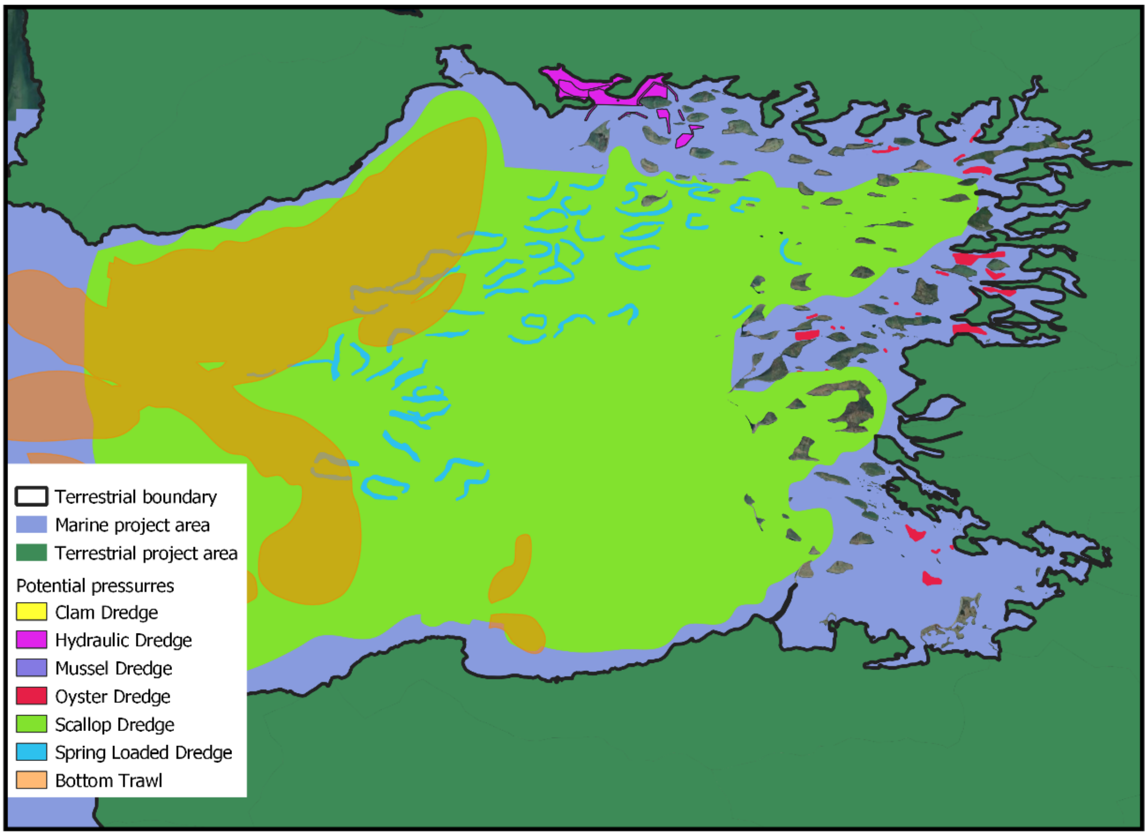
3.6 Pressures

Pressures can have an adverse effect on ecosystems and the benefits that people depend on. The use of ecosystems (see dependencies described above), and pressures related to drivers such as climate change (for example, sea surface temperature) and population growth (for example, wastewater) have the potential to affect the condition of the ecosystems that the economic actors in Clew Bay depend on. This relationship calls for careful management of the use of ecosystems, and other pressures that may exist.

There are a number of activities within Clew Bay that may be linked to pressures. Figure 33 shows where dredge fishing and bottom trawl occurs, such as the hydraulic dredge, the oyster dredge, and the spring-loaded dredge. Dredging can impact marine organisms negatively through habitat degradation, noise, remobilization of contaminants, sedimentation, and increases in suspended sediment concentrations (Todd *et al.*, 2015). These are all areas of potential pressures and monitoring of the ecosystems on continued basis is required to understand the short to long term impacts of these activities.

Licensed aquaculture sites, see Figure 9, are also areas for potential pressures. Some of the pressures arising from shellfish culture, identified in the Appropriate Assessment reports for Clew Bay include current alteration, surface disturbance, organic enrichment and introduction of non-native species.

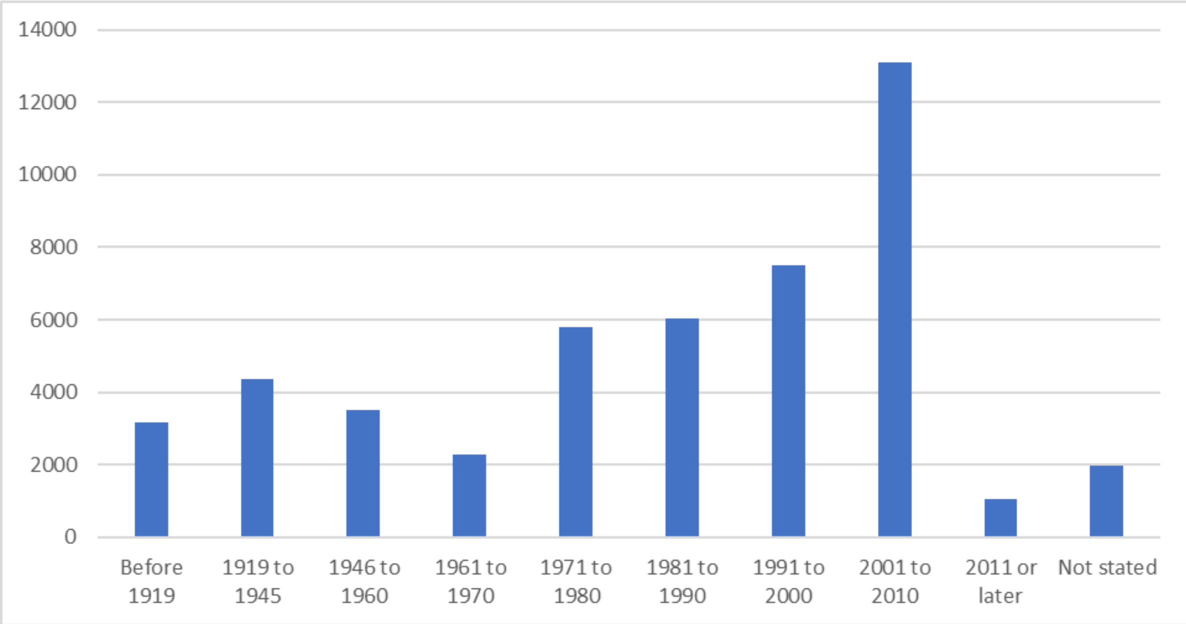
Figure 33 Dredge fishing and bottom trawl



Source: OS_010

Figure 34 presents the number of private households in permanent housing units. It is clear that there is an increasing trend from 1919 to current in the number of new private households in permanent housing units. A greater number of permanent residents could be linked to increased pressures which are correlated with a development footprint, for example waste and litter in the area, water discharge (sewage / private water treatment) and water demand – mains supply or group scheme. The exact nature of the pressures on Clew Bay cannot be determined without further evidence.

Figure 34 New Private Households in Permanent Housing Units



Note: contains data from small areas that are within the accounting area. Not all small areas are perfectly inside the area.
Source: Census 2016 Small Area Population Statistics.

Land use is an important driver of pressures on marine ecosystem. There are 12,300 ha of pasture, and 19,038 ha of land that is principally occupied by agriculture, with significant areas of natural vegetation, in the area of interest (see Table 22 and Table 23). This accounts for approximately one third of the area in the region. Agricultural activity is linked to pressures such as pluviometry, climate variability and other natural phenomena, surface runoff, water demand, landscape manipulation, mineral fertilisers, organic contaminants, and animal waste (A Troian, 2021). Conversions between ecosystems can also change the level of potential pressures (see Table 23). For example, conversions from coniferous forests to other ecosystems can reduce the quantity of regulating ecosystem services that are provided (for example, water purification services) and therefore increase the flow of poor-quality water into Clew Bay. Monitoring is required to determine the impact of such activities on the marine ecosystems.

Table 22 Extent of terrestrial change, 2012 to 2018

Classifications >>	Urban	Agriculture	Forest	Natural grasslands	Moors and heathland	Transitional woodland-shrub	Beaches, dunes, sands	Bare rocks	Sparsely vegetated areas	Inland marshes	Peat bogs	Salt marshes	Intertidal flats	Water bodies	Coastal lagoons	Other	Estuaries	Large shallow inlets and bays	TOTALS
Opening Extent	894	31,137	6,453	1,859	3,555	3,969	289	1,057	1,571	519	51,439	43	323	1,292	58	1,299	-	6	105,761
Additions to extent	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Managed Expansion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unmanaged Expansion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unclassified Expansion	7	234	614	7	22	1,068	8	15	13	-	254	-	7	-	-	1	-	-	2,246
Total Additions	7	234	614	7	22	1,068	8	15	13	-	254	-	7	-	-	1	-	-	2,246
Reductions in extent	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Managed Reductions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unmanaged Reductions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unclassified Reductions	-	30	1,124	-	-	597	-	-	-	-	7	-	3	-	-	479	-	6	2,246
Total Reductions	-	(30)	(1,124)	-	-	(597)	-	-	-	-	(7)	-	(3)	-	-	(479)	-	(6)	(2,246)
Net change in extent	7	204	(511)	7	22	471	8	15	13	-	247	-	3	-	-	(479)	-	(6)	-
Closing extent	900	31,341	5,943	1,866	3,577	4,441	297	1,072	1,583	519	51,685	43	326	1,292	58	820	-	-	105,761

Source: Data from OA_091 and OA_094

Table 23 Terrestrial Change matrix (000's of hectares)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	TR
A	-	-	-	-	-	0.0	-	-	0.0	0.0	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-	0.0
B	-	0.8	-	-	-	0.0	-	0.0	0.0	0.1	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0	-	0.2	-	0.0	-	-	0.5
C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D	-	0.0	-	-	-	-	-	-	0.0	0.0	-	-	-	-	-	-	-	-	-	-	0.0	-	0.0	-	-	0.0
E	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F	-	-	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
I	-	-	-	-	-	-	-	-	12.3	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0
J	-	-	-	-	-	-	-	-	-	18.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L	-	-	-	-	-	-	-	-	-	0.1	-	4.6	-	-	-	1.1	-	-	-	-	-	-	-	-	-	1.1
M	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
N	-	-	-	-	-	-	-	-	-	-	-	-	-	1.9	-	-	-	-	-	-	-	-	-	-	-	-
O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.6	-	-	-	-	-	-	-	-	-	-	-
P	-	-	-	-	-	-	-	-	-	-	-	0.6	-	-	-	3.4	-	-	-	-	-	-	-	-	-	0.6
Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-
R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1	-	-	-	-	-	-	-	-
S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6	-	-	-	-	-	-	-
T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.5	-	-	-	-	-	-
U	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	51.4	-	-	-	-	0.0
V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-
W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-
X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.3	-	-
Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
TA	-	0.0	-	-	-	0.0	-	0.0	0.0	0.2	0.0	0.6	-	0.0	0.0	1.1	0.0	0.0	0.0	-	0.3	-	0.0	-	-	-

Note: A = Tidal Mudflats and sandflats, B = Other, C = Estuaries, D = Large shallow inlets and bays, E = Continuous urban fabric, F = Discontinuous urban fabric, G = Industrial or commercial units, H = Sport and leisure facilities, I = Pastures, J = Land principally occupied by agriculture, with significant areas of natural vegetation, K = Broad-leaved forest, L = Coniferous forest, M = Mixed forest, N = Natural grasslands, O = Moors and heathland, P = Transitional woodland-shrub, Q = Beaches, dunes, sands, R = Bare rocks, S = Sparsely vegetated areas, T = Inland marshes, U = Peat bogs, V = Salt marshes, W = Intertidal flats, X = Water bodies, Y = Coastal lagoons, TR = total reductions, TA = total additions
Source: Data from OA_091 and OA_094

3.7 Impacts

Impacts may include changes in the extent and condition of marine ecosystems, changes in the species counts (for example, fish stocks), and changes in ecosystem services. Changes in extent and condition, and fish stocks, are linked to the drivers and pressures described above, while a change in ecosystem services can be linked to both pressures and changes in the use of ecosystem services.

