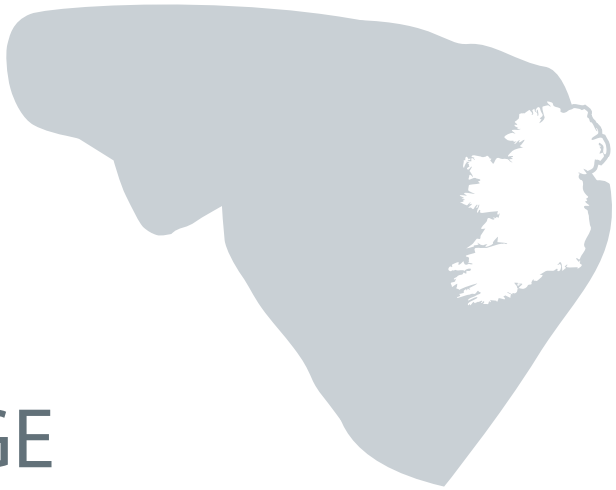

SEA CHANGE (2007-2013) PART II

Marine Foresight Exercise for Ireland

Marine Institute
Foras na Mara

"to undertake, to co-ordinate, to promote and to assist in marine research and development and to provide such services related to marine research and development that, in the opinion of the institute, will promote economic development and create employment and protect the marine environment" Marine Institute Act 1991.

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Further copies of this publication, and the associated report,
Sea Change – A Marine Knowledge, Research & Innovation Strategy for Ireland (2007-2013),
can be obtained from:

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Alternatively you can download a pdf version of both reports from **www.marine.ie**

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Foreword

The task from Government to develop Sea Change – A Marine Knowledge Research and Innovation Strategy for Ireland (2007-2013) was a very welcome challenge for the Marine Institute.

A relatively small Marine Institute team, supported by the management team, were tasked to lead the strategy development process to the inclusion of significant background research; a Foresight Exercise and an extensive Stakeholder Consultation Process.

The objectives for the Strategy are;

> Assist the existing and largely indigenous marine sub-sectors to improve their overall competitiveness and engage in activity which adds greater value to their outputs by utilising knowledge and technology arising from research in the natural science, engineering & science

> Build new research capacity and capability as well as utilise fundamental knowledge & technology to create new marine related commercial opportunities and companies

> Contribute to the achievement of key national objectives in transport, energy, environment and health

> Inform public policy, governance and regulation of the sector, and support the delivery of more innovative, customer-driven public services by applying the knowledge derived from marine research and monitoring

> Underpin the competitiveness and commercialisation of the marine resource in a manner that ensures sustainability and which protects the marine biodiversity and ecosystems

> Strengthen the economic, social and cultural base of regional communities that depend on the marine resource

The Foresight Exercise involved 29 international (22%) and 89 national experts drawn from public (50%), private (33%) and third-level (17%) sectors. The range of expertise spanned seven Foresight Panels reflecting the great diversity of enterprise and governance activity associated with the marine resource, as follows:

> Aquaculture, Seaweed & Seafood

> Marine Environment & Sustainable Development

> Marine Technology

> Oil & Gas and Offshore Renewables

> Sea Fisheries

> Shipping & Maritime Transport

> Water-based Tourism & Leisure

Background research activity commissioned to inform this Foresight Process included the reports: Marine Industries Global Market Analyses; Ireland's Ocean Economy & Resources; and Climate Change – Impacts for Ireland's Marine Environment and Resources.

The outcome of the Foresight Exercise, with draft scenarios for 2020, were then put through an intensive and wide-ranging stakeholder consultation process, including workshops, to further evolve our strategy planning process.

This Sea Change Part II publication reflects the outputs of the Foresight and Stakeholder Consultation Process and I would like to express my warm appreciation for the efforts of all who contributed to these processes. From the perspective of the Marine Institute such support and involvement greatly enriched our efforts to develop the Sea Change Strategy.

A measure of the success of our joint efforts can be gleamed from the fact that Marine resources were an integral component of the Government Strategy for Science Technology Innovation 2006-2013, published in June 2006, thus accommodating an appropriate scale and focus for National Marine STI programmes in the years ahead, as detailed in Sea Change – A Marine Knowledge Research and Innovation Strategy for Ireland (2007-2013).

Dr Peter Heffernan
Chief Executive, Marine Institute

Contents

1 Introduction

1.1 The Background

The Irish marine sector has a turnover of €3 billion and supports over 44,000 jobs directly and indirectly, 56% of which are outside the most developed regions of the country. However, the significance and potential of the marine sector in Ireland is far greater, for a number of reasons.

The sector is a key enabler of other industry:

> Ireland has one of the highest ratios of exports to GDP in Europe. In 2004, over 95% (€120 billion) of all imports & exports were transported via Irish seaports. Shipping, seaports and logistics infrastructure support 150,000 jobs in foreign-owned and indigenous export-dependant companies.

The seas around Ireland contain many untapped and under-developed resources:

> The wind and wave regimes off the coast of Ireland are among the most favourable in the world. Although there are challenges associated with building an offshore renewable energy industry in Ireland, the potential for developing world-class, export-oriented technologies in an area with phenomenal global growth prospects, is immense.

> In some areas of the Irish seabed, unique environments exist where there is a high probability of finding organisms that are of specific interest for pharmaceutical or industrial chemical applications. The Porcupine Ridge on the Irish Continental Shelf is one such area. The global marine biotechnology industry was worth €2.4 billion in 2003. It is growing at 10% per annum. Worldwide, scientists have patented more than 5,000 chemical compounds from marine organisms.

There are major new market opportunities associated with the marine sector worldwide:

> World demand for seafood products is projected to increase by 60% to 2025. The aquaculture market is projected to continue growing at 4% per annum and presents significant opportunities for Ireland, particularly in organic and high quality fish and shellfish products.

> Realisation by consumers and food manufacturers that certain foods or food ingredients can promote health has led to the emergence of a new range of products called 'functional foods'. This market could eventually reach 5% ($100 billion) of total developed world food expenditure. Functional seafood products represent a major niche opportunity for Irish seafood producers and processors.

> Asia is the centre of a large and valuable market for seaweed products; valued at €6 billion in 2004. Ireland's potential in this sector is largely under-developed.

> There is a widely shared international vision for 2020 of a globally connected system of marine and freshwater environmental monitoring. This presents significant opportunities for the development and application of new technology-intensive products and services.

> The world market for angling, boating and water sports is valued at €168 billion and there is huge potential to attract overseas tourists to Ireland for exciting water-based experiences in a quality marine environment.

> The world cruise ship market is experiencing very rapid growth rates (56% since 1999). Strong growth is expected globally, resulting in a market worth €14.8 billion in 2009[1]. There is significant potential for smaller specialised cruises in Northern European waters.

The oceans around Ireland are important to our environmental well-being and climate:

> Global climate change is one of greatest challenges facing us in the 21st century. For Europe, these changes will be primarily mediated by the Atlantic Ocean, where significant temperature changes and shifts could result in major economic, social and environmental consequences. The North Atlantic Drift, which regulates the Irish and north-west European climate, comes closer to Ireland than to any other European nation. Ireland is in a good position strategically to contribute to, and benefit from, international scientific efforts in monitoring and understanding climate change.

Ireland's marine location and extensive marine resources represent a unique asset supporting a wide spectrum of interlinked sectors with potential to advance knowledge-based economic, social and environmental opportunities.

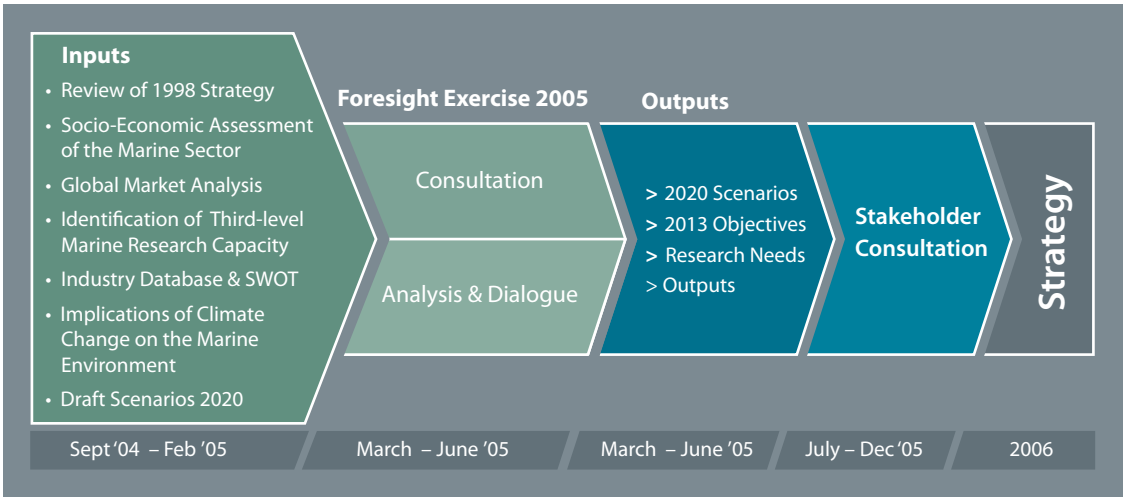
1.2 The Process

In July 2004, the Department of Communications, Marine and Natural Resources and the Marine Institute agreed on a broad set of objectives to direct the development of a new Marine Knowledge, Research and Innovation Strategy for Ireland for the period 2007–2013. As part of the process of preparing the new Strategy, a Marine Foresight Exercise was undertaken.

The Marine Institute has drafted this report arising from an in-depth assessment of the marine sector, a Marine Foresight Exercise, and widespread consultation with stakeholders, policy makers and the marine industry. The report contains the background analysis and evaluations that underpin the accompanying high-level strategy document *'Sea Change: A Marine Knowledge, Research & Innovation Strategy for Ireland (2007–2013)'.*

The process for developing the Strategy is outlined in the following diagram. Further details are provided in Appendix A.

[1] Douglas Westwood Ltd. (2005). Marine Industries Global Market Analysis, Marine Foresight Series 1. Marine Institute.



The National Marine Foresight Exercise (March–April 2005) convened seven sector panels (Shipping & Maritime Transport, Energy & Offshore Resources, Aquaculture, Seaweed & Seafood Processing, Sea Fisheries, Water-based Tourism and Leisure, Marine Environment & Sustainable Development, and Marine Technology). The panels brought together 29 international experts and 90 Irish experts; representing the public, academic and commercial sectors (see Appendix B). The panels were asked to:

> Examine the current status of the marine sector;

> Identify the opportunities and challenges to be faced;

> Identify future scenarios for 2020;

> Use these scenarios as drivers and identify objectives for 2013;

> Identify the key research, technology, development and innovation (RTDI) that would be required to deliver on the objectives by 2013; and

> Identify the major prerequisites for successful delivery of the 2013 Objectives.

International experts from various sectors contributed significantly to position the R&I objectives within the rapidly evolving marine sector. The planning process delivered a clear set of realistic, yet challenging, scenarios and objectives for future marine research and innovation that maximise the potential of the significant Irish marine resource.

Subsequently, extensive consultations were held with stakeholders, industry and policy makers as follows[2]:

> Inter-agency meetings were held to further define and refine research requirements (See Appendix C);

> Briefings with Industry Representative Groups;

> Consultation with Third-level Institutions;

> Stakeholder Meeting—Dublin Castle 12th July 2005 (over 300 invitees); and

> Web Consultation—12th–29th July 2005.

Further consultation with key stakeholders took place up to June 2006.

[2] See Appendix C for a list of organisations and stakeholders consulted.

1.3 The Result—A Marine Knowledge, Research and Innovation Strategy for Ireland 2007–2013

The Marine Institute in bringing forward, on behalf of government a Marine Knowledge, Research and Innovation Strategy 2007–2013, aims to provide a framework for a programme of selective and managed investment that will help to maximise the potential of the marine sector and resource. The Strategy, aimed at transforming the Irish maritime economy, outlines a knowledge agenda comprising science, research, innovation and management.

The Strategy builds on the achievements of the 1998 Marine RTDI Strategy[3], taking advantage of the solid foundation that has been established since then in terms of marine research infrastructure and the significant strengthening of marine research capacity.

Sea Change – A Marine Knowledge, Research and Innovation Strategy for Ireland 2007–2013 sets out the following new overall vision for the marine sector in 2020:

2020 VISION FOR THE MARINE SECTOR

In 2020, the Irish marine sector will sell into specialised global and local markets in a dynamic, innovative and technologically driven manner, by means of strong industry research partnerships, a skilled workforce and a strategic capability that responds to markets and technology. It will be internationally recognised for its high quality marine environment and characterised by coherent policy and regulation.

The Strategy has six objectives, to:

OBJECTIVES

1 Assist the existing, and largely indigenous, marine sub-sectors to improve their overall competitiveness and engage in activity that adds greater value to their outputs by utilising knowledge and technology arising from research in the natural sciences, engineering and commerce.

2 Build new research capacity and capability and utilise fundamental knowledge and technology to create new marine-related commercial opportunities and companies.

3 Contribute to the achievement of key national strategic objectives in transport, energy, environment and health.

4 Inform public policy, governance and regulation of the sector and support the delivery of more innovative, customer-driven public services by applying the knowledge derived from marine research and monitoring.

5 Increase the marine sector's competitiveness and stimulate the commercialisation of the marine resource in a manner that ensures its sustainability and protects marine biodiversity and ecosystems.

6 Strengthen the economic, social and cultural base of regional communities that depend on the marine resource.

[3] Marine Institute (1998). A Marine Research, Technology, Development and Innovation Strategy for Ireland.

Central to the achievement of this vision and objectives is:

> An array of new investment and Research and Development (R&D) measures to grow a stronger innovation culture among marine businesses;

> Alignment of public and third-level research to the needs of marine businesses;

> Measures to increase the number of research-active firms in the sector;

> New mechanisms that will help companies to acquire and develop competencies in business development and planning, new product and process development, and research management;

> The fast-tracking of capability development within firms by creating stronger industrial linkages and networks, including links to third-level research and technology;

> Development of stronger links with the venture capital community; and

> Measures that will strengthen the image and reputation of the marine sector in public policy terms and that will result in a higher profile for the sector in industrial and economic development programmes and interventions.

The Strategy will be implemented via three Research Measures and two Supporting Programmes (see Figure 1.1):

> Industry Research Measure – designed to integrate the existing research base with market and commercial opportunities and to grow stronger in-house business research and innovation.

> Discovery Research Measure – to pursue long-term development of new research and economic opportunities associated with bio-pharmaceuticals, industrial chemicals, diagnostics and environmental technologies, marine functional foods, renewable ocean energy and rapid climate change.

> Policy Support Research Measure – to provide stronger support for the determination of public policy relating to the marine sector.

> Infrastructure Supporting Programme – an investment programme to deliver essential infrastructure that will enable research and innovation.

> Innovation Supporting Programme – targeted specifically at improving in-company R&D management and commercialisation capabilities.

These mechanisms are complementary and provide a clear and structured implementation framework. Their implementation is predicated on the collaborative efforts of the relevant funding and implementing agencies. Securing that inter-agency collaboration is a key task for the Marine Institute.

This document should be read in association with the accompanying strategy overview document, which sets out the high-level objectives, delivery mechanisms and investment programme needed to deliver on identified research needs and proposed outcomes. It also highlights the new forms of collaboration needed at national and international level to achieve the objectives of the Marine Knowledge, Research and Innovation Strategy 2007–2013.

The Innovation Supporting Programme is dealt with entirely within the main Strategy document *(Sea Change: A Marine Knowledge, Research and Innovation Strategy 2007-2013)*

Figure 1.1 Structure and Content of the Marine Knowledge, Research and Innovation Strategy for Ireland 2007–2013

1.4 Structure of Report

This report sets out the analysis and proposed actions that underpin each of the **Research Measures** and associated **Research Programmes**. These are addressed in the following sections:

Section 2 Industry Research Measure

- **2.1** Shipping & Maritime Transport Research Programme
- **2.2** Seafood Processing Research Programme
- **2.3** Aquaculture
  - **2.3.1** Finfish Aquaculture Research Programme
  - **2.3.2** Shellfish Aquaculture Research Programme
- **2.4** Fisheries Resources Research Programme
- **2.5** Seaweed Research Programme
- **2.6** Offshore Oil & Gas (including Gas Hydrates) Research Programme
- **2.7** Water-based Tourism & Leisure

Section 3 Discovery Research Measure

- **3.1** Marine Biodiscovery/Biotechnology Research Programme
- **3.2** Marine Technology Research Programme
- **3.3** Marine Functional Foods Research Programme
- **3.4** Renewable Ocean Energy Research Programme
- **3.5** Rapid Climate Change Research Programme

Section 4 Policy Support Research Measure

- **4.1** Marine Environment Research Programme
- **4.2** Knowledge & Information Management Research Programme
- **4.3** Policy, Socio-Economic & Legal Research Programme

For the Research Programmes listed above, the following assessment is provided:

> **Current status** of the relevant marine sector or research field;

> Review of associated **Opportunities and Challenges;**

> Identification of future **Scenarios/Visions for the year 2020**—these represent desirable outcomes for 2020;

> **2013 Objectives**, used to identify RTDI Requirements and Outputs;

> Current **research capacity**[4] and **capability**[5] in relation to research needs; and

> An identification of the **prerequisites**, in addition to the research and innovation actions, for successful delivery of the 2013 Objectives.

[4] Research capacity relates to the number of researchers engaged in an activity.
[5] Research capability relates to competency in a research field.

In the case of Marine Functional Foods and Rapid Climate Change, the research capacity and capability are included as a sub-sector of the Seafood Processing and Marine Environment Research Programmes, respectively.

Finally, Section 5 of the report provides a detailed description of the specialist infrastructures required under the Strategy for the period 2007–2013:

> Seabed & Resource Mapping

> High-End Computing Capacity (Access)

> Test & Demonstration Facilities for Coastal & Marine Observatories and Monitoring Technologies

> Extension of Ocean & Coastal Monitoring Network

> Research Vessel – Fund to access ship time

> National Equipment Pool

> Robotic Platforms

> Test Facilities for Offshore Energy

> Specialist Laboratories & Facilities.

2 Industry Research Measure (2007–2013)

The Industry Research Measure aims to **strengthen the competitiveness of existing marine industries and to support activities that add value to their outputs in an environmentally sustainable manner**. The Measure targets existing and largely indigenous marine sub-sectors; primarily the marine food, ocean energy and shipping and transport sectors. It will support applied industry research initiatives, which improve competitiveness and sustainability and directly influence or create new industrial and commercial opportunities by utilising knowledge and technology arising from research in the natural sciences, engineering and commerce.

The Industry Research Measure comprises seven major **Research Programmes**.

In addition to these research programmes, the outputs of the Water-based Tourism and Leisure foresight panel are included in this section. Many of the requirements identified by the panel in relation to this sector are development related. These outputs have been built upon and incorporated into a stand-alone development Strategy for Marine Tourism and Leisure (2007-2013). The relevant **research** requirements for the marine tourism and leisure sector are environment related and thus are considered under the Marine Environment Research Programme.

2.1 Shipping and Maritime Transport Research Programme

2.1.1 Introduction

The shipping and maritime transport industry in Ireland is a dynamic, multi-faceted industry employing approximately 6,000 people (direct employment). It has an estimated annual turnover of approximately €1.3 billion. It is the largest sub-sector of the marine industry in Ireland. The sector, which is primarily service driven, encompasses a variety of businesses varying in size from very large (1,200+ employees) to two-person SMEs. It can be broken down into two distinct strands of commercial activities, (1) Shipping Services Sector and (2) Ports and Maritime Logistics. The seafaring sector, although not a stand-alone sector, is an important element of the Irish shipping industry, employing just over 2,000 people.

Collectively, these elements form an essential part of the strategic infrastructure that allows the Irish economy to connect with the global market place. In 2004, in excess of €130 billion worth of goods passed through the Irish maritime transport supply chain.

The sector has experienced a number of significant policy changes in recent years. In 1999, Government established the Irish Maritime Development Office (IMDO). The IMDO is the dedicated national body responsible for the promotion and development of the Irish Shipping Services sector and related industries. A key role of the IMDO is to provide assistance to the Irish maritime industry in order to support and maintain competitiveness in the international marketplace. A particular focus of the IMDO is the attraction of foreign direct investment. The IMDO is also the designated Short Sea Shipping Promotion Centre for Ireland and participates in a number of EU initiatives related to the promotion of research and development.

In 2002, the Government introduced a special tax measure, the 'Tonnage Tax regime', to support the Irish shipping industry. The measure also aims to cultivate an environment that attracts foreign direct investment from the international shipping services sector. Competitive taxation policy and clear pro-business legislation provide an excellent platform for international shipping companies to grow.

In January 2005, the Government launched its Ports Policy Statement 2005. It requires that ports operate commercially, without Exchequer support, and provide adequate capacity for the future needs of the economy. A process is underway to investigate how the ports will address future capacity and investment issues.

In 2000, the European Commission published a White Paper on Maritime Transport[6]. This paper set out requirements for future research and aid programmes for the European shipping sector. The next EU Framework Programme (FP7) will provide funding for identified priorities.

2.1.2 Sector Profiles

Shipping Services Sector

The sector is made up of a wide range of specialist services to, or conducted by, ship-owners, operators and managers. It consists primarily of onshore services and ancillary service elements that connect Irish industry through an international maritime services network of trade. Many foreign shipping companies operating on Irish routes have established shore-based operations in Ireland. These companies are predominately involved in containerised trades. The shipping and operating segment of the sector has seen considerable investment by the owners and operators over the past decade. This investment has increased capacity on key trade corridors and provided innovative modal and transport solutions, while at the same time maintaining a cost symmetry that has enabled Irish companies involved in international trade to grow and expand their overseas markets. New direct shipping services have been created around Ireland, linking Ireland's regions and its trade with access to new markets.

In recent years, a number of new and emerging high-value niche sectors have been created. In particular, ship banking and finance activities are beginning to emerge due to the recent introduction of a highly competitive and transparent tax regime for the shipping sector. Recent measures introduced by the Government now make Ireland one of the most competitive locations to own, operate and manage ships in Europe. These measures could provide an additional new layer of high added-value activity in the intellectual management of foreign direct investment in shipping companies' assets and activities in Ireland. This could provide lateral opportunities for the other niche emerging sectors to benefit and grow.

Shipping and Maritime Transport (2003 Turnover - €1.3 Billion)

Shipping Services	Port and Maritime Logistics	Seafaring
> Maritime Financial Services	> Port Companies	> Maritime Education
> Marine Insurance	> Liner and Port Agents	> Maritime Training
> Maritime Law and Legal Services	> Container Services	
> Ship Management	> Stevedores	
> Ownership and Operations	> Freight Forwarders	
> Roll-On/Roll-Off Operators	> 3pl and 4pl Logistics Providers	
> Load-On/Load-Off Operators	> Supply Chain Services	
> Ship Broking, Chartering, Sale and Purchase	> Dredging	
> Shipping Agents and Brokers	> Pollution Control	
> Marine Engineering	> Salvage Companies	
> Marine Technology and Innovation	> Software and ICT	

[6] European Commission (2001) White Paper: European Transport Policy for 2010: Time to Decide. COM (2001) 370.

Ports and Maritime Logistics Sector

Irish commercial ports are highly significant economic motors of national and regional industrial activity. Irish ports are facilitators of growth and provide a gateway for Irish industry to access the global market place. Ports are also areas where value can be added to the activity linked to the import and export of commodities, in particular through the emergence of leading logistics companies and supply chain capabilities in Ireland. As an island economy, the role of ports in the national transport infrastructure grid and their connectivity with this network is hugely important. As the shape and structure of Irish industry and trade continues to change and evolve, it is essential that our ports continue to innovate and evolve in step with the demands of our economy.

It is clear that the competitiveness of Ireland's transport linkages with the rest of the world, and in particular the rest of the EU, has a considerable bearing on the overall competitive performance of the Irish economy. The total value of Irish merchandise exports in 2004 is estimated to be €84 billion; with imports valued at €50 billion. Goods valued in excess of €120 billion passed through the Irish maritime supply chain and its ports and shipping services.

Ireland's dependence on shipping, combined with opportunities and challenges in the international operating environment, currently present unparalleled opportunities for the sector to develop. To make the best use of these opportunities, Ireland must ensure that future planning (including infrastructure planning) and development takes place to service the evolving Irish economy. Developing and integrating intelligent transport information systems, GIS-based planning systems, e-commerce logistics and supply chain design technologies should also form part of this future vision.

Seafaring Employment

Seafaring is one of the oldest and most traditional trades remaining in Ireland today. It is, without doubt, an important sector within an island economy. The development and retention of maritime knowledge is central to Ireland's place in the shipping service economy. The Irish seafaring sector consists of approximately 2,000 seafarers, of which 1,000 are serving on Irish vessels and the balance on foreign owned and flagged ships.

The Government is seeking to replicate its successful education policy in the areas of science, business and IT by an unprecedented development in maritime training. The new National Maritime College of Ireland (NMC) is at the centre of this commitment and represents a €60 million investment, ensuring that along with other initiatives to develop Ireland as an international shipping centre, the skilled workforce will be there to meet the future demands of the sector. In addition, a valuable internationally traded service can be developed by offering training courses for overseas students. This investment represents a significant opportunity for Ireland to position itself as a centre of maritime training excellence in Europe.

2.1.3 Key Opportunities and Challenges

Opportunities for the Irish Ports and Shipping Services Sector

> Although Ireland cannot change the trend of globalisation, it can prepare itself to evolve ahead of change. Globalisation will affect the future shape of the international shipping industry; an area where Ireland could target niche growth opportunities.

> It is essential that capability to deliver a-fit-for purpose Ports and Shipping Master Plan that incorporates trade changes, technology drivers and cost and competitive issues be developed. The changing type and size of vessel, and their impact on Irish trade, also need constant review.

> Increasing Irish imports will provide excess transport capacity for exports, especially containers. There may, therefore, be a continued focus on the comparative advantages of Irish export costs.

> The transfer of goods from road to sea motorways and removing cargo bottlenecks are top priorities for the European Commission, with several EU funding opportunities in this area including Motorways of the Sea under the TEN-T Programme, and the Marco Polo Programme. These programmes essentially provide grant-aid to sustainable transport services such as short-sea shipping. It is important that Ireland aligns itself to this European strategy and maximises any lateral opportunities for funding for its sector.

> Socio-economic benefits would accrue from a fully integrated shipping policy and strategy where regional and national transport infrastructure planning and management decisions are co-ordinated among all the relevant government, semi-state and industry stakeholders.

> Ireland has a reputation in aircraft leasing and a strong financial capability built through the Irish Financial Services Centre. A potential high-value opportunity exists for Ireland to replicate this success through the creation of competence in international ship leasing and finance.

Challenges for the Sector

> The trend towards increased globalisation and the future role, connectivity, size and position of our ports in facilitating and evolving with the changing patterns of globalised trade present a significant challenge.

> The efficiency of Ireland's role as a pan-European location with an efficient integrated transport network will influence future decisions of multinationals to invest here.

> The drive to reduce logistics costs throughout the supply chain is continuing to exert pressure on integrating the transport modes and nodes using satellite-based technologies for seamless route and traffic planning. The Uniform Rules of Conduct for Interchange of Trade Data by Teletransmission (UNCID) estimate the costs of data flows associated with international trade to be between 4 and 7% of the value of the goods.

> A central trend in global manufacturing in the next decades is likely to be the customisation of mass produced products. A part of the mass customisation is providing improved and timely information to customers, increasing perceived value of logistic services. This strengthens the drive for the development of increasingly 'Intelligent' Supply Chains.

> The cost of congestion, or 'bottlenecks', in the Irish supply chain, and the scarcity of infrastructure space are key challenges in the logistics sector, both on a national and global scale.

> The Irish exports profile is expected to continue to change to more high-value, knowledge-based products. It is also believed that the imbalance in the trade balance in favour of imports will continue, This presents challenges in the change of pattern of shipping and logistics supply chains.

> There is no long-term or continuous central master plan for the shape and future role of Irish ports and their important macro position as facilitators to the Irish economy.

> R&D intensity is currently very low and there is an acknowledged gap in strategic research aimed at building up maritime logistics knowledge in terms of business expertise and maritime economics. There is also a lack of detailed information on port productivities benchmarking.

> The ports and maritime logistics sector is not traditionally innovative. Companies are not generally pro-active in searching for IT solutions to address productivity issues or infrastructure difficulties relating to efficient utilisation of space.

> The energy market, through rising fuel costs, will continue to have major implications for the sector.

Regulation and Technology

In addition to the opportunities and challenges outlined above, the following regulatory and technological issues will have implications for the future of the shipping and maritime transport sector.

> Maritime-related activities will be subject to increased regulation.

> Security issues will be a central element in the regulation of the sector.

> The 'Polluter Pays' principle and 'Road Pricing' equivalents, such as green taxes, will increasingly be applied to the sector and thus be critical economic factors.

> The management and control of ships as polluting entities will be integral to the successful operation of the shipping sector.

> Overall, a convergence of regulations worldwide in relation to environmental matters in the shipping sector is expected.

> The sector will see increased recognition of the economic, environmental and societal impact of ports. This will affect development of existing and new ports, with, for example, land access issues being important in new ports outside city/urban areas.

> Technology will play an important role in the development of the sector with, for example, the development of improved IT and logistics systems affecting both its operation and management, and the use of technology to assist in environmental mitigation and design issues.

> Resources to direct Irish IT expertise towards the area of maritime transportation have not been identified or allocated.

2.1.4 2020 Scenario

2020 SCENARIO

Port and Shipping Services Sector

The Irish shipping and maritime transport sector will have grown at a rate of nearly 6% per annum since 2005. New foreign companies will be attracted to Ireland in the services and technology sub-sectors. Port infrastructure will be fit for purpose and operate efficiently; supported by technology investments.

Ports and Maritime Logistics

This will be a vibrant sub-sector driven by a continuing vibrant economy, with expanded capacity and extensive use of technology. It will have successfully transferred and integrated intelligent transport through its entire supply chain and through its international intermodal traffic management systems, and have developed niche capabilities in supply chain technologies and intelligent traffic handling systems. Ireland will be the 'best connected' island economy in Europe.

Shipping Services and Maritime Commerce

Vibrant new high-growth services will be attracted to Ireland, aided by a pro-business regime and strong R&D.

2.1.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Develop the capacity and capability to plan strategically for the development of the Ports and Shipping sector. This includes the ability to incorporate trade changes, capacity issues, cost and competitive issues, and changing vessel characteristics into planning and investment strategies.

2 Establish niche capabilities in the development of Intelligent Supply Chain Management systems and e-commerce technologies.

3 Adapt Information & Communications Technology (ICT) and Intelligent Traffic Systems (ITS) applications to national and regional intermodal infrastructure and traffic planning systems.