Data on habitats was available for both 2012 and 2019. Table 24 is an extent account, showing the opening and closing balances for each ecosystem type and Figure 35 shows habitat extent for 2012 and 2019 geographically. The change in ecosystem type can be analysed using a change matrix (Table 25). The rows in Table 25 show 2012 ecosystem types, and the columns show 2019 ecosystem types. The extent of ecosystem types that have remained the same between 2012 and 2019 is shown along the diagonal.

There was a small change in the extent of the habitat types between 2012 and 2019. It is unclear whether this is due to a change in approach of data collection / improved accuracy, or whether there are changes in the underlying stock of ecosystems.

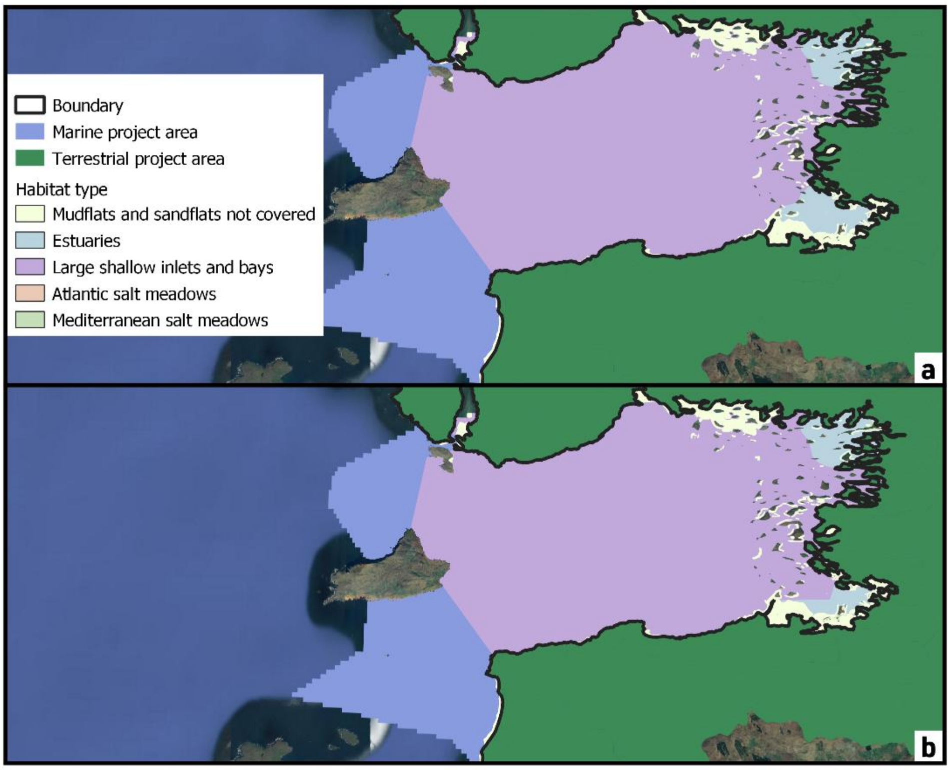
Table 24 Clew Bay Extent Account 2012-2019, hectares

Classifications >>	**Tidal Mudflats and sandflats**	**Other**	**Estuaries**	**Large shallow inlets and bays**	**Salt meadows**	**TOTALS**
Opening Extent	1,663	9,750	1,772	25,601		38,786
Additions to extent	–	–	–	–	–	–
Managed Expansion	–	–	–	–	–	–
Unmanaged Expansion	–	–	–	–	–	–
Unclassified Expansion	168	404	69	535	12	1,188
Total Additions	168	404	69	535	12	1,188
Reductions in extent	–	–	–	–	–	–
Managed Reductions	–	–	–	–	–	–
Unmanaged Reductions	–	–	–	–	–	–
Unclassified Reductions	309	10	64	305	–	188
Total Reductions	(309)	(10)	(564)	(305)	–	(1,188)
Net change in extent	(141)	394	(495)	230	12	–
Closing extent	1,523	10,144	1,277	25,831	12	38,786

Note: salt meadows not included in 2012 – there is no polygonal data, but it is acknowledged saltmarsh does exist.
Source: OA_077 to OA_87 and OA_96 to OA_100

There have been changes in ecosystem condition in Clew Bay. Data collected for SACs show that the loss of eelgrass beds was a principle reason for the change in condition. Significant changes were documented in the areas previously recorded for eelgrass beds between 2005 and 2009. IN Clew Bay the loss of entire eelgrass beds has been recorded, as well as significant decrease in the abundance of eelgrass within a bed from the previous baseline survey. Further changes in condition and changes in ecosystem services and benefits cannot be determined at this time. Further monitoring is required.

Figure 35 Habitat extent 2012 (a) and 2019 (b)



Source: OA_077 to OA_87 and OA_96 to OA_100

Table 25 Ecosystem extent change matrix, Clew Bay Marine area, 2012 to 2019

	Tidal Mudflats and sandflats	Other	Estuaries	Large shallow inlets and bays	Salt meadows	Total Reductions
Tidal Mudflats and sandflats	1354.5	119	67	113.75	9	308.75
Other	2.75	9739.5	1.25	6.25	–	10.25
Estuaries	70.75	75.5	1208.25	415	2.5	563.75
Large shallow inlets and bays	94.5	209.75	0.5	25295.5	0.25	305
Salt meadows	–	–	–	–	–	0
Total Additions	168	404.25	68.75	535	11.75	–

Note: '–' = 0. Other represents an unknown ecosystem type.
Source: OA_077 to OA_87 and OA_96 to OA_100

4 Case study 1 – Native Oyster (Ostrea edulis) Habitat restoration

The natural capital framing applied in section 3 can be applied to specific actions in Clew Bay. With appropriate data, the framing can be applied to understand the impacts of different actions. For example, what are the benefits associated with restoring native oyster habitats? This is largely an impacts story, whereby impacts are projected into the future by linking a management action to some change in the stock of natural capital, and then services and benefits provided by that stock. An analysis of dependencies describes the users that ultimately benefit. A complete assessment of the impacts of native oyster habitat restoration is not performed here, largely due to data and time constraints, but a framing is provided to support this work if it were to occur in the future.

4.1 Introduction

The European flat oyster (*O. edulis*) naturally inhabits intertidal to subtidal zones ranging from Norway to Morocco in the Atlantic and the North Sea (Lapègue et al. 2006, Pogoda 2019). Depleted remnant oyster populations are present in UK, Ireland, France, the Netherlands, Denmark, Portugal and Spain. Oysters are functionally extinct in the German and Belgian North Sea. On the west coast of Sweden and the southern coast of Norway larger wild populations of native oysters can still be found.

Extensive offshore native oyster beds existed in the North Sea until the 19th century. Presently most of these oyster beds have been lost. The Oslo-Paris-Commission (OSPAR) included native oysters on the list of threatened and declining species and habitats, for which restoration measures should be developed. Further, the EU Habitats Directive calls for the protection, conservation and restoration of biogenic reefs, such as native oyster reefs.

Within the OSPAR area of NW Europe, the status of the European flat oyster has been critical since 2009. Currently there are restoration efforts underway in all regions to aid remnant populations and reintroduce the oysters into suitable areas that were formerly populated. There are a number of restoration projects in Ireland, including Clew Bay. Key pressures like fisheries, habitat damage, introduction and further distribution of non-indigenous species or diseases/pathogens still pose a significant threat to oyster beds.

Oyster habitats are hot spots of biodiversity and are vital to the health of surrounding ecosystems. As an ecological keystone species native oysters offer a substrate, spawning ground, food and shelter for many more species. High fishing pressure and poor shell management practices not only resulted in the decline of living oysters, but also in the loss of the most important natural settlement substrate for oyster larvae: oyster shells. In waters with sufficient larval abundances, the lack of suitable substrate can be the limiting factor for the recovery of oyster populations.

Throughout much of Europe, a lack of brood stock in sufficiently high density for successful breeding is another reason for low larval abundances. Furthermore, in many European ecoregions the invasive protozoan parasite Bonamia ostreae increases mortality of native oyster populations. Against this background, ecological restoration measures are crucial to support the recovery of self-sustaining oyster habitats. Across Europe, a number of restoration projects are in the process of being developed and implemented (see https://noraeurope.eu). To ensure long-term preservation of the species and the habitat it creates, including the related positive ecological effects, steps for upscaling oyster restoration have to be undertaken.

This case study describes how investments in both built capital and natural capital contribute to the restoration of native oysters in Clew Bay. It follows the same steps as those described in the natural capital profile (section 3, page 10).

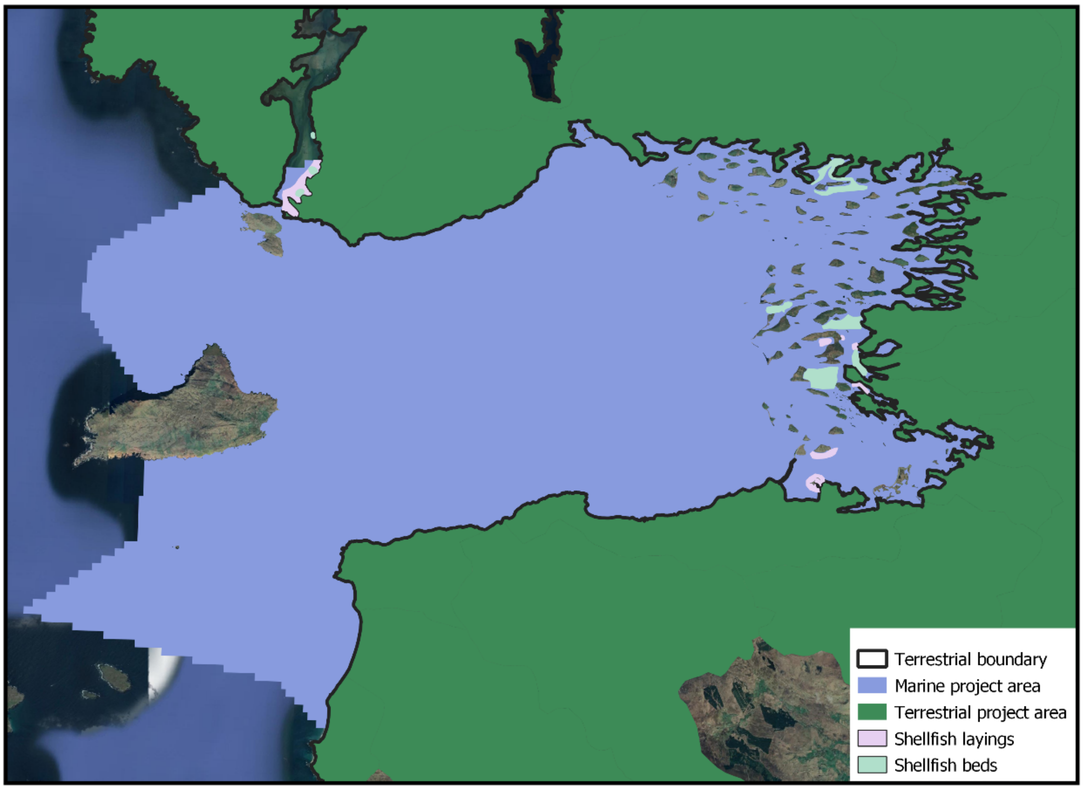
4.2 Clew Bay

Clew Bay is situated in County Mayo within the Western River Basin District. It is a complex series of interlocking bays with many islands made up of glacially formed drumlins. The Inner Bay is shallow with an average depth of 10 metres increasing seawards to an average depth of 20 metres and the tidal range is approximately 5 metres. The outer bay is open to westerly swells and winds from the Atlantic with Clare Island giving a small amount of protection.

The contributing water catchment of the shellfish area is 663.67 km^2 in area. On the northern shore is the Nephin Beg Mountain range. Croagh Patrick lies to the south and to the east are steep undulating drumlin hills of boulder clays with glacial sand and gravel deposits. All of the 11 rivers flowing into the inner bay are short spate rivers (i.e. fast flowing mountain rivers subject to floods or high water) with the exception of Newport River (Black Oak River).

Oyster fishing has been a feature of Clew Bay for decades if not centuries (see Figure 36 for evidence of shellfish beds in 1904). The oyster fishery order governed by the Clew Bay Oyster Co-operative Society Ltd was granted in 1979. The fishery thrived for nearly a decade before in the late 1980s, *Bonamia ostrea*, a lethal shellfish parasite was accidentally introduced. This devastated the oyster stocks, and the Clew Bay fishery. Catch was drastically reduced, and in some years, the fishery was voluntarily closed altogether. Fishery development work by the co-op persisted through to 2012 but was reliant on external funding.

Figure 36 Shellfish beds and layings, 1904



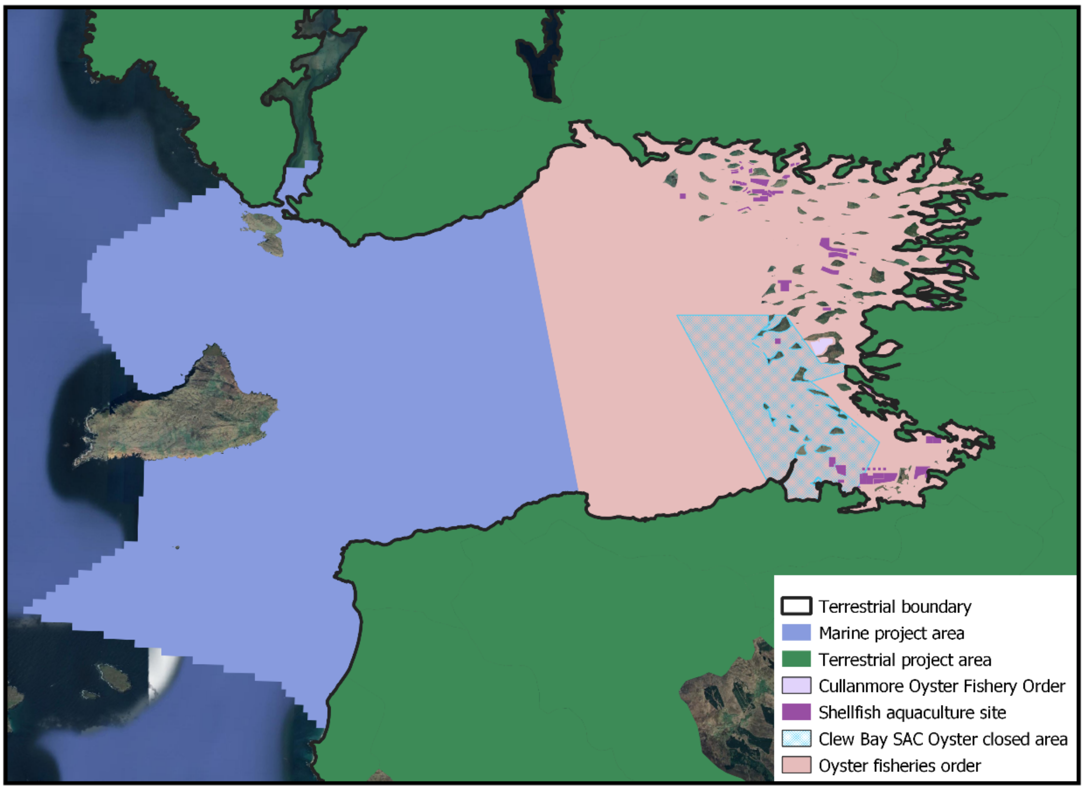
Source: OC_036

4.3 Natural capital managers

The Clew Bay Oyster Cooperative Society Ltd. has managed the native oyster beds in Clew Bay since it was granted an Oyster Fishery Order in 1979. The order was granted to the Clew Bay Oyster Cooperative Society Ltd (founded in 1976) when an abundance of oysters was discovered in Clew Bay. The society has control over the fishery and oyster fishing and membership in the society grew rapidly. When the National Parks and Wildlife Services sought to designate a large biologically sensitive area as closed to dredging oysters and other bottom fishing, this too was embraced by the Coop. Any oysters in this area would be a reservoir of breeding oysters providing spawn for the rest of Clew Bay.

The designated shellfish area within Clew Bay covered by the Oyster Fishery Order is 172.3 km^2 in area and includes all the area enclosed by a line drawn from the most northerly point at Old Head to the most easterly point at Gubbaun Point (see Figure 37).

Figure 37 Current oyster dependencies



Source: OC_036, OA_070, OA_060, Mul_003

4.4 Natural capital

There are two forms of natural capital to consider for native oyster restoration, the reefs/beds (area) where the oysters live/grow and the stock (number) of oysters that exist at any one time.

Managing the oyster stocks

The native flat oyster (*Ostrea edulis*) beds in Clew Bay are of both national and international importance. They are self-seeding and are one of only nine such native oyster beds in the country.

The Clew Bay Native Oyster Co-op actively manages the fishing activities and has ensured the continuity of oyster stocks by initiating a fishing rotation, fallowing of beds, stock enhancement & disease control programmes. The Cooperative has also collectively managed the local approval of aquaculture licence applications, where all applicants within the Oyster Fishery Order area consult with and must be members of the Co-op.

In addition to changing the fishing season there is also a fishery management plan under development. The objective is to increase the available saleable stocks of oysters throughout Clew Bay, whilst enhancing the oyster beds (reefs) and their biodiversity. Particular actions include:

- Increase spat (juvenile oyster – attachment to a surface) through spat fall enhancement
- Allow newly settled oysters to grow to maturity without being silted over and without being disturbed

- Reduce the pressure of *Bonamia* on existing oyster stocks.
- Increase broodstock in select areas around Clew Bay – this will increase larvae availability.
- Divide the north and south sections of Clew Bay each into five (or more) segments. Fishing will be open in only two of the segments in both the north and south each season.
  - This method will keep any given area of the bay open for fishing for two consecutive years. In the third year the area will be closed. It will receive spat fall enhancement work (sediment removal and cultch application).
  - In the fourth and fifth years the area will remain closed to fishing and will be subject to ongoing sediment lifting work, to ensure that the young oysters are not buried.
  - This will allow stock to grow and reduce mortality of young oysters caused by dredging.

Managing native oyster reefs - habitat restoration

In the oyster's reproduction cycle, fertilized oyster eggs develop into free-swimming larvae. Feeding on microscopic marine algae cells, they eventually need to settle onto a clean hard surface (shell beds, rocky reefs) where they develop into oyster spat and then grow into oysters. The 'spatfall' can be enhanced by two methods:

1. Depositing clean shell or cultch on the bottom. This increases the surface area of suitable habitat available for settlement and recruitment of spat.

1. Cleaning silt off the bottom and exposing existing shell. The premise is that oyster beds will naturally silt up, which is detrimental to the oysters as they are unable to move and will be buried. The silt comes from two sources: natural sedimentation of particulate matter stirred up by wave action, or faeces and pseudo faeces produced by the oysters themselves. If oysters are buried they will die by smothering, and this is particularly true for small oyster spat

Silt removal is an important element of habitat restoration which has yet to be initiated and will not form part of this study. This case study will focus on one component of the Habitat Restoration project within Clew Bay: the deployment of Cultch at two sites in the Bay to encourage spat settlement and recruitment. This process started in 2020 with ongoing monitoring throughout 2021. The project is ongoing at the time of writing.

Acquisition of Cultch

Cultch is a mass of stones, broken shells, and grit of which forms an oyster bed. Deploying clutch is expanding the areas for oysters to settle and grow thus increasing the stock (area) of natural capital. Clean calcium carbonate shell provides an ideal settlement surface for spat and is the ideal material to create cultch. It can be obtained from shellfish farms or shellfish processing plants. Depending on the source location, this can be costly as transporting such a bulky product overland is cumbersome. The shell can come from any species of mollusc. Most commonly used for this purpose are whole mussel shell, oyster shell, or crushed oyster shell. If crushing is called for, this adds to the expense, time and other logistical issues.

As there are active oyster farms in Clew Bay and a mussel processing facility, these are an ideal source of cultch. Sourcing cultch from within the bay has obvious cost benefit advantages because it reduces transport, and it also minimises disease and alien species risks. Due to the high water content of oyster flesh it readily decomposes following death of the animal and a clean shell remains. Rather than being considered a waste product such shell can be considered an important and useful by-product that can contribute to cultch restoration and native oyster populations.

To deploy the shell, it needs to be bagged and transported to the oyster bed by boat at high tide for manual distribution and spreading on the foreshore at low tide. This is a labour-intensive operation. Deployment of cultch is most valuable in areas where there is little or no available shell. For the 2020 Trial, shell was acquired from several sources and delivered to Clew Bay by BIM.

There was concern that using large Pacific oyster (C. gigas) shell as cultch might produce malformed and unmarketable oysters. Breaking these large shells into smaller pieces using a crusher was trialled to investigate the impact of shell size on recruitment. Shell crushing adds time and cost to the process and does not appear to lead to more successful recruitment at this stage in the project.

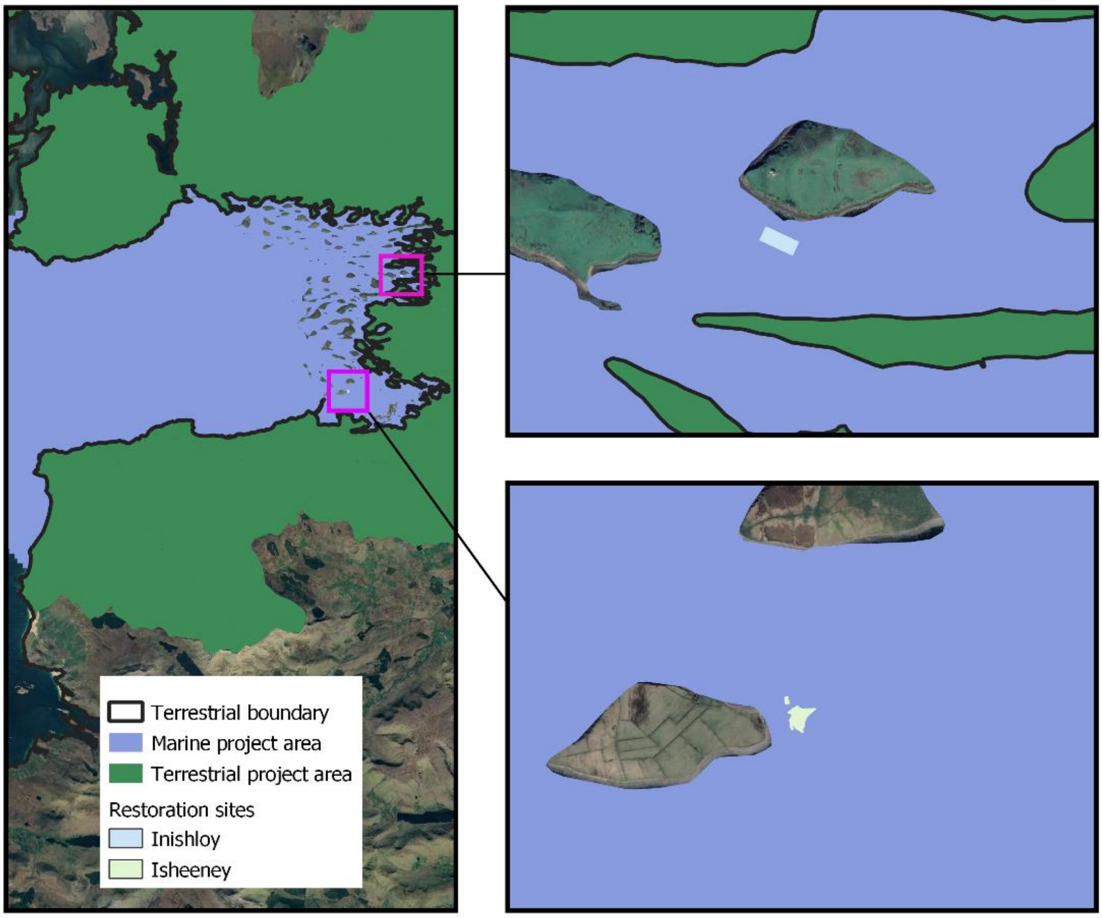
Cultch deployment

Two sites were selected for the 2020 trial cultch deployment work. One in Newport Bay (Inishloy South) and one in Westport Bay (Inisheeney East). Both sites were recommended by Co-op members and have been the focus of attention in previous years. An initial survey was done at these two sites by the Co-op, supported by scientists and equipment from BIM.