2.1.6 RTDI Requirements & Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 2.1 Research Requirements & Key Outputs for the Shipping and Maritime Transport Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Develop the capacity and capability to plan strategically for the development of the Ports and Shipping sector. This includes the ability to incorporate trade changes, capacity issues, cost and competitive issues, and changing vessel characteristics into planning and investment strategies.	> Research and establish trade patterns in and out of Ireland by country/ region, commodity and mode of appearance > Forecast these trade patterns, considering potential developments, using existing studies or gathering new data where necessary > Establish inland pattern of demand, including future land-use patterns and location of distribution warehouses > Establish capacity of existing system, including ports and inland infrastructure > Research and develop reliable databases of traffic, trade flows and economic time-series from which models can be tried and tested for econometric analysis; thus enhancing our understanding of where, why and how trade is moving, and the strategic requirements of the ports and transport sector to facilitate this trade	> Long-term strategic integrated transport framework that can effectively meet future traffic demands on all transport modes and nodes > Long-term (up to 2020) forecast scenarios of maritime traffic, port developments, port capacity, investment strategies, ownership models, pricing and competitive market factors, changes in manufacturing and industry trends
2 Establish niche capabilities in the development of Intelligent Supply Chain Management systems and e-commerce technologies.	> Research and harness existing ICT competence and academic research in Ireland in the areas of traffic management systems (i.e. door -to-door IT structures), integrating tracking and tracing systems and Electronic Data Interchange systems > In collaboration with global shippers based in Ireland, research and identify methods and technologies to increase efficiency of the supply chain in Ireland to reduce time deficiencies and increase cargo productivity	> Advanced logistic chain management systems and tools that will optimise supply chain performance for Irish and international shippers moving goods inwards and outwards from Irish ports
3 Adapt Information & Communications Technology (ICT) and Intelligent Traffic Systems (ITS) applications to national and regional intermodal infrastructure and traffic planning systems.	> Collaborate with existing transport planners and users of ITS and GIS applications to adapt existing know-how for broader intermodal traffic planning > Research the feasibility of applications that would enable planning, simulation, and routing of traffic along the different transport modes and nodes. The planning tool should also have the objective of simulating scenarios to match forecast traffic and capacity requirements on a regional and national basis	> Software applications that can cost-effectively meet objectives > Performance evaluation of pilot and recommendations for further actions

2.1.7 RTDI Capacity/Capabilities

Current Research Capacity

Third-level Sector

There is very little dedicated research associated with shipping and transport in the third-level sector in Ireland. However, there are currently a number of research groups and individual researchers (approximately 35 researchers in total) within the third-level sector with skills and technology that are directly relevant to the objectives outlined above. The research focus of these groups includes the areas of supply chain management and logistics, advanced technologies and logistics trends, spatial analysis, GIS technologies, e-commerce, maritime law, transport economics and policy research, and ICT.

One third-level institute undertakes dedicated maritime transport research. Through the Marine RTDI programme of the NDP, the Marine Institute is currently funding a PhD at the International Maritime Studies Institute (National College of Ireland) focusing on research into maritime clusters.

The National Maritime College of Ireland is primarily an education and training facility with an important role in contributing to a vibrant shipping industry. It has the potential for research in the future.

Table 2.2 Research Groups with Capabilities Related to Shipping and Maritime Transport

Institute	Research Focus	Institute	Research Focus
NUI Galway	Marine law and ocean policy International Law of the Sea E-commerce market cluster research	TCD	Sustainable freight distribution
DCU	Transport economics and policy research Logistics and trade corridors	Tipperary Institute	Focus on levels of ICT & plans for upgrading Mapping of e-commerce activities ICT regional strategy development
NUI Maynooth	Geocomputation Spatial analysis Intelligent and graph based systems research	UCC	Constraint-based reasoning and programming Infrastructure modelling Planning & scheduling Supply chain modelling
UCD	Supply chain management		

State Sector

The Irish Maritime Development Office (IMDO) is involved in promoting and supporting research activities. Research topics include port productivity, ro-pax ferries, ICT in ports, origin destination of traffic, Inter-European trade corridors and the potential development of a maritime cluster in Ireland. The data generated by this research are used by industry and state bodies to increase the level of understanding of the importance of the shipping industry and to develop Ireland's potential as a globally competitive market for shipping and related services. The IMDO also promotes participation in the European Union's research agenda.

Industry

The commercial maritime transport sector conducts very little research, with the exception of market analysis for the development of new services or analysis of future demand. However, industry has

expressed interest in, and is providing support for, R&D initiatives carried out by and through the IMDO.

There are a number of small private companies participating in international research programmes and offering consultancy expertise in the areas of modelling intermodal transport networks, ICT for maritime transport and logistics, port and terminal operations, safety at sea, and shipping and environmental law.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives, is presented in Table 2.3. Also included in Table 2.3 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 2.3 Competencies Required to Meet Future Research & Innovation Requirements for the Shipping and Maritime Transport Sector

Objectives 2013	Competencies Required	Assessment
1 Develop the capacity and capability to plan strategically for the development of the Ports and Shipping sector. This includes the ability to incorporate trade changes, capacity issues, cost and competitive issues, and changing vessel characteristics into planning and investment strategies.	> Strategic development in relation to planning for ports	R
	> Economic research	R
	> Quantitative and qualitative analysis of key components	R
	> Econometric modelling and data analysis	G
	> Traffic and trade flow expert analysis	G
2 Establish niche capabilities in the development of Intelligent Supply Chain Management systems and e-commerce technologies.	> Market research and benchmarking of existing ICT	S
	> Strategic planning for ICT	G
	> Developing tools for optimal supply chain performance	G
3 Adapt Information & Communications Technology (ICT) and Intelligent Traffic Systems (ITS) applications to national and regional intermodal infrastructure and traffic planning systems.	> Market research	R
	> Route and traffic planning and management	R
	> Application development for planning, simulation and routing of traffic	R
	> Identification and promotion of new and innovative technology development	G

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

The lack of third-level participation in the area of maritime transport research is a constraint to the development of the sector. Many third-level institutions and private companies have research strengths in a range of disciplines that are not currently, but potentially could be, applied to shipping and maritime transport. The challenge lies in attracting and harnessing appropriate research groups to develop and apply their skills to the specific RTDI needs of the maritime transport sector.

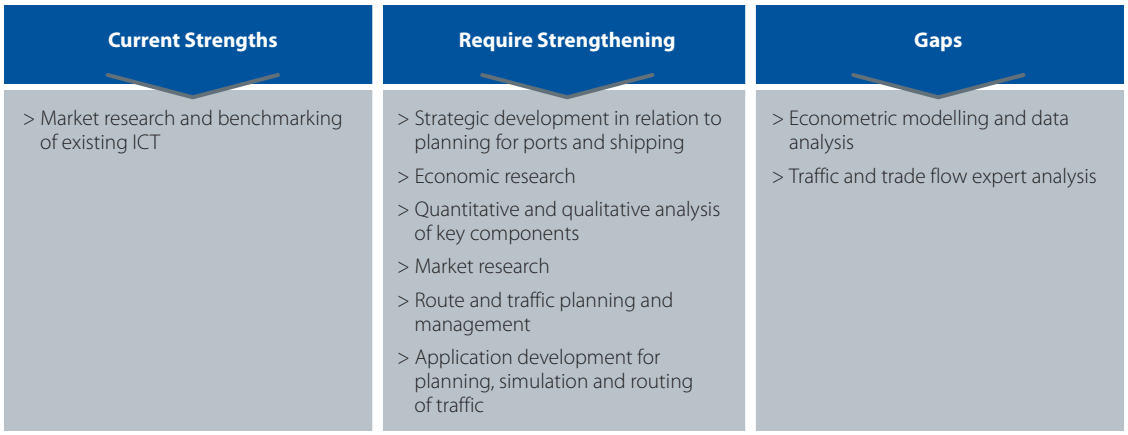


Figure 2.1 Research Competencies Required to Meet 2013 Objectives for Shipping & Maritime Transport

2.1.8 Prerequisites for Achieving Objectives

The following are considered as prerequisites for the successful delivery of the objectives for the shipping and maritime transport research programme:

> A fully integrated transport policy for the island of Ireland;

> Significant investment in port infrastructure needs and major improvement in port productivity and work practices (e.g. move to 24 x 7 operations);

> Joint agency/enterprise/academic initiatives to identify existing ICT technologies that have the potential for port and maritime logistics applications in GIS-based transportation planning systems, e-commerce logistics and supply chain design technologies; and

> Identification of world leaders in logistics and distribution (or shippers) who are based in Ireland to partner and test the new technologies listed above.

2.2 Seafood Processing Research Programme

2.2.1 Introduction

In the last 50 years, fish consumption per person has doubled on a worldwide basis. Japan, the US and the EU are major seafood markets and depend on imports for approximately half of their consumption.

The global value of processed seafood products in 2004 was €79.6 billion. This is predicted to increase into the future due a combination of factors, e.g. higher disposable incomes, sophistication of tastes, and declining cooking skills. These factors have resulted in an increase in value-added seafood sales, creating more opportunities for the processing industry.

2.2.2 Sector Profile

Ireland's 140 seafood processing companies operate in an industry that was worth €670m in 2004. Retail sales accounted for €520m (home market €143m, exports €377m) and food service accounted for €150m. Value-added product from the Irish industry accounted for €292m, which, when taken in the context of the world market (€79.6 billion), accounts for 0.37%.

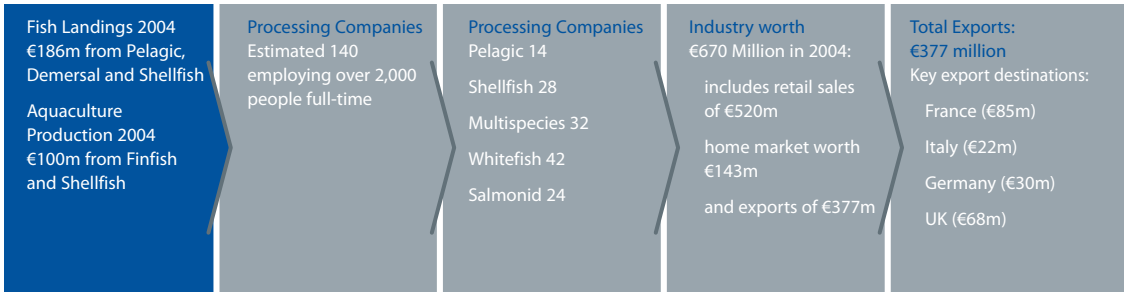


Figure 2.2 Key Components of the Irish Seafood Processing Sector

2.2.3 Key Opportunities & Challenges

Raw Material Supply

A key driver of future success is the issue of raw material supply. This affects the sector by impacting on capacity utilisation, which adversely affects profitability and long-term viability. The key issues are overall volume and continuity of supply.

The sources of wild raw material are limited in quantity (especially whitefish) and are extremely seasonal (especially pelagic, where the season can be as short as 8–10 weeks). Aquaculture is an important future source of raw material for processing; however, the ability to achieve continuity and quality of supply is a key factor.

Growth within the whitefish processing sector has been curtailed due to continuity of supply from Irish landings. This has led to processors within the sector sourcing raw material from countries such as the Faeroes and Iceland. Imports of whitefish are likely to increase as processors develop more value-added products to meet market demands.

Growth within the salmon processing sector has been curtailed due to lack of Irish raw material. In 2004, only 15% of salmon aquaculture output went towards value-added processing and this resulted in processors sourcing most of their raw material from Scotland.

Raw material supply within the shellfish processing sector has grown as a combined result of continued investment within the aquaculture sector and an emerging trend towards strong imports of wild shellfish species for processing. The prospects for further growth are positive and Irish shellfish processing companies are now selling in global markets.

The overall development of the seafood processing sector towards critical additional scale/scope will be hindered by raw material availability and may have to be facilitated by the tertiary processing of (farmed) primary products sourced in third countries.

Competitiveness

The Irish seafood processing sector is comprised of small firms whose plant size and economies of scale are perceived as low in comparison with international competition. Rationalisation of the sector will be necessary to underpin future competitiveness.

Low capacity utilisation and constraints on raw material supply have already led to consolidation within the sector. Within the past few years, the pelagic sector has rationalised from 38 to 14 plants. Rationalisation has also taken place in the whitefish and aquaculture sectors, resulting in some companies widening their product range and introducing value-added shellfish and salmon products.

The challenge for the finfish aquaculture sector, as a minor player compared to Norway, Chile and Scotland, is to position Irish salmon in markets that will generate a premium compared to the average market price. The Irish industry enjoys a reputation for the production of high quality product. A small, but increasing, portion of this is organic salmon. Industry consolidation may result in the sector becoming branded, with prices more stable.

As within other sectors, the need to build scale through initiatives towards mergers and acquisitions is key to growth within the sector. The synergies of a joint marketing programme for a 'family' of complementary products under a strong single brand and produced to an objectively assessed quality

standard should also be evaluated as a model for addressing consolidation and scale/scope economies in this sector.

Growth in the sector is very dependant on development in the aquaculture sector. There is likely to be a trend towards vertical integration between the processing sector and the production sector. There are already examples of this; Bantry Bay Seafoods in the mussel sector and Marine Harvest Ireland in the salmon sector.

Consumer Patterns

Consumer patterns are changing rapidly and increasingly reflect individual needs and quality. There is a high demand for variety in 'ready to heat' and 'ready to eat' products and this leads to major challenges in areas such as food safety, hygiene and packaging. In the coming 15-20 years, there will be increasing international attention to public health, with obesity and malnutrition becoming major concerns. The reputation of seafood products as healthy and nutritious has risen significantly in recent years. Those that can master food quality where safety is an intrinsic part will enjoy commercial success.

Quality

Attention to the nutritional and health aspects of seafood brings increasing demands for food quality monitoring and assurance. Therefore, more accurate and rapid screening methods for chemical and pathogenic contaminants will be required. Demands will increase for quality tracking and consumer information related to the entire production, processing and transport chain. Added-value approaches to upgrading and utilisation of by-products will be required.

New Products

The ability of the sector to develop new higher added-value products to international quality standards has been identified as key to the future of the industry. There is a new niche opening up in the so-called 'Functional Foods' sector, through the development of products using fish as a carrier for pro-biotics or health supplements, thus providing a health benefit beyond the purely nutritional content of the fish. The focus of functional foods is based on the identification of biologically active compounds in food that have the potential to optimise physical/mental well-being and even reduce the risk of disease. Substantial research and development funds will be required to fully optimise the opportunities that can be generated from new, highly profitable products in this area. **A stand-alone research programme for Marine Functional Foods is outlined in the Discovery Research Measure of this document.**

2.2.4 2020 Scenario

2020 SCENARIO

By 2020, Irish seafood products will be perceived as high quality and high value with a strong 'Blue/Green' seafood brand. The sector will have evolved through rationalisation and will be characterised by:

> A mix of small and large companies;

> Automation in larger-scale operations;

> Close working ties with the aquaculture sector and the third-level research sector;

> Niche products and niche markets, e.g. functional foods, with an identified health benefit;

> High value-added processing activity, with a focus on export markets; and

> Processing carried out to EN45011 or ISO65 quality standards.

The need for rationalisation of the Irish processing sector will be clearly recognised. The number of companies in the sector will be reduced to around 70 (from 140 companies in 2005), with resulting efficiencies and economies of scale. These companies will have become the largest producers within the seafood processing sector, having grown through mergers, acquisitions and new product development.

Given increased fuel costs and its proximity to the fishing grounds of the North East Atlantic, Ireland will have developed specialised fish handling facilities for European fleets. All landings will receive added value in specialist processing and packing facilities. Facilities in the major Fishery Harbour Centres (Killybegs, Rossaveal, Castletownbere, Dunmore East and Howth) will encourage increased international landings. The home market will account for 25% of seafood production via direct consumption. The remaining 75% will be exported (mainly to EU countries).

2.2.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Support Irish companies to enable them to produce a large variety of value-added, convenient, functional seafood for the home and export markets[7].

2 Improve production efficiencies with the introduction of the latest technology, world-class manufacturing processes, to underpin our international reputation for quality and safety.

3 Enhance quality, shelf life and traceability through the application of smart packaging and labelling technologies.

4 Ensure waste is minimized and by-products recycled into alternative value-added products.

5 Maximise raw material supply from Ireland and other countries and ensure its optimal utilisation.

6 Co-ordinate the expertise in food/seafood processing within state agencies and third-level institutes.

[7] A stand-alone research programme for Marine Functional Foods is outlined in the Discovery Research Measure of this document.

2.2.6 RTDI Requirements & Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 2.4 Research Requirements & Key Outputs for the Seafood Processing Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Support Irish companies to enable them to produce a large variety of value-added, convenient, functional seafood for the home and export markets.	> Develop nutritional research opportunities for seafood products that target the expanding demand for functional foods > Develop new value-added products based on supplies of pelagic species	> A range of functional seafood products that take advantage of the trend and demand for food to promote healthy eating > New value-added pelagic products range
2 Improve production efficiencies with the introduction of the latest technology, world-class manufacturing processes, to underpin our international reputation for quality and safety.	> Develop or adapt state-of-the-art technology to increase and optimise processing output > Develop Supply Chain Management systems with industry to maximise product quality > Benchmark the quality assurance and seafood safety programmes against global best practice	> High degree of automation of raw product and processing lines > Operational Supply Chain Management systems in place > Improved quality assurance and food safety
3 Enhance quality, shelf life and traceability through the application of smart packaging and labelling technologies.	> Develop and apply smart consumer packaging as required for indication of seafood safety and quality, and to facilitate consumer awareness	> Growing percentage of product shipped with smart packaging/labelling to assist consumer confidence and provide more choice
4 Ensure waste is minimized and by-products recycled into alternative value-added products.	> Investigate or adapt technology for better fish waste management > Continue efforts to identify options for extraction of novel products from fish and shellfish waste	> Improved management practice and reduced waste tonnage to landfill > Series of new products developed based on by-products of fish processing lines
5 Maximise raw material supply from Ireland and other countries and ensure its optimal utilisation.	> Promote opportunities and design customised facilities & services for the landing and handling of fish at Irish ports > Undertake common research with aquaculture industry on optimising supply of farmed fish and shellfish to the domestic processing sector > Conduct feasibility study on economics of new species > Identify high margin products (e.g. abalone, nori) as potential raw material sources for Irish production	> Improved port infrastructure will assist with maximisation of product quality and range > Contract production of aquaculture species to agreed specifications and timelines a feature of the sector > Additional raw material supply > Increased production for Irish suppliers to develop their market range of products
6 Co-ordinate the expertise in food/seafood processing within state agencies and third-level institutes	Not applicable.	

2.2.7 RTDI Capacity/Capabilities

This section reviews the RTDI capacity and capability available to support the Seafood Processing Sector. Research effort focused on seafood processing is a small subset of the total food processing research effort within the state and third-level sectors and draws on such disciplines as chemistry, biochemistry, food science, human nutrition and dietetics. Although the number of research groups and researchers working specifically on seafood related research is low, they are, in many cases, part of larger institutions/departments/companies with considerable expertise in the relevant disciplines.

Current Research Capacity

Third-level Sector

Within the third-level sector, five research groups are currently carrying out seafood processing research. Together, these research groups comprise approximately 17 researchers in seafood processing related research (Table 2.5). Current research topics within these groups include food safety, the role of seafood in human nutrition, utilisation of fishery waste products for novel applications and seafood pathogen diagnostics.

In addition, a further 5-6 research groups and many individual researchers have skills/technologies with direct application to identified, future RTDI requirements. These encompass areas such as smart packaging and labelling systems, food chain traceability, fish quality, novel methods for assessment of seafood quality and safety, and market research.

Table 2.5 Overview of Current Seafood Processing Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
UCC DCU LYIT DIT	2 Large Groups 3 Medium Groups	17	> Role of seafood in human nutrition > Seafood sensory quality > Utilisation of fishery waste products for novel application > Novel seafood and marine product development > Assessment of aquaculture activities on composition, quality and shelf-life issues associated with seafood products > High pressure processing of shellfish > Colorimetric indicators of fish spoilage/quality > Autonomous temperature logging for the fishing industry > Modified atmospheric mussel packaging > Marine waste processing > Seafood pathogen diagnostics > Novel optical methods for assessment of seafood quality and safety

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 45-50.

State Sector

Researchers at the National Food Centre (Teagasc) carry out research on food quality and safety, and product and process innovations; with obvious applications to the future RTDI requirements of the seafood processing sector, e.g. functional foods, safe seafood, etc. Teagasc is one of three Irish partners, along with UCC and UCD, in a large FP6-funded integrated research programme (SEAFOODplus). The overall objective of the programme is to *"reduce health problems and to increase well-being among European consumers by applying the benefits obtained through consumption of health promoting and safe seafood products of high eating quality".*

BIM provide marketing support to Irish seafood companies to assist in identifying and securing market advantage for Irish seafood products. The BIM Seafood Development Centre carries out new product development and testing.

Industry

A number of seafood processing companies are involved in developing innovative seafood products and packaging methods. For example, frozen oyster products, and an innovative method for processing and packaging mussels, making them available 12 months of the year, have been developed. Convenient, organic, ready-to-cook meals have been developed for sale on world markets.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 2.6. Also included in Table 2.6 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 2.6 Competencies Required to Meet Future Research & Innovation Requirements for the Seafood Processing Sector

Objectives 2013	Competencies Required	Assessment
1 Support Irish companies to enable them to produce a large variety of value-added, convenient, functional seafood for the home and export market.	> Food technology > Human nutrition > Fish nutrition > New product development (pelagics)	S S R G
2 Improve production efficiencies with the introduction of the latest technology, world-class manufacturing processes, to underpin our international reputation for quality and safety.	> Processing and packaging technology > Supply chain management systems	R R
3 Enhance quality, shelf life and traceability through the application of smart packaging and labelling technologies.	> Advanced technologies (sensors etc.)	R
4 Ensure waste is minimized and by-products recycled into alternative value-added products.	> Waste management > Applied biotechnology > Development of novel waste products	R R R
5 Maximise raw material supply from Ireland and other countries and ensure its optimal utilisation.	> Market research > Farm/production management	R R

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

Although research strengths exist in both the public and third-level research community in the areas of human nutrition and food technology, these strengths need to be applied to the specific area of the development of functional seafood. In support of this objective, the development of appropriate finfish diets is an area that requires strengthening.

Other competencies that require strengthening include the development of processing and packaging technology (including smart labelling); market research; supply chain management; and fish waste management and utilisation. Existing research groups are currently addressing many of these areas but are doing so on an ad-hoc basis without the benefit of structured research programmes.

A major challenge and research gap exists in the development of value added products based on supplies of pelagic species (e.g. horse mackerel).

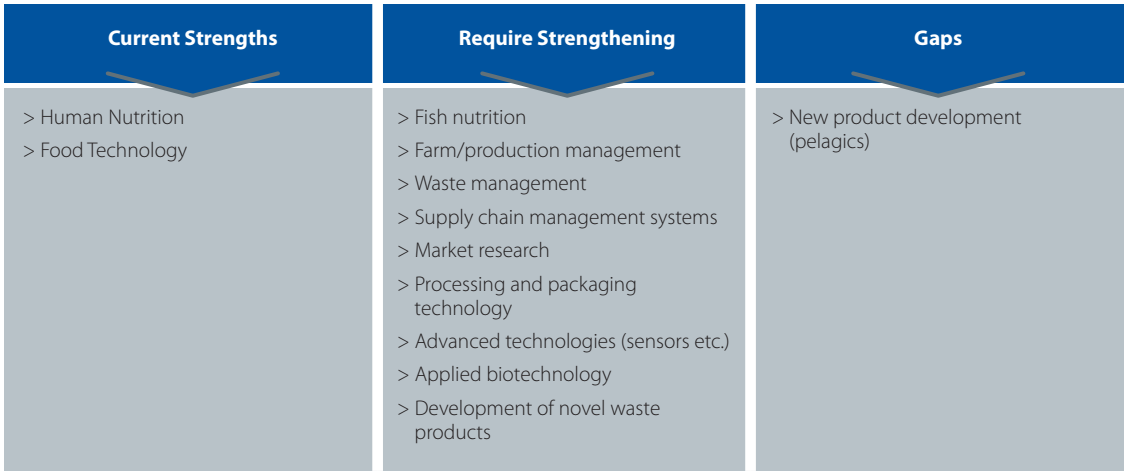


Figure 2.3 Research Competencies Required to Meet 2013 Objectives for Seafood Processing

2.2.8 Prerequisites for Achieving Objectives

The following are considered as prerequisites for the successful delivery of the objectives for the seafood processing research programme:

> Appropriate rationalisation and consolidation in the processing sector;

> Access to new sources of raw material to meet industry growth potential—the development of supplies from aquaculture will be of increasing importance;

> The development of a strong, international brand and a reputation for safe, high quality, organic seafood—this will require market research and segmentation to support companies in identifying new product development and marketing opportunities;

> The development of seafood processing clusters or hubs;

> The requirement to increase and foster collaboration and build scale between companies for service needs of major supermarket chains and international markets;

> New approaches to increase R&D intensity within the seafood sector to enable companies to develop or gain access to significant R&D capabilities, targeted on new product development;

> The need to strengthen management capabilities through participation in the Enterprise Ireland Seafood Processing Strategic Management Development Programme and recruitment of key managers under the Enterprise Ireland Key Worker Programme; and

> Stronger collaboration and communication amongst fishermen, fish farmers, processors, state agencies, research institutions, third-level institutions and industry associations.

2.3 Aquaculture

Introduction

The Irish aquaculture sector is valued at approximately €100 million and employs approximately 1,600 people (2004). Aquaculture activity centres on salmon and trout as the main finfish species and on shellfish species such as oysters and mussels. Finfish farms typically employ around 20–30 and are located on the west coast. Shellfish operations are significantly smaller (averaging three employees), are typically family-owned, and are more dependent on part-time/casual labour. More than half are based in Cork, Kerry, Donegal and Galway.

At least 75% of aquaculture production is exported, mainly to France, Germany, the UK and Spain.

2.3.1 Finfish Aquaculture Research Programme

2.3.1.1 Sector Profile

Salmon and rainbow trout are the two principal species farmed at sea. Salmon consistently accounts for 85–95%, by volume, of annual finfish production. Finfish farming is restricted to five western seaboard counties – Donegal, Mayo, Galway, Kerry and Cork. Production of turbot in land-based facilities has been conducted on a small-scale, and research is being carried out into the feasibility of culturing new species such as cod and halibut.

Over the period 2002–2004, farmed salmon production fell from 21,423 tonnes to 14,067—a 34% decrease. The decline resulted from a combination of factors forcing company receiverships and difficulties resulting from stock survival at sea. There was also a significant drop in sea-reared trout production over the same period—from 890 to 280 tonnes. The total value of finfish production in 2004 was €56.9m, with salmon accounting for €51.3m of this (>90%).

Some significant progress has been achieved in the cultivation of new species, with ongoing development of existing projects focused on the production of farmed cod.

Key Facts: Finfish aquaculture employment (2004) - 275 Full-time, 160 Part-time and 51 Casual = 366 FTEs
Output: Production peaked at 23,000 tonnes in 2001, dropping to 14,000 tonnes in 2004.

Figure 2.4 Key Components of the Irish Finfish Aquaculture Sector

2.3.1.2 Key Opportunities and Challenges

Market Trends

World production of salmon is about 1 million tonnes and Ireland had about a 2% share of that market in 2002. The EU25 market for 2003 was approximately 500,000 tonnes. Over 80% of Irish salmon exports are sold in fresh form, the balance being mainly smoked with a small amount of frozen product. Irish salmon holds a high price compared to Norwegian and UK salmon but visibility in markets tends to be low because of low critical supply volumes. Quality schemes and labels have become very important. Irish organic salmon was a product leader in Europe and continues to enjoy an increasing margin. Higher margins are also a feature of the general increase in demand for organic products. The increasing trend towards organic products will put the EU market for organic seafood at over €300 million by 2009. BIM estimate that the main markets of Europe and USA offer significant opportunity for Irish exporters to market niche products.

Public Perception

The finfish aquaculture sector faces a continuing challenge to gain public acceptance as a sustainable use of the marine coastal resource. The operation of a well-regulated industry will require policy makers to assist a willing industry to operate within sensible environmental guidelines that ensure a secure future for the sector. The sector will face a continuing challenge to maintain and continue to update production methodologies to lead the way in environmentally sensitive operations.

New Species

Species diversification is vital to the further development of fish production in Ireland. A twin-track approach has been adopted to consolidate the production of high quality salmonids in addition to addressing a focus on the requirements of new species such as cod. A consortium of the Carna laboratory of NUIG, industry, Taighde Mara Teo., BIM and the Marine Institute have together initiated a programme to investigate cod hatchery and farm production methods. This group have now progressed to growth trials at sea, which are progressing well. This technical capability can also address the needs for the evaluation of other white fish species as required; as well as char, turbot and halibut.

New species production will also enhance supply and product development opportunities for the seafood processing sector.

The key to driving production forward on targeted species at a faster pace will be the execution of national R&D priorities on new species, in tandem with the use of technology transfer, and joint venture R&D approaches, to take advantage of husbandry techniques and new technologies developed in other countries.

Development and Application of New Technologies

Technology development and application is of major importance to the aquaculture sector. New technologies have the potential to significantly impact on current production operations in the main species, e.g. salmonids. The economic and technical feasibility of offshore locations for finfish culture has yet to be proven.

In addition, there are development opportunities in new species production. New species production will have its own set of challenges, e.g. the use of land-based re-circulation technologies for the production of turbot and halibut, and the differing requirements for the cage culture of cod and other white fish species. Various species have specific challenges associated with them, providing a range of opportunities for technology companies. Requirements include new remote feeding, observational and telemetry systems; other automation-led requirements that come with the development of offshore locations for existing salmonid and new species (e.g. cod); and the advanced re-circulation systems that are required for the development of turbot production.

Environmental and Food Safety Issues

The key challenges for the finfish sector are sea lice management and environmental monitoring to ensure that the seabed and water quality are sensibly managed. Ireland has a rigorous programme of aquaculture protocols that need to be regularly updated in the light of scientific advancements. The national surveillance of residues in farmed fish will become increasingly important for the production of organic fish.

2.3.1.3 2020 Scenario

2020 SCENARIO

By 2020, finfish aquaculture will be a vibrant industry supporting coastal communities to meet their social, cultural, environmental and economic objectives. The sector will be an important employer in the regional economy and will be a key supplier to the domestic seafood consumer and seafood processing markets.

The sector will be characterised by strong environmental practice and the application of science and technology to all key aspects of the production process.

Production will reach **45,000 tonnes**, valued at approx. €155 million, by 2015. This will consist of:

> 30,000 tonnes of salmon, grown in inshore sites, with a significant proportion grown to organic standards;

> 10,000 tonnes of superior quality salmon produced in existing/new offshore sites to Irish Quality Salmon or Label Rouge standards; and

> 5,000 tonnes of gadoids and marine flatfish (cod or other white fish species).

Further development to a level of 60,000 tonnes of salmonids (by 2020) will be dependant on overcoming challenges in the offshore sector.

The sector will be competitive, producing high quality product in land-based re-circulation systems and at sea. Domestic production of juvenile marine fish will be sufficient to meet the home market and there will be a growing export market to Europe. The production of salmonid smolts will stand at up to 20 million individuals. This will be sufficient to supply the home market and a small export market. There will be several small but profitable producers growing trout and char for high quality, niche markets.

The cost of production will be competitive. The key factors underpinning the unit cost of production and ensuring competitiveness will be:

> Production at an appropriate scale (5–10,000 tonne units);

> The strains being cultivated are the best available;

> Good vertical integration within the industry;

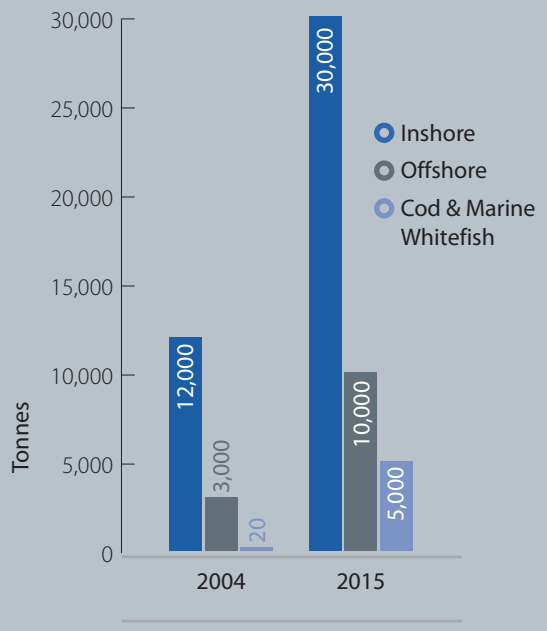


Figure 2.5 2015 Production Scenario for the Finfish Aquaculture Sector

> An industry organised in nodes or clusters with a high degree of co-operative use of common facilities, both within the industry and with related sub-sectors (fisheries, food processing);

> A highly automated industry with employees that have a high skills base;

> Remote telemetry as a key to monitoring, management and control of processes within the industry; and

> Health management has been developed and consolidated into a holistic code of practice that is underpinned by effective vaccines for key problems including sea lice, Pancreas Disease (PD) and Infectious Salmon Anaemia (ISA).

The industry will be attractive to international processors/venture capitalists and will attract significant inward investment. Key factors are:

> Good, sustained profitability;

> Transparent regulation, giving confidence to consumer and investor alike; and

> Licenses and regulations combining to ensure there is security of tenure and production sites are regarded as solid assets.

2.3.1.4 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Focus on production and marketing of higher value, safe seafood (including organic).

2 Develop and refine Codes of Best Practice for farm management and fish health and establish an effective health management regime.

3 Improve marine planning and management of aquaculture, in order to optimise standards, maximise production and minimize negative interactions in the coastal zone.

4 Further develop and refine environmental monitoring and forecasting capabilities and develop environmental monitoring systems for aquaculture that will provide the basis for a new suite of indicators and incentive-based regulation.

5 Identify sites and develop technologies/management systems for offshore finfish aquaculture.

6 Transfer technology and commercialise hatchery, juvenile production and on-growing capabilities for char, cod, turbot and halibut.

7 Foster R&D in the production of other white fish and related technologies.

8 Build capability in onshore re-circulation technologies, in both sea and fresh water.

2.3.1.5 RTDI Requirements & Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 2.7 Research Requirements & Key Outputs for the Finfish Aquaculture Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Focus on production and marketing of higher value, safe seafood (including organic).	> Market research for organic products and finfish produced by 'environmentally friendly' means > Research opportunities to add functional food properties to organic production	> Increased product penetration in the growing consumer market category for healthy product
2 Develop and refine Codes of Best Practice for farm management and fish health and establish an effective health management regime.	> Integrate monitoring, management and licensing regimes into a seamless process > Evaluate and refine codes of practice/protocols for aquaculture management and monitoring > Develop and refine Single Bay Management/CLAMS and the implementation of integrated single bay-based code of practice for on-farm health management > Contribute to research, development and licensing of appropriate vaccines for key viral diseases and parasites (PD, ISA, sea lice)	> Series of protocols on monitoring and management directly linked to license requirements > Agreed and enforceable health code in place > Optimised fallowing and proactive management > Effective vaccines available for the main disease and parasite threats

Continued

Table 2.7 Research Requirements & Key Outputs for the Finfish Aquaculture Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
3 Improve marine planning and management of aquaculture, in order to optimise standards, maximise production and minimize negative interactions in the coastal zone.	> Develop effective carrying capacity modelling capability to support environmentally sustainable aquaculture	> Inshore/near shore models in active use, contributing to sustainable use of the marine resource for aquaculture production; in line with good coastal zone management practice
4 Further develop and refine environmental monitoring and forecasting capabilities and develop environmental monitoring systems for aquaculture that will provide the basis for a new suite of indicators and incentive based regulation.	> Improve environmental forecast monitoring methodology > Develop management and mitigation measures for harmful phytoplankton and zooplankton (jellyfish) > Assess system for development of an indicator/incentive based management system that will reward operators implementing environmentally sound best management practice, yet optimise production capacity	> Real-time monitoring and management systems for environmental variables > Early warning systems for harmful species > State approved incentive-based monitoring and regulatory system in operation
5 Identify sites and develop technologies/ management systems for offshore finfish aquaculture.	> Develop/transfer technology to assist with cage development and management systems, including ancillary technology needs (cages/feed systems, telemetry and integrated marine engineering/design systems) > Develop 'test-bed' sites for technology evaluation	> Offshore cage technology refined, creating business opportunities for industry > Management systems and technology for operations offshore and in exposed locations
6 Transfer technology and commercialise hatchery, juvenile production and on growing capabilities for char, cod, turbot and halibut.	> Use of R&D and technology transfer to commercialise hatchery, juvenile and on-growing stages of turbot, halibut and char production (f/w + s/w) > Continue the development of perch production (f/w) > Develop appropriate cage-based grow-out technologies for cod > Scale up and commercialise existing shore-based hatchery technology > Develop broodstock programmes for screening native species as suitable aquaculture strains	> Reliable Irish hatchery & grow out technology in a range of marine species giving increased diversification of species production > Cage culture of cod established in existing licensed finfish sites > Commercial cod hatchery and nursery facility, with an increasing production of other marine finfish > Native whitefish strains available for aquaculture
7 Foster R&D in the production of other white fish and related technologies.	> Promote R&D in other white fish and related technologies > Develop the necessary broodstock programmes with view to culture potential	> The beginning of technological capability to farm other whitefish species including selected broodstock strains
8 Build capability in onshore re-circulation technologies, in both sea and fresh water.	> Adapt and develop technology for Irish needs in development of onshore fish farming	> Suitable systems tested/ selected for a variety of finfish species in Irish conditions

RTDI Capacity/Capabilities in Finfish Aquaculture is considered together with Shellfish Aquaculture in Section 2.2.3.

2.3.1.6 Prerequisites for Achieving Finfish Aquaculture Objectives

The following are considered as prerequisites for the successful delivery of the objectives for the finfish aquaculture research programme:

> Building public understanding and support for aquaculture as a sustainable marine sector among consumers, local communities and Government bodies;

> Policy support for integration of management, monitoring, and regulation—a DCMNR forum/facilitator to resolve administrative and licensing issues should be considered;

> Market research and brand development support, based on quality assurance and Irish origin;

> Policy support to deliver on new species development; and

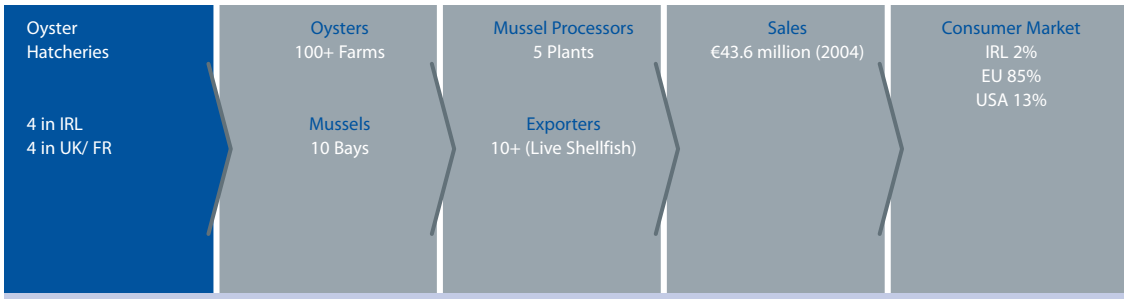
> Suitable international networks of experts/researchers/business interests to underpin and drive R&D and commercialisation in the sector.

2.3.2 Shellfish Aquaculture Research Programme

2.3.2.1 Sector Profile

Mussels, Pacific oysters (*C. gigas*), native oysters (*O. edulis*), clams and scallops are the main shellfish species produced in Ireland. Mussels, which are farmed using both suspended ropes (intensive) and bottom-culture (extensive), account for 80-90%, by volume, of annual shellfish production. Oysters (principally Pacific oysters) account for a further 10-15%. Other species farmed on a smaller scale include abalone and purple sea urchins. Shellfish farming takes place in every coastal county with the exceptions of Wicklow and Dublin. Steady progress made in shellfish production levels over the last few years was consolidated during 2004 because of favourable environmental conditions and continuing strength in market price and demand.

Production in the shellfish sector for 2004 amounted to 43,000 tonnes, of which mussels accounted for almost 37,300 tonnes (90%). The total value of shellfish production in 2004 was €43.6m, with mussels accounting for €27.9m, or 65%, of this. Bottom mussels alone accounted for almost 50% (€21m) of the total value of shellfish production in 2004.



Key Facts: Shellfish Employment (2004) - 443 Full-time, 584 Part-time and 419 Casual = 806 FTEs

Output: Production of bottom mussels has grown from 9,500 in 1999 to over 28,000 tonnes in 2004. Rope mussel output fell due to biotoxins in 1999/2000, recovering to 9,000 tonnes in 2004. *Gigas* oyster production has grown from 1,000 in 1991 to over 5,000 tonnes in 2004. Production of clams and scallops remains small at <300 tonnes in 2004.

Figure 2.6 Key Components of the Irish Shellfish Aquaculture Sector.

2.3.2.2 Key Opportunities and Challenges

The main markets for Irish shellfish production continue to be Europe and the USA. The US market is heavily reliant on imports from Europe—estimated to have amounted to €154 million in 2004. Ireland's trade in seafood with the USA has dramatically increased from around €1 million in 1993, made up of salmon and related products, to over €5 million in 2004. The major contribution in 2004 came from frozen molluscs, which accounted for €3.4 million. These niche markets will remain very important to Irish producers. There are significant opportunities for expansion with retailers in the US; with Irish produce sold to high-end customers. A significant opportunity in the US market for Irish exporters is the development of the organic seafood sector. The consumer market in the US for organic seafood is worth an estimated €415 million[8]. Similarly, the European market for organic seafood will be worth an estimated €332 million in five years (Naturland, Germany).

The European market will continue to offer opportunities for shellfish and vacuum-packed frozen product will remain important. Bottom grown mussels will continue to be in good demand with a focus more on Modified Atmosphere Packaging (MAP) products, which even now account for 40% of the French market. Demand is likely to remain steady for good quality mussels in the main European outlets. However, producers will face increasing challenges from imports of frozen product from countries such as Chile. Demand for good quality Pacific oysters is expected to remain steady and new species such as clams and scallops will maintain niche market opportunities. Production of abalone and urchins are likely to offer high-end opportunities for quality Irish produce and demand will exceed supply for the foreseeable future.

Innovative production and processing technology will continue to pose challenges and, specifically, the 'fresh-frozen' patented technology used by several prominent mussel processors will come off patent in 2007, exposing Irish shellfish processors to increased competition from low-cost mussel producers such as Chile.

The shellfish sector will continue to face the challenge of maintaining product quality and safety, arising from factors such as harmful algal blooms and water quality in shellfish growing areas.

The sector has an opportunity to build on the 'green' image that Irish seafood currently enjoys and through the process of diversification, will provide many opportunities for developers and investors. Although challenging, there are potential opportunities for those willing to engage in new species development (e.g. abalone and urchins). The pace at which development occurs will depend heavily on the support of the third-level research community and state agency R&D support. A rational, concerted strategy between agencies, researchers and industry will assist in providing a sensible way forward towards expanding the shellfish aquaculture sector.

[8] Johnson, H.M. (2003). U.S. Seafood Market in 2020. Global Aquaculture Advocate.

2.3.2.3 2020 Scenario

2020 SCENARIO

By 2020, the sector will have continued its steady growth since the 1990s, with the benefits of science-based management systems, managed seed supply, integrated hatcheries and better farm efficiencies. The industry, researchers and state agencies will have evolved a framework for science-based, rational management of seed supply in the mussel sector. The industry, supported by key agencies, continues to build its reputation for a high standard of food safety. Ireland provides a source of top quality, fresh shellfish, including *Gigas* oysters for European markets, supported by pro-active management of shellfish water quality.

Shellfish will be a diversified sector, with four main species (mussels, oysters, abalone and urchins) and a volume of 96,000 tonnes (increase from 43,000 in 2004), valued at €135m.

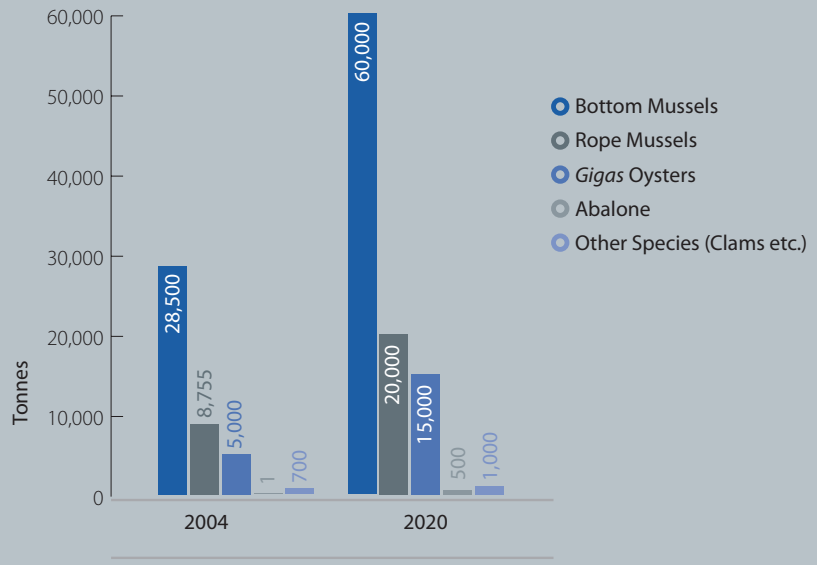


Figure 2.7 2020 Production Scenario for the Shellfish Aquaculture Sector.

2.3.2.4 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Develop and implement a science-based management system for each species and each stage of production.

2 Provide dynamic carrying capacity models for each major shellfish bay and pro-actively facilitate the rationalisation of shellfish production sites.

3 Promote scale of production (including hatcheries) and processing.

4 Strengthen capability and foster international collaboration on shellfish health.

5 Improve efficiencies in production by application of technology.

6 Improve environmental monitoring and food safety capability in support of the industry.

2.3.2.5 RTDI Requirements & Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 2.8 Research Requirements & Key Outputs for the Shellfish Aquaculture Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Develop and implement a science-based management system for each species and each stage of production.	> Carry out applied research on biomass, seed availability and optimisation of production methods (e.g. wild mussel seed) as inputs to a science-based management programme	> Agreed framework, involving industry, science and state agencies, for the management of the resource, based on scientific advice
2 Provide dynamic carrying capacity models for each major shellfish bay and pro-actively facilitate the rationalisation of shellfish production sites.	> Develop dynamic nutrient and/or chlorophyll driven carrying capacity models for key production bays	> Optimisation of sustainable carrying capacity of shellfish production areas maximising shellfish productivity and yields > Rationalisation of production sites in line with best management practice and the scope of legislation
3 Promote scale of production (including hatcheries) and processing.	> Applied research and innovation in the mechanisation and improved efficiency of all shellfish culture systems **Mussels** > Basic research into all stages of life cycle > R&D on juvenile production and handling methodology > Monitoring of potential pathogens and pests (e.g. *Mytilicola*) in shellfish with an emphasis on mussels and the impact of ocean warming on these dynamics ***Gigas* Oyster** > Develop integrated facilities for hatchery, nursery and on-growing of Irish *Gigas* strain > Research into shellfish health management incl. viral diseases and unexplained mortalities (with international collaboration) > Improve genetic stock with selective breeding programme ***Edulis* (Native) Oyster** > Research into the life cycle of Bonamia and the breeding of resistant strains **New Species** > Selective breeding programmes for abalone > Development of indigenous feed supply (seaweed based) for both abalone and urchins > Refinement of re-circulation technology for shore-based cultivation	> Increased mechanisation of processes with associated drop in unit production cost **Mussels** > Improved management of juvenile supply and improved yield > Strengthened protocols for protection of seed supply > Predictive models for spat falls and seed supply ***Gigas* Oyster** > Availability of reliable supply of seed of Irish origin with improved survival > Improved survival of oysters based on a better understanding of shellfish health and environmental parameters > Higher quality Irish oyster products ***Edulis* (Native) Oyster** > Availability of resistant strains in bays that have been affected by *Bonamia*. **New Species** > Commercial strains of abalone with certified growth profile > Commercially available high quality rations for abalone and urchins > Efficient, cost effective shore-based production systems for urchins and abalone

Continued
Table 2.8 Research Requirements & Key Outputs for the Shellfish Aquaculture Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
4 Strengthen capability and foster international collaboration on shellfish health.	> Foster R&D linkages with international experts on shellfish health, including participation in joint international R&D projects on diseases such as *Bonamia* in native oysters, brown ring disease of clams, and Summer Mortality Syndrome (SMS) in *Gigas* oysters	> Increased national capability in shellfish health on foot of successful international collaborative R&D projects
5 Improve efficiencies in production by application of technology.	> Adapt and/or develop continuing technology enhancement to improve production efficiencies > Investigate/adapt new procedures/ technology for moving some production to offshore locations > Identify areas of high productivity offshore to allow for further development	> More cost-effective farm production systems > Increasing tonnage produced from offshore locations
6 Improve environmental monitoring and food safety capability in support of the industry.	> Research into alternatives to bio-assays and development of rapid assays/field tests for biotoxins > Remote monitoring/predictive systems for Harmful Algal Bloom (HAB) occurrences > Interactions between shellfish aquaculture and the environment, with an emphasis on inter-tidal culture/bird interaction	> Improved rapid toxin detection methods leading to increased food safety levels and optimal production/marketing management for industry > National HAB and environmental real-time data system (including pigment and nutrient data) available live to industry > Codes of best practice for shellfish cultivation in sensitive areas

2.3.2.6 Prerequisites for Achieving Shellfish Aquaculture Objectives

The following are considered as prerequisites for the successful delivery of the objectives for the shellfish aquaculture research programme:

> Appropriate consolidation of the sector either by rationalisation and/or the development of co-operative business units;

> State policy support to rationalise production, based on predictive models and data on carrying capacity of shellfish production areas; and

> Development of an Irish shellfish 'brand'.

2.3.3 RTDI Capacity/Capabilities (Finfish & Shellfish)

Aquaculture research draws on a wide range of disciplines including marine sciences (botany, zoology, microbiology and oceanography), engineering, veterinary science and genetics, and is currently being carried out within the third-level sector, state agencies and industry.

Current Research Capacity

Third-level Sector

In the third-level sector, 10 research groups are currently carrying out aquaculture research. Together, these groups comprise approximately 60 researchers in aquaculture research (Table 2.9). Current topics of research within these groups include Harmful Algal Blooms (HABs); biotoxin identification, isolation and analysis; salmonid genetics; new species development (e.g. cod and abalone); and fish and shellfish health and immunology. Other groups carry out research that is applicable, but not directly related to, aquaculture. Much of this is in the area of water quality modelling, marine biology/ecology; ecosystem functioning; and marine biodiversity conservation, and, as such, is of importance within the context of ensuring a sustainable aquaculture industry.

Table 2.9 Overview of Current Aquaculture Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
NUIG UCC UCD LYIT DIT GMIT	5 Large Groups 4 Medium Groups 1 Small Groups	60	> Finfish and shellfish aquaculture, aquaculture systems, new species > Fish & shellfish health and immunology > Salmonid genetics, genetic interactions > HABs > Seaweed culture, fish feed > Biotoxin identification/testing > Molecular biology of salmon > Functional genomic approaches to stock selection > Toxicology, development of *in vitro* tests for biotoxins > Sea lice biology > Biotoxin analysis & isolation > Identification of bivalve larvae > Shellfish spat production > Salmon smoltification > Shellfish histology and pathology > Salmon disease and stress diagnostics

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 140.

In addition, a further 8–10 research groups and individual researchers (approximately 75–100 researchers) have relevant skills/technologies to become involved in aquaculture research, based on the identified future RTDI requirements. Many of these groups carry out research in the fields of technology and biotechnology with obvious potential for the transfer of skills/technology to aquaculture related research.

Aquaculture research facilities available within the third-level sector include re-circulation units, and finfish and shellfish hatchery and on-growing facilities.

State Sector

The Marine Institute is involved in various ongoing nationally and internationally funded aquaculture research projects. Key areas include biotoxin research, disease and parasite control, new species development, and coastal zone management.

Researchers at the National Food Centre (Teagasc) carry out research on food quality and safety, and product and process innovations. This has obvious applications to the future RTDI requirements of the aquaculture sector; specifically, the objective of producing higher value, safe seafood.

Two other state agencies (BIM and Taighde Mara) have aquaculture research capacity/capabilities. Although primarily research funding and development agencies—e.g. providing grants towards the cost of feasibility studies and commercial trials on new species development, technology transfer and opening up of new locations for aquaculture—they are involved in aquaculture research with Irish and international partners.

Industry

Aquaculture research is carried out by a small number of companies (3–5), and focuses on new species development (e.g. turbot, abalone, perch and char), fish health, and cage design. In addition, there is a strong tradition of innovation in the aquaculture sector including technical adaptations of equipment, site selection, and the development of suitable strains of finfish and shellfish for Irish conditions.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 2.10. Also included in Table 2.10 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements (2007–2013), within the existing research community. The competencies required are, in some cases, common to one or more objectives.

Table 2.10 Competencies Required to Meet Future Research & Innovation Requirements for the Aquaculture Sector

Finfish Aquaculture

Objectives 2013	Competencies Required	Assessment
1 Focus on production of higher value, safe seafood (including organic).	> Food technology > Human nutrition > Fish nutrition	S S R
2 Develop and refine Codes of Best Practice for farm management and fish health and establish an effective health management regime.	> Fundamental marine sciences > Marine veterinary science > Vaccine development > Development of management systems/codes of practice	S R R R
3 Improve marine planning and management of aquaculture, in order to optimise standards, maximise production and minimize negative interactions in the coastal zone.	> Fundamental marine sciences > Physical & biological modelling > Development of carrying capacity models	S R G
4 Further develop and refine environmental monitoring and forecasting capabilities and develop environmental monitoring systems for aquaculture that will provide the basis for a new suite of indicators and incentive-based regulation.	> Fundamental marine sciences > Development of management systems > Physical & biological modelling > Statistical analysis of data sets	S R R R
5 Identify sites and develop technologies/management systems for offshore finfish aquaculture.	> Cage design/technology > Advanced technologies (telemetry, robotics) > Site assessment	R R R
6 Transfer technology and commercialise hatchery, juvenile production and on-growing capabilities char, cod, turbot and halibut.	> Production of juveniles > Commercialisation of hatchery technology & juvenile production > Commercialisation of on-growing stages > Development of grow-out technologies > Broodstock programme development	R G G G R
7 Foster R&D in the production of other white fish and related technologies.	> Aquaculture systems > Broodstock programme development	R R
8 Build capability in onshore re-circulation technologies, in both sea and fresh water.	> Re-circulation technology > Aquaculture systems	R R

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

Continued

Table 2.10 Competencies Required to Meet Future Research & Innovation Requirements for the Aquaculture Sector

Shellfish Aquaculture

Objectives 2013	Competencies Required	Assessment
1 Develop and implement a science-based management system for each species and each stage of production.	> Fundamental marine sciences > Resource assessment	S R
2 Provide dynamic carrying capacity models for each major shellfish bay and pro-actively facilitate the rationalisation of shellfish production sites.	> Fundamental marine sciences > Physical & biological modelling > Development of carrying capacity models	S R G
3 Promote scale of production (including hatcheries) and processing in the shellfish sector.	> Fundamental marine sciences > Shellfish juvenile production/handling > Marine veterinary science > Genetics/selective breeding > Development of integrated culture facilities > Development of shellfish diets	S R R R G R
4 Strengthen capability and foster international collaboration on shellfish health.	> Marine veterinary science	R
5 Improve efficiencies in production by application of technology.	> Offshore technology > Site identification/assessment	G R
6 Improve environmental monitoring and food safety capability in support of the industry.	> Biotoxin isolation & analysis > Development of bio-assay alternatives for biotoxins > Remote monitoring and prediction of HABS > Assessment of aquaculture-environment interactions	S R R S

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

There are gaps in the competencies required for all stages of new finfish species culture, the development of carrying capacity models in support of environmentally sustainable aquaculture, and the development of integrated shellfish culture facilities.

Areas that require strengthening include competencies in support of onshore re-circulation technology (finfish and shellfish), offshore technologies, finfish and shellfish health, broodstock programmes/selective breeding, environmental monitoring and prediction, and development of fish and shellfish diets.

Areas with current strengths include biotoxin isolation and analysis, assessment of aquaculture-environment interaction and fundamental marine sciences.

Although individual disciplines and skills may be available, the challenge lies in aligning research capacity and the application of expertise to the specific issues that will address the RTDI requirements and meet the overall objectives set for 2013.

Current Strengths	Require Strengthening	Gaps
> Assessment of aquaculture-environment interactions	> Development of management systems/codes of practice	> Commercialisation of hatchery technology & juvenile production (new finfish)
> Biotoxin isolation & analysis	> Site identification/assessment	> Commercialisation of on-growing stages (new finfish)
> Fundamental marine sciences	> Shellfish resource assessment	> Development of carrying capacity models
> Human nutrition	> Broodstock programme development	> Development of grow-out technologies (new finfish)
> Food technology	> Genetics/selective breeding (shellfish)	> Development of integrated culture facilities (shellfish)
	> Production of juveniles (new finfish)	
	> Shellfish juvenile production/handling	
	> Marine veterinary science	
	> Vaccine development	
	> Development of shellfish diets	
	> Fish nutrition	
	> Aquaculture systems	
	> Development of bio-assays alternatives for biotoxins	
	> Remote monitoring and prediction of HABS	
	> Physical & biological modelling	
	> Advanced technologies (telemetry, robotics)	
	> Cage design/technology	
	> Re-circulation technology	
	> Offshore technology (shellfish)	
	> Statistical analysis	

Figure 2.8 Research Competencies Required to Meet 2013 Objectives for Aquaculture

2.4 Fisheries Resources Research Programme

2.4.1 Introduction

Humans consume around 86 million tonnes of fish per year, almost 15.7 kg per person (versus 7 kg in 1950). Global demand for fish proteins, for human consumption and other uses, continues to rise. Recent predictions suggest that world fish consumption will increase to around 17.1 kg per person in 2020, although consumption rates in the EU are most likely to remain stable at 23.7 kg per person (23.6 kg in 1997). The proportion of total fish production obtained through aquaculture is predicted to increase markedly over the next two decades, reaching 41% by 2020, a growth of around 2% per annum. In contrast, capture fisheries are predicted to grow by less than 0.7% per year, as many stocks have become over-exploited. The EU accounts for about 5% of the global total in capture fisheries, making it the third largest producer after China and Peru. Within the EU, the largest producers are Denmark and Spain.

Global capture fisheries are now confronted with a growing structural imbalance between catch capacities and the biological potential of fisheries resources, resulting in over-exploitation of these resources and alteration of marine ecosystems. As fisheries management and nature conservation in the marine environment pursue common objectives—in particular the safeguarding of marine ecosystems and responsible use of living marine resources as part of sustainable development—they require better co-ordination and coherence.

The EU, under the Common Fisheries Policy (CFP), manages the main commercially exploited fish stocks in the waters around Ireland. The main instruments of the CFP are the annual Total Allowable Catches (TACs), supplemented by various technical measures; including closed areas/seasons, effort regulation and mesh size. Scientific advice underpins the CFP and international stock assessments are carried out in a number of international fora, including the International Council for the Exploration of the Seas (ICES), the International Council for the Conservation of Atlantic Tuna (ICCAT) and the EU Scientific, Technical and Economic Committee for Fisheries (STECF). Irish scientists play a key role in all these international fora, providing the advice that underpins the fisheries management and policy process.

In the 2001 European Commission 'Green Paper' on the future of the Common Fisheries Policy in Europe, stock development trends since the early 1970s were summarised as follows:

1 Almost all roundfish stocks have declined and the current harvest is, in most cases, not sustainable.
2 Several flatfish stocks are harvested at excessively high levels, but some are close to sustainable levels.
3 Pelagic species and species subject to fishing for industrial purposes are in better condition but harvest rates need to be maintained at current levels or reduced, to secure sustainability.
4 Several deep-sea species show signs of over-exploitation and some might have reached critical levels.

The EU fisheries resources need to be rebuilt to allow profitable and sustainable fisheries. Harvest rates and indirect effects of fishing on all species will have to be considered (i.e. an ecosystem approach) in order to ensure the rebuilding process. This rebuilding must be coupled with a rationalization of the overall size of the EU fishing fleet, driven by economic factors and the available fish resources. The many international instruments signed by governments are beginning to impact on the way in which fisheries resources are managed. Regional Advisory Councils (RACs) were established in 2005 and allow input from stakeholders to the EU management process.

Ireland's inshore fisheries sector is of major importance and does not come under the remit of the CFP. In 2005, the national Species Advisory Groups (SAGs) and Local Advisory Committees (LACs) were established. They will produce national and local Management Plans (MPs) for inshore resources and will develop the interactions between stakeholders, government and scientists. These MPs will be underpinned by credible scientific advice and will include the introduction of appropriate measures (e.g. effort and gear limitations) to maintain and, where necessary, rebuild stocks.

2.4.2 Sector Profile

The Irish fishing fleet consists of a little over 1,400 vessels and is divided into three segments; polyvalent, pelagic trawl and purse seine, and beam trawl. There are about 6,000 people working in the fishing fleet and associated activities.

Figure 2.9 Key Components of the Irish Sea Fisheries Sector

In 2004, landings of pelagic species achieved a first sale value of €56m, representing some 29% of the €193m value of national landings (Figure 2.10). Demersal landings were valued at €53m, or 27%, of national landings value. Shellfish, with a first sale value of €84m, accounted for the remaining 44%.

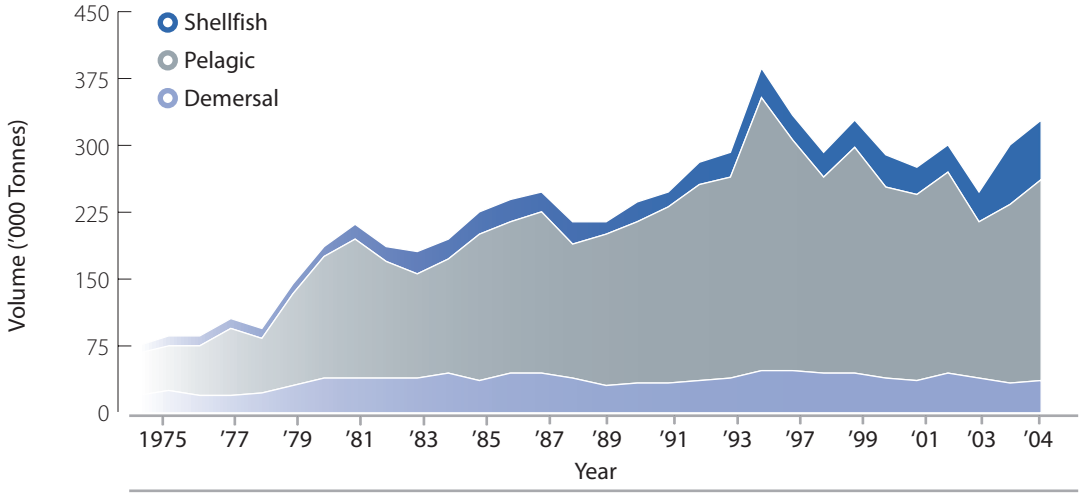


Figure 2.10a Irish Landings Volume (live weight) by Species Category, 1975–2004

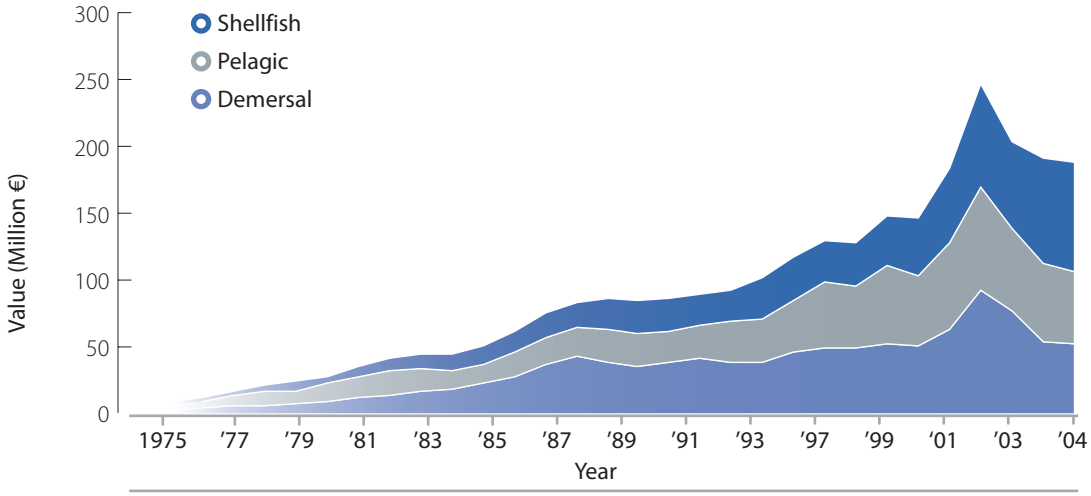


Figure 2.10b Irish First Sale Landings Value by Species Category, 1975–2004

In the waters around Ireland (ICES Sub Areas VI and VII), the total landings of marine fish and shellfish species taken by all nations in 2004 amounted to approximately 1.5 million tonnes with an estimated value of €1.4 billion. It is important to remember that research on the fisheries resource has implications for the entire international stocks and not just the 'Irish quotas'.