The deployment of mussel and oyster cultch onto the two Clew Bay areas, Inisheeny and Inishloy, took place on Friday 10th, Monday 14th, and Tuesday 15th July 2020, using a local aquaculture vessel.

22 bags of 1 tonne mussel shell, 26 bags of 1-1.5 tonne bags of crushed *Magallana gigas* shell, and 15 bags of 1-1.5 tonne bags of whole *Magallana gigas* shell from Connemara Seafoods were deployed on the Inishloy-South bed over a two-day period. 20 bags of 1.5 tonnes of whole *Magallana gigas* shell of various sizes from Cleggan were deployed on the Inisheeney bed. The mapped area is estimated to 1,300 m2 just off the eastern end of the island. The area the shell was actually deployed, extended slightly further south and further west than had been intended, but the deployment here proved successful on subsequent inspection.

Figure 38 Cultch deployment map area

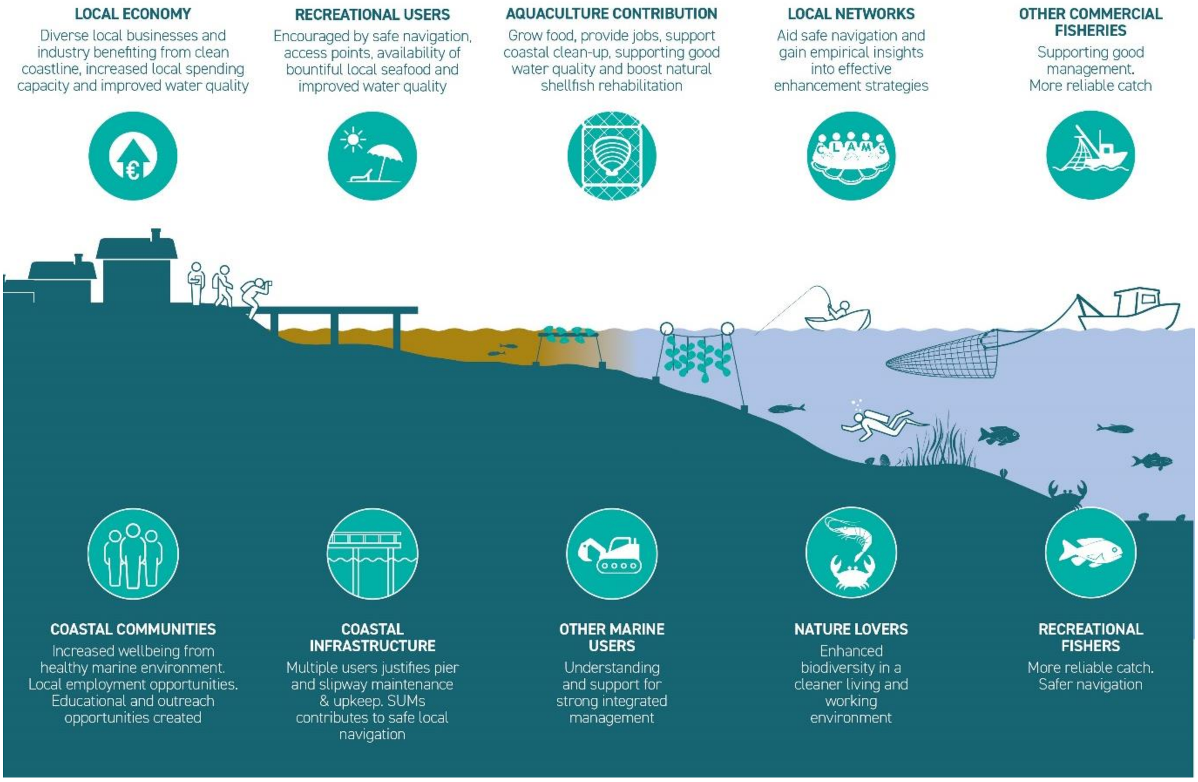


Source: ET_001 and ET_002

4.5 Dependencies

Describing the dependencies on oyster reefs is important for understanding the distributive impacts resulting from restoration actions. The restoration project is not likely to change the nature of the dependencies in the bay (given that a stock of native oysters already exists), but it may enhance the long-term viability of the sector and enhance the role the sector plays in supporting other economic, social and environmental outcomes. Figure 39 shows the different dependencies in the area.

Figure 39 Dependencies in Clew Bay



Source: IDEEA Group

All seafood operators in the bay are dependent on the ecosystem services provided by the stock of native oysters and other filter feeding shellfish in the bay. The most obvious dependency is that co-op members rely on a healthy stock of oysters to sustain their fishery. Increasing the stock of native oysters may enable a greater number of operators to harvest oysters sustainably, or may prevent the oyster stock from declining, if it is already on a downward trend, hence protecting current operations. An increase in the stock is likely to increase the quantity of the supply and use of a given ecosystem service or smooth supply and use over time.

There are a number of regulating services that are used by the households and government. All oysters are filter feeders, filtering particles from the water column. A single oyster can filter up to 200 litres of seawater per day, which can significantly improve water quality and clarity. Oysters can also assimilate excess nutrients and promote microbial activity in the underlying sediments to denitrify nitrates and nitrites, thus removing them from the water body.

The unique three-dimensional habitats created by native oysters support a higher biodiversity and biomass of species than the surrounding sediment/seabed. Oyster reefs can increase fish production by providing a protective nursery ground for juveniles, that acts as a refuge from predation and provides a source of food through increasing the abundance of prey. Protected restoration areas can provide spill-over of larvae that may seed and support sustainable fisheries.

Despite the growing recognition of the ecosystem services of restoring native oysters, and the long history of harvesting and culturing the native oyster, the ecosystem service benefits of this species specifically are poorly quantified. Identified knowledge gaps include the long-term carbon sequestration capacity of native oyster reefs, quantification of nutrient cycling services such as denitrification, phosphate burial and carbon assimilation in shell tissues.

While there are currently no estimates of nutrient loss (denitrification) and sequestration (assimilation in shell and burial) for the native oyster, measurements from the eastern oyster (Crassostrea virginica) can provide some insight into the potential scale of this ecosystem service. Whilst ecosystem process and function data from comparable species provide us with a tool to better understand the potential ecosystem services and function of native oyster habitat, we still lack datasets specific to the native oyster. Such data is needed to increase confidence in the degree of ecosystem service benefits oysters may provide.

4.6 Pressures

The most obvious pressure on oyster stocks is fishing and removal of the oysters for sale. However, there are now closed areas which are rotated over time to ensure oyster stocks can recover following a period of fishing.

Bonamia ostrea, a lethal shellfish parasite was inadvertently introduced into Clew Bay in the late 1980s, devastating the oyster stocks, and damaging the performance of the fishery. Fishing was drastically reduced and, in some years, closed altogether. The prevalence of *Bonamia* in *Ostrea edulis* throughout the area is monitored on an annual basis.

The introduction of alien species could threaten the oysters. However, the CLAMS group has agreed that aquaculture farms in the bay will only source oyster seed from certified hatcheries (no wild seed or half-grown oysters are imported to Clew Bay) thus minimising the risks of aquaculture linked introductions.

Water quality in Clew Bay can potentially impact on the ability to produce high quality and safe oysters and hence limit harvest times. The population around Clew Bay varies quite significantly as it is a popular tourist destination which can have an impact of water quality. There are also potential water quality issues linked to landfill leachate, agriculture and forestry/deforestation. Statutory water quality monitoring and shellfish flesh monitoring are carried out to fulfil food safety and environmental requirements. This can affect ability to harvest and requirements for further treatment post harvest, which in turn adds to production costs.

4.7 Impacts

The outcome that is most clear in this example is the increase or change in the stock of oyster reefs. Over time as the cultch settles and matures it will start to resemble a natural reef. As it passes through the stages from fresh laid cultch to near natural reef the change can be reflected in the reef ecosystem extent account initially and then in the condition of the reef. The following observation for Inishloy and Inisheeney contain a mixture of reef changes and condition observations.

With respect to the Inishloy South reef expansion, quite a few 2-3-year-old oysters were scattered throughout the area, with less larger oysters being present. There were good signs of growth across all age classes. There was very little sign of recent mortality in the area surveyed. There were many dead larger oysters on this site which may be a result of the dredging that was carried out in the last season or Bonamia but either of these is pure speculation at this stage without further investigation. However, based on the marine fouling of the shells they were not recent mortalities. The ground here has a lot of old shell, mostly old oyster shell and cloisins (Chlamys varia). The layer of old shell is perhaps 2-3 inches in depth and is mixed in with silt, sitting on top of firmer ground. It was decided that crushed oyster shell and mussel shell would be deployed on this site.

With respect to the Inisheeney reef expansion, the ground in the selected site is generally a mix of coarse sand and little shell. It is a lot less silty than Inishloy. There were native oysters of all year classes present. There was good evidence of settlement, mostly settled on old gigas and edulis shells. There was little evidence of mortality in the larger oysters, which was very encouraging

Cultch restoration - Stylised impact analysis

The analysis above is a partial representation of the links between expanding cultch areas and the impacts this may have on spat recruitment and oyster production. Figure 40 shows a stylised representation of changes in oyster reefs as a result of laying cultch for reef building linked to the condition of the reefs and in turn oyster production. The lower part of the figure shows a times series of three oyster reef areas changing every five years over a 15 year time period. Reef 1 remains stable with no cultch added across the 15 years, Reef 2 expands in area between year 0 and year 10, and reef 3 expands between year 0 and year 5.