The following generic diagram (Figure 2.11) is indicative of the current general state of the marine fisheries resource in the waters around Ireland. The green area represents stocks at a high level with a greater probability of achieving profitable and sustainable fisheries. The amber area represents stocks at a lower level with increased probability of non-sustainable and less profitable fisheries. The red area represents increased risk of stock collapse with non-sustainable and non-profitable fisheries.

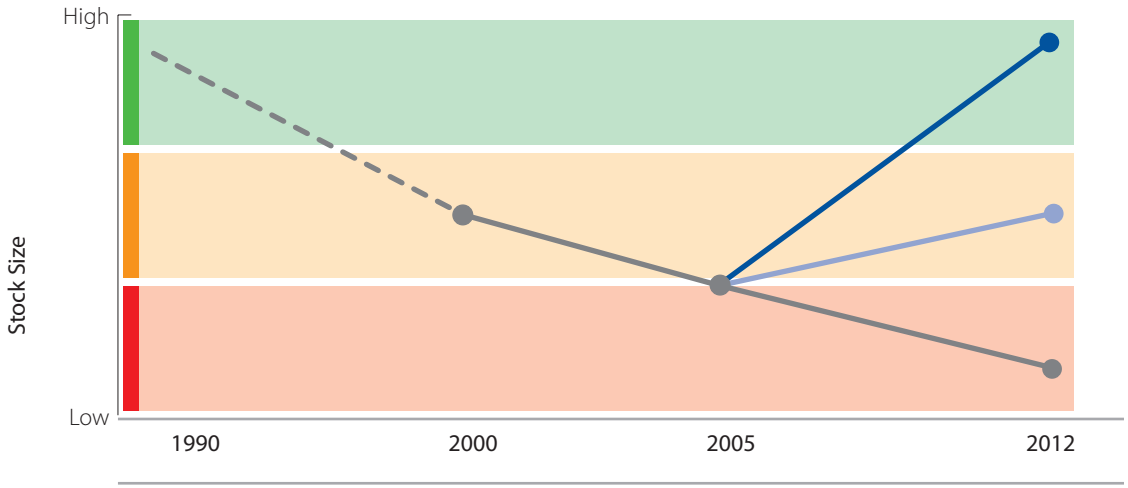


Figure 2.11 Past Trends and Future Scenarios for the General Marine Fisheries Resource

In general, stock size has declined over the period 1990 to 2000 and most fish stocks are either in the amber or red area. From 2000 to 2005, stock size has continued to decline due to high fishing mortality, poor recruitment patterns and climatic factors. Fisheries managers, scientists, industry and society face great challenges over the coming decade in relation to the rebuilding and utilisation of the fisheries resources. If we continue to fish as now, there is no doubt that stocks will continue to decline and move deeper into the red area. If we stop fishing altogether, the fishing industry will disappear and stocks may recover into the green area. However, there is no guarantee of recovery. These two options are a simplistic view but they do indicate the challenges. The answer is complex and lies between these two extremes. It hinges on the incremental adoption of the ecosystem approach to fisheries management over the next 10 years.

It is now accepted that all aspects of the ocean are inter-related and should be treated as an integrated system. In order to achieve a more rational management of resources and thus to improve the quality of the marine ecosystem, Ireland must adopt an integrated and co-ordinated approach to fisheries management and development planning. This will ensure that development is compatible with the need to protect and improve the marine ecosystem for the benefit of society. The ecosystem approach will be a feature of ocean management in the near future. The new fisheries science required will rely on the coming together of communities of marine scientists. These scientists may never have had meaningful dialogue with each other or may never have been exposed to the global, ocean governance

policy requirements that currently drive us towards a holistic ocean management and the ecosystem approach. (See Turrell, 2004)[9]

2.4.3 Key Opportunities and Challenges

Understanding of Resource

The waters around Ireland contain some of the most important spawning and nursery areas for the main commercially exploited fish stocks in the northeast Atlantic. They also contain some of the most important commercial fishing areas in the EU. As EU fisheries management moves towards integrated, holistic, science-based management, developing our knowledge of the life history, dynamics and ecology of fish stocks and the socio-economics and ecosystem role of fisheries resources becomes a key challenge. Ireland must invest in multi-disciplinary research with our international partners in order to meet this challenge.

Management Regimes (CFP)

The main instrument of the CFP is the annual Total Allowable Catch system. This short-term, year-to-year system of annual management decisions has been heavily criticised. The industry only knows what they can catch the following year; they cannot plan. Fisheries management must take a longer-term view. The annual policy decisions of the EU must be guided by longer-term strategies for each ecosystem and fish stock, rather than relying on year-to-year perceptions.

Recovery of Stocks

The EU (DG Fisheries and Maritime Affairs) will shortly release a policy paper that reaffirms the agreements reached in relation to fisheries management at the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002. The Johannesburg Declaration (2002) committed governments to restore fisheries to their maximum sustainable yields by 2015.

Fleet Size

Fleet overcapacity is a global problem in fisheries. We must achieve a balance between fleet capacity and the resource base in order to achieve the sustainable exploitation of fisheries.

Hub

In 2004, the total landings of marine fish and shellfish species taken by all nations in the waters around Ireland (ICES Sub Areas VI and VII) amounted to approximately 1.5 million tonnes, with an estimated value of €1.4 billion. Increased fuel costs will make steaming to fishing grounds a major factor in profitability. Ireland's strategic position in relation to the important EU fishing grounds represents a key opportunity to develop Ireland as a hub. This hub would encourage foreign vessels to land, trans-ship, exchange crews, purchase chandlery and supplies, undertake repairs and seek other services.

Improved Advice to Managers

The EU will move towards integrated ocean management and adopt the ecosystem approach to fisheries management. This new integrated management must be underpinned by sound and credible scientific advice. A key challenge will be to provide clear, reliable and impartial advice on the stocks of economic importance to Ireland.

[9] Turrell (2004). The Policy Basis of the 'Ecosystem Approach'. EuroGOOS Publication, No. 21.

International Scientific Profile

Ireland must continue to raise its fisheries science profile through participation in international research and chairing and participating at key scientific meetings on fisheries research. The Irish research vessels and Marine Institute laboratory infrastructure at Oranmore provide Irish fisheries scientists with a great opportunity to sustain this high and effective international scientific profile. However, a suite of multi-disciplinary marine science projects that allows Irish scientists to participate on the international stage must underpin this profile. Furthermore, there must be support for a new generation of marine scientists through appropriate funding mechanisms, training programmes and career structures.

Climate Change

Scientific data has confirmed the reality of global climate change. Ireland and Europe have become measurably warmer in the past two decades. This warming will have profound impacts on the marine ecosystem, through increases in sea temperature, sea level and storm intensity and changes in ocean currents. This will affect fish stock abundance, distribution and recruitment. Medium- and long-term development strategies over the next decade must take account of predicted climate impacts. Innovative policies and approaches to marine resource management, guided by sound marine science and advice, will be needed.

Data Integration

Ireland collects a large amount of data on the ocean ecosystem from a broad range of disciplines including fisheries, aquaculture, oceanography and environmental science. These data sets are housed as disparate databases in various institutes. Data integration will add value to these data sets and transform them into information and knowledge. This knowledge will be the cornerstone in developing the integrated advice that future ocean management demands.

Stakeholder Involvement

Stakeholder participation is now a feature of the fisheries management process. The establishment of the five Regional Advisory Councils (RACs) throughout the EU represents a key opportunity for scientists to interact with stakeholders. This will allow increased transparency of the scientific advice and the use of fishing industry information in the scientific advisory process.

International Obligations

Global societal concerns regarding use of the earth's natural resources have been translated into marine policy under the UN Convention on the Law of the Sea (UNCLOS), the UN Conference on Environment and Development (UNCED), and the UN Food and Agricultural Organisation (FAO). In the Stockholm Declaration (1972), governments (including Ireland) expressed the wish to work towards integrated, holistic, science-based management, employing decentralised, transparent decision-making involving local communities and users. These original founding concepts have been reaffirmed over the past three decades in numerous declarations and agreements made within UNCLOS, UNCED and FAO. A key challenge will be to provide scientific advice that informs this new ocean management policy.

2.4.4 2020 Scenario

2020 SCENARIO

By 2020, Ireland will have an economically viable fishing industry that contributes to the generation of prosperity in coastal communities, from a well managed and sustainably exploited resource base, informed by clear, reliable and impartial marine science and built on a foundation of strong stakeholder participation.

1 CFP Stocks – Global Sustainability Driven

The focus will be on the amount of global fisheries resource we can exploit without causing ecosystem harm. The fisheries resources will have been rebuilt to allow profitable and sustainable fisheries. The overall size of the EU fishing fleet will be rationalised, driven by economic factors and available resources. Fisheries in Europe will continue to be managed under the CFP; however, an effort-based control system is implemented with multi-annual quotas. Other migratory species (e.g. eels and salmon) that require new management thinking will be brought into the CFP framework. The many international instruments signed by governments will have an increased impact on fisheries management (e.g. the Johannesburg Declaration 2002 and the Convention on Biological Diversity). Regional Advisory Councils (RACs) will be well established and allow input from stakeholders to the EU management process. Greater integration will occur in the delivery of credible scientific advice coupled with effective control and enforcement through pan-European agencies. Where stocks are approaching precautionary limit points, fisheries will be closed until stocks recover. All fish caught will be landed (i.e. no discarding allowed). Any juvenile fish caught will count towards quota. Harvest rates and indirect effects on all species will be considered (i.e. an ecosystem approach) in order to ensure there are no stock collapses. There will be strong international restrictions/mitigation measures to protect seabirds and marine mammals. Closed areas will be established to protect sensitive habitats and others to protect stocks. Exploitation of deep-sea fish stocks will be tightly regulated. Real-time management measures and strong science/stakeholder interactions will be important components of the management process.

2 Ireland's Inshore Stocks – Nationally Driven

Ireland will continue to develop and strengthen the co-management framework for inshore non-TAC stocks introduced in 2005. The national Species Advisory Groups (SAGs) and Local Advisory Committees (LACs) will have produced national and local Management Plans (MPs) for the stocks and will continue to develop the interactions between stakeholders, government and scientists. The MPs will be underpinned by credible scientific advice and include the introduction of appropriate measures (e.g. effort and gear limitations) to maintain and, where necessary, rebuild stocks. Many fisheries will be accredited as being sustainable.

2.4.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013. Many of the key objectives can be met by adding value to, and maximising the use of, the data sets from the Data Collection Regulation (EU Council Regulation 1543/2000). It is essential that these data sets are accurate.

2013 OBJECTIVES

1 Increase transparency of scientific advice through increased stakeholder interaction and participation and use of fishing industry knowledge in the scientific advisory process.

2 Increase our understanding of the life history, ecology, socio-economics, dynamics and ecosystem role of fish stocks.

3 Improve scientific advice for stakeholders—to deliver clear, reliable and impartial advice on the fish stocks of economic importance to Ireland.

4 Contribute to the rebuilding of depleted fish stocks.

5 Build integrated data capacity and knowledge management.

2.4.6 RTDI Requirements & Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 2.11 Research Requirements & Key Outputs for the Fisheries Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Increase transparency of scientific advice through increased stakeholder interaction and participation and use of fishing industry knowledge in the scientific advisory process.	> Develop strategies/procedures to assess and integrate fishing industry knowledge into scientific assessment and advisory process > Develop user-friendly interactive models that can be used to discuss the implications of different management strategies and current scientific advice with Regional Advisory Councils (RACs) and other stakeholders > Continue to improve the transparency of the scientific assessment and advisory process in relation to national and international assessment practices	> Protocols and methodologies for use in assessment and advisory process > Improved effectiveness of regional management within CFP > Improved effectiveness of national management of Inshore stocks (e.g. Species Advisory Groups) > Increased understanding and 'buy in ' by stakeholders to scientific advice > Improved inputs to the international assessment process (e.g. ICES)
2 Increase our understanding of the life history, ecology, socio-economics, dynamics and ecosystem role of fish stocks.	> Map the spatial and temporal distribution of spawning and nursery areas for fish stocks in the waters around Ireland and integrate with seabed survey data and oceanographic data > Expand knowledge of fishing impacts on target stocks and non-target species (through by-catch and discarding), and the impacts on food-web interactions, habitats and biodiversity > Study the biological basis of existing management areas through tagging and genetic research > Explore the relationship between fish stock recruitment (i.e. spawning success), migration, oceanography and climate change	> A better understanding of the fisheries resource base, feeding into and improving scientific advice and facilitating, e.g. 'real-time' management of the resource > Essential fish habitat maps for the waters around Ireland > Information and knowledge to inform new management measures > Scientific data available to support revisions to management areas > Improved understanding and prediction of fish stock size > Marine science has a greater impact on shaping EU and national fisheries policy

Continued

Table 2.11 Research Requirements & Key Outputs for the Fisheries Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
3 Improve scientific advice for stakeholders—to deliver clear, reliable and impartial advice on the fish stocks of economic importance to Ireland.	> Conduct assessments and provide clear, reliable and impartial advice on stocks of economic importance to Ireland, both nationally (e.g. inshore stocks) and internationally (i.e. fish stocks managed under the CFP and migratory species) > Develop and trial practical assessment methods that use both commercial fleet data sets and survey data sets > Model impact of fishing gear changes, closed areas and seasons, and fleet activity (e.g. decommissioning) on stock assessment and advice. > Develop mixed fisheries, harvest control rules and long-term management scenarios, and model their impacts > Develop strategies and procedures to assess and integrate ecosystem knowledge into current management models used to provide scientific advice > Research and analyse the socio-economic factors that influence the day-to-day behaviour of vessel owners/skippers with regard to investment decisions, target species, choice of gear, fishing grounds, level of discarding etc. Ensure that the results feed into scientific assessment and management plans (See Policy Support Measure Section 4.3)	> Robust scientific advice on all stocks exploited by the Irish fleet > A toolbox of available and new stock assessment methods > Improved stock assessment methodology for offshore, migratory and inshore fisheries > Improved suite of short-term and long-term management options available to stakeholders > A suite of new fisheries management frameworks developed that incorporate ecosystem and socio-economic considerations > Research outputs that directly support the work of international organisations (e.g. ICES, NASCO) and national bodies (e.g. National Salmon Commission, inshore SAGs) > Conservation and restoration of habitats to meet international obligations in relation to the conservation of fish stocks and the maintenance of overall biodiversity targets
4 Contribute to the rebuilding of depleted fish stocks.	> Research and develop technology in the area of fishing gear and practices to improve gear selectivity and reduce the impact of gear on ecosystems > Research the potential impact of various management regimes (e.g. artificial habitats and Marine Protected Areas—MPAs) for fish stock recovery	> Science-based proposals to help protect sensitive habitats and rebuild fish stocks > Science-based proposals on recovery plans > Input into Coastal Zone Management (CZM) and measures for the 'Biologically Sensitive Area' off the south-west of Ireland > Effective measures to help rebuild depleted stocks (implemented with stakeholders)
5 Build integrated data capacity and knowledge management. *This objective is broad and has been identified as key to a number of sectors. See Knowledge & Information Management section.*	> Integrate and add value to the disparate marine data sets (fisheries, oceanography, environmental and others) that exist both nationally and internationally	> Integrated knowledge products that provide a broader range of advisory options for fisheries and ocean management

2.4.7 RTDI Capacity/Capabilities

Current Research Capacity

Third-level Sector

Historically, fisheries research within the third-level sector has been relatively low-key. This has changed in recent years with availability of funding under the Marine RTDI programme of the NDP for a range of fisheries related research. This mechanism now funds strategic projects, post-doctoral studies and PhDs in a number of third-level institutes. However, a small number of research teams are carrying out this work. There are five research teams in two universities and one Institute of Technology currently active in fisheries related research. Together, these groups comprise approximately 37 researchers (Table 2.12). In some cases, these researchers are not engaged in full-time fisheries research but also participate in teaching and in other marine research areas. Areas of research amongst these groups include genetic stock identification, fisheries/mammals interactions, modelling and simulation of fish stock dynamics, the impact of discard data on assessment and management, multi-disciplinary approach to stock identification, and management of fisheries resources.

In addition, a further 10–12 research groups and individual researchers (approximately 100 researchers in total) have the skills/technologies to become involved in fisheries research, based on the identified future RTDI requirements and objectives for 2013. These groups presently carry out research in the fields of marine biology, ecology and biodiversity; physical oceanography; and seabed mapping; with obvious contributions to make to the goal of adopting an ecosystem approach to fisheries management. Other research groups outside of the 'marine' community have skills in the areas of information technology and population modelling with potential for the transfer of skills/technology to fisheries related research.

Table 2.12 Overview of Current Fisheries Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
UCC UCD GMIT	2 Large 3 Medium	37	> Management of fisheries resources > Ecology of pelagic fish > Fish population genetics > Fisheries acoustics > Stock assessment > Modelling & simulation of fish stock dynamics > Discard data (impact on assessment & management) > Fisheries/mammals interactions > GIS & fisheries > Shellfish biology, fisheries assessment and management > Early life history cycles and recruitment dynamics > Genetic stock identification

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one marine-related theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 55.

State Sector

The remit of the Marine Institute in relation to fisheries is to 'research, assess and advise' on the sustainable exploitation of the marine fisheries resource. The Institute's Fisheries Science Services (FSS) group carries out this work. FSS conduct an extensive data collection programme including the sampling of landings at ports, sampling for discards, analysis of fleet activity, research surveys on commercial and research vessels, and laboratory based work on age estimation, egg and larval identification, and histological work on fish reproduction. These data are used in the national and international stock assessments that form the basis of the scientific advice on the status of the stocks. This activity contributes significantly to Objectives 1 and 2 for 2013.

The active research programme of the FSS focuses on improving the knowledge base for the main commercial fisheries. Research currently underway includes linking fish spawning with oceanographic features, herring stock identification, cod tagging, and the development of tools for fisheries management. FSS also supports fisheries research programmes carried out in third-level institutes and there are currently several PhD students based with FSS. Altogether, the research activity of FSS amounts to approximately 7–10 FTEs.

The Institute's Aquaculture and Catchment Management Services group (ACMS) covers migratory fish species. The main functions of ACMS are to research, monitor, analyse and advise in the areas of finfish aquaculture, salmonid rearing, wild salmon & eel stock dynamics, and freshwater catchment studies. The team's migratory research currently focuses on long-term monitoring of wild eel and salmonid stocks, providing advice on current stock status and refining the methods used to provide this advice. Currently, the major challenges facing Atlantic salmon and eels lie in the marine environment and ACMS is a key player in NASCO's SALSEA initiative, designed to assess factors affecting marine survival of salmon (www.salmonatsea.com). ACMS is also playing a major role in the compilation of an EU-wide eel conservation programme.

Although primarily a development agency, BIM, through its Fisheries Development Division, funds research and has ongoing involvement in research projects that promote the sustainable development of the sea fisheries sector. Areas of work include the effects of temperature and salinity on shrimp recruitment, assessment of scallop fisheries using acoustic mapping methods, developing alternative gear modifications and fishing tactics to reduce non-target by-catch and improve selectivity, and the use of radar altimetry and other remotely sensed oceanographic parameters in fisheries management.

Industry

The fishing industry participates actively in ongoing research programmes. The Marine Institute and BIM regularly use commercial fishing vessels on research surveys and gear selection/assessment trials.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 2.13. Also included in Table 2.13 is an assessment of whether there are current strengths (S), areas that require strengthening (R) or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 2.13 Competencies Required to Meet Future Research & Innovation Requirements for the Fisheries Resources Sector

Objectives 2013	Competencies Required	Assessment
1 Increase transparency of scientific advice through increased stakeholder interaction and participation and use of fishing industry knowledge in the scientific advisory process.	> Sociological studies	R
	> Multimedia applications	S
	> Information and communications technology	S
2 Increase our understanding of the life history, ecology, socio-economics, dynamics and ecosystem role of fish stocks.	> Seabed habitat mapping	S
	> Data handling, integration and management	G
	> High-end computing	R
	> Fishing gear technology/design and impact assessment	R
	> Biodiversity and ecosystem functioning	S
	> Fish population genetics	S
	> Physical oceanography and modelling	R
	> Fisheries surveys	S
	> Stock/recruitment modelling	R
3 Improve Scientific Advice for Stakeholders —to deliver clear, reliable and impartial advice on the fish stocks of economic importance to Ireland.	> Population modelling and simulation	R
	> Scenario modelling	G
	> Data handling, integration, analysis and management	G
	> Ecological modelling	R
	> Socio-economics	R
4 Contribute to the rebuilding of depleted fish stocks.	> Fishing gear technology/design and impact assessment	R
	> Scenario modelling	G
5 Build integrated data capacity and knowledge management.	> Data handling, integration and management	G

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

The Marine Institute has built up a strong fisheries team over recent years. This team carries out fisheries surveys in support of the goals of fisheries assessment and the provision of management advice. This is clearly a national strength. There is, however, scope for promoting and expanding such skills in the third-level sector. Biodiversity and ecosystem functioning, and habitat mapping are other areas where there are current strengths that need to be applied to the area of fisheries in order to reach the 2013 Objectives. Strengths clearly exist also within the third-level and private sector in areas such as ICT and multimedia applications. However, the challenge lies in identifying and harnessing the appropriate research groups and applying their skills to the specific RTDI requirements.

Understanding fish population ecology and dynamics, population modelling and simulation, ecological modelling capability, and inshore and offshore modelling are all skills that can contribute to the objective of understanding life history and dynamics and adopting an ecosystems approach to fisheries management. All of these are areas that require strengthening. In some cases, e.g. population modelling,

skills may exist outside of the 'marine' research community. Other areas that require strengthening relate to the design and testing of new 'environmentally-friendly' fishing gear and the compilation of socio-economic and sociological data.

Large volumes of data are collected annually in support of fisheries assessment and the provision of management advice. With the evolution towards the ecosystem approach to fisheries management, the integration of other data sets (e.g. environmental data) with fisheries data will be vital. Data handling, integration and management are a major gap and will be vital in achieving a number of the 2013 Objectives.

Current Strengths	Require Strengthening	Gaps
> Fisheries surveys	> Stock/recruitment modelling	> Data handling, integration, analysis and management
> Seabed habitat mapping	> Population modelling and simulation	> Scenario modelling
> Biodiversity and ecosystem functioning	> Ecological modelling	
> Fish population genetics	> Physical oceanography and modelling	
> Information and communications technology	> Fishing gear technology/design and impact assessment	
> Multimedia applications	> Socio-economics	
	> Sociological studies	
	> High-end computing	

Figure 2.12 Research Competencies Required to Meet 2013 Objectives for Fisheries Resources

2.4.8 Prerequisites for Achieving the 2013 Objectives

The following are some of the prerequisites for the successful delivery of the objectives for the fisheries resources research programme:

> Support a new generation of marine scientists by appropriate funding mechanisms;

> Provide training programmes and career structures for marine scientists;

> Make available appropriate laboratory infrastructure and research vessel ship-time;

> Increase international scientific and management co-operation;

> Develop and implement a suite of multi-disciplinary marine science projects;

> Further develop meaningful stakeholder participation;

> Increase public awareness;

> Implement the fisheries component of the new EU Marine Strategy;

> Improve scientific advice through the implementation of the EU Data Collection Regulation; and

> Develop integrated ocean management processes underpinned by a strong scientific base.

2.5 Seaweed Research Programme

2.5.1 Introduction

Seaweed is a sustainable natural resource with industrial potential that is not fully utilised[10]. The industry is broadly based, with the product being supplied to agriculture/horticulture, cosmetics, thalassotheraphy, the biopharma sector (functional foods/nutraceuticals), and for human consumption. At present, about 32,000 tonnes of wet weed is harvested to supply the constituent sub-sectors and there is considerable interest in expanding the potential product range; especially in adding value to extracted components for a wide range of uses.

2.5.2 Sector Profile

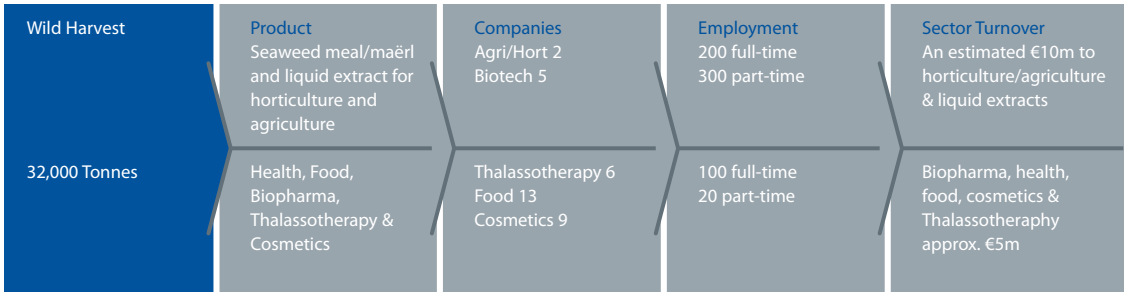


Figure 2.13 Key Components of the Irish Seaweed Sector

2.5.3 Key Opportunities and Challenges

Raw material supply will be a key driver for the sector going forward. It is increasingly difficult to maintain the supply of *Ascophyllum* sp. from hand-harvested weed as the age profile of traditional cutters is increasing and there is less interest in this activity amongst younger generations. It will be challenging for the seaweed sector to maintain sustainable harvests and raw material supply—as has been the case with rotational hand cutting over the last 60 years—using a mixture of hand-harvested weed and the development of more mechanised processes.

There are opportunities to develop new organic product ranges and considerable R&D effort will be required to take advantage of the large potential of seaweed as a raw material base for the development of further cosmetic products, functional food and nutraceuticals. There is considerable interest in the use

[10] National Seaweed Forum (2000). National Seaweed Forum Report. Dublin.

of seaweed in bioremediation processes, e.g. through reducing excess nutrients in discharge waters from sewage treatment plants and onshore aquaculture production units, and treatment of tannery wastes.

There are significant R&D challenges related to the development of aquaculture techniques to produce targeted algae with specialist product potential.

Building on the past success of good management of the wild resource in developing harvesting regimes for kelp, and other species with potential for commercial harvest, will require considerable and sensible progression by regulators and industry. The resulting environment will offer a more attractive opportunity for entrepreneurial investment and significant sector development.

2.5.4 2020 Scenario

2020 SCENARIO

By 2020, the seaweed sector will have evolved from the current hybrid of declining wild harvest and fledgling aquaculture production into a sector with:

> Sustainable, scientifically based harvesting of kelp, *Ascophyllum nodosum*, fucoids and maërl;

> Seaweed from aquaculture production forming the basis for downstream processing of value-added biopharma and nutraceutical products; and

> Regular use of seaweed in biotechnology.

The seaweed production and processing sector will be worth **€30 million** p.a. and play an increasing socio-economic role as part of the mosaic of marine resource utilisation, in the context of marine spatial planning in the coastal zone.

2.5.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Agree, with National Parks & Wildlife Service (NPWS), Department of Communications, Marine & Natural Resources (DCMNR) and research agencies, a regulatory framework and management plan for sustainable harvest of wild seaweed.

2 Develop integrated systems for seaweed aquaculture, including polyculture methodologies and seed hatchery production.

3 Develop a screening programme for potential seaweed products (including nutritional and biochemical analysis) across the range of candidate species.

4 Improve availability and dissemination of applied R&D outputs to potential new industry entrants.

2.5.6 RTDI Requirements/Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 2.14 Research Requirements & Key Outputs for the Seaweed Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Agree, with National Parks & Wildlife Service (NPWS), Department of Communications, Marine & Natural Resources (DCMNR) and research agencies, a regulatory framework and management plan for sustainable harvest of wild seaweed.	> Trials in mechanical harvesting and rotation for the key species > Monitoring and assessment of environmental impacts of mechanical harvesting > Assess constraints, profile other users and integrate seaweed harvesting within Marine Spatial Plans > Assess resource and draft long-term harvest and management plans	> Map of resource availability and identified harvesting sites and cycles > Best practice/regulatory guidelines for mechanical harvesting of seaweed
2 Develop integrated systems for seaweed aquaculture, including polyculture methodologies & seed hatchery production.	> Develop seed hatchery and on-growing techniques, including spore release and rope-seeding technology > Model and assess the production carrying capacity of bays with polyculture > Assess mitigation benefits of integrated culture systems	> Technologies developed for a range of farmed seaweed products > Algae as an integrated tool for polyculture
3 Develop a screening programme for potential seaweed products (including nutritional and biochemical analysis) across the range of candidate species.	> Screen seaweeds to identify and develop a range of value-added products, including biomedical compounds, functional foods, enzymes and bioactive derived compounds > Biochemical analysis of seaweed compounds. > Market segmentation to determine possible applications of seaweed products	> A range of downstream products. > Seaweed compounds identified as an input to biotechnology projects
4 Improve availability and dissemination of applied R&D outputs to potential new industry entrants.	> Develop mechanisms for transfer and licence of seaweed production technology, including commercialisation opportunities resulting from national and international R&D results	> Industry awareness of the R&D results and product potential, including opportunities from overseas technology transfer > Improved commercialisation methodology

2.5.7 RTDI Capacity/Capabilities

Current Research Capacity

Third-level Sector

Active seaweed research within the third-level sector comprises six research groups. Together, these research groups comprise approximately 23 researchers in seaweed research (Table 2.15). By far the most active Institute is NUIG, with three of the six research groups. Current topics of seaweed research within the third-level sector include seaweed culture, seaweed resource assessment, identification and extraction of novel compounds, and the use of seaweed for bioremediation.

A further 10 research groups and a number of individual researchers have the capacity to contribute to the future RTDI requirements and objectives for the development of the seaweed sector. Much of this expertise is within the areas of marine biology, ecology and ecosystem functioning; and marine biodiversity conservation, and, as such, is of importance within the context of developing a sustainable seaweed harvest industry. Expertise also exists in the fields of pigment extraction, harvesting technology and polyculture.

Table 2.15 Overview of Current Seaweed Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
NUIG UCD WIT	4 Medium Groups 2 Small Groups	23	> Seaweed culture > Development of algae as fish feed > Development of edible seaweed products > Bio-purification/remediation uses for seaweed > Kelp resource assessment and management > Mechanical harvesting > Impact assessment > Algal biodiversity > Investigation and identification of novel/potential bioactive compounds of algal origin and their uses > Isolation and structure determination of polysaccharides from seaweeds > Iodine content in seaweed > Use of seaweed extracts for animal nutrition > Seaweed growth optimisation and biochemical studies > Seaweed genetic studies

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 90.

State Sector

Arramara Teo., a commercial state company, is actively involved in the ongoing development of new products for the agriculture, horticulture and cosmetic industries. It is also involved in collaboration with NUI Galway (Biochemistry Dept.) in the evaluation of high-value, novel biotechnological applications for seaweed extracts.

Industry

A range of established and start-up companies are actively involved in the development and innovation of new compounds/extracts from seaweed for human consumption, agriculture/ horticulture, cosmetics, thalassotheraphy and the biopharma sector. Many of these companies receive funding from Údarás na Gaeltachta or Enterprise Ireland.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 2.16. Also included in Table 2.16 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 2.16 Competencies Required to Meet Future Research & Innovation Requirements for the Seaweed Sector

Objectives 2013	Competencies Required	Assessment
1 Agree regulatory framework and management plan for sustainable harvest of wild seaweed with NPWS, DCMNR & research agencies.	> Mechanical harvesting > Monitoring/impact assessment > Integrated marine planning > Resource assessment	G S R S
2 Develop integrated systems for seaweed aquaculture, including polyculture methodologies and seed hatchery production.	> Seaweed culture methodologies > Seaweed hatchery techniques > Polyculture > Re-circulation technology > Carrying capacity models	R G R R G
3 Develop a screening programme for potential seaweed products (including nutritional & biochemical analysis) across the range of candidate species.	> Human nutrition > Biotechnology/biodiscovery > Market research	S R R
4 Improve availability and dissemination of applied R&D outputs to potential new industry entrants.	> Commercialisation/technology transfer	R

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

The competencies required to develop a sustainable seaweed harvesting sector are largely available. However, what is clearly lacking is experience in mechanical harvesting and the formulation and application of management plans for the seaweed resource.

Seaweed culture in Ireland is clearly in its infancy and the research competencies required to develop a successful industry are either lacking or will require strengthening to meet the 2013 Objectives. Similarly, research competencies required to promote integrated polyculture require strengthening. An important aspect of the development of successful polyculture is the development of carrying capacity models. Although there are research strengths in the areas of physical modelling, carrying capacity modelling requires input from a number of disciplines and it is considered a gap area.

The competencies required for the identification/isolation and development of new seaweed-derived products fall within those identified for the wider biotechnology/biodiscovery programme. Clearly, there are research strengths in many of the relevant disciplines that could easily be applied in the investigation and development of interesting biologically-derived compounds from algae.

Finally, research effort is just the first step towards developing a viable seaweed sector. The commercialisation of research outputs is a vital step and is an area that requires strengthening.

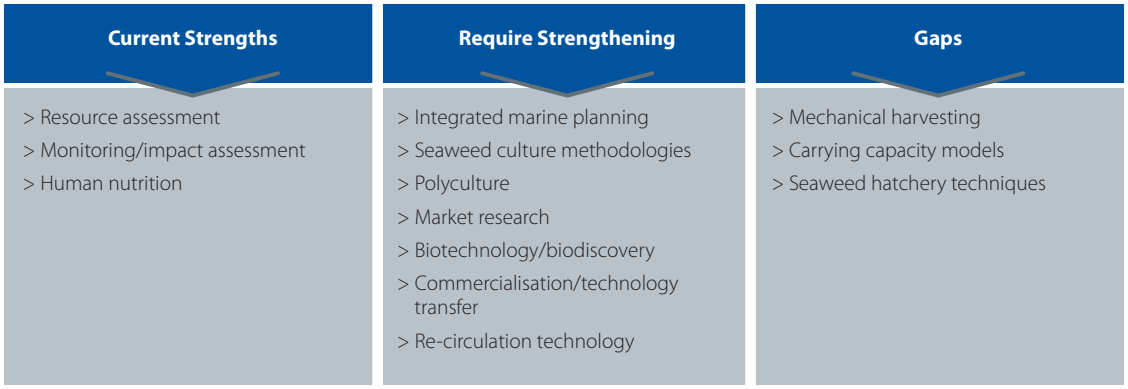


Figure 2.14 Research Competencies Required to Meet 2013 Objectives for Seaweed.

2.5.8 Prerequisites for Achieving Objectives

The following are considered as some of the prerequisites for the successful delivery of the objectives for the seaweed research programme:

> Consensus on a regulatory framework for sustainable harvest of wild seaweed;

> State policy support for technology transfer, diversification and new product development; and

> Entrepreneurs to commercialise the R&D.

2.6 Offshore Oil & Gas Research Programme

2.6.1 Introduction

Oil and gas continue to be a major component of the global energy portfolio, with 35% of global oil production and 27% of global gas production coming from the offshore sector. Although there have been small/moderate sized discoveries of gas in the Porcupine Basin and Celtic Sea, no Irish oil production has been achieved to date and none is forecast in the immediate future.

Ireland's offshore gas resources, however, currently supply about 22% of the economy's primary energy requirement (TPER) including generating about 55% of the electricity required. This places Ireland above the average in EU terms but well behind producer countries such as the Netherlands (47%) and UK (38%). Projections suggest that demand for gas will grow by over 75% in the period 2000–2015. Ireland has been a producer of offshore gas since 1978, with production coming from fields off the south coast at Kinsale, Ballycotton and Seven Heads fields. These resources are progressing towards depletion but new production is scheduled to come on-stream at the Corrib Field off the Mayo coast.

For the immediate future, Ireland is forecast to be a small producer of gas unless there are some major discoveries. This said, in 2003, gas production generated €115 million for Irish firms. Irish companies received €22m of the €350m worth of contracts awarded for the exploration and development of the Corrib Field, and Irish-based and Irish-owned companies supply some niche technologies to a number of key foreign markets.

Methane, occurring as a gas hydrate in deep marine sediments, is considered by many to be a strong candidate for a new energy resource and is currently the target of many international research programmes. Methane hydrate is stable in ocean floor sediments in water depths greater than 300 metres and at low temperature and is thought to be widespread in ocean sediments, including those off the Irish coast. Ireland is believed to have a major, but un-quantified, offshore methane hydrate resource that, given the appropriate extraction and utilisation technology, may be of future significance.

2.6.2 Sector Profile

Oil and gas exploration is a truly international activity dominated by multi-national Exploration and Production (E&P) companies and serviced by internationally trading contractors, often located far from the production fields, offering a full suite of services (including R&D). In the North-east Atlantic, Norway

and the UK are forecast to account for 86% of European E&P expenditure over the next five years, the remainder being mainly divided between Denmark, the Netherlands, Italy and Ireland. Offshore Europe is a mature region and is entering an irreversible long-term decline. However, there may be some significant discoveries, particularly along the under-explored Atlantic margin. Although capital expenditure is already seeing decline, operational expenditure will remain high for many years to come.

2.6.3 Key Opportunities and Challenges

An ability to fully assess and quantify the Irish oil and gas resource, and other non-renewables (e.g. methane hydrates), is fundamental. The data that are now available from the Irish National Seabed Survey (INSS) can contribute significantly towards this, although further surveying and data interpretation are necessary.

Promoting Ireland's deep Atlantic margin as a laboratory and testing ground for deepwater E&P technology will add value to existing marine and petroleum research programmes and create opportunities for SMEs and research institutes to win international business in the E&P sector. As the E&P sector is well supported by the oil majors, industry funded research programmes such as the Petroleum Infrastructure Programme (PIP) should be actively encouraged and should include core E&P research (evaluation, seismic interpretation, etc) and related down-stream (processing, storage, etc) and environmental protection aspects.

The utilisation of methane hydrate as an energy resource poses many technological challenges and opportunities, including:

> Identification and quantification of the methane hydrate resource;

> Extraction, storage (e.g. gas to liquid) and use as an energy source; and

> Potential environmental issues – for example gas hydrates may cause landslides on continental slopes.

The ongoing development of the sector requires a clear government energy policy based on security of supply, competitiveness and environmental protection. This must include a transparent planning process that allows for public engagement on energy issues, a long-term vision on licensing and planning, and the opening of the gas market.

There are a range of Irish companies supplying services into the international exploration and production market; e.g. construction and engineering, power generators, environmental assessment, seismic interpretation and processing, on-line learning, precision engineering, and floating production systems design. These activities are not constrained by low levels of investment in Irish exploration activities. There may be opportunities to substantially increase participation by Irish manufacturing and service companies in the E&P market through strategic alliances and co-operative targeting of niche markets.

2.6.4 2020 Scenario

2020 SCENARIO

Key opportunities and challenges in oil and gas will vary depending on the amount of oil and gas discovered and developed in offshore Ireland over the coming decade.

In the event of several major oil and/or gas finds and with the Atlantic resource at our doorstep, Ireland could find itself actively involved in advanced engineering projects related to deepwater operations, sub-sea processing and floating production systems.

A more likely scenario, however, is that a smaller number of new finds will be made and the focus of research and development will be on efficient exploitation of existing oil/gas resources, the development of marginal fields, secondary market developments (storage, transportation, etc), and the development of niche services for international markets. The industry will operate to a high standard of environmental best practice.

By 2020, Ireland will:

> Be an attractive location for research activities associated with the oil and gas environment. Strong, industry-led research programmes will have been established and interdisciplinary research teams will be focused on the development of niche expertise and participation in internationally funded collaborative programmes.

> Have quantified its methane hydrates resource and be involved in international research programmes and collaborations to examine the opportunities and implications of exploiting this resource.

2.6.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Achieve a high international profile for Ireland as an attractive location for offshore activities by developing a range of information products and services that build on the availability of data from the Irish National Seabed Survey.

2 Implement a strong, industry-led, targeted research programme.

3 Develop strong interdisciplinary research expertise in a range of niche areas.

4 Achieve a high standard of Environmental Best Practice.

5 Identify and quantify the Irish methane hydrates resource, and participate in international research programmes to examine the issues surrounding the exploitation of the resource.

2.6.6 RTDI Requirements/Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 2.17 Research Requirements & Key Outputs for the Offshore Oil and Gas Sector (including gas hydrates) to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Achieve a high international profile for Ireland as an attractive location for offshore activities by developing a range of information products and services that build on the availability of data from the Irish National Seabed Survey.	> The frontier Atlantic margin region, which is currently the focus of most interest in Ireland, was surveyed during Phase 1 of the INSS. Available data can be used to derive products tailored to suit exploration (gas seeps, geohazard and stability assessments, e.g. gas hydrate extraction); field development (regional bathymetry, EIS, sea floor characteristics); refining seismic interpretation (lithology-controlled velocity pullup and pulldown); installation (stability, geotechnics, environmental); and rapid assessment techniques (data mining, classification) > Exploration data released by the Petroleum Affairs Division (DCMNR) will also be vital for many of these areas of research	> Demand led products & services
2 Implement a strong, industry-led, targeted research programme.	> Some of the key RTDI challenges, which could constitute a collaborative third-level/ industry research programme include: • Reservoir modelling • Novel seismic imaging techniques in reservoir management • Wireless telemetry for well monitoring • Fibre optic communications for production control	> Supporting technologies relevant to the stage of development of the Irish offshore oil and gas sector
3 Develop strong interdisciplinary research expertise in a range of niche areas.	> Build up research teams & capabilities in: • Seismic modelling and data processing • Metocean services • Sidescan sonar acquisition and interpretation • Refraction seismic acquisition and interpretation • Gravity and magnetic modelling • Fluid inclusion studies	> Research expertise and capability

continued

Table 2.17 Research Requirements & Key Outputs for the Offshore Oil and Gas Sector (including gas hydrates) to 2013

Objectives 2013	RTDI Requirements	Key Outputs
4 Achieve a high standard of Environmental Best Practice.	> Understand and adapt best practice from the North Sea on relevant techniques and technologies for monitoring oil and gas exploration and production	> Codes of practice for environmental monitoring and management
5 Identify and quantify the Irish methane hydrates resource, and participate in international research programmes to examine the issues surrounding the exploitation of the resource.	> Establish the location and quantity of gas hydrates in Irish waters > Assess environmental impacts of gas hydrate extraction/usage	> Irish methane hydrates resource identified and quantified > Understanding of the environmental impacts of gas hydrate utilisation > Participation in international research programmes aimed at gaining a better understanding of the issues surrounding the utilisation of gas hydrates for energy supply

2.6.7 RTDI Capabilities/Capacity

Current Research Capacity

Third-level Sector

Five research teams in five third-level institutes are currently actively involved in offshore oil and gas research (Table 2.18). The research focus of these groups covers areas such as marine geology and geophysics, seismics, basin analysis and sedimentary geodynamics.

A further 6–8 research groups and a number of individual researchers (approximately 60 researchers in total) have relevant skills and research interests that could be applied to the future oil and gas RTDI requirements. These skills are applicable to such areas as environmental monitoring, marine robotics and advanced instrumentation and control systems.

Table 2.18 Overview of Current Offshore Oil and Gas Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
UCC TCD DIAS UCD NUIG	4 Large 1 Small	22	> Marine geology and geophysics. > Petroleum geology. > Sedimentary geodynamics. > Marine seismics and basin analysis. > Marine electromagnetics. > Rheological and geodynamic. modelling. > CO2 sequestration. > Hydrate and fluid inclusion.

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 55–60.

State Sector

Since the inception of the Irish National Seabed Survey (INSS), the Geological Survey of Ireland (GSI) and the Marine Institute have built up considerable seabed mapping expertise, e.g. in geophysics, hydrography and data management. At present, there are approximately 20 staff (Geological Survey of Ireland, Marine Institute and external contractors) involved in seabed mapping in Zone 2 (50–200m water depth) of the INSS. Many of these personnel have capabilities that can contribute to achieving the 2013 Objectives for the oil and gas sector.

The Petroleum Affairs Division (PAD) of the Department of Communications, Marine and Natural Resources, is responsible for the promotion, regulation and monitoring of oil and gas exploration and development and has expertise in seismic surveying, seismic data interpretation and petroleum geology. The division identifies areas with potential, preparing interpretative reports and releasing basic geological, geophysical and well data to the industry. PAD administers the Petroleum Infrastructure (research) Programme (PIP), which is designed to promote hydrocarbon exploration and development activities by funding research data gathering and land-based research in Irish offshore areas, and provide a forum for co-operation amongst exploration companies and researchers. Close co-operation also exists between the GSI and PAD/PIP on the use of National Seabed Survey data in regional studies.

Industry

The oil and gas industry carries out considerable research and innovation in support of its activities. This research is difficult to quantify given the irregular nature of exploration by licence-holders. In addition, the industry funds third-level research via financial support to the PIP.

Apart from direct industry involvement in research and innovation, a small number of consultancy firms and individual consultants provide services to the oil and gas industry and participate in research, e.g. work carried out under the PIP. This expertise can contribute towards achieving the 2013 Objectives set out above.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 2.19. Also included in Table 2.19 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 2.19 Competencies Required to Meet Future Research & Innovation Requirements for the Oil & Gas Sector

Objectives 2013	Competencies Required	Assessment
1 Achieve a high international profile for Ireland as an attractive location for offshore activities by developing a range of information products and services that build on the availability of data from the Irish National Seabed Survey.	> Hydrography	R
	> Seismic modelling	R
	> Offshore engineering	G
	> Data mining	G
	> Environmental impact assessment	S
	> Geotechnics	R
	> Ocean modelling	R
2 Implement a strong, industry-led, targeted research programme.	> Reservoir modelling	G
	> Novel seismic imaging	R
	> Wireless telemetry	S
	> Fibre optic communications	S
	> Drill-bit design	G
	> Robotics	S
3 Develop strong interdisciplinary research expertise in a range of niche areas.	> Seismic modelling	R
	> Metocean services	R
	> Sidescan sonar acquisition and interpretation	R
	> Refraction seismic acquisition and interpretation	R
	> Gravity and magnetic modelling	R
	> Fluid inclusion studies	R
4 Achieve a high standard of Environmental Best Practice.	> Environmental monitoring	R
	> Development of management systems/codes of practice	R
	> Advanced monitoring technologies (incl. remote monitoring)	G
5 Identify and quantify the Irish methane hydrates resource, and participate in international research programmes to examine the issues surrounding the exploitation of the resource.	> Seismic modelling	R
	> Environmental impact assessment	S

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

Clearly, the majority of competencies required to meet the 2013 Objectives require strengthening or they are considered gap areas in the available research expertise. The research strengths that exist in relation to the 2013 Objectives for the oil and gas sector are not specific to the sector, e.g. they apply equally well for other research programmes. These strengths relate primarily to the delivery of Objective 2 (creating a strong industry-led interdisciplinary research programme in a range of niche areas).

Delivering products and services to the oil and gas sector in support of Objective 1 relies, largely, on maximising available data from Phase 1 of the INSS. The expertise to interpret and utilise these data (e.g. hydrography, ocean modelling and seismic modelling) requires strengthening. The expertise in survey

data acquisition built up over the course of the INSS (in the Marine Institute, GSI and third-level sector) can contribute significantly to Objective 3. However, expertise in seismic and sidescan sonar data acquisition requires strengthening and there are gaps in the available expertise to process, interpret and model such data. These gaps have implications also for the achievement of Objective 5 (identification and quantification of offshore methane hydrate resources).

Finally, the development of the oil and gas sector will require the highest standard of environmental best practice (Objective 4). Although there are current strengths in the generic area of environmental impact assessment, the adaptation of this expertise to the oil and gas sector and expertise in environmental management systems and codes of practice for monitoring/management require strengthening.

Current Strengths	Require Strengthening	Gaps
> Wireless telemetry	> Hydrography	> Reservoir modelling
> Fibre optic communications	> Seismic modelling	> Data mining
> Robotics	> Novel seismic imaging	> Advanced monitoring technologies
> Environmental impact assessment	> Geotechnics	> Offshore engineering
	> Ocean modelling	> Drill-bit design
	> Metocean services	
	> Sidescan sonar acquisition and interpretation	
	> Refraction seismic acquisition and interpretation	
	> Gravity and magnetic modelling	
	> Environmental monitoring	
	> Development of management systems/codes of practice	
	> Fluid inclusion studies	

Figure 2.16 Research Competencies Required to Meet 2013 Objectives for Offshore Oil & Gas (including Gas Hydrates)

2.6.8 Prerequisites for Achieving Objectives

The non-renewable energy sector (oil, gas, methane hydrates, etc) is governed by international markets and energy prices, and is dominated by multinational Exploration and Production companies. It is serviced by internationally trading contractors, sometimes owned by the multinationals, which offer a full suite of services, including R&D, and are invariably located far from the producing fields.

Success in achieving the stated objectives depends largely on the availability of indigenous energy resources and the attractiveness of Ireland to Multinational Corporations (MNCs) as a base from which to carry out R&D. Clearly, Ireland cannot hope to be a leading R&I performer unless there are major future finds, but can aspire to developing niche knowledge-based specialities and capabilities.

2.7 Water-based Tourism and Leisure

Many of the requirements identified by the Marine Tourism and Leisure Foresight Panel in relation to this sector are development related. These requirements have been built upon and incorporated into a stand-alone development Strategy for Marine Tourism and Leisure (2007-2013). The relevant research requirements for this sector are environment related and thus are considered under the Marine Environment Research Programme (Section 4.1). The following section presents a summary of the outputs of the Water-based Tourism and Leisure foresight panel.

2.7.1 Introduction

In 2004, Irish tourism attracted 6.38 million visitors, generated €4 billion in expenditure, and accounted for approximately 130,000 jobs. When earnings from domestic tourism are included, the overall value of the industry increases to €5 billion. The Irish tourism industry is arguably the most important Irish-owned sector for enterprise, national and regional wealth creation, and employment generation.

Ireland's marine and inland waterways and their associated commercial and leisure opportunities are a significant asset to the tourism sector. The asset includes 4,000 miles of coastline with a myriad of harbours, piers, bays, beaches and scenic views; 4,000 lakes; 75 major river catchments; and over 450 miles of navigable inland waterways. These natural assets underpin the tourism product as a whole and in their own right generate some important niche commercial opportunities. Water-based tourism and leisure is an integral element of tourism in Ireland and encompasses a broad range of both active and passive pursuits (Table 2.20).

Table 2.20 Water-based Tourism and Leisure Activities

Active Water-based Pursuits	Passive Water-based Pursuits
Pleasure Boating	Beaches & Coastal Recreation
Sail Training	Visits to Islands
Wind/Board Surfing	Coastal Passenger Boats/Pleasure Cruises
Water Skiing	Inland Passenger Boats/Pleasure Cruises
Scuba Diving	Aquaria
Sea Angling	Maritime Museums/Interpretative Centres
Game Angling	Nature Tourism
Coarse Angling	Marine Mammal Watching
Sea Kayaking	Marine Archaeology
Canoeing	Coastal/Lake Touring Routes
Swimming	Cruise Ships

2.7.2 Sector Profile

Economic Profile

The economic impacts of marine and water-based tourism and leisure in Ireland, based on the value of domestic tourism and leisure, overseas tourism and the associated services sectors, are summarised in Figure 2.17.

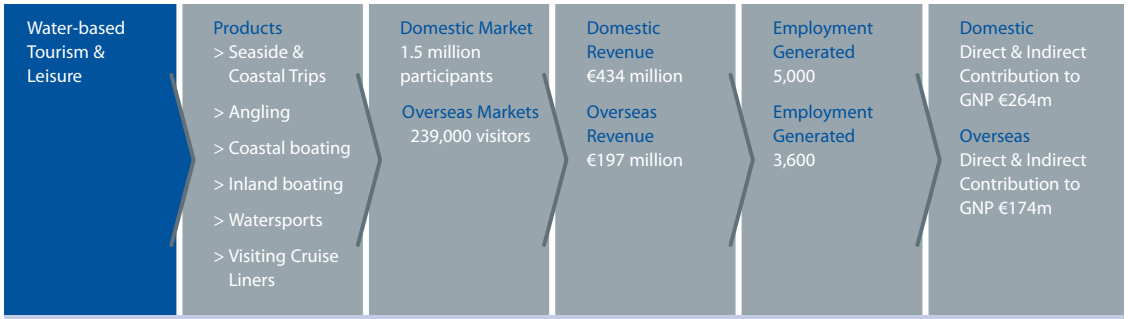


Figure 2.17 Key Components of the Irish Water-based Tourism & Leisure Sector

Economic Performance

The total revenue derived from marine and water-based tourism in Ireland in 2003 is estimated at €631 million.[11]

Table 2.21 Estimated Annual Revenues from Water-based Tourism, by Sub-sector, in 2003

Activity	Domestic Revenue 2003 (€m)[1]	Overseas Revenue 2003 (€m)[2]	Estimated Annual Revenue (€m)[3]
Seaside and Coastal Trips	290	(no overseas figures available)	290
Angling	59	55	114
Boating	50	19	69
Watersports	35	19	54
Cruise Ship Visits	0	66	66
Carrier Receipts	0	38	38
Totals	**€434m**	**€197m**	**€631m**

[1] Domestic Revenue includes: Domestic Overnight Tourism Spend + Domestic spend on day trips + domestic spend on Equipment and other spend.

[2] Overseas Revenue includes: Overseas tourism spend on limited number of activities. Angling Spend per Head is calculated at €633 by Fáilte Ireland. Cruise Liner spend is estimated by the Centre for Policy Studies, University College, Cork. All other overseas figures are based on the CSO Average Estimate of Overseas Visitor Spend per Head of €526.

[3] Estimated Annual Revenue includes: Overseas Tourism Spend + Domestic Overnight Tourism Spend + Domestic spend on day trips + domestic spend on Equipment and other spend.

[11] Marine Institute (2005). Ireland's Ocean Economy and Resources. Marine Foresight Series No. 4.

Domestic Market

Analyses by Fáilte Ireland and the Irish Tourist Industry Confederation show that the general domestic tourism market in Ireland has been growing steadily. The strongest performers generally are the south west, west and south east. The midland and border areas lag a considerable distance behind.

In terms of domestic marine or water-based visitors, the tourism industries of Kerry and Cork lead the way. Opportunities have been developed in almost all marine and water-based activities by accommodation providers and tourism entrepreneurs and their level of professionalism and business acumen sets a standard for others to follow.

The BMW region has performed well in the niche areas of watersports and angling. In particular, Mayo and Galway have developed strong reputations for angling and attract a lot of domestic visitors. Donegal, which has the most significant element of cross-border tourism, has a rich inventory of marine resources and is actively working to organise these and create links with its tourism industry.

Seaside trips are a mainstay of domestic tourism. These include significant levels of overnight stays as well as the traditional day trip to the beach during peak months.

In overall terms, there is strong evidence to show that marine and water-based activities make a very significant contribution to domestic tourism in Ireland. Although marine tourism may not attract a large specialist domestic market, it makes a major contribution to the overall tourism proposition and the experience of a great many domestic tourists.

In 2003, the domestic market for water-based tourism and leisure generated €434 million in revenue. By applying a fairly conservative displacement ratio of 50 per cent, the ESRI estimates that this level of expenditure generated approximately 5,000 full-time jobs. Some 2.5 million overnight trips were undertaken by those engaging in water-based activities with an associated spend of €229 million. €54 million of this was spent in the BMW region. Not surprisingly, seaside/resort trips accounted for a significant portion of this level of activity, with an estimated 1.8 million overnights and a corresponding spend of €186 million. Although the overall number of people participating in water-based activities remained static in the period 1996–2002, there was a slight decline in participation rates, as the population increased by 7% during that period. However, significant increases were recorded for participation in watersports (+39%), sea angling from boats (+24%), inland cruising, boating and sailing (+7%), and trips to beaches and islands (+3%).

Overseas Market

In 2003, it was estimated that some 160,000 overseas visitors spent €93 million on angling, boating/sailing and watersports, with a further expenditure of some €38 million on fares to Irish ferry companies. In terms of performance, there was a decline in the overall numbers of holidaymakers participating in all sub-sectors over the period 1997–2002. However, specialists (those for whom engaging in the activity was the sole purpose of their holiday) increased as a percentage of all visitors who participated in these activities from 49% (1997) to 57% (2002). This increase was particularly pronounced during the same period for angling (from 57% to 72%) and sailing (from 33% to 61%).

Visiting cruise liner activity has shown strong growth from a base of 60 visits in 1994 to 127 in 2003. Examination of the visitor numbers over the period 2000–2003 shows the clear upward trend, with the number of ships increasing from 77 in 2000 to 127 in 2003. The growth performance of passenger visitor numbers is impressive, especially in the context of the recent difficulties experienced in world tourism.[12]

[12] Moloney, R. and O'Sullivan, D. (2004). The Economic Contribution of the Cruise Sector to the Island of Ireland. Centre for Policy Studies, National University College Cork.

In 2003, more than 116,000 cruise ship passengers and crew travelled to Ireland, an increase of over 80% from the figure of 64,000 in 2000. The ports of call included Cork, Dublin, Belfast, Waterford, Derry, Killybegs, and Bangor. This growth has come through both an increase in the number of cruise ship visits and the attraction of vessels with larger passenger capacity.

Associated Services

Table 2.22 summarises the economic impacts of the retail/services sector in 2003, broken down by sub-sector values and regional distribution.

Table 2.22 Water-based Leisure Retail/Services–Turnover, Employment and Exports 2003

Retail/ Services	Turnover (€m)	Dublin (€m)	S&E (€m)	BMW (€m)	Employees	Exports (€m)
Boat & Engine Sales	40.9	23.4	14.6	2.9	131	4.3
Chandlery	22.8	14.3	7.4	1.1	70	1.7
Yacht & Boat Charter	10.1	0	0.8	9.3	168	1.6
Marinas	10.8	5.3	3.1	2.4	83	0.5
Dive Centres	6.4	1.8	3.1	1.5	59	0
Insurance	6.6	3.1	2.0	1.5	25	0
Sail Training	4.6	1.6	2.1	0.9	156	0.2
Aquaria	2.7	0	1.7	1.0	32	0
Sea Angling	1.8	0.02	1.0	0.8	89	0
Publishing	0.3	0.3	0	0	4	0.05
Totals	**€107m**	**€49.9m**	**€35.9m**	**€21.4m**	**817**	**€8.4m**

Source Marine Institute.

Total turnover for the marine leisure retail/services sector amounts to some €107 million, with an export value of €8.4 million. Employment is estimated at 817. Although Dublin-based companies show the highest turnover in retail/services in overall terms, there is a significant regional distribution of earnings from service industries associated with supporting water-based tourism and leisure.

Regional Significance of the Tourism Industry

Generally speaking, Ireland's most outstanding marine and water-based natural resources are located in rural areas. These include scenic coastal walks and drives, beaches, fisheries, inland waterways and dive sites. The annual expenditure on overnight trips for the domestic market for water-based tourism is estimated by the ESRI at €228.7 million.[13] Although three-quarters of associated overnight spend is concentrated in the S&E region, in relative terms overnight spend on watersports and angling is higher in the BMW region. Despite the region's wealth of natural marine and water-based resources, these resources are not particularly well directed at tourism and the organisation of visitor products around them tends to be haphazard.

[13] Marine Institute (2003). A National Survey of Water-based Leisure Activities in Ireland – 2003.

Product Development

The sector demonstrates positive trends in investment in product development. Since 1996, the numbers of marinas has grown from six to 24, with a corresponding increase of 2,500 berths (including the provision of 600 visitor moorings). Investment in watersports and activities has also been positive and some significant international watersport events have benefited from the availability of good quality sporting facilities and infrastructure.

Approximately €25 million in BES (Business Expansion Scheme) funding was invested in the sector during the period 1994–1997. A further €11.6 million was invested under BES from 1998-2003. There has been a considerable reduction in the level of public investment in water-based tourism and leisure since 2000, compared with the preceding period. Measures such as the Marine Tourism Measure (€25.4m) and the Tourist and Recreational Angling Scheme (€30.47m) were suspended under the current National Development Plan (2000–2006). However, €2.6 million has been invested through the Special Interest Tourism Measure 2000 and another significant investment channel is the Tourism Product Development Scheme of the NDP. Other sources of investment funding included the PESCA scheme, the Fisheries Inshore Diversification Programme, LEADER and PEACE funds.

2.7.3 Key Opportunities and Challenge

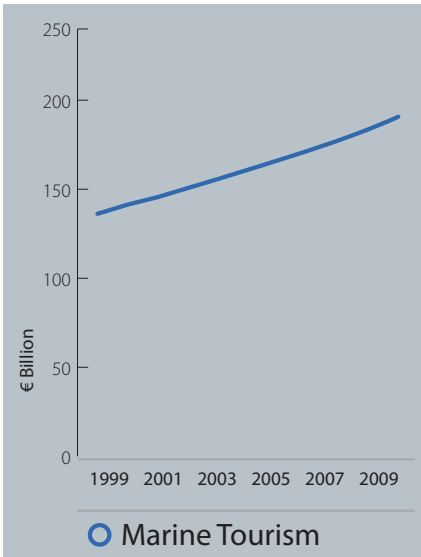
Market Opportunities

International Markets

There are few statistics on the potential of international markets for marine tourists to Ireland. However, figures are available on the international strength and value of relevant marine activities, giving an indication of the potential that could be exploited through marketing and promotional effort.

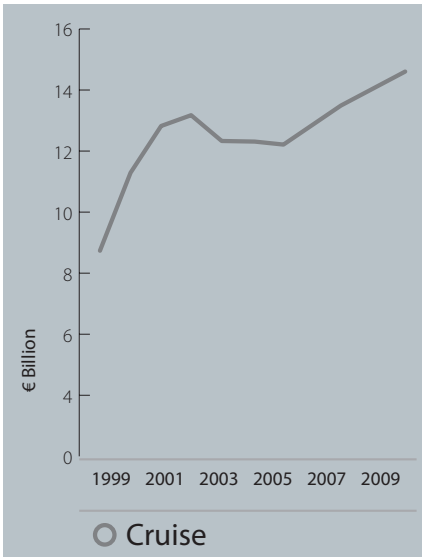
A recent study of the current and future global market for marine industries[14] shows that marine tourism[15] was valued at €168 billion in 2004. This amounts to approximately 11% of total tourism revenues globally (€1,523bn). On top of this, the world cruise market was valued at €12bn in the same period. The study indicated that the global market for angling, coastal and inland leisure boating, and watersports is forecast to enjoy continuing long-term growth to €198 billion in 2009, representing 3.3% annual growth from 2005. Strong growth is also expected in the cruise liner sector, projected to be 4.4% per annum on average during the forecast period, giving a value of €14.8 billion by 2009.

[14] Douglas Westwood, Ltd. (2005). Marine Industries Global Market Analysis. Marine Foresight Series No.1. Marine Institute.
[15] This includes angling, coastal and inland leisure boating, and watersports



Global Market
The graph above indicates that the global market for angling, coastal and inland boating and watersports is forecast to grow to €198 billion in 2009.

European Market
In Western Europe, angling, boating and watersports were valued at €72bn in 2004. Over the five years from 1999 this totalled €328bn. Growth is expected to continue its long-term trend of 3% increase annually, giving a total for the period 2005-2009 of €393bn.



Global Market
The global market value of the cruise sector is €12 billion (2004). The sector has grown from €7.7 billion in 1999, representing 56% growth over the period. Strong growth rates of 4.4% per annum are forecast for the period to 2009.

European Market
The European market, valued at €2.3 billion in 2004, is set to grow steadily, with developments including casual family-orientated 'resort' ships and smaller ships associated with cultural touring.