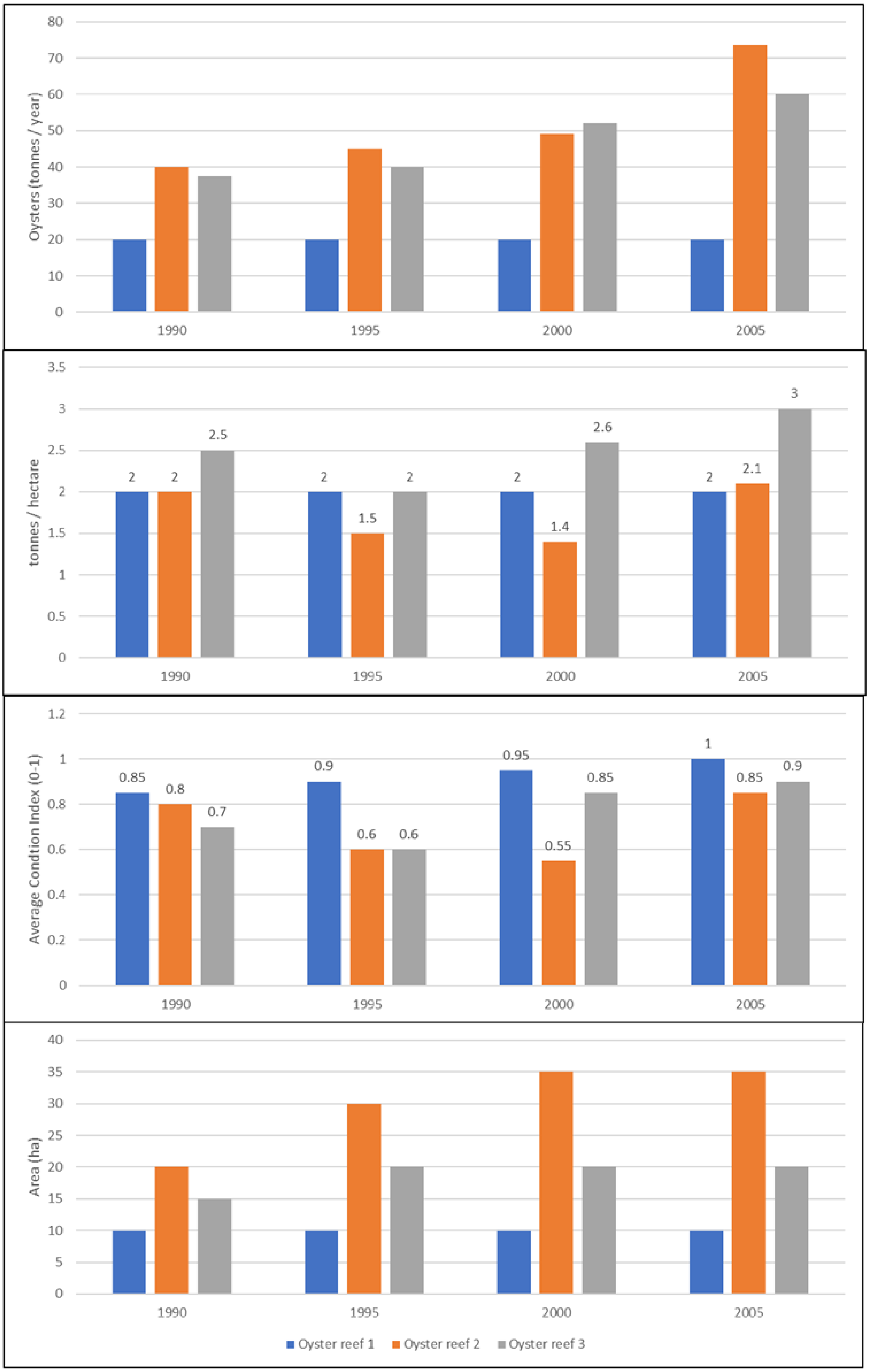
The graph which is second from bottom shows the average condition for each reef. The condition of reef 1 is relatively stable but increases naturally with time. The average condition of reef 2 has fallen because new cultch has been laid which needs to settle and develop into a reef that is close to natural where the condition would be measured as 1, very good. However, reef 2 in the final year has settled very well and its condition has increased. Reef 3 had clutch laid, also resulting in a fall in the average condition of the reef 3. However, reef 3 has settled and developed in a high condition reef relatively quickly with its average condition being close to natural (0.9) in the final reporting period.

There has been an increase in the stock (area) of reef and a change in the condition of the reefs. Both these changes will result in a change in ecosystem services. This is shown in stylised form as a change in the tonnes of oysters produced per hectare, which is equivalent to a measure of productivity per hectare for each of the reefs. Reef 1 has remained stable over time, reef 2 falls for two periods and finally increases in the last period, and reef 3 has a small fall but increase quite quickly over the remaining years. The productivity of the reefs is closely correlated with the condition of the reefs, water quality, spat fall and the condition of surrounding ecosystems.

Finally, the production of oysters in shown in the top graph. Production is either stable or increasing over time reflecting the combined effect of a change in area of reef and a change in the condition of the reefs.

These graphs could be presented each year if appropriate data were collected on changes in reef area, reef condition and measures of reef productivity. It would then be a relatively straight forward exercise to link investments in natural capital (oyster reefs) via cultch deposition to economic, social and ecosystem benefits.

Figure 40 Stylised representation of cultch expansion



Source: IDEEA Group
Note: This is a stylised example

5 Case Study 2 – the CLAMS program

Within any given context (for example, Clew Bay), there are many different interventions that can improve economic, social, and environmental outcomes. These interventions are typically targeted across one of the four capitals, produced capital, natural capital, social capital and human capital. This case study aims to understand how investments in social capital in Clew Bay contribute to improved natural capital outcomes.

This section describes and then measures the benefits associated with one form of social capital, the Coordinated Local Aquaculture Management System (CLAMS) group, in Clew Bay. This work is exploratory, because there are no agreed standards for measuring social capital, like there are for natural capital. However, it is possible to conceptualise social capital in the same way as we have natural capital. For instance, there is a stock of social capital, it has a condition that influences its ability to provide services which are of benefit to people. This section is not intended to be exhaustive, however it provides an example of how social capital can be measured and linked to natural capital.

5.1 Introduction

Improvements in natural capital in Clew Bay can be achieved by making investments in produced capital, human capital, and social capital. A combination of investments across the capitals is typically needed to ensure sustainable economic growth. This case study focusses on how investments in social capital can be considered.

Social capital is a network (or group) of individuals, entities or other units that share similar norms, values and understandings that facilitate cooperation within or among groups (OECD, 2001, p 41.). The pervasiveness of social capital means that its creation and continued management can provide benefits for all members of society, including the private sector, the public sector, and the broader public.

5.2 CLAMS - Coordinated Local Aquaculture Management System

The Coordinated Local Aquaculture Management System (CLAMS) program, established by the Irish Government in 1998, encouraged the formation of social capital among aquaculture operators, such as fish and shellfish farmers. CLAMS is a nationwide initiative to manage the development of aquaculture in bays and inshore waters throughout Ireland at a local level.

The aim of the program is to support the *sustainable* development of aquaculture by facilitating a coordinated approach to management by:

1. Establishing a local CLAMS group – a local CLAMS group is a self-governing network of operators with shared norms, values and understandings. There are a number of these groups spread throughout Ireland with similar or the same set of shared norms, values and understandings
2. Supporting the groups to develop management activities by providing seed funding and secretariat support. For example, the Clew Bay CLAMS Group has agreed to a number of operating protocols for the area, which are incorporated into working routines, practices

and policies. These cover hygiene, biosecurity, waste management, and ensuring sites, shore bases and access points are maintained in a clean, tidy and environmentally sound order.

The CLAMS program has been widely adopted by fish and shellfish farmers in Irish bays and inshore waters as a proactive step to encourage public consultation on their current operations and future plans. The management approach is a locally based all-embracing system designed to maximise production and environmental management through the integration of production goals with minimal conflict with other resource users.

An individual management plan is drawn up for each CLAMS bay or area, which clearly lays out what fish and shellfish farmers are currently doing in the bay, how they operate and what their future plans are. In each case, the plan aims to fully integrate aquaculture interests with relevant national policies. There are a range of projects determined and prioritised by the CLAMS members and which vary in type and intensity depending on local needs and groups preferences including:

- Navigation Plans
- Deployment of navigation markers
- Re-alignment and rationalisation of mussel lines
- Oyster trestle recycling
- Improvement of mussel training areas
- Beach and pier clean-ups
- Water quality monitoring

Assessing the benefits of CLAMS as a form of social capital requires an understanding of the services that are being provided by the groups both individually and collectively at national level. This case study provides a social capital profile for the Clew Bay CLAMS group. For consistency it follows the same steps as those described in the natural capital profile (section 3, page 10).

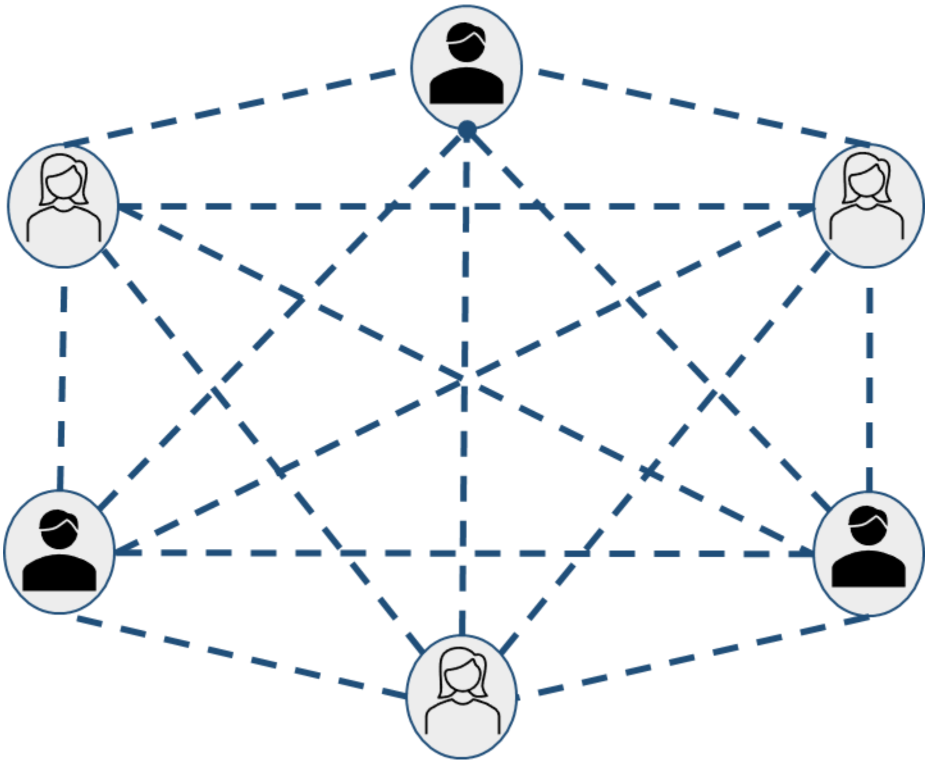
5.3 Social capital managers

The CLAMS Group in Clew Bay was formed in 2001. It includes participation from both the private and public sector. The group is currently chaired by Michael Mulloy of Blackshell Farm Ltd., and is supported by BIM and Marine Institute officers.

The CLAMS group is social capital that is made up of a network of human capital - people. The management of the CLAMS group is reliant on the chair and each of the members within the CLAMS Group (see Figure 41). Some members may have more or less influence on the quality of the network, based on their role in CLAMS, their skills (human capital), personal objectives, and the objectives of their aquaculture business/operation. For example, the role of the BIM officer within the network is different to the role of a seafood operator. Further, a node's (represented by each circle in Figure 41) experience and time in the network is important in determining the level of influence they have in managing the network.

Each network (social capital) will typically set its own rules and norms. These rules and norms are formed throughout time and are aligned with the values and objectives of the network.

Figure 41 Depiction of social capital as a network of huan capital members



Source: IDEEA Group

5.4 Social capital

The CLAMS group is a network of human capital, people. Each person (human capital) is a member of the network and the more members the larger the social capital and each persons inputs (in terms of time, effort and for example, local knowledge or specialists skills) contributes to the condition of the network and the ability of the network to provide services. An increase in inputs by one or many members (nodes) may increase the strength of the network. Further, the more active the network is, the more likely it is to be recognised and attract additional human capital, because as a member you have access to the social capital services and can influence the services it is providing. Participation and retention in the network may depend on the perceived economic, social and environmental benefit of being in the network and the benefits the network is providing to other non-members.