Niche Markets

It is difficult to make a conventional assessment of market opportunities for marine tourism based on the available data. Nonetheless, the Marine Institute has, for the purposes of informing the forthcoming *Marine Tourism and Leisure Strategy (2007–2013)*, made an assessment of potential niche markets in consultation with key agency and industry stakeholders. This assessment shows that on the basis of conservative estimates for growth in the key niche markets, overseas and domestic markets can grow from a current value of €303 million (including visiting cruise liners but excluding carrier receipts) to €470 million by 2013, an increase of €167 million (Table 2.23).

Table 2.23 Revenue Targets for Key Niche Markets 2013

Product/Service Type	Domestic Value 2003 (€m)	Domestic Value 2013 (€m)	Overseas Value 2003 (€m)	Overseas Value 2013 (€m)
Angling	80 (+45%)	80 (+45%)	80 (+45%)	80 (+45%)
Boating & Sailing	40 (+110%)	40 (+110%)	40 (+110%)	40 (+110%)
Water Sports	35 (+84%)	35 (+84%)	35 (+84%)	35 (+84%)
Cruise Ships	130 (+97%)	130 (+97%)	130 (+97%)	130 (+97%)
Totals	**285 (+85%)**	**285 (+85%)**	**285 (+85%)**	**285 (+85%)**

Source Marine Institute.

Product Development Opportunities

Recent market research conducted by Tourism Ireland highlights the need for the rejuvenation/ revitalisation of the regional tourism product base. This has been endorsed by industry[16], the Tourism Policy Review Group and various research reports. In response, Fáilte Ireland commissioned a National Product Development Audit (2006) to assess tourism product gaps as an input into the preparation of the tourism component of the next National Development Plan (2007-2013).

In parallel, the Marine Institute undertook a detailed product audit of marine tourism and leisure activities.[17] Its conclusions in relation to marine and water product development opportunities and needs include:

> Beach facilities and services for families need to be improved, concentrating on the establishment of public services centres at a limited number of busy resort beaches around the coast, with the aim of developing a national beach management policy. These centres should link with local accommodation and activity providers to offer family adventure holidays.

> The complete absence of visitor marina facilities between south Clare and north Donegal needs to be addressed if Irish sailing is to be fully developed and branded.

> Improved sea angling and tourism vessel access via small piers and harbours could be developed quickly on the east, southeast, west and northwest coasts.

> Coastal walking routes are completely under-developed along the entire coast.

> There is a shortage of sea trips/small tourism vessels on the east and southeast coast and in the area from Clew Bay to Donegal Bay.

> The west and east coasts have insufficient accredited dive centres.

> There may be scope for additional marine themed visitor centres in, for example, Mayo, Donegal and Louth. Every effort should be made to come up with new ideas.

> On the west coast and in the Gaeltacht there may be scope for island visits linked to Irish culture and language.

> There is huge scope for harbour visits linked to local cuisine and seafood right around the coastline.

In overall terms, there are numerous opportunities to build on Ireland's unique location as Europe's most westerly island promoting 'wet & wild' or passive marine leisure activities set in a natural environment with spectacular coastal scenery.

Product Clustering and Key Tourism Attraction Opportunities

There are a number of major opportunities to develop product clusters and *'signature products'* capable of international 'must see/must do' appeal. The development and packaging of product clusters at county/regional/inter-regional level could have wide market appeal, both in overseas target markets and in the domestic market place. Marine tourism signature products would be integrated with wider tourism products and services, creating clusters of attractions and activities. The availability of high-quality accommodation, services and other essential tourism infrastructure, together with good access for overseas visitors, are prerequisites for achieving *'signature'* status.

Five indicative signature/cluster product themes are proposed for the marine tourism sector:

> Escape to the Islands – an island experience linked to culture, language, nature, traditional boats,

[16] How Tourism in Ireland is Changing: Regional Distribution, Report commissioned by the Irish Tourism Industry Confederation, Dublin, June 2005
[17] Marine Institute/Royal Haskoning (2006). Marine Tourism & Leisure Product Assessment.

fishing, and walking;

> Themed cruising routes on the inland waterways – (potentially an all-Ireland initiative), taking in family activities, historic and cultural sites and events, restaurants, and other places of interest;

> Tour the Irish Coast – driving, cycling, walking, themed around visiting small ports and harbours, places of special beauty and noted seascapes, and quality seafood;

> Signature Seaside Resorts – linked to Blue Flag beaches, family activities, watersports and activity centres; and

> Cruise the South West Coast – leisure boating along the South West coast, taking in bays, harbours, islands, marinas, pubs and restaurants, festivals and events.

Challenges

Key challenges have been **identified by stakeholders**, (see Appendix C) as follows:

There is broad agreement among stakeholders that Ireland's marine and water leisure resources have the potential to support major tourism growth up to 2020 and beyond. However, in order for the sector to reach its full potential, there is an identified need to establish a transparent and co-ordinated mechanism for delivering on policy, development and research. This must create the right investment environment and balance the requirement for leadership with the need for a range of agencies and product providers to work together. Partnership at county, regional and national level is viewed as essential to the delivery of a co-ordinated strategy for the development of water-based tourism and leisure.

Clear views were expressed by stakeholders in relation to the need to speed up regulatory reform, promote physical access to the resource and increase investment in public infrastructure. In terms of efficiently enhancing the 'public good' from which the local community and the holidaying and visiting tourists derive, it is felt that specific policies need to be developed and integrated in order to optimise the economic potential of state held assets. A number of business models could be explored depending on the scale of the undertaking, the mix of investment, the form of ownership, the degree of access required and the potential for commercial spin-offs.

A high quality environment is fundamental to the development of the sector. The environment must be protected, while at the same time facilitating a logical development process. Integrated Coastal Zone Management (ICZM), with stakeholder involvement, is required to support the management of the sector and assist Local Authorities in the planning process.

Local Authorities find it difficult to finance and manage development, in the absence of a clear national policy. They see a need for ICZM and highlight the potential for County and City Development Boards to drive marine and water-based tourism in conjunction with investors and relevant government agencies. Local Authority bye-laws should be framed in the context of a full development plan for the sector.

The decision-making process in relation to foreshore development needs to be streamlined so development of essential infrastructure can be undertaken in a consistent and predictable manner in line with national and regional planning guidelines. In a similar vein, beach management by local authorities could be greatly improved in the context of a properly framed national policy.

Physical access to the resource (including coastal walks, fisheries, boats and beaches) can be difficult or dangerous. It is difficult to package water-based activity holidays in the absence of clear and reliable arrangements for use of the resource.

In overall terms, stakeholders are calling for a much more pro-active and professional approach to new product development, capacity building, and branding and promotion of the sector, both to domestic and overseas markets. There is relatively little promotion of water-based activity breaks either to overseas or Irish visitors, particularly for off-peak or shoulder periods.

Finally, issues have arisen around management of the resource; for example, conflict arises around tourism versus local leisure needs for angling, and in some bathing areas there is conflict between activities. The development of resource management guidelines, protocols and codes of best practice would enable effective conflict resolution and establish mechanisms for shared resource usage.

2.7.4 2020 Scenario

2020 VISION

Ireland has capitalised on its impressive range of marine and coastal resources to achieve international recognition as *'Europe's most westerly island'* promoting 'wet and wild' or passive marine leisure activities set in a high quality, natural environment with spectacular coastal scenery. Strategic investment and integrated product development has delivered a high quality, sustainable and well-managed suite of marine tourism and leisure activities, which maximise economic, social and environmental benefits at local level.

2.7.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

Tourism

1 Increase domestic and overseas tourism revenue from niche markets from €303 million to €470 million by focusing on the development of highly attractive *niche products* (sailing, angling, watersports and international cruise) to contribute to increasing the demand for holiday experiences in regional/rural Ireland.

2 Enhance the regional tourism product base to provide new and interesting quality experiences for domestic and overseas tourists through:

> Addressing key *product gaps* identified in the resource audit;

> The development of new *signature products* linked to marine activities and themes; and

> *Clustering and packaging* existing marine tourism activities and attractions at local and regional level to create new tourism products and experiences.

2013 OBJECTIVES

Leisure & Recreation

3 Ensure that marine and coastal resources are fully developed for the well-being of local communities.

4 Achieve safe and responsible use of coastal and marine resources for leisure and recreation.

Environment & Local Development

5 Achieve balanced local/regional development of marine and coastal resources to maximise economic, social and environmental benefits.

6 Promote sustainable development and management of the marine and coastal environment for tourism and leisure use through co-ordinated and integrated planning, development and management.

2.7.6 RTDI Requirements & Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives are presented below. RTDI requirements are defined only for elements of Objectives 1, 2 and 3. Objectives 4 and 5 have no specific research requirements. Research requirements relating to Objective 6 are covered within Objective 4 of the Marine Environment Research Programme (Section 4.1).

Table 2.24 Research Requirements & Key Outputs for the Water-based Tourism & Leisure to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Increase domestic and overseas tourism revenue from niche markets from €303 million to €470 million by focusing on the development of highly attractive niche products (sailing, angling, watersports and international cruise) to contribute to increasing the demand for holiday experiences in regional/rural Ireland.	> Work with relevant agencies to research the potential for niche products based on high-quality specialised activities. Target products include: > Angling based on top-class, well-organised venues and facilities comparable with international competitors in the top-end of the market. > Visiting cruise ships to a number of designated Irish ports capable of providing the requisite services and facilities. > 'Fly-to-Sail' holidays based on themed coastal and inland routes and events. > Specialist centres for diving and surfing based on availability of support services and top-class venues.	> A suite of top-class, regionally dispersed niche products, capable of attracting high-spending overseas visitors
	> Advise on county or regional master plans for management and development of marine & water leisure resources to achieve the identified potential for each product. Where feasible, research and develop product/management benchmarks and/or case studies as a standard for others to follow.	> Best practice standards and benchmarks

continued

Table 2.24 Research Requirements & Key Outputs for the Water-based Tourism & Leisure to 2013

Objectives 2013	RTDI Requirements	Key Outputs
2 Enhance the regional tourism product base to provide new and interesting, quality experiences for domestic and overseas tourists through: > The development of new signature products linked to marine activities and themes; and	> Research the potential for development of key signature products around the marine theme, linked to existing tourism clusters and key tourism attractions. Five indicative themes around which signature initiatives could be developed are identified: 1 Tour the Irish Coast - themed around visiting small ports and harbours, places of special beauty, and quality seafood 2 Cruise the South-West Coast - boating along the South West coast taking in bays, harbours, islands, marinas, pubs and restaurants, festivals and events 3 Themed cruising routes on the inland waterways of Ireland (All Ireland Initiative), taking in family activities, restaurants, historic and cultural sites, events, islands and other places of interest 4 Signature Resort Holidays - linked to Blue Flag beaches, family activities, adventure centres, surfing and other key watersports 5 Escape to the Islands -an island experience linked to language, culture, traditional boats, fishing and walking	> Increase in tourism revenues > Increase in regional tourism > Clear focus and framework for: • Investment in product and infrastructure • Marketing by tourism bodies and product providers
> Clustering and packaging existing marine tourism activities and attractions at local and regional level to create new tourism products and experiences.	> Analysis of existing projects (successes and failures) to determine critical success factors for investment in the sector. Examples might include marinas and sea angling centres, beach services centres, game and coarse angling venues, coastal walking & adventure centres, waterways and shorefront developments	
3 Ensure that marine and coastal resources are fully developed for the well-being of local communities.	> Examine existing case studies to address resource access issues and management problems that have arisen. Examples might include: > Access to fisheries for both local leisure and tourism, in conjunction with Fisheries Boards > Access to coastal walking routes and beaches over private lands (in conjunction with Comhairle na Tuaithe and local authorities) > Zoning of beach activities, including use of personal water craft on Blue Flag beaches (in conjunction with local authorities, An Taisce and the Water Safety Council) > Use of foreshore by local authorities to support marine tourism	> Clear and readily available guidance on access issues to streamline management of the marine and water-based leisure resource by local authorities, relevant statutory bodies and product providers

3.7.7 RTDI Capacity/Capability

Water-based Tourism and Leisure research draws on a wide range of disciplines, including marine sciences, market research, socio-economics, engineering, spatial planning and business research.

Current Research Capacity

Third-level Sector

In the third-level sector, two research groups are currently carrying out water-based tourism and leisure research. Together, these groups comprise approximately five researchers in water-based tourism and leisure research (Table 2.25). A number of research groups (e.g. in DIT and UL) carry out general tourism related research that is directly transferable to the water-based sector. Finally, a number of other research groups within the third-level sector have research interests applicable to the future RTDI requirements for water-based tourism and leisure, e.g. spatial planning, ICZM and environmental assessment.

Table 2.25 Overview of Current Water-based Tourism and Leisure Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
UCC GMIT	2 Small Groups	5	> Tourism policy. > Tourism infrastructure. > Access issues. > Carrying capacity. > Socio-economic impacts. > Sustainable tourism.

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, a research group may focus on more than one theme and are larger than indicated here. The total number of researchers in the groups identified is approximately 30.

State Sector

The Water-based Tourism and Leisure programme of the Marine Institute undertakes, in partnership with a broad range of agencies, R&D projects aimed at catalysing sustainable development of the sector. Examples of these include strategic development frameworks, resource assessments, domestic and international market research, and development of innovative information technology applications. In addition, the Aquaculture and Catchment Management Services of the Institute undertakes research, monitoring and data analysis and provides advice on several angling species, e.g. salmon and sea trout. Fáilte Ireland, the national Tourism Development Authority, plays a key role in support of the tourism industry. Of particular relevance are their market services, which undertake domestic and international market research and analysis to inform marketing strategies and product development. The Central Fisheries Board undertakes and provides services relevant to the sector, in the areas of conservation, protection, development and management.

Industry

In the private sector, a range of management, engineering, economic and environmental consultants offer services (and, in some cases, have carried out applied research) of relevance to the water-based tourism and leisure sector. Activity covers generic areas such as tourism policy, resource management,

spatial planning, engineering issues and resource audits. Specific areas covered include angling, marina development and management, and Integrated Coastal Zone Management.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

The competencies required to achieve the 2013 Objectives in relation to water-based tourism and leisure are primarily business/marketing related. Although competencies exist within the wider context of tourism and leisure and business development, identifying and harnessing these competencies to focus on achieving these Objectives will be a major challenge.

3.7.8 Prerequisites for Achieving Objectives

The following are considered as prerequisites for the successful delivery of the objectives for Water-based Tourism and Leisure:

> Adoption of an agreed strategy for water-based tourism & leisure by government departments, national and regional development agencies, local authorities and stakeholders;

> Area-based partnerships at regional and county level spanning public and private sectors, to deliver strategy on the ground;

> Assurance of funding resources/support to catalyse investment and development;

> Compliance with professional management practices in order to consistently deliver high quality products and services;

> Clarity on ownership/access issues, and management role of relevant statutory bodies, local authorities, government agencies and Government Departments; and

> An Integrated Coastal Zone Management Strategy to balance conservation with development, to agree protocols for sharing use of the marine resource, and deliver on EU Environmental Directives, e.g. Birds Directive, Habitats Directive, WFD and Bathing Water Directive, etc.

3 Discovery Research Measure (2007–2013)

The Discovery Research Measure involves the **development of leading edge, multidisciplinary research programmes in Marine Biotechnology, Marine Technology, Marine Functional Food, Renewable Ocean Energy and Rapid Climate Change**. One of the Measure's objectives is to build new research capacity and capability in areas that offer high growth potential. It is a knowledge generation programme, providing pre-competitive research outputs on which to build new marine-related business opportunities. The Discovery Research Measure will support and stimulate areas of basic and applied sciences to engage in new scientific discovery and technological developments with marine potential. It will bring together knowledge and expertise from non-marine areas and focus it on priority areas of the Irish marine sector. This Measure will add further value to the already significant investments in research infrastructure and human capital that the state made during the life of the last National Development Plan. In doing so, the Measure will build a new understanding of the importance and potential of the marine and generate future research capacity.

The Discovery Measure consists of five major **Research Programmes**:

Introduction

The marine sector in Ireland, as is outlined in this Strategy, faces challenges and opportunities across the whole spectrum of activities that constitute the sector. There is a very broad range of marine-based activities where existing practice will be transformed and others where new activities and commercial opportunities will be created; both by new knowledge and technology, and by major contextual global events such as climate change and energy issues.

The dynamics of the ocean economy are changing rapidly. The application of science and technology to increasing the productivity and success of ocean-related industries affects the ocean economy as a whole and, thereby, the social fabric of coastal communities. Technological innovation is an essential part of business success and leads to improved international competitiveness. This presents significant challenges and opportunities for Ireland to more effectively harness technological innovation in support of its marine economy.

There are two dimensions to the challenge of accelerating and strengthening the technology innovation process in the marine sector in Ireland (see Figure 3.1).

> The first, which is short-term and ongoing, is to develop improved and accelerated mechanisms for technology innovation and transfer into industry, in order to bridge technology gaps and improve competitiveness and growth.

> The second is longer-term and strategic, and concerns the need for Ireland to identify novel emerging technologies with significant industrial potential and to put in place the research and innovation strategies and programmes that are required to enable Irish enterprises to become technology leaders in selected niche marine industry sectors.

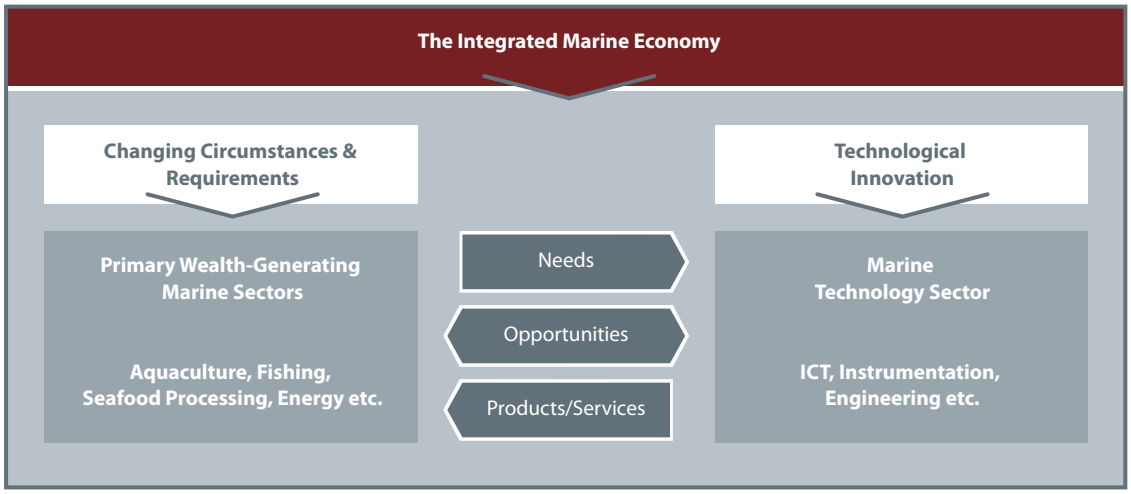


Figure 3.1 The Integrated Marine Economy

The oceans are becoming more important both economically and environmentally. The ongoing extension of national jurisdictions to Exclusive Economic Zones (EEZs), the awareness of the potential impact of scientific and technological advances, and the opportunity to commercialize on these ideas, are giving rise to new marine economic activities. The challenge (and the opportunity) for Ireland in

developing and applying new technology and technological innovation mechanisms in the marine sector is illustrated in Table 3.1.

Table 3.1 Key Technology Areas, Products, Services and Applications

Technology	Sample Marine Product/Services	Sample Uses
Acoustics	Remote sensing, sub-sea communications, sonar (sounders, side-scan, multi-beam), bottom & sub-bottom profilers	Navigation; fishing; fisheries management; oil & gas exploration; development & production; defence; coastal zone management; ocean research
Biotechnology	Sensors, aquaculture species development, aquaculture feedstock development, pharmaceutical, nutraceutical, chemical identification & extraction from marine species, biofouling control, invasive species control, remediation of polluted areas	Aquaculture, environmental management, coastal zone management, drug development, functional foods
Environmental Engineering	Aquaculture systems design, pollution prevention/control systems, risk management	Aquaculture, coastal zone management, environmental management
Information & Communications Technology	Instrumentation/controls signal processing, systems integration, data acquisition, processing, modelling & display, data storage/retrieval, operations simulation, operations management, intelligent systems, automated systems, software applications/ information services	Electronic navigation, seabed/sub-sea survey & mapping, control systems/robotics/AUVs/ROVs, ship/fleet management, ports management, integrated ship/shore management, ocean research, training
Materials & Adhesives	Offshore systems design, aquaculture systems design, instrumentation, biomedical engineering	Offshore oil & gas exploration, development, & production, marine transportation, ocean research
Nanotechnology	Sensors & instrumentation	Fisheries management, aquaculture, ocean research
Ocean & Other Engineering	Offshore systems design/modelling, fish harvesting & processing systems design, aquaculture systems design, wave and tidal energy devices	Offshore oil & gas exploration, development and production; fishing; aquaculture; coastal zone management; renewable energy
Oceanography/Meteorology	Offshore systems design modeling, risk management	Offshore oil & gas exploration, development & production; marine transportation; ocean research
Optics	Sensors, sub-sea observatories, underwater vehicles	Fish processing, marine environmental monitoring
Radar	Remote sensing, hazard & target detection	Navigation, su rveillance, defence, coastal zone management

Source National Research Council Canada (2003). Canadian Marine and Ocean Industry Technology Roadmap – Thinking Beyond our Shorelines.

In Ireland, the convergence of a number of factors provides an opportunity to develop new technological and commercial capabilities in support of the development and growth of the marine sector. These factors are:

> The intensifying convergence across science and engineering disciplines—which provides Ireland with opportunities to foster flexibility, speed and creativity in research and innovation as a counter to our relative lack of scale;

> The recent creation of a number of critical-mass centres of high and/or world-class capability in areas of advanced technology, which are critical inputs or components for new marine technology products and applications, e.g. sensors, communications, biotechnology, software and data products;

> The development of a capacity for strategic long-term planning for the marine sector—as exemplified by the process involved in defining this Strategy; and

> The emergence of a national commitment to, and resources to support, long-term strategic R&I programmes and associated measures.

The Discovery Research Measure proposed in this Strategy seeks to position Ireland to exploit new commercial opportunity, over a 10–15 year timeframe, by systematically developing targeted programmes, building research capacity and co-ordinating existing and emerging multi-disciplinary capabilities in a number of areas; e.g. Biotechnology and Advanced Technologies.

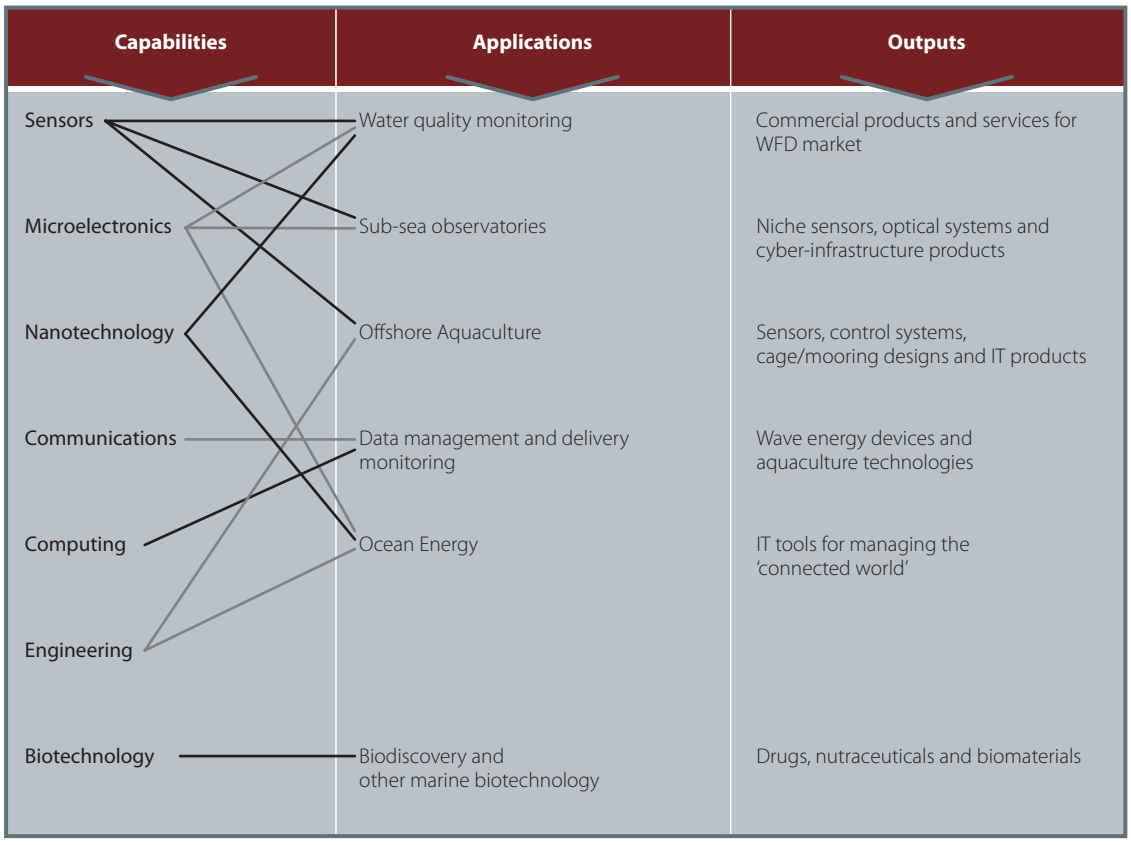


Figure 3.2 The Interactive Web of Capabilities, Applications and Outputs Involved in Implementing the Discovery Research Measure

The necessity for close linkage and co-ordination mechanisms across disciplines and the challenge for Irish efforts to develop capabilities in these technologies is illustrated, in the case of environmental monitoring systems, in the following:

"The next generation of tools and devices—and the systems and infrastructure in which they are embedded—will move towards characterising both the environmental response to manmade perturbations, from the molecular to the global scale, and the feedbacks to and responses from social systems. However, measurements alone are not sufficient. Scientists and engineers need to define what should be measured and how these measurements relate to the understanding of interconnected environmental processes. Further, it will be necessary to develop approaches that integrate data from different observing systems, for instance, by linking land- and ocean-based sensor networks with satellite-derived information. Additionally, the utility of these data can be enhanced by improved visualisation capability. Visualisation is a way to link various kinds of observations and can be used to more efficiently convey results to decision-makers, students, and the public. Finally, the data from observing systems will enable the development of mathematical models."[18]

These principles are reflected in the programme of RTDI activities outlined in the Marine Technology section (Section 3.2).

[18] NSF (2004). Complex Environmental Systems, Pathways to the Future. NSF Advisory Committee for Environmental Research and Education.

3.1 Marine Biodiscovery/ Biotechnology Research Programme

3.1.1 Introduction

Biotechnology is widely expected to be one of the major technologies of the 21st century. It has already had a major impact on healthcare, and is rapidly realising its potential to dramatically affect agriculture and environmental management. Biotechnology is also expected to be a significant force in the marine sector. Biotechnology is based essentially on using nature's own technology for the production of goods and services. The seas are a major source of organisms with novel biological materials and unique metabolic mechanisms. These can be a source of new mechanisms and materials for further biotechnological applications.

In addition to the opportunity to identify new bioactive substances and processes, biotechnology may also have direct impacts on current marine industries by, for example, introducing breeding technologies and veterinary therapeutics to fish farming, or providing technologies to upgrade marine materials or treat problematic waste materials. It will also continue to be a major driver in the development of functional foods and nutraceuticals.

Furthermore, broader advances in interdisciplinary science—such as information technology, nanotechnology and bio-complexity—provide significant new dimensions for the development of marine biotechnology. There is a strategic opportunity for Ireland in the intensifying convergence of science and engineering disciplines.

3.1.2 Current Status

In considering Ireland's strategic position to undertake a marine biotechnology programme, our assets include a relatively strong (and rapidly growing) research base and a high output of trained graduates. There is also a small cohort of marine and biotech companies that could exploit the outcomes of a marine biotechnology programme.

> Ireland has biotech expertise within several S&T institutions that can support a national effort in marine biotechnology. National capability in biotechnology research will increase because of current national investment in expertise (e.g. through SFI) and research facilities (through PRTLI—the HEA Programme for Research in Third-Level Institutions). This national capability can be applied in the marine sector if there is an appropriate programme to highlight the opportunities, provide the specific

supports required, and manage the inter-disciplinary activities that will be needed.

> In addition to the availability of suitable R&D support for a national effort in marine biotech, there is also significant support for the commercialisation of the output of such research. Funding and support for the transfer of research outputs, and for the creation and growth of viable new marine biotech companies, are available from Enterprise Ireland and other agencies.

Within Ireland, no single institution has the capabilities to undertake all elements of a marine biotech programme. In addition to the Marine Institute, there is a range of institutions that clearly have roles to play in such an initiative. The Institute has been proactive in the recent past in identifying the opportunities for Ireland to develop a marine biotechnology programme. This has primarily concentrated on Marine Biodiscovery—the investigation of marine organisms for their potential to provide novel biomaterials for use in the drugs, biopharma and materials industries.

A programme is currently being prepared, for funding approval, which will leverage significant investments that have already been made in marine research infrastructure—Marine Institute facilities and vessels—and, through PRTLI and SFI, in Ireland's biotechnology research infrastructure. This covers a linked chain of activities (see Figure 3.3).

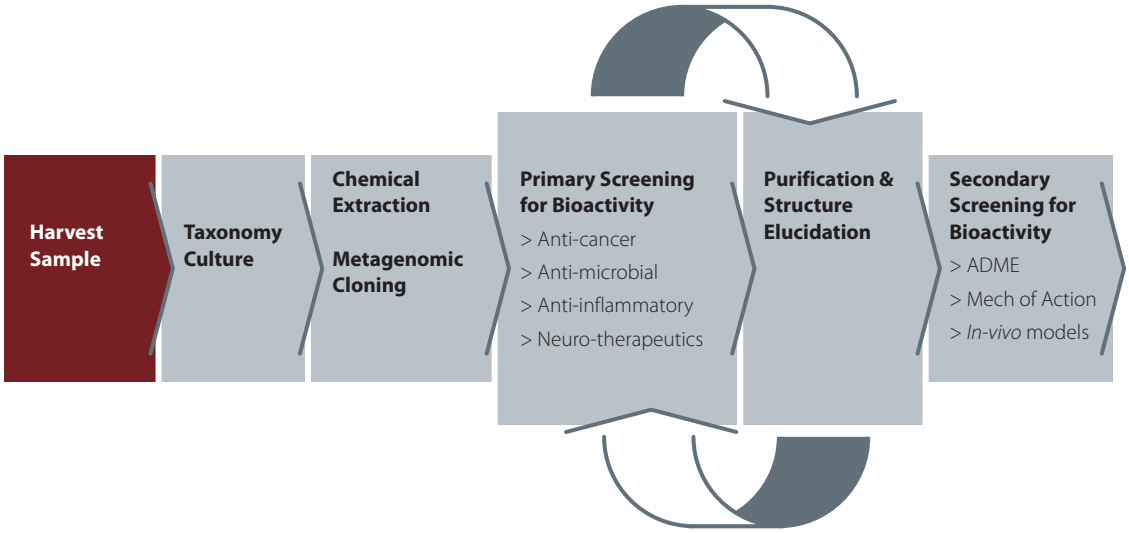


Figure 3.3 Linked Chain of Activities to Create R&D Platform to Underpin Development Opportunities in Biopharma and Medical Device Industries

3.1.3 The Rationale for Marine Biotechnologies

Eighty percent of living organisms are found only in aquatic ecosystems, yet little is known about their biochemical characteristics. The marine biotechnology sector is, therefore, in the early stages of its development, with growing levels of activity in the USA, Japan, the UK and other countries.