The condition of the social capital is largely based on trust between the nodes in the network. Trust is largely built by nodes having positive experiences such as value-sharing. For example, people may be more likely to reciprocate and share information with others in the network if the network is sharing valuable information with them. The adoption of a decision-making process in the network also builds trust. For example, the adoption of democratic processes are likely to build trust because members in the network see that decision making is conducted openly and fairly.

5.5 Dependencies

A number of different actors depend on social capital in Clew Bay, including the seafood sector, government and households. Each of these actors are interested in achieving the sustainable development of aquaculture. As a form of social capital, CLAMS is a favourable asset, as it can support the delivery of low-cost sustainable development objectives, for example, objectives associated with marine spatial planning in Clew Bay.

Seafood sector

The seafood sector depends on social capital to reduce **transaction costs** when performing activities that contribute to the sustainable development and management of aquaculture. Examples of such activities include day-to-day business activities; sharing knowledge and innovation, creating knowledge and innovations; and cooperation and coordination.

Where social capital does not exist, transaction costs may be higher than the benefit that is attainable from cooperating, bargaining or negotiating with other parties. Transaction costs, which consist of search and information costs, bargaining and decisions costs, and policing and enforcement costs, exist due to a lack of information (Box 3). The role of social capital for the seafood sector is therefore to facilitate information sharing within the network and between different networks.

Box 3 Transaction costs

There are three types of transaction costs: search and information costs, bargaining and decision costs, policing and enforcement costs.

Both search and information costs owe their existence to imperfect information about the existence and location of trading opportunities or about the quality or other characteristics of items available for trade.

Bargaining and decision costs represent resources spent in finding out the desire of economic agents to participate in trading at certain prices and conditions. What is being revealed in a bargaining situation is information about willingness to trade on certain conditions, and decision costs are resources spent in determining whether the terms of the trade are mutually agreeable.

Policing and enforcement costs are incurred because there is lack of knowledge as to whether one (or both) of the parties involved in the agreement will violate his part of the bargain: if there were adequate foreknowledge on his part, these costs could be avoided by contractual stipulations or by declining to trade with agents who would be known to avoid fulfilling their obligations.

Transaction costs may prevent the establishment of a desirable allocation of resources, one that everyone would agree is better than the one attained when transactions are costly. Economic theory implies one of two corrective measures:

- find out if there is a feasible way to decrease the costs of transacting between market agents through government action (e.g. formation of social capital), or

- if that is not possible, the analysis would suggest employing taxes, legislative action, standards, prohibitions, agencies, or whatever else can be thought of that will achieve the allocation of resources.

Trust, as a characteristic of social capital, is the foundation of most relationships, and can help to minimise the emotional and monetary costs of doing business and delivering on shared goals. For example, in a workplace, trust can improve information flows between staff, reduce the need for employers to monitor their employees, and facilitate the introduction of more flexible work arrangements that improve productivity. High levels of trust between members can lessen the need for detailed contracts to cover all possible interpretations and contingencies, and for monitoring of the other members to ensure their compliance.

Government

The government depends on social capital to support the delivery of its programs that contribute to the sustainable development of aquaculture. It is more efficient and effective for government to use CLAMS as a single contact point, when appropriate, rather than delivering its programs to each individual member. In many instances, social capital can be used to deliver information and is a substitute for other forms of government intervention, including advertising campaigns or other one-to-one communication. Social capital can generate benefits for government in several ways:

- institutions that facilitate low transaction costs boost economic growth for the seafood sector and associated sectors
- by reducing the cost of government (governance) by establishing community governance
- government benefits from social capital networking services to share government information
- government depends on network services from social capital to mediate and resolve conflict with respect to use of common resources

The existence of social capital reduces the transaction costs for government when interacting with businesses in the seafood sector. The government can communicate via CLAMS rather than to each of the members alone which benefits both the government and CLAMS members. The government can invest in and create positive returns, especially when private investment does not create the socially optimum quantity and quality of social capital. In turn the government can use the groups as a source of information in relation to emerging issues and their potential impacts and to sense check potential impacts and attitudes to change. This is the basis for collaborative working, adaptive and consensus-based management.

CLAMS meetings in Clew Bay typically include government presentations on current and emerging policies and legislation. The appropriate assessment process for aquaculture licensing in an adjacent to Natura 2000 sites is a key example of government using CLAMS. Over a number of years, in the appropriate assessment example, this engagement helps to inform the seafood sector about the protected areas and highlights what is expected from the sector to contribute to the assessments and ongoing management to meet the site conservation objectives. It is an efficient way of improving the understanding of new and/or difficult topics and can help to encourage the sector to embrace change, engage and even present ideas on the best approach for future management.

Marine Spatial Planning (MSP) is another government run initiative that depends on social capital. MSP is a "public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process" (Ehler & Douvere, 2009). In a nutshell, MSP is a practical way to organize the use of the ocean space, and the interactions among human uses (e.g., fisheries, aquaculture, shipping, tourism, renewable energy production, marine mining) and between uses and the marine environment (Catarina Frazão Santos, … Larry B. Crowder, in

World Seas: an Environmental Evaluation (Second Edition), 2019). In 2021 Ireland adopted the National Marine Planning Framework. It is the first Maritime Spatial Plan for Ireland, preparted in accordance with the EU's Maritime Spatial Planning Directive. From an aquaculture perspective, it is anticipated that CLAMS social capital will be crucial for information exchange on the plan and can form an integral part of the wider Marine Spatial Planning process as new policies and legislation in relation to Marine Planning are implemented.

Households and other industries/sectors

Households also benefit from having a sustainable aquaculture industry. Households can use the CLAMS group to communicate their interests and where possible support or invest in activities that attain a sustainable aquaculture industry. Research suggests that social capital can generate benefits for society in several ways :

- by promoting cooperative and/or socially-minded behaviour in situations where narrow self-interest alone does not generate beneficial outcomes for society; and
- through individual benefits — people with good access to social capital tend to be more 'hired, housed, healthy and happy' than those without

There are also many other industries that are economically dependent on the seafood sector, and they also wish to ensure the sector is sustainable in the long term. For instance, cafes rely on quality local produce, tourism relies on having a high-quality environment for visitors, tour operators rely on having quality access to the bay and a high quality marine environment.

Both households and other industries can use the CLAMS group to communicate their interests, negotiate and cooperate, and where possible support or invest in activities that contribute to attaining a sustainable aquaculture industry.

5.6 Pressures

There are some pressures which can affect the operation of CLAMS. This includes limited resources and misinformation – anything that detracts members from the group.

- Limited resources
    - Size – not enough members contributing to achieve the objectives
    - Competing demands of members in the network
    - Absence of BIM and Marine Institute support (e.g. lack of funding / officer work absence)
    - Seed funding
    - Project funding
- Misinformation
    - Negative publicity trying to detract from the objectives of the network (for example, competing interests or anti-aquaculture lobby groups)
    - individual reputations impacts on the credibility of the network as a whole
    - Poor information transmitted within the network, ultimately resulting in a breakdown of trust and commitment.

5.7 Impacts

To consider the impacts of social capital we employ a multiple capitals approach. The members of CLAMS are human capital, with each member contributing to the CLAMS group, and the CLAMS group contributes to the sustainable management and use of natural capital and finally by sharing knowledge the members can maximise their use of produced capital.

Social capital supports increased knowledge leading to more efficient and sustainable aquaculture production. Social capital can contribute to improved environmental performance, reduced environmental impact, high quality and safer aquaculture products. It also contributes to wellbeing benefits for human capital, through better connections and feeling part of a collective group.

Table 26 provides examples of how an investment in social capital can be linked to impacts across natural, human and produced capital. It is beyond the scope of this project to comprehensively examine the relationship between investments in social capital and the impacts on other capitals quantitatively, but the framing provides guidance for future data collection by both CLAMS and those that use social networking services of CLAMS. Further detail on impacts is provided below.

Table 26 Multiple capital approach to assessing social capital (CLAMS) in Clew Bay

Types of investment in SC	Benefits			
	SOCIAL CAPITAL	**NATURAL CAPITAL**	**HUMAN CAPITAL**	**PRODUCED & BUILT CAPITAL**
Government seed funding to establish CLAMS and support the secretariate	CLAMS as a group of people can provide networking services	Knowledge is efficiently transferred between human capital, benefiting natural capital	Human capital gains knowledge via networking faster and more efficiently	Produced capital is better utilised via shared knowhow between human capital
Time contributed by each of the members	BIM have access to knowledge and information that they put into the group	Share knowledge about natural capital	Training and building a shared knowledge base of key issues	Engagement with COCO on condition of piers and other access points
Time and resources contributed by supporting agencies including BIM and Marine Institute officers	Shared approach lowers the cost of water quality coordination and installation	What activities are being undertaken to manage the NC better? Sustainable seafood harvest due to improved information flows? Water quality improvements that contribute to maintaining healthy NC	Joint monitoring of invasive alien species (awareness) Human capital more knowledgeable and can act more responsibly contributing to positive NC condition	Lower cost investment in produced capital – environmental monitoring / data loggers.

5.7.1 Examples of impacts

The Clew Bay CLAMS group receives financial support from both the European Maritime and Fisheries Fund and core government budgets to support its collective activities. Financial support is managed by the BIM CLAMS liaison officer for the group. A breakdown of spend by intervention for the period from 2014 – 2021, which is the duration of the EMFF programme, is provided in Box 4. This is the duration of the EMFF programme. A new programme, EMFAF, will commence in 2022.

Box 4 CLAMS expenditure

- CLAMS projects – Shore and Pier Clean up operations, and oyster trestle recycling circa €13,765

- CLAMS Biosecurity Area Management Standard (2019) approximately € 22,000

- CLAMS Plan Review and Addendum (2020) €10,625

- The Special Unified Marking Scheme (SUMS) is an integrated navigation planning initiative that is managed through the CLAMS group (further information included below). It is funded through core government budgets. Approximately € 30,000.

Examples of CLAMS initiatives within Clew Bay are explored to demonstrate the benefits of the social capital, and in the case of the Water quality monitoring examine how further benefits can be obtained.

Litter

Shore clean ups have become a core component of the work of CLAMS groups over the last 10-15 years. There is a high level of awareness of the problems of marine litter and working on the shore provides aquaculture operators with firsthand experience of its impacts. Seafood businesses often bear the brunt of negative publicity about marine litter and they do acknowledge that their operations can be a source. Storms can wreak havoc at aquaculture sites by dislodging gear and increasing storm frequency and intensity (a factor of climate change already being experienced) means that these issues will continue. However, first hand experience also shows that a lot of marine litter is derived from other anthropogenic sources (takeaway packaging, fly tipping etc). Figure 42 provides an example of the litter found in Clew Bay and cleaned up by the CLAMS group.

Figure 42 Litter in Clew Bay being removed during a CLAMS organised Clean up.

Source BIM 2019

CLAMS shore clean ups are organised at regular intervals and after storms to minimise the impact from the sector and others. Table 27 shows the quantity of marine litter collected between 2012 and 2020. They help to promote responsible farm practices, and maintain a high quality environment for the production of safe seafood. Co-ordinating efforts through the CLAMS group helps to engage wider participation, maintain momentum and generate a greater impact (the efforts of a co-ordinated single clean up are easier to see).