A recent report commissioned by the UK's Foresight Marine Panel states that "with a global market valued at $2.4 billion in 2002, and a predicted growth rate exceeding 10% per annum over the next three years, there is no doubting that marine biotechnology represents one of the most exciting emerging technology sectors"[19]. An earlier report described the US marine biotechnology industry and the emerging market for marine biotechnology products and services, and predicted that the global

[19] Biobridge Ltd. (2005). Study into the Prospects for Marine Biotechnology Development in the United Kingdom. (http://www.dti.gov.uk/marine_biotechnology_report.html)

marine biotechnology market would surpass $3.2 billion by 2007, with the non-U.S. segment comprising the bulk of the market.[20]

Marine biotechnology is unlike other areas of biotechnology, in that it is defined in terms of its source material, rather than the market it serves. It is anticipated that it will eventually contribute to nearly every industry sector, from healthcare to bio-remediation and cosmetics to nutraceuticals. The fact that marine biotechnology is at an early stage of development means that much more of the potential global market is open for development by Ireland than is the case in other sectors. Given that Ireland has built up significant R&D capabilities in health-related biotechnology, and that there is a growing pharmaceutical and biopharma industry sector, marine biotechnology, and particularly biodiscovery, could have significant potential to develop the marine knowledge economy. Other areas for which there is strategic rationale for a focused RTDI effort are Genomics and Functional Foods.[21]

1 Biodiscovery—Bioactive Materials

There is an international resurgence of interest in natural products as a source of novel bioactive substances for the development of novel drugs and therapies.

Ireland has developed much of the marine research and biotechnology and medical research infrastructure and capability necessary to establish an integrated chain of marine biodiscovery activities. In addition to creating a significant 'value-added' aspect to a wide range of research investments, the opportunities that will arise from exploring Ireland's marine resources from an entirely different perspective include:

Drugs

> Novel business opportunities for Ireland in the areas of drugs, industrial enzymes and biological probes as discoveries are made and optimised;

> Provision of chemical and protein drugs for disease (targets identified as part of the State's research programmes in biotechnology); and

Biomaterials for the Medical Device and Diagnostics Sectors

> The creation of a strong synergy with the medical device and diagnostics sectors to test compounds isolated as part of the Marine Biodiscovery programme.

2 Functional Foods/Nutraceuticals

Other potential areas in which biotechnology could play a role include foods and feeds. These include the so-called functional foods, which have a health benefit beyond their nutritional content. The Marine Institute, working in association with other stakeholders, is defining a marine functional foods research programme. The vision, objectives and key research outputs for a marine functional foods programme are presented in Section 3.3.

[20] McWilliams (2003). Biomaterials from Marine Sources. (http://www.bccresearch.com/biotech/C184R.html)
[21] CIRCA (2004). A Comparative Study of Marine Biotech RTD and Industrial Development Strategies 2004.

3.1.4 2020 Vision

2020 VISION

By 2020, Ireland will have a leading capability in the utilisation of marine organisms and materials for the production of drugs, advanced biomaterials and nutraceuticals. This will feature:

> A strong collaboration with the growing biopharma sector in Ireland;

> A synergy with the medical device and diagnostics sector; and

> Emergence of a number of successful companies selling highly advanced products and services.

Marine materials will form the basis of high added-value products in the new and emerging industry sectors of functional foods, health treatment, diagnostics and informatics and in environmental monitoring. The nanotechnology sector will use marine materials as fundamental components in novel nano-bio health, environment and energy applications. There will be a strong inter-agency partnership and synergy with other RTDI performers across these areas.

3.1.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Create a strong, interdisciplinary capability in the utilisation of marine biodiversity, using novel high-throughput techniques, for the development of drugs, therapies and biomaterials.

2 Develop core research capabilities and teams in taxonomy, natural products chemistry, chemogenomics and bioinformatics.

3 Develop capabilities for the isolation and identification of novel chemical compounds or proteins for use by the medical device industry (e.g. adhesives and biofilms).

4 Create science-based capability to support development of opportunities in functional foods based on marine raw materials, and develop strong synergies with research and development programmes in the seafood, food and health sectors.

5 Develop opportunities for participation in internationally funded programmes.

3.1.6 RTDI Requirements/Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 3.2 Research Requirements & Key Outputs for Marine Biotechnology/ Biodiscovery to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Create a strong, interdisciplinary capability in the utilisation of marine biodiversity, using novel high-throughput techniques, for the development of drugs, therapies and biomaterials.	> Identification and analysis of biodiversity 'hotspots' in the Irish marine environment > Implementation of a sampling, processing and storage procedure for marine biomaterials > Enhancement of marine taxonomic capabilities > Implementation of high-throughput systems for metagenomics > Establishment of a chain of primary screening activities to identify novel bioactivities for compounds developed > Development of current core capabilities and collaborations to purify and elucidate the structure of novel compounds with bioactivity > Enhancement of core capabilities in synthetic chemistry to design new drugs based on novel compounds with bioactivity > Establishment of a chain of secondary screening tests to examine the safety and toxicology of the novel compounds with bioactivity	> Novel chemical compounds or proteins that will serve as starting structures to design and develop new drugs > New synthetic methodologies for pharmaceutical production > New enzymes identified and isolated for use in chemical synthesis of pharmaceutical products > New enzymes and new methods to improve the manufacturing of drugs
2 Develop core research capabilities and teams in taxonomy, natural products chemistry, chemogenomics and bioinformatics.	> Co-ordinated inter-agency and multi-disciplinary projects, funded over extended time-periods, which will allow for the building of essential scientific capabilities to explore, map and exploit Ireland's marine bio-resources	> Unique marine database linking marine, biological and chemical information within a single system > Closer collaboration between biologists and chemists > New MSc and PhD degrees > Alliances and collaborations with international groups
3 Develop capabilities for the isolation and identification of novel chemical compounds or proteins for use by the medical device industry (e.g. adhesives and biofilms).	> Screening programme to identify other resources for use by medical device and diagnostics industry > Development of expertise in niche areas relevant to compounds that could be used by medical device industry	> Novel chemical compounds or proteins that may have uses in other sectors, e.g. medical devices, diagnostics, food additives, industrial uses > Increased R&D in medical device industry based on new materials > An indigenous diagnostics industry > Enhanced glycobiology research

continued
Table 3.2 Research Requirements & Key Outputs for Marine Biotechnology/ Biodiscovery to 2013

Objectives 2013	RTDI Requirements	Key Outputs
4 Create science-based capability to support development of opportunities in functional foods based on marine raw materials, and develop strong synergies with research and development programmes in the seafood, food and health sectors.	> The Marine Institute, working in association with other stakeholders, is defining a marine functional foods research programme	> Key research outputs for a marine functional foods programme are presented in Section 3.3
5 Develop opportunities for participation in internationally funded programmes.	> Not applicable	

3.1.7 RTDI Capacity/Capabilities

Current Research Capacity

Third-level Sector

In the absence, to date, of targeted marine biotechnology research programmes and funding opportunities, research expertise has developed in an *ad hoc* and opportunistic manner. However, a number of the larger marine research groups have attracted funding for marine biotechnology-related projects, e.g. in UCC and NUIG. A small number of research groups with applied marine biotechnology focus have also emerged recently, e.g. DIT (Marine Biotechnology Research Group) and Letterkenny IT (Centre for Applied Marine Biotechnology). Other groups with research interests beyond purely marine topics also participate in marine biotechnology research, e.g. National Diagnostics Centre, NUIG.

Ten research groups in six third-level institutes are currently actively involved in marine biodiscovery/biotechnology research. Together, these groups comprise approximately 52 researchers with research interests covering a wide range of topics (Table 3.3).

Table 3.3 Overview of Current Marine Biodiscovery/Biotechnology Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
NUIG UCC UCD LYIT DIT WIT	7 Large Groups 2 Medium Groups 1 Small Group	52	> Molecular biology > Functional genomics > Differential gene expression technology > Molecular glycobiotechnology > Biodiscovery > Molecular phylogenetics & population genetics of sponges > Taxonomy, classification and evolution > Extraction of novel compounds from marine algae > Enzyme screening of macroalgae > Nutritional value of seaweeds > Analytical biochemistry > Biosampling and bioanalysis > Novel uses for marine extracts > Endocrinology > Proteomics > Fluorescence methods for detection of algal species > Stress biomarkers in fish > Tissue culture > Applied marine biotechnology (e.g. molecular methods for detection of shellfish larvae - DNA biosensors, molecular beacons) > Multiplex diagnostics > Use of seaweed for bioremediation of metals

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one marine-related theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 100.

In addition to these teams, a large number of research groups throughout the third-level sector have relevant expertise/technologies in the broader field of marine research and/or biotechnology (including environmental biotechnology). A recently completed study of marine biotechnology RTD opportunities in Ireland provides a broad overview of marine biotechnology and general biotechnology research and expertise in Irish Universities and Institutes of Technology[22].

Marine Biodiscovery

The Marine Institute recently conducted an exercise to identify third-level and state sector research expertise in support of a Marine Biodiscovery Programme. Much of the expertise identified in the third-level sector comes from large research groups with no previous links to marine related research (Table 3.4).

[22] CIRCA (2004). A Comparative Study of Marine Biotech RTD and Industrial Development Strategies.

Table 3.4 Third-level Research Expertise in Support of a Marine Biodiscovery Programme

Institute	Research Focus	Institute	Research Focus
NUI Galway	> Taxonomy of marine macro and micro-organisms > Glycobiology > Bioinformatics > Bio-medical devices	DCU	> Primary and secondary screening of compounds > Diagnostics > Fluorescent compounds > Bioinformatics
UCC	> Metagenomics > High-throughput technology > Primary and secondary screening of compounds > Synthetic chemistry (structure identification and elucidation) > Synthesis of bioactive compounds	RCSI	> Mass spectroscopy based sequencing > Bioinformatics > Proteomics > Genomics
TCD	> Primary screening for bioactivity (Cellomics platform) > Secondary screening	NUI Maynooth	> Bioinformatics > Metagenomics > Systematics
UCD	> Synthetic chemistry (structure identification and elucidation) > Sequencing technology > Bioinformatics	Athlone IT	> Biopolymers > Drug discovery

State Sector

The Marine Institute research vessel has sophisticated mapping technology to identify biodiversity hotspots. Dedicated lab facilities for sampling, processing and storage of marine material are being developed at the Marine Institute's new facility in Galway. The Marine Institute has close relationships with the National Cancer Institute (US) and the Australian Institute of Marine Science to help develop the biodiscovery programme.

Teagasc are developing research strength in nutraceuticals and could develop a screening programme as part of the biodiscovery programme.

The Biotechnology Directorate team of Enterprise Ireland (EI Bio) forms a crucial link in the commercialisation chain for biotechnology research; connecting the researchers, entrepreneurs and industry. The team works to commercialise the outputs of publicly funded research for Ireland's food, health and life sciences sectors. EI Bio has five strategic focus areas (Pharma & Healthcare, Food & Agriculture, EU Programmes, Publicly Funded Research, and Bioincubation) each with a multi-disciplinary team skilled in the three core competencies of project/strategic management, relevant technologies, and research commercialisation. This expertise can contribute to achieving the 2013 Objectives in relation to marine biotechnology.

Industry

The extent of R&I capacity within the Irish biotechnology industry is difficult to quantify. Capacity within the marine biotech industry, which is a subset of the larger biotech industry, is even more difficult to quantify. A 2002 report on the Irish biotech sector reported that the 59 biotech companies in Ireland (41 indigenous and 18 multinationals) had approximately 400 R&D staff (out of a total of 2,800)[23].

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 3.5. Also included in Table 3.5 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 3.5 Competencies Required to Meet Future Research & Innovation Requirements Related to Marine Biodiscovery/Biotechnology

Objectives 2013	Competencies Required	Assessment
1 Create a strong interdisciplinary capability in the utilisation of marine biodiversity, using novel high-throughput techniques, for the development of drugs, therapies and biomaterials.	> Sample collection and identification > Marine taxonomy > Extract production > Biological testing (primary assay) > Chemistry (Natural products) > Chemistry (Synthetic/Development) > Biological testing (secondary assay) > *In-vivo* assessment > Metagenomics > Chemogenomics > Proteomics > Gene-chip technology	S R G R G S G G R G R R
2 Develop core research capabilities and teams in taxonomy, natural products chemistry, chemogenomics and bioinformatics.	> Marine taxonomy > Chemistry (Natural products) > Chemogenomics > Bioinformatics	R G G R
3 Develop capabilities for the isolation and identification of novel chemical compounds or proteins for use by the medical device industry (e.g. adhesives and biofilms).	> Chemistry (Natural products) > Extract production > Biomedical engineering > Advanced materials	G G S R
4 Create science-based capability for development of opportunities in functional foods, based on marine raw materials, and develop strong synergies with research and development programmes in the seafood, food and health sectors.	Not applicable	
5 Develop opportunities for participation in internationally funded programmes.	Not applicable	

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

[23] Circa Group (2002). Mapping Study of the All-Island Private Biotechnology Sector. Report submitted to InterTrade Ireland.

Although there is some current strength in the expertise required to implement a marine biodiscovery programme (Objectives 1-3), there are also many gaps (e.g. chemogenomics, natural products chemistry and extract production). Other areas of expertise require further strengthening and broadening (e.g. metagenomics, proteomics and bioinformatics).

In addition, current marine biotechnology research expertise is fragmented and un-focused. However, as with many of the programme areas in this Strategy, marine biotechnology development can draw on a large pool of research expertise in the wider biotechnology area in both the third-level and industry sectors. Focusing this expertise on marine biotechnology related research would assist greatly in meeting the 2013 Objectives.

Current Strengths	Require Strengthening	Gaps
> Sample collection and identification > Chemistry (Synthetic/ Development) > Biomedical engineering	> Marine taxonomy > Biological testing (primary assay) > Metagenomics > Proteomics > Gene-chip technology > Bioinformatics > Advanced materials	> Extract production > Chemistry (Natural products) > *In vivo* assessment > Chemogenomics > Biological testing (secondary assay)

Figure 3.4 Research Competencies Required to Meet 2013 Objectives for Marine Biodiscovery/Biotechnology

3.1.8 Prerequisites for Achieving Objectives

The key prerequisite for delivering the objectives in the marine biotechnology field is the creation and funding of an initial co-ordinated core programme that will:

> Establish new collaborative working relationships between relevant institutions and disciplines;

> Develop new awareness and approaches to the mapping, sampling and utilisation of Ireland's marine biodiversity; and

> Initiate new value-added collaborative chains with indigenous industry and multinationals.

Related requirements include:

> Recruitment into Ireland of high-level experts in a number of areas, including taxonomy, natural products chemistry and chemogenomics;

> Enhancement of sampling infrastructure, e.g. ROV and/or manned submersible, (see Infrastructure Programme), and chemical extraction, processing and repository capability; and

> Implementation of efficient processes for the treatment of Intellectual Property (IP), e.g. by applying the ICSTI Code of Practice[24].

The implementation of a Biodiscovery Programme also requires the further development of the marine research infrastructure that gives rise to the possibility of such a programme in the first place. In particular, adding value to resources identified through mapping Ireland's marine biodiversity necessitates that the tools for this mapping continue to be enhanced, notably the Seabed Survey and infrastructure items such as ROVs.

[24] ICSTI (2004). National Code of Practice for Managing Intellectual Property from Publicly Funded Research. Irish Council for Science, Technology and Innovation.

3.2 Marine Technology Research Programme

3.2.1 Introduction

Technology is a key enabler for the achievement of developmental and management objectives across the entire marine sector. It is also a sector in its own right, capable of generating high-value commercial products and services. To date, Ireland has largely been an importer of marine technologies (structures, equipment and instrumentation). This arises both from the historical under-development of the marine sector, including the traditional associated engineering industries, and from the absence of a high technology defence industry. The potential now exists to create a new, knowledge-intensive industry sector competing in the growing international market.

3.2.2 Sector Profile

The Irish marine technology sub-sector comprises approximately 50 companies with a combined turnover of €69m, employing nearly 500 people.

It is a very diverse sub-sector and most companies are small-to medium-sized enterprises. Despite its relatively small size, there are significant opportunities for growth in marine technology, particularly in niche technology areas where Ireland has, or can build, a strong international reputation.

3.2.3 Key Opportunities and Challenges

Market Opportunities

There is growing technology content in all marine sectors. Internationally, the Marine Technology sector, is characterised by many high-tech sub-sectors including software, underwater connectors, telemetry and communications and control systems. It is within these that the main opportunities for Irish SMEs exist. The market for marine technology products will continue to grow as development and management activity in the oceans increases. It will be characterised by increasingly sophisticated solutions involving the synthesis of a wide range of advanced technologies. The UK Greenwich Report[25] estimated that the marine information sector would grow from €3bn to €7bn by 2020, with the largest growth areas expected to be in monitoring, forecasting and information systems. This will entail the development of new techniques in observation and data analysis and management.

[25] Marine Foresight Task Force (1999). The Greenwich Project - A Marine Information Strategy for the United Kingdom.

Some of these activities, and the technologies to which they give rise and will employ, are outlined in Table 3.6.

Table 3.6 Advance Technologies Supporting Marine Activities

Activities	Technologies
Continuous monitoring of oceanic and atmospheric conditions	Networks of land-based, sea-based and satellite observatories
Measuring and monitoring ocean currents	3D and 4D models and computer simulations
Monitoring the dynamics of deep-water masses	Autonomous deep drifters and seabed observatories
Seafloor mapping and surveying	Multi-beam and other high performance sub-bottom profilers, ultrasound spectroscopy and deep-sea observatories
Expansion of ocean-drilling capabilities	Riser technology and down-hole logging tools
Marine environmental monitoring	Autonomous data acquisition systems incorporating novel, energy supply and bi-directional data transfer over long distances
Nutrient and pollution measurement, particularly biological and chemical parameters	Sensors incorporating innovations in nanotechnology, medicine and molecular biotechnology

Environmental Measurement and Monitoring

Increasing concerns for environmental quality and the use of satellite earth observation and other remote sensing technologies are opening up new opportunities in the area of smart sensors and dispersed observation systems. These will be linked to central computers with enhanced visualisation capabilities, to assist management and control decisions. There is a widely shared international vision, for 2015–2020, of globally connected systems for environmental monitoring. This is particularly applicable in freshwater and marine monitoring.

The application of remote sensing and information technologies for environmental measurement and monitoring represents an opportunity for Ireland to capitalise on the rapid evolution of technology in this area, and on the advanced capabilities developed in leading national technology research centres. These applications include aerial and *in-situ* sea surface, water column and seabed observatories for coastal zone and marine resource management in the context of the EU Global Monitoring for Environment & Security (GMES) Initiative and the EU Water Framework Directive. Technologies being developed globally to support these applications are illustrated in Figure 3.5.

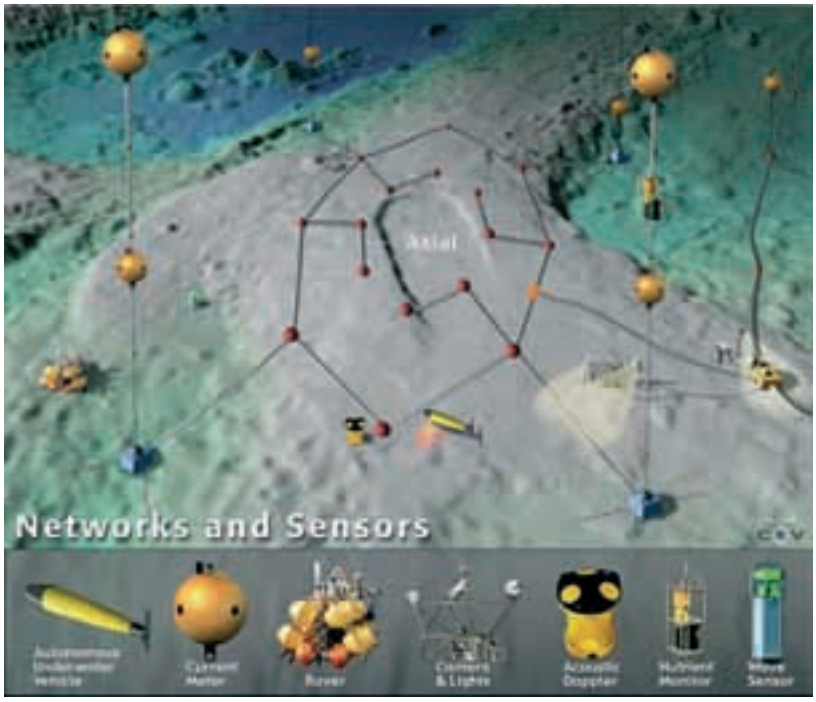


Figure 3.5 Environmental Sensor Networks (Monterey Bay Aquarium Research Institute)

Within this context, there is an accelerating development of extended observing systems involving co-ordination of new sensor technology with environmental cyber-infrastructure. Environmental cyber-infrastructure involves managing and enabling access to large databases and data arrays over extended periods. Together with the development of new, sophisticated models and advanced data assimilation techniques, these technologies will lead to powerful methods for understanding environmental dynamics and predicting spatial and temporal changes in environmental processes. Cyber-infrastructure also addresses the effective relaying of information in an appropriate form to various stakeholder groups, e.g. specialist researchers, agency engineers and scientists, public service providers, government committees and the public.

Offshore Aquaculture

Over the past 15–20 years, commercial aquaculture farms have been establishing in increasingly dynamic environments. Operators have been utilising improving technologies and methodologies, based almost entirely on the use of floating cages. Novel or alternative technologies are also being developed and there is a trend towards the use of submerged systems, particularly in open ocean situations. This technology will continue to develop. For example, a recent policy statement on aquaculture from the European Commission[26] states: *"Fish cages should be moved further from the coast, and more research and development of offshore cage technology must be promoted to this end. Experience from outside the aquaculture sector, e.g. with oil platforms, may well feed into the aquaculture equipment sector, allowing for savings in the development costs of technologies."* The continuing development of these systems will require the development, adaptation and application of a range of technological innovations in fields such as advanced materials for structural design; and sensors, robotics and telemetry for feeding, biomass and health monitoring.

[26] European Commission (2002). Communication from the Commission to the Council and the European Parliament - A Strategy for the Sustainable Development of European Aquaculture. COM/2002/0511 Final.

Ocean Energy

The rapid acceleration of international efforts to commercialise R&D in renewable ocean energy technologies provides opportunities for Ireland. These are considered in Section 3.4. The deployment and operation of large wave and tidal energy arrays will entail the use of a wide range of technologies for environmental monitoring and prediction, continuous monitoring of moorings and structural integrity, and real-time communications and control systems.

Challenges

The major challenges facing the marine technology sector in Ireland are:

> The lack of 'drivers' for technology development that exist in other countries, e.g. defence industry in Norway, the UK and the US;

> The lack of a large home market;

> No tradition of an 'Irish' brand in this sector, or of Ireland as a place where high quality RTDI in the marine sector takes place;

> Attracting 'flag ship' multinationals with strong potential marine tech focus to establish operations in Ireland;

> A general lack of understanding and appreciation of the potential impact of disruptive technologies; and

> The need to promote understanding of enabling technologies, e.g. Grid computing.

In essence, the challenges in realising opportunities and achieving objectives in this sector are also those that characterise the challenge for Ireland in creating a strong knowledge economy. It is, generally, not feasible for Ireland to compete in terms of scale with the large developed economies. Japan, the USA and other European countries are investing heavily in both the marine biotechnology and advanced technology fields. China and the larger emerging Asian economies are also investing. Ireland must compensate for the 'scale' factor by achieving a high degree of co-operation, agility and innovative creativity in implementing these programmes. These issues are addressed in the main Strategy document (Sea Change: A Marine Knowledge, Research and Innovation Strategy for Ireland 2007-2013).

3.2.4 2020 Vision

2020 VISION

By 2020, the marine technology sector will be a vibrant knowledge-based sector featuring:

> A globally-aware industry, with 75% of output exported;

> Annual turnover of €500m (up from €69m in 2003);

> Strong R&D infrastructure (third-level research centres with facilities and expertise relevant to the marine research priorities); and

> Strong linkages and synergies with companies in related and generic technology sectors; including communications, materials and process technology, and collaborations with high technology MNCs.

The sector will have achieved excellence in the development, manufacture and commercialisation of niche technology products and services in the areas of environmental monitoring, offshore aquaculture, ocean energy and seafood processing (Figure 3.6). It will have a strong focus on the application of information and communication technologies to the marine environment. Technology developments will support marine resource development through the creation of an industry leadership capability in intelligent systems for marine monitoring and management.

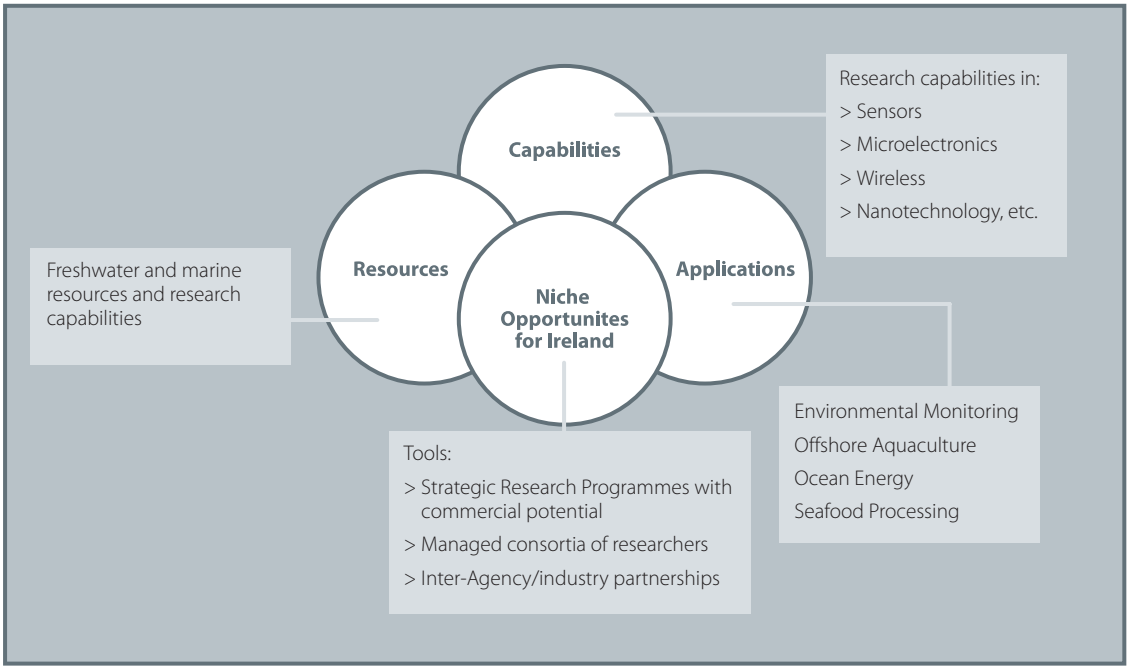


Figure 3.6 Niche Opportunities for Ireland in Marine Technology

3.2.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Create a critical mass, multi-disciplinary and industry-oriented research grouping in the field of sensors, intelligent systems and sensor platforms.

2 Create a focused capability in the application of information and communication technologies to the marine sector.

3 Harness the synergies between the above to deliver innovative technology solutions to targeted sectors (aquaculture, seafood processing, environmental monitoring, and ocean energy).

3.2.6 RTDI Requirements/Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 3.7 Research Requirements & Key Outputs for Marine Technology to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Create a critical mass, multi-disciplinary and industry-oriented research grouping in the field of sensors, intelligent systems and sensor platforms.	Some of the key RTDI requirements, which are closely linked with those in the ICT area (see objectives), and which constitute the elements of a programme to develop intelligent systems, include: > Sensitivity for low levels of trace chemical concentrations; > Fouling of sensors; > Selectivity limitations; > Limited stability of sensor chemistry and material; > Correlation of pressure and depth sensors data to allow in-situ instruments to match satellite altimeter data; > Interfacing of sensor systems with networks and communication and data infrastructure mechanisms; > Instrument capabilities and functions in respect to data acquisition and analysis; > Design and operation of sensor platforms; and > Integration of fibre-optic technology with sensors, communication and power sources.	> A multi-disciplinary, industry-oriented research grouping in the field of sensors, intelligent systems and sensor platforms > A portfolio of IP and of novel and innovative products > A number of new companies and stronger existing companies, both from within the sector and in related sectors > Active joint development projects with a number of MNCs and with international partners

continued

Table 3.7 Research Requirements & Key Outputs for Marine Technology to 2013

Objectives 2013	RTDI Requirements	Key Outputs
2 Create a focused capability in the application of information and communication technologies to the marine sector.	Some of the key RTDI requirements in Marine ICT, include: > Automatic identification and tagging of events in sensor data streams; > Wireless technologies for use offshore and their integration with on-shore communications networks; > Underwater communications - acoustics, distance, reliability, speed, power and their integration with on-shore communications networks; > Web service workflow tools allowing users to bind processes together for particular applications; > Integration of instruments and sensors into a grid computing environment with web services interfaces; > Techniques for simulation and visualization of complex data sets; > Automatic linking of instruments and metadata production; and > Development of methodology for 'grid enabling' instruments.	> A leading capability in the application of information and communication technologies to the marine sector > A critical mass of research and technical capability virtually networked in national centres of expertise > Active collaborative partners with MNCs and other companies from outside the 'marine' sector
3 Harness the synergies between the above to deliver innovative technology solutions to targeted sectors (aquaculture, seafood processing, environmental monitoring, and ocean energy).	A fundamental RTDI requirement is for the creation and maintenance of an overlapping series of dynamically networked groups with multi-disciplinary capabilities, organised around strategic technology projects, in partnership with industry. **Offshore Aquaculture Systems** > Sensor systems for feeding, biomass and health monitoring > Feed control > Telemetry and communications > Cage design, materials, structural testing and modelling **Environmental Monitoring** > Housings for instrument packages > Visualisation > Nano-biomaterials for component manufacture > Biofouling prevention **Seafood Processing** > Microbe Sensors > Traceability systems **Ocean Energy** > Telemetry/Monitoring Technologies > Modelling > Storage technologies	> Rapid development and prototyping of new products and services > Competitive advantage to Irish companies operating in these sectors > New start-up SMEs and new niche products for established technology companies > Participation in internationally funded programmes and bi-lateral international collaborations

3.2.7 RTDI Capacity/Capabilities

Current Research Capacity

Third-level Sector

Marine technology research and innovation encompasses a wide range of disciplines, many of which are not focused purely, or at all, on marine technology research. Five research groups are currently actively involved in marine technology research. Together these research groups comprise approximately 28 researchers in marine technology research (Table 3.8). The research focus of these groups covers areas such as advanced sensors and sensor platforms, ocean optics and marine robotics. Of particular relevance to the 2013 Objectives are three research groups in DCU and UCC that are involved in a suite of strategic advanced marine technology projects in the area of advanced sensors for water quality monitoring.

A further 10 research groups and a number of individual researchers (approximately 50-75 researchers in total) have relevant skills and research interests that, although not currently marine-orientated, could be applied to the future RTDI requirements for marine technology. The expertise in these groups covers areas such as sensors (including fibre-optic sensors), composite materials, biosensors, telemetry and communications, smart packaging and labelling systems, food traceability (using RFIDs—Radio Frequency Identification Devices) and control and instrumentation systems.

Table 3.8 Overview of Current Marine Technology Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
UCC UCD DCU UL	4 Large Groups 1 Small Group	28	> Advanced water quality sensors > Sensor platforms > Microelectronics > Photonics > Nanotechnology > Optical-based sensor systems > Wireless autonomous sensing > Microbe sensors > Spectrophotometry/radiometry > Satellite calibration/validation > Airborne remote sensing > Ocean optics > Robotics > Control & instrumentation systems

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 40-50.

State Sector

Although the Marine Institute has no staff actively participating in marine technology research, it provides strategic direction and financial and technical support to third-level and private sector researchers. Enterprise Ireland and Shannon Development provide other funding, technical and commercialisation support.