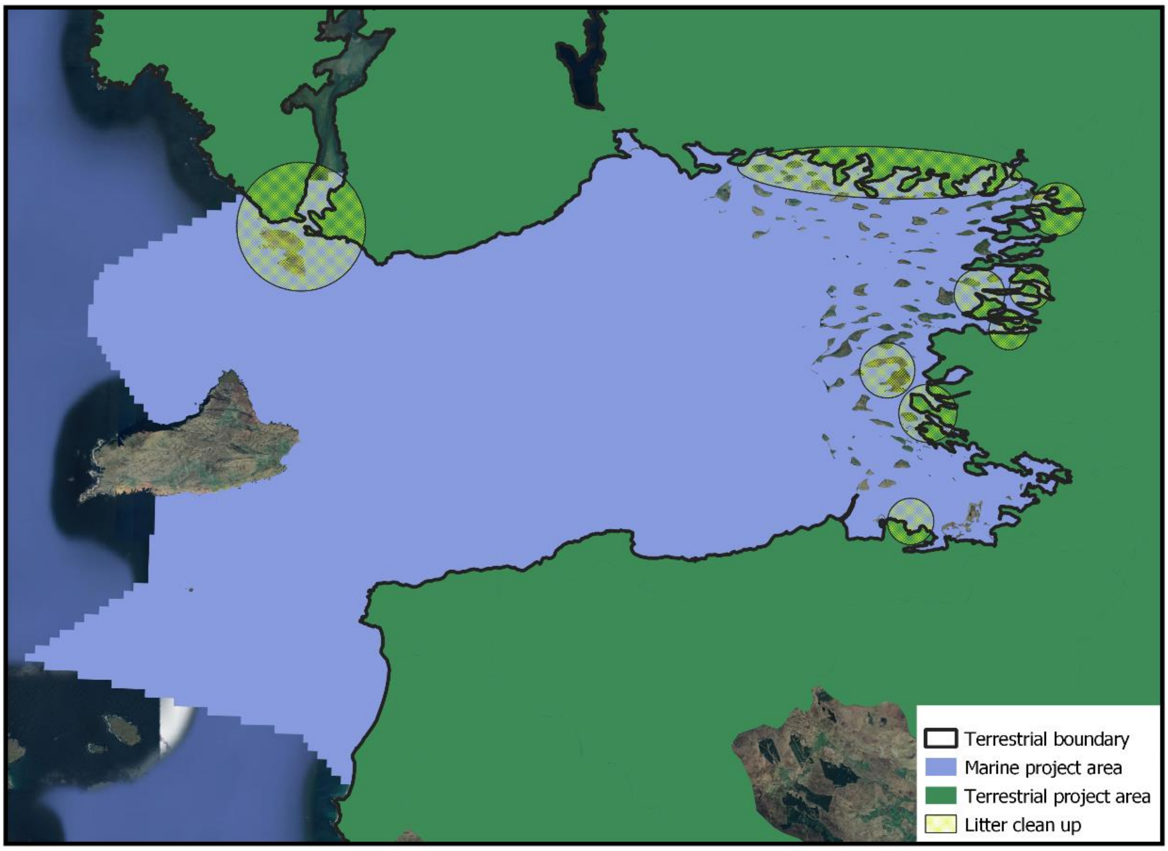
In relation to the recycling of old trestles, through the coordination facilitated by the CLAMS process, it is possible act when there is a critical mass which allows for collection and reduces associated costs. Figure 43 shows the coverage of litter clean-up operations by the Clew Bay CLAMS group. Events are often publicised in local media and help to enhance the reputation of the sector and its social licence to operate. For individual businesses, such participation can contribute to the attainment and retention of environmental or sustainability certification, which in turn may help gain market access and better prices for their products.

Table 27 Clew Bay shore clean ups 2012 to 2020

Year	Marine Litter Collected (kg)
2012	2,000
2013	7,400
2014	2,160
2015	0
2016	0
2017	4,040
2018	9,200
2019	7,400
2020	4,500
Total kg 2012 – 2020	36,700
Total Tonnes 2012 – 2020	36.7t

Source OC_037

Figure 43 Litter clean up areas



Source OC_038

Special Unified Marking Scheme

As part of the CLAMS process BIM's regionally based Development Officers co-ordinate and manage a range of projects including the installation and maintenance of Special Unified Marking Schemes (SUMS).

SUMS provide improved navigation and safety for all users of the marine environment in areas where aquaculture coexists with other users. The SUMS marking schemes uses fewer, higher quality marks with a long lifespan, achieving efficiencies for the producers. BIM and the Commissioners for Irish Lights (CIL) ensure that marks are included in the UK Hydrographic Office's Admiralty Charts which informs visiting vessels of the perimeter of the production areas.

Box 5 Licence Requirements

Typically a modern aquaculture licence states the following for inter tidal shellfish culture.

Navigation and Safety

4.1. The Licensee shall ensure that Statutory Sanction from the Commissioners of Irish Lights is in place prior to the commencement of operations, regarding all aids to navigation.

4.2. The Licensee shall ensure that the site is marked in accordance with the requirements of both the Marine Survey Office and the Commissioners of Irish Lights as specified in Schedule 3.

4.3. The Licensee shall comply with any specification requirement relating to navigational aids, flotation and mooring devices, supporting/marking posts/poles, as required by the Minister or any other competent State authority.

4.4. Prior to commencement of operation the Licensee . shall inform the UK Hydrographic Office at Taunton, of the location and nature of the site in order that charts and nautical publications can be updated. Licensee shall submit proof to the Department within 14 days of the date of this licence that the UK Hydrographic Office has been so informed.

SCHEDULE 3

Schedule 3 contains:

• requirements of the MSO and/or CIL

• the applicant shall secure statutory sanction from the Commissioners of Irish Lights for the aids to navigation i.e. four posts, projecting two metres above sea level at highest astronomical tide and with a topmark of a diagonal St Andrews cross, painted yellow, erected at the four corners of each development.

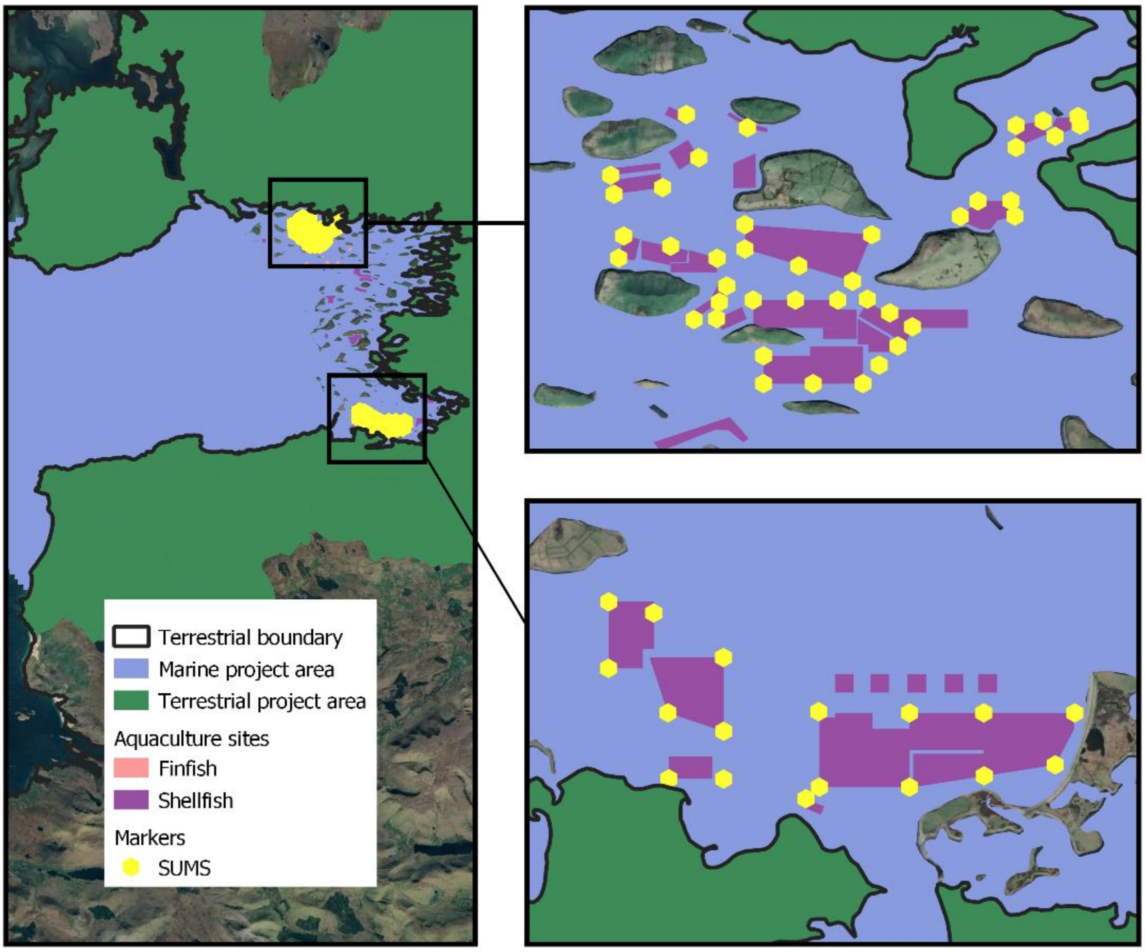
• Multiple sites shall be marked as a block and comply with CLAMS scheme in the bay. Poles shall be of the design approved by the Marine Survey Office and the Commissioners of Irish Lights.

• The size and specification of aids to navigation must be agreed in advance with the Commissioners of Irish Lights.

• The aids as required shall be verified in position before development commences.

This is an exploratory demonstration of the monetary benefit of participating in the SUMS initiative vs individual site marking by the different aquaculture operators in the bay. It focuses only on Clew Bay North where there are a large number of oyster aquaculture licences spatially distributed in a clustered pattern. Figure 44 shows the location of sums markers and aquaculture sites.

Figure 44 SUMS locations



Source OA_102

CLEW Bay North

There are 20 licenced sites in Clew Bay North which comprise of various polygons. Working through the CLAMS group, the SUMS initiative has procured, installed and maintains 41 marks in this area. 8 of these marks are lighted, 3 are cardinal south and 30 are standard.

A cost breakdown has been extrapolated from a similar exercise completed by the CLAMS group in Dungarvan, Co Waterford (see Table 28). Costs for co-ordinated time and efforts for installation and maintenance are not included. Pole replacement is required after 5 years. All other marker components have an 8-to-20-year lifespan.

Table 28 SUMS initiative costings

Cost per lighted pole per year	Number of poles	Total cost per year
162.23	8	€1,297.84
52.25	33	€1,724.25
		€3,022.09

Source: BIM Internal information.

By contrast, a cost breakdown in a scenario where individual licence holders work alone to meet their licence requirements for site marking has also been developed. Prior to the SUMS initiative this would have been the typical approach. (Note: There is no value in investigating what was officially marked previously as sites have changed, there are additional sites and marking requirements have also changed.) The following scenario applies the old marking regime to the current licences in Clew Bay North. At a crude level where each site was to be marked individually at four points, that would equate to 80 marks. Marking all site corners (some sites are 5+ sided polygons) this equates to roughly 92 marks. Installation and maintenance is carried out individually and at the operators own expense and time. These costs are based on the typical marks that were used across Ireland prior to the development of the SUMS initiative. It is important to note that the labour and time requirement for installation and maintenance would be much higher in this scenario due to an average marker lifespan of 2 years. In addition, none of these marks would have lights.

Table 29 Old Type Mark costings

Cost per pole per year	Number of poles per year	Total cost per year
80	37.50	3,000
92	37.50	3,450

Source: BIM Internal information.

Based on the above calculations, while the financial saving is limited to nil (depending on the scenario, SUMS may even cost more), it must be noted that labour costs are not included. Working individually, the old type marks require replacement every two years compared to the 8–20-year lifespan of the SUMS marks. If a monetary value were to be placed on the equivalent labour costs in each scenario it can be inferred that the monetary savings of the SUMS marker would be significantly higher.

There are a number of benefits beyond the monetary savings on capital costs:

- As mentioned above a major factor is the time required for maintenance. 92/80 poles painted annually is a lot of time with associated labour costs compared with the lower maintenance schedule required by the 41 modern beacons. Annual maintenance is no longer required, saving time and business costs further.
- The initial cost is higher but the materials are more durable and overall fewer materials are used. This means less waste and a lower risk ending up in the marine environment (lost to storms etc)
- The lights are a major safety feature used by aquaculture operators (for example a sudden fog on a rising tide) and other marine users for safe return to shore in poor weather or fading light.
- The collaborative aspect of the project means that deployment is centralised and maintenance schedules are also centralised meaning that a reminder can be provided to the responsible operators whenever work needs done.

Coordinating the monitoring of water quality

Water quality monitoring is carried out in Clew Bay and wider catchments for a range of purposes, the data from which, varies in spatial coverage and timeseries. The Water Framework

Directive associated monitoring provides the most comprehensive coverage but in addition there are other data which support the seafood sector. There is a need to monitor the quality of the water to ensure seafood products are not contaminated. Shellfish classification (based on shellfish flesh) and biotoxin status (based on water phytoplankton and shellfish) are vital to the production of safe seafood and inform harvesting open / closed periods, and post- harvest purification requirements. Additionally, many aquaculture operators monitor water quality parameters such as temperature and salinity in the vicinity of their licensed sites. This can assist them to understand growth rates and the potential for fish and shellfish to experience health impacts, and thus impacts on productivity. The data can be used to monitor the health of aquaculture sites, and also to understand how water quality may impact on ecosystems.

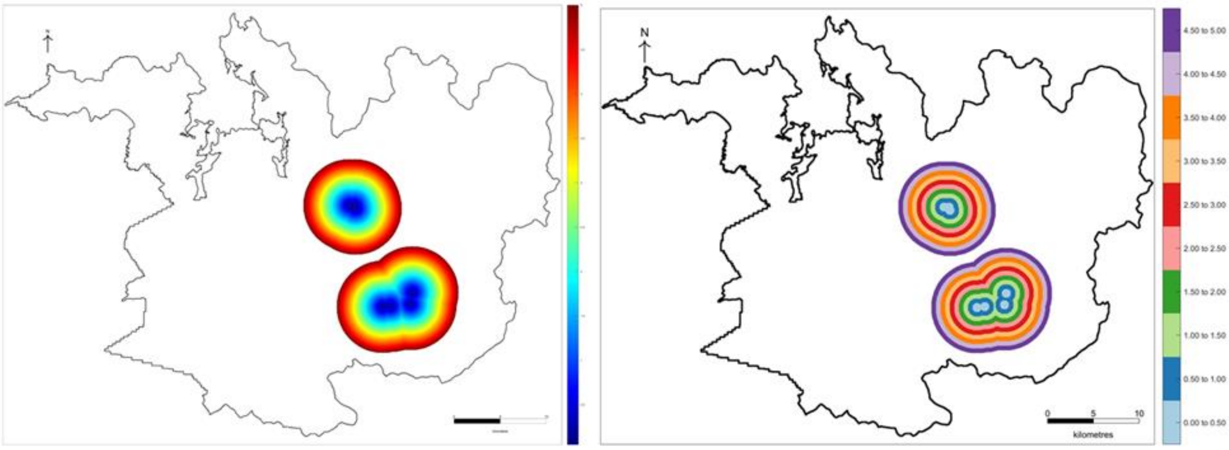
In relation to shellfish (live bivalve mollusc) classification there are a number of classified production areas within Clew Bay. Classification is based on microbiological criteria. EU regulations exist to control the public health risks associated with consumption of microbiologically contaminated shellfish. The risk of contamination of shellfish with bacterial and viral pathogens is evaluated by reference to (i) the sources and types of faecal contamination (human and animal) in the vicinity of the shellfish production areas and (ii) the results obtained, based on the indicator bacteria E. coli, from shellfish samples taken in these areas. Areas are classified following a full assessment of this risk and the classification given to an area determines whether shellfish harvested in that area require post-processing treatment and, where appropriate, the level of such treatment. Most areas are assigned an annual classification although some areas received a seasonal classification. Classifications are based on previous records from the area. Ongoing monitoring establishes if the level of risk has changed and thus whether short-term controls need to be applied or if the classification status needs to be changed. In some instances a spike in ecoli can be traced back to a one-off event which happened to coincide with the sampling location and time. An example may be where the sample was collected following unusually heavy rainfall. In this instance, evidence of lower salinity, indicating higher freshwater influx, together with meterological records have helped the shellfish operators to make a case to the Molluscan Shellfish Safety Committee (MSSC) that the sample results were an outlier and hence justify a more representative classification for their production area.

To support statutory monitoring each producer could monitor the water alone, but the cost can be lowered and spatial coverage improved by coordinated their monitoring. Members of CLAMS can coordinate their water quality monitoring efforts and data can be combined to generate a holistic picture of water quality in the bay, rather than having discrete standalone observations for each producer. The existence of social capital in the form of CLAMS enables the optimisation of locating water monitoring sites and reduces the total cost of installation as less sites are needed.

Figure 45 below shows the north and south loggers with a 5km radius. For this analysis the 5km was assumed to approximate the area which the logger's data would represent. In future iterations of this work the area of influence for data loggers should be refined and take account of the physical geography of the bay.

The left-hand side shows a heat map with the distance from the data loggers. The right-hand side shows distance discretised into 0.5km increments, where pale blue is 0-0.5km and dark purple is 4.5-5.0km.

Figure 45 North and south data loggers 5km coverage



Source: OC_031 and OC_035

The total area covered by the north and south loggers is 8,688 and 11,905 ha, respectively. Table 30 shows the breakdown of distance from each logger and the number of hectares in each 0.5km band.

Table 31, Table 32 and Table 33 show the coverage of the data loggers for SACs, aquaculture sites and marine habitats, respectively. The total area of Clew Bay Complex SAC is 11,986 ha with the data loggers covering 74 percent. Fifty two percent of the SAC is within 3km of the data logger suggesting the data is relevant for reporting on how the condition of the SAC may be impacted by water quality.

Table 30 Area of bay covered by north and south loggers

Distance (km) from Logger	South Logger	North Logger
0.00 to 0.50	301	161.5
0.50 to 1.00	720	321.25
1.00 to 1.50	882	474
1.50 to 2.00	981	634.25
2.00 to 2.50	1113.5	785.75
2.50 to 3.00	1269.75	945.75
3.00 to 3.50	1423.5	1104
3.50 to 4.00	1577.75	1259
4.00 to 4.50	1742.25	1424.5
4.50 to 5.00	1888.25	1573.25
5.00 to 5.50	6.25	5.5
Total	11905.25	8688.75

Source: OC_031 and OC_035

Table 31 Data logger coverage for Clew Bay Complex SAC

SAC	Distance (km) from Logger										
	0.00 to 0.50	**0.50 to 1.00**	**1.00 to 1.50**	**1.50 to 2.00**	**2.00 to 2.50**	**2.50 to 3.00**	**3.00 to 3.50**	**3.50 to 4.00**	**4.00 to 4.50**	**4.50 to 5.00**	**5.00 to 5.50**	**Tota l**
Clew Bay SAC	432	810	895	806	804	866	958	1065	1140	1119	4	8897
Total	432	810	895	806	804	866	958	1065	1140	1119	4	8897
Percent covered	5%	14%	24%	33%	42%	52%	63%	75%	87%	100%	100%	

Source: OC_031, OC_035 and OA_010

Table 32 shows the shows the aquaculture sties with data logger coverage. Just under 90% of the shellfish sites are covered by the loggers with 70% of the area within 2.5km of a logger.

Table 32 Aquaculture sites associated with data logger coverage

Aquaculture sites	Distance (km) from Logger										
Sum of Area (ha)	**0.00 to 0.50**	**0.50 to 1.00**	**1.00 to 1.50**	**1.50 to 2.00**	**2.00 to 2.50**	**2.50 to 3.00**	**3.00 to 3.50**	**3.50 to 4.00**	**4.00 to 4.50**	**4.50 to 5.00**	**Gran d Total**
Finfish			4	10	2						16
Shellfish	106.5	46.25	8.25	1	4	10.5	19.25	29.75	3	13.5	242
Grand Total	106.5	46.25	12.25	11	6	10.5	19.25	29.75	3	13.5	258

Source: OC_031, Mul_003 and OC_035

Table 33 shows the Clew Bay Complex marine habitats covered by data loggers. The total marine habitat areas is 10,138ha of which 5011ha (50%) are covered by data loggers Reef fauna, Laminaria dominated community, Sandy mud with polychaetes and bivalves community complex and shingle have very good coverage ranging from 100% through to 48%.

Information is a form of produced capital that can be used spread through different networks and used by human capital. Information often has a public benefit and can be used by many different people. For example, both the aquaculture sector through CLAMS and the NPWS as SAC managers can benefit from data provided by loggers. The logger data on salinity can be paired with rainfall data (from Met Eireann). As detailed earlier, large freshwater influxes to the bay (storm overflow and increased agricultural runoff) may corresponds with a spike in bacterial (e-coli) counts, which are regularly monitored to inform bay classification status for food safety purposes.

Table 33 Extent of marine habitats within coverage of data loggers, hectares

Marine communities with data loggers	Distance (km) from Logger													
	0.00 to 0.50	0.50 to 1.00	1.00 to 1.50	1.50 to 2.00	2.00 to 2.50	2.50 to 3.00	3.00 to 3.50	3.50 to 4.00	4.00 to 4.50	4.50 to 5.00	5.00 to 5.50	Total data log area	Total marine area	Percent of marine area
Fine sand dominated by Nephtys cirrosa community													296.75	na
Intertidal sandy mud		10	57.25	40	30.5	34	23	24.25	8	20.5		247.5	791.5	31%
Laminaria dominated community		7.75	21.75	56.25	37	106	163.25	181.5	202.5	202.75	0.5	979.25	1634.5	60%
Maerl dominated community										0.5		0.5	287	0%
Reef Fauna		12.25	38.25	31.75	20.75	24	22.5	28.75	31.75	5		215	215	100%
Reef Intertidal	5	18.25	34.25	31	22.75	25.25	27.75	24.25	39.5	27	0.75	255.75	835.75	31%
Sandy mud with polychaetes and bivalves community complex	123	223.5	223	257.25	383.5	363.5	378	430.25	456.5	399.75	0.25	3238.5	5788	56%
Shingle	5.5	4	3.25	3.75	3.75	7.5	11.75	11.25	12.25	7.25	0.25	70.5	148	48%
Subtidal reef community													0.25	na
Zostera community							4					4	142	3%
Grand Total	133.5	275.75	377.75	420	498.25	560.25	630.25	700.25	750.5	662.75	1.75	5011	10138.75	

Source: OC_031, OC_035, OA_010

6 Conclusion

This project delivered a series of natural capital information, covering ecosystem extent and condition, the flow of a set of ecosystem services and the benefits or value (monetary and non-monetary) these services provide. It also provided information on produced, social and human capital for the seafood sector.

This case study applied the principles in the United Nations System of Environmental-Economic Accounting to organise information for natural capital. There were numerous data sources used, and several more that were discovered during the project. However, there was a lack of time series information, and coverage of most data were incomplete for the purpose of accounting for Clew Bay.

There are a number of areas of future research:

- Extending the coverage of detailed mapping to Clew Bay
- Developing an approach to measuring condition following the UN SEEA
- Measuring ecosystem services, for example regulating services and cultural services, for Clew Bay
- Exploring the potential impact of CLAMS (social capital) projects on the environment, using a natural capital framing.

There is a need to embed consistent monitoring of the environment into statistical processes. The way data is collected currently may be useful for one purpose, but it is not for the purpose of telling a coherent story about the environment and the link to the economy in Clew Bay. Alignment between different data collection processes can be explored. The study provides insights into how future accounts could be developed for other sites and Ireland.

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