Industry

Many of the 50 companies in the marine technology sub-sector conduct in-house research/innovation into the development/adaptation of new technologies. It is however, difficult, to quantify the research effort in the private sector. Furthermore, a number of companies participate in collaborative research with third-level institutes and state agencies. For example, three SMEs, together with two third-level institutes and two state sector bodies, are involved in a cluster of advanced marine technology projects funded under the National Development Plan Marine RTDI Measure. The focus of these projects is on the development of advanced water quality monitoring technologies.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 3.9. Also included in Table 3.9 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 3.9 Competencies Required to Meet Future Research & Innovation Requirements for Marine Technology

Objectives 2013	Competencies Required	Assessment
1 Create a critical mass, multi-disciplinary and industry-oriented research grouping in the field of sensors, intelligent systems and sensor platforms.	> Analytical chemistry	S
	> Advanced sensors and sensor-platform development	R
	> Advanced materials	R
	> Surface technology (coatings)	R
	> Communications/telemetry	S
	> Photonics	S
2 Create a focused capability in the application of information and communication technologies to the marine sector.	> Communications/telemetry	S
	> Data stream analysis	G
	> Underwater communications	G
	See also note 1 below	
3 Harness the synergies between the above to deliver innovative technology solutions to targeted sectors:		
Aquaculture	> Communications/telemetry	S
	> Cage design, modelling & testing	R
	> Development/adaptation of biomass sensors	G
Environmental Monitoring	> Data handling, analysis & visualisation	R
	> Surface technology (coatings)	R
	> Nano-biomaterials	G
Seafood Processing		
	> Traceability systems	R
	> Microbe sensors	R
Ocean Energy		
	> Communications/telemetry	S
	> Ocean energy modelling	S
	> Energy storage technologies	G

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

[1] The ICT competencies required to achieve this objective are similar to those required to achieve the Knowledge and Information Management objectives (Policy Support Research Measure) and are dealt with in further detail in the relevant

The current capacity in marine technology research is relatively modest. However, marine technology development can draw on a large pool of research expertise in the wider technology area in both the third-level and industry sectors. Focusing this expertise on marine technology research will assist greatly in meeting the 2013 Objectives. Although some of the expertise required to achieve Objective 1 is available, much of it requires further strengthening and broadening.

Many of the competencies required in support of the application of information and communications technology to the marine sector (Objective 2) are similar to those required to achieve the Knowledge and Information Management objectives (Policy Support Research Programme) and are dealt with in further detail in the relevant section (4.2). Apart from these, gap areas exist in relation to (sensor) data stream analysis and underwater communications.

Delivering innovative technology solutions to targeted sectors (Objective 3) requires a broad range of competencies. Some research strengths already exist, e.g. in the area of communications/telemetry. Competencies that require strengthening include fish cage design, modelling and testing; coatings technology; seafood traceability systems; and microbe sensors. Gap areas include nano-biomaterials, energy storage technologies and biomass sensors.

Figure 3.7 Research Competencies Required to Meet 2013 Objectives for Marine Technology

Current Strengths	Require Strengthening	Gaps
> Analytical chemistry	> Advanced sensors and sensor-platform development	> Data stream analysis
> Communications/telemetry	> Advanced materials	> Underwater communications
> Ocean energy modelling	> Surface technologies (coatings)	> Development/adaptation of biomass sensors
> Photonics	> Cage design, modelling & testing	> Nano-biomaterials
	> Data handling, analysis & visualisation	> Energy storage technologies
	> Traceability systems	
	> Microbe sensors	

3.2.8 Prerequisites for Achieving Objectives

Foresight exercises in a number of countries have all shown that many important inventions, and the emerging technologies to underpin them, are characterised by the coming together of a number of disciplines. This creates the need for multi-disciplinary, multi-institutional, and even multi-national efforts and hence for networks, co-operation and partnerships. Furthermore, many of the policy issues, such as intellectual property rights and the commercialisation of new ideas, need effective links between research systems, on one hand, and financial and legal systems, on the other. The development of such links is critical for Ireland's future success in marine technology development and use.

There are a number of prerequisites for success in the development of a dynamic marine technology sector:

> Creating critical mass and greater continuity in funding support;

> Developing test and demonstration mechanisms;

> Developing effective networking mechanisms; and

> Establishing effective market research intelligence mechanisms.

Mechanisms that address the realities of high-tech micro SMEs must be established. R&I support must bridge the gap between development of 'laboratory demonstrators' from current applied research programmes and the delivery of near- or at-market products that need 2–4 additional years development, with scale-up and proper field trials. These support measures need not be large but must be fast and flexible.

The existence of industry development mechanisms, such as WiSen (the Wireless Sensor Network) and the Photonics Association are critical to the success of this programme.

3.3 Marine Functional Foods Research Programme

3.3.1 Introduction

A significant current driver of food choice among consumers is health. Marine products have the advantage of being perceived as natural, and therefore healthy, by many consumers. Because of the high consumer priority on health, functional foods and dietary supplements (physiologically active ingredients, nutraceuticals) are product areas in which marine resources have a high potential. 'Functional Foods' are foods or dietary components that may provide a health benefit beyond basic nutrition.

Several classical functional foods and dietary supplements (e.g. prebiotic and probiotic products based on fish oils, algae or other marine sources) are derived from marine sources and there is potential for more. Among the potentially important areas for research are:

> Chitin and related compounds from shellfish waste;

> Omega 3 and other fatty acids from fish oils; and

> Alginates, carrageenans, etc. from marine algae.

Some of the opportunities in the area of functional foods are dependent on economic factors, e.g. the quantities and value of the source materials available for extraction of potential products and the logistics associated with their coastal or offshore locations.

The Marine Institute, working in association with other stakeholders, is defining a marine functional foods research programme. The 2020 Scenario and 2013 Objectives that will guide this programme are laid out as follows.

3.3.2 2020 Scenario

2020 SCENARIO

By 2020, the Irish marine sector will be a major supplier of raw materials to the international food sector. There will be a wide awareness of the beneficial effect of marine origin materials and extracted compounds on human health. An aging population and high disposable incomes will drive the demand to address disease prevention though food. A range of ailments and diseases including cancers, obesity, diabetes, and immunity development will be targeted using marine functional foods. Research in these areas will have created strong linkages between the marine sector and the pharma-chem, food and health sectors.

Ireland will possess a science-based capability and the capacity to develop new functional food opportunities, adding value to available marine materials, organisms and extracted compounds. Traditional marine food processing firms will become proficient in new processes designed to extract, separate, purify and package marine origin compounds. Marine products will make an important contribution to the development of a high added-value functional foods industry and there will be a strong inter-agency partnership and synergy with other RTDI performers in the food sector.

3.3.3 2013 Objectives

2013 OBJECTIVES

1 Create a strong, interdisciplinary research capability in the identification and utilisation of marine biodiversity as a source of materials for use in functional foods.

2 Develop capabilities to process marine based materials for use by the functional food sector.

3 Create a new research capability in marine functional foods linking indigenous and multi-national food and pharmaceutical industries with researchers at state and third level research institutions.

3.3.4 RTDI Requirements/Outputs

The detailed research requirements and outputs for the marine functional foods research programme are being defined by the Marine Institute, working in association with other stakeholders. The key programme outputs are:

> Active participation by state and third-level research institutions and industry in nationally and internationally funded programmes and international collaboration;

> The discovery of marine-based functional food materials;

> New processing methods to extract functional materials from marine materials; and

> A knowledge base that will support food companies to produce novel and innovative marine-based functional food products.

Expertise in the area of marine functional foods research is outlined under the Seafood Processing Research Programme (Section 2.2).

3.4 Renewable Ocean Energy Research Programme

3.4.1 Introduction

Ireland's offshore renewable energy resources, in the form of wave and offshore wind, are considered as being among the best in the world. This resource, with the exception of the recently commissioned Arklow offshore wind farm, is completely unexploited.

3.4.2 Sector Profile

Offshore Wind

Foreshore leases have been granted for the operation of a 520 MW wind farm on the Arklow Bank and a 1,100 MW wind farm on the Codling Bank, both in the Irish Sea. To date, seven turbines totalling 25 MW have been installed on the Arklow Bank. This development features the world's largest installed offshore turbines. Licences have been granted for many of the other east coast offshore banks, as well as some west coast sites. There is potential to deliver a large energy supply into the system from offshore wind with existing technology. However, the key issues in respect to utilising offshore wind resources and developing technological solutions are:

> Policy

The successful development of an offshore wind energy industry depends, largely, on policy decisions.

> Infrastructure

The major limiting factor in respect to the introduction of the large electricity supply that the offshore wind sector can deliver in the short to medium term is the national grid's capacity to cope with this large intermittent resource.

> Price

Linked to the Policy issue mentioned above is the fact that there are financial implications for energy pricing associated with subsidies to renewable power generators. In turn, price is clearly an issue in respect to the viability of offshore wind schemes.

Since the dominant issues in respect to utilizing offshore wind resources are non-technical, this Strategy does not propose any significant RTDI effort in respect to this technology.

Tidal Energy

A recently completed tidal resource assessment for Irish coastal waters has indicated that there are marginal resource levels in Irish waters utilising existing technologies.[27] Significant activity in harnessing tidal stream energy for electricity generation is unlikely to occur in Ireland until technology that can operate effectively with low tidal flows is available. The overall status of tidal stream technology does not warrant a significant research effort at this time. However, a number of Irish groups are involved in the development of tidal devices for which there may be significant international markets and this provides justification for including technology development and innovation aspects of tidal energy in this Strategy.

Wave Energy

In terms of potential usefulness, the wave climate off the west coast of Ireland is one of the most favourable in the world. The development potential in respect to second-generation floating devices moored offshore is very significant. A comprehensive assessment of the offshore wave resource estimates the accessible wave energy resource as being up to 20.76 TWh/yr.[28]

There is a significant level of activity in Ireland in respect to the development of technologies to exploit wave energy resources.

> Two Irish developers of wave energy devices are ready to proceed to large-scale prototype phase.

> One developer has constructed a large-scale device, although funding and technical difficulties have resulted in delays to the programme.

> One company is successfully developing salt-water hydraulic pump systems for wave energy converters.

The critical issue for the wave energy sector, internationally and in an Irish context, is the demonstration of device prototypes in a real operational environment. This is the essential step in the process, which is gathering momentum internationally, of developing commercialisation models for a wave energy industry.

In view of its potential, the prospect that Ireland can become a significant player in this industry, and the high level of RTDI content in developing the technologies involved, this Strategy focuses primarily on wave energy, although aspects of the Strategy significantly affect tidal device deployment.

3.4.3 Key Opportunities and Challenges

There is increasing international recognition of the long-term potential for wave energy. A recent report by ESBI and Peter Bacon Economic Consultants concluded that Ireland has an important opportunity to develop an industry based on ocean energy.[29] This has the potential to lead to the creation of valuable intellectual capital, economic wealth and employment opportunities.

Furthermore, it would have a desirable regional spread, in the sense that much of the development would take place in areas of the country that are lagging economically.

Opportunities

> There is a very significant resource globally and a potentially large market in a number of key countries, in addition to niche markets elsewhere.

> There is, as yet, no proven 'winning' wave converter design. This provides a significant opportunity for Ireland to achieve a frontline position in the sector.

[27] Kirk McClure Morton (2005). Tidal and Current Energy Resources in Ireland, 2005. (Report Commissioned by SEI).
[28] ESB International (2005). Accessible Wave Energy Resource Atlas Ireland, 2005. (Report Commissioned by Marine Institute & SEI).
[29] Peter Bacon & Associates/ESBI (2005). Analysis of the Potential Economic Benefits of Developing Ocean Energy in Ireland. www.marine.ie

> A number of Irish companies are actively developing wave and tidal energy devices. Therefore, Ireland has the potential to establish commercially viable designs and exploit these locally, or in collaboration with overseas players.

> There is a growing level of investment in Research, Development & Demonstration (R,D&D) internationally; an increasing level of confidence that viable technologies will emerge, and evidence that effective development consortia are being formed, e.g. around the Pelamis system of the UK company, Ocean Power Delivery.

> Direct synergies exist with offshore wind, which should accelerate the development of wave and tidal service capabilities.

> Wave energy resources can provide sustainable energy to meet Ireland's growing demand for electricity in the medium to long term.

Challenges

Better pre-commercial support (e.g. capital grants and power-purchase terms) being provided elsewhere, may delay or stultify Ireland's development in the field. For example, the Scottish Marine Energy Group[30] predicts that by 2020:

> *10% of Scotland's electricity production can come from marine resources;*

> *There will be 1,300 MW of marine energy capacity installed in Scottish waters, increasing at a rate of 100 MW per year;*

> *Scottish-based marine energy companies could be supplying major international export markets;*

> *7,000 direct jobs could be created in a diverse marine industry in Scotland, supported by sustainable research development and skills bases; and*

> *Scotland should lead the world in the research, development and certification of marine energy devices.*

Greater market size and the development of standard designs abroad, coupled with economies of scale in production and rising costs in Ireland, may lead to manufacturing being carried out elsewhere.

The research resource could easily disappear, as it is led by a small number of key individuals facing uncertainty in securing regular funding leads it.

[30] Marine Energy Group (2004). Harnessing Scotland's Marine Energy Potential. Scottish Executive.

3.4.4 2020 Scenario

2020 SCENARIO

By 2020, given the continuing rise in the price of energy and the rise in demand for cleaner energy, the commercial prospects for Renewable Ocean Energy Technology will be clearly established.

Because of pro-active investment in Research, Demonstration & Development, Ireland will be a world leader in the manufacture and use of ocean energy systems. A programme of measures since 2006 will have enabled the systematic development and growth of an ocean energy sector. These include:

> development of research and technical support capabilities in the third-level sector;

> provision of a range of R&D and capital support measures for device developers;

> establishment of benign and open-sea test sites for prototype trials; and

> a co-ordinated approach to the delivery of an ocean energy research, development and demonstration programme.

A vibrant and growing export industry will have been established (conservatively valued as per Table 3.10).

Ireland will be recognised as a Centre of Excellence in Renewable Ocean Energy research and will have established competence in the design, modelling, deployment and operation of wave energy devices and in key technical areas of renewable energy, such as forecasting, power intermittency and management, and energy storage.

Table 3.10 Value of Renewable Ocean Energy Devices for Domestic & Export Markets (Peter Bacon & Associates/ESBI, 2005)

Activity	2020	2025
Annual Device Sales	119 MW	383 MW
Cumulative Device Sales	444 MW	2,072 MW
Annual Value of Market	€144 million	€478 million
Cumulative Value of Market	€541 million	€2,405 million
Number of Jobs Created	887	2,240

3.4.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Achieve international recognition as a Centre of Excellence for Renewable Ocean Energy research with established competence in a number of key areas:

- Model Testing & Performance Validation
- Hydrodynamics & Modelling
- Power Take-off Technologies
- Mooring Design
- Wave Forecasting

2 Have a minimum of two full-scale, prototype ocean energy devices operational as pre-production models.

3 Establish suitable, and effective, technical approaches in the areas of forecasting, power intermittency and management, and energy storage.

4 Have in place user-friendly information systems that support the needs of offshore energy companies for access to environmental data.

3.4.6 RTDI Requirements/Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 3.11 Research Requirements & Key Outputs for the Renewable Ocean Energy Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Achieve international recognition as a Centre of Excellence for Renewable Ocean Energy research with established competence in a number of key areas:		
i) **Model Testing & Performance Validation**	i) **Model Testing and Performance Validation** > Maintenance and expansion of expertise in model testing & performance validation > Investigation of device array interaction and effect on performance > Use of remote systems for power and performance monitoring during large- scale benign site testing	> Availability of facilities and expertise for model testing at a useful scale and reliable performance assessment and validation for industrial device developers > Accelerated and more effective development of scaled energy devices
ii) **Hydrodynamics and Modelling**	ii) **Hydrodynamics and Modelling** > Maintenance and expansion of expertise base in hydrodynamics and modelling > Power take-off/hydrodynamics interaction	> Expertise in hydrodynamics and modelling

continued

Table 3.11 Research Requirements & Key Outputs for the Renewable Ocean Energy Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
iii) Power Take-off (PTO) Technologies	iii) Power Take-off Technologies	
	Hydraulics	
	> Investigation of use of seawater as hydraulic fluid, including seal effectiveness and longevity	> Use of 'environmentally friendly' fluids or seawater as hydraulic fluid devices and concepts
	> Effects of high forces during extreme events on hydraulic systems and components	> Reliable and efficient hydraulic PTO systems with short-term energy storage providing smooth output across a broad range of sea states
	> Investigation of short-term energy storage methods	
	Pneumatics	
	> Optimisation of impulse turbine design system and comparison with existing Wells turbines	> Proven high efficiency impulse turbine optimised for use in offshore devices
	> Optimisation of pneumatic turbines for use in offshore devices	
	Control Systems	
	> Technical and economic comparison of constant speed versus swash plate generator systems	> Analysis of the economic and technical benefits of various power quality and control strategies/ methods
	> Power quality optimisation and strategies for fault management	
	> Modelling of PTO effects on device (critical damping)	
iv) Mooring Design	(iv) Mooring Design	
	> Value engineering of mooring systems and components	> Optimised design for device arrays and reduction in mooring costs
	> Investigation of use of synthetic/high-tech materials	> Mooring systems for offshore wind devices capable of exploiting deep or exposed waters
	> Mooring design optimisation for array deployment	
	> Development and optimisation of mooring technologies for deep water offshore wind devices	
v) Wave Forecasting	v) Wave Forecasting	
	> Use of remote sensing and model prediction for accurate short- and medium-term prediction of wave climate and application of forecast to control strategies	> Tools to allow optimisation of operation and instigation of survival strategies for offshore wave devices

continued

Table 3.11 Research Requirements & Key Outputs for the Renewable Ocean Energy Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
2 Have a minimum of two full-scale, prototype ocean energy devices, operational as pre-production models.	> Provide test facilities, including (a) a benign near-coast site for testing scale-models, and (b) an open-ocean test-site with power cable for testing full-scale devices and device arrays > Provide technical product R&D support for device developers in the following areas: • Modelling • Tank testing and performance validation • Access to basic open ocean test site for scale models • Deployment support for scale models in open ocean • Prototype design & build • Prototype deployment & monitoring	> Fully licensed, cabled and instrumented site allowing rapid deployment of prototype devices > Full-scale devices providing valuable long- term data allowing optimisation of device design
3 Establish suitable, and effective, technical approaches in the areas of forecasting, power intermittency and management, and energy storage.	Power Quality & Conditioning *Technical Considerations* > Investigation of in-situ onshore power rectification and conditioning *Economic Considerations* > Comparison of economics of differing strategies for power rectification and conditioning *Energy Storage Solutions* > Investigation of technical and economic benefits of a broad range of energy storage technologies with application for offshore energy in an Irish context	> Cost effective methodologies for generation of high quality power from offshore devices > Analysis of benefits of existing or novel energy storage solutions allowing storage of offshore generated energy
4 Have in place user-friendly information systems that support the needs of offshore energy companies for access to environmental data.	> There is a requirement to provide environmental monitoring data for use by developers and regulators of the sector. (See Knowledge & Information Management Section)	> Easily accessible database of relevant environmental data to Ocean Energy companies

3.4.7 RTDI Capacity/Capabilities

Although the area of general renewable energy and technologies research has shown significant increase in recent years, Ireland has a relatively small, but active, renewable ocean energy research community in the private and third-level sector.

Table 3.12 Overview of Current Renewable Ocean Energy Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
UCC UL NUIM	2 Large Groups 1 Medium Group	23	> Hydrodynamics of overtopping wave power devices. > Optimal formation of arrays of wave power devices. > Physical and numerical modelling > Tidal current research. > Development of turbine technology for wave power. > Pendular wave energy converter > Development of wave energy devices. > Control and electrical systems for ocean energy systems.

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 35-40.

Current Research Capacity

Third-level Sector

Three research groups in three universities are actively involved in wave and tidal energy research. Together, these groups comprise approximately 23 researchers in renewable ocean energy research (Table 3.12).

Other research groups in UL, UCD, NUIG and UCC have skills and research capabilities that can be drawn upon to meet the identified RTDI requirements. These include near-shore modelling, marine robotics, advanced materials, computational fluid dynamics, power system operation and integration of renewable energy in the electricity system, and wind and wave data analysis. In addition, several of the main third-level institutions have core competencies in the general area of electrical engineering and related fields.

Industry

There are 4–5 private companies, totalling 10–12 researchers, actively engaged in renewable ocean energy research. These include device developers and engineering consultancies engaged in resource assessment and device design and analysis.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 3.13. Also included in Table 3.13 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 3.13 Competencies Required to Meet Future Research & Innovation Requirements for the Renewable Ocean Energy Sector

Objectives 2013	Competencies Required	Assessment
1 Achieve international recognition as a Centre of Excellence for Renewable Ocean Energy research with established competence in a number of key areas.	> Model testing and performance validation > Hydrodynamics and modelling > Power Take-off (PTO) technologies > Mooring design > Wave forecasting > Wave climate modelling	S S R S R S
2 Have a minimum of two full-scale, prototype ocean energy devices, operational as pre-production models.	> Prototype design, specification and construction > Electrical connection design and specification > Operational and deployment strategies > Data acquisition and performance validation	R R R S
3 Establish suitable and effective technical approaches in the areas of forecasting, power intermittency and management, and energy storage.	> Power quality and conditioning technologies > Application of energy storage methodologies > Economic modelling	R G S
4 Have in place user-friendly information systems that support the needs of offshore energy companies for access to environmental data.	Refer to Environmental and Knowledge & Information Management Programmes	

* S – Current Strength; R – Requires Strengthening; G – Gap Area.

Considerable strengths exist in the competencies required to meet Objective 1. However, research capabilities need to be strengthened in the areas of power take-off technologies and wave forecasting. Many of the R&D competencies required in support of the objectives to have operational prototype devices also require strengthening. Additionally, infra-structural support, in the form of near-coast and open-ocean test sites, is required to meet this objective.

Research competencies to address the issue of power quality require strengthening. Although one dedicated research centre is active in this field, several of the main third-level institutions have core competencies in the general area of electrical engineering and could contribute to future requirements through accurately targeted research programmes. Finally, a major issue facing ocean energy devices is that of energy storage. This issue is being addressed by the wider renewable energy industry, specifically in relation to onshore and offshore wind energy. A gap exists within the research community with respect to the application of existing and/or novel energy storage solutions for ocean energy devices.

The competencies required to achieve the final objective, access to environmental data, are generic to many of the programme areas and specific to the Knowledge & Information Management programme of the Strategy and are not considered here.

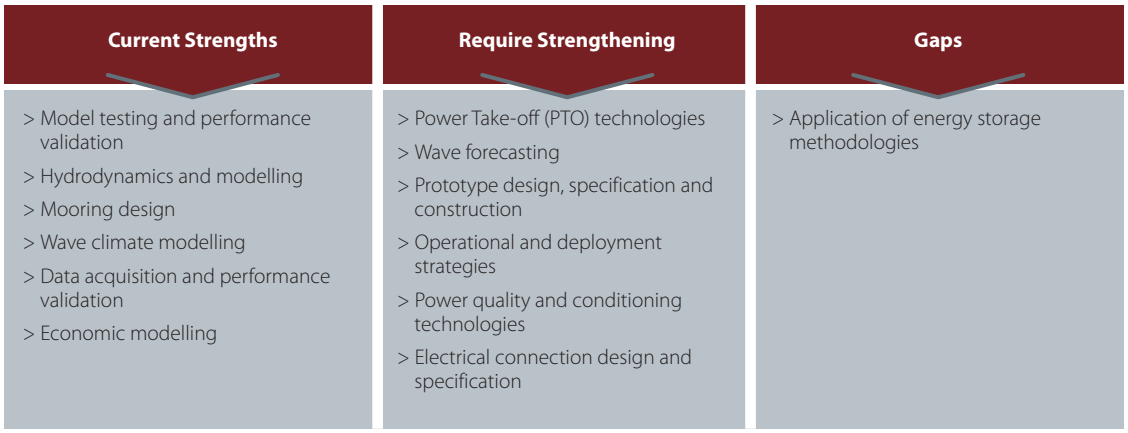


Figure 3.8 Research Competencies Required to Meet 2013 Objectives for Renewable Ocean Energy

3.4.8 Prerequisites for Achieving Objectives

Internationally, as well as in Ireland, the critical factor both for device technology and for emerging business models for the sector is the demonstration of full-scale prototypes in operational, open-sea environments. In view of the competitive international environment that exists for wave energy technology, the following general prerequisites for the successful delivery of the objectives for the renewable ocean energy research programme are suggested:

> Policy

A national commitment to maximising energy generation from renewable sources and, particularly, to supporting the development of indigenous technical and industrial capabilities in respect to the technologies involved.

> Support

Close collaboration between the agencies with relevant responsibilities and the establishment of an executive implementation mechanism.

> Funding

A commitment to a sustained programme of funding support, addressing the range of RTD and capital and price support measures necessary to provide a climate of confidence within which the private sector can raise and commit the significant funds necessary to create industrial offshore energy power arrays.

3.5 Rapid Climate Change Research Programme

3.5.1 Introduction

One of the greatest challenges currently facing human populations in the 21st century is rapid climate change brought about by global warming. The change in Ireland's climate—both Ireland and Europe are now warmer than they were 20 years ago—is likely to continue into the next century. The potential large-scale impacts of global warming on the oceans include: increase in sea-level and sea-surface temperatures; decreases in sea ice cover; and changes in salinity, alkalinity, wave climate and ocean circulation. The consequences of these changes and in the marine environment include: increased storminess, coastal inundation and flooding, changes in species biogeography (including species of economic interest) and invasive species (including microbes and pathogens). Although there can be no certainty regarding the precise nature and rate of changes to Ireland's marine environment, it is clear that changes in the marine environment have the potential to have serious social, economic and environmental impacts.

3.5.2 2020 Scenario

2020 SCENARIO

By 2020:

> Ireland will be a key player in European-North Atlantic climate change modelling, prediction and scenario development.

> Ireland, as part of a pan-European-North Atlantic network, will be using sophisticated climate prediction models, drawing data from real-time *in-situ* ocean and coastal monitoring stations, to prepare reliable local climate impact predictions, including warnings on storm surges, coastal inundation and flooding, and species movements and migrations.

> Climate change predictions and scenarios will be used routinely in all large-scale, medium-to long-term social, economic and environmental development strategies.

> Knowledge-based adaptive strategies will enable Ireland to anticipate and benefit from climatic induced environmental changes, while avoiding the negative aspects of climate change.

3.5.3 2013 Objectives

2013 OBJECTIVES

1 Increase our understanding of the drivers and regulators of climate so as to improve the accuracy and reliability of predictive models.

2 Downscale global climate model predictions to the regional/local level in order to refine local impact scenarios.

3 Develop and use real (e.g. temperature/salinity) and proxy (e.g. biogeographic species shifts, phenology, etc) climate change indicators.

4 Include climate change scenarios in all major social, economic, environmental strategies.

3.5.4 RTDI Requirements/Key Outputs

Recommendations for marine climate change research requirements are contained in a report prepared by the Marine Institute as part of the development of this Strategy.[31]

The key programme outputs for marine climate research are:

> A suite of usable and informative marine climate change indicators and assessment tools;

> An ability to model/predict the impact of climate change on the Irish marine environment; and

> The provision of informed, knowledge-based scenarios on climate change impacts on the various marine sectors.

Expertise in the area of marine climate change research is outlined under the Marine Environment Research Programme (Section 4.1).

[31] Boelens, R., Minchin, D. and O'Sullivan, G. (2005). Climate Change: Implications for Ireland's Marine Environment and Resources. Marine Foresight Series, No. 2. Marine Institute.

4 Policy Support Research Measure (2007–2013)

The Policy Support Research Measure will use the knowledge derived from marine related research, and data obtained by monitoring the marine environment, and marine related issues, to inform public policy. It will contribute to the governance and regulation of the sector and inform marine related decision making in the public and private sectors. The Measure will provide information to support the spatial and economic development of coastal and ocean areas. Decision making in relation to Ireland's international position and the impact of decisions taken elsewhere as they relate to marine matters, will be informed by this Measure. The Measure also supports research into knowledge and information management systems required to capture and disseminate marine data and information and hence is relevant to a wide customer base. In meeting the needs of various groups, a more innovative, customer driven and market conscious ethos and practice in the public sector will be visible.

The Policy Support Research Measure consists of three major **Research Programmes,** as follows:

4.1 Marine Environment Research Programme

"Ireland's environment is a vital natural resource, which we all depend on and consequently must cherish. It has its own intrinsic worth; it is central to a good quality of life; it is vital for the well being of future generations; and it is a key part of what attracts people and investment to Ireland. In short, a high quality environment is essential for economic progress and for sustainable development".[32]

4.1.1 Current Status of the Marine Environment

Ireland is fortunate amongst European countries in having relatively unpolluted marine and coastal waters, though they are not pristine[33]. The environmental quality of Ireland's estuaries, bays and coastal waters remains generally high in a European context, despite substantial population growth and economic development over recent decades.

However, it should be noted that the 2004 State of the Environment Report highlighted the fact that several estuarine areas are seriously affected by direct municipal and, in some instances, industrial discharges, in combination with nutrient loads carried down by rivers. The most significant sources of organic matter and nutrients are agricultural runoff and urban wastewater discharges. A number of major estuaries, predominantly in the east and south of the country, have been classed as eutrophic under assessments carried out by the EPA. As well as impaired water quality, the potential impacts of direct and indirect discharges include loss of amenity value, interference with fisheries and aquaculture, and changes in natural plant and animal communities.

The marine waters around Ireland are considered some of the most productive fishing areas of the northwest European continental shelf. However, exploitation rates in recent years have been very high. Of the 56 commercially targeted marine fish stocks in Irish waters, 25 are overexploited and the status of many others is uncertain. Fishing can also give rise to adverse impacts on non-target species, e.g. damage to deep-sea coral reefs off the west coast.

Contaminant levels in fish and shellfish are low, according to the most recent monitoring surveys, and the overall quality of Irish seafood produce remains high.

In 2004, the number of marine bathing waters that complied with EU Bathing Water Directive standards reached 122. Of these, 97% complied with the minimum mandatory standards and 83.6% complied with

[32] Dept. of Environment and Local Government (2003). Making Ireland's Development Sustainable.
[33] EPA (2004). Ireland's Environment 2004.

the more stringent guideline standards of the Directive. Seventy three beaches and two marinas were awarded Blue Flags in 2005.

Although litter on beaches continues to be a problem, the 2002 plastic bag levy has significantly reduced the use and disposal of plastic bags in recent years.

4.1.2 Key Opportunities and Challenges

Implementing Current and New Environmental Legislation

Ireland will take a proactive role in the development of tools and methodologies for the implementation of the Water Framework Directive (2000/61/EC), which requires monitoring and assessment of ecological quality in coastal and transitional waters. Ireland will seek to take a lead role in the evolution of the EU Marine Strategy, which is likely to provide a basis for a Marine Framework Directive and integrated, ecosystem-based management of the EU's marine resources. The implementation of the EU Marine Strategy is likely to strengthen the legislative status of the OSPAR Convention for EU member states. In order to achieve this, Ireland will mobilise marine research capabilities to inform legislative and policy choices.

Sustainable (Sectoral) Development

The National Sustainable Development Strategy sets out the need for a well-managed environment that sustains a healthy economy and a good quality of life. This reaffirms the requirement for mutually supportive policies to achieve a balance between society, economy and environment. Within this context, the ecosystems approach has emerged as a fundamental delivery mechanism for achieving sustainable development, based on maintaining fully functioning ecosystems. Progress will require more coherence and better integration of management and regulatory systems across all sectors. Although there are existing measures in place to reduce and control pressures and threats on the marine environment, e.g. relevant EU Directives and OSPAR strategies, they have typically been developed and implemented on a sector-by-sector basis.

Most sectoral policies address diverse uses, pressures, impacts, and major ecosystem components (fish, seabirds, water quality and habitat features) separately. However, there is growing acceptance of the need to consider interactions and cumulative effects arising out of multiple uses of the marine ecosystem and to address these through policy instruments that adopt a more integrated and holistic approach.

Within Europe, the Ecosystems Approach features prominently within the reformed Common Fisheries Policy, OSPAR and the new EU Marine Strategy. Although guidance will be provided through these mechanisms, research will be required at member state level to determine the specific objectives, approaches and indicators.

Environmental Understanding

Ireland needs to invest in research to provide an adequate baseline of the characteristics of the marine and coastal environment. This would include a programme of research in physical, chemical and biological properties and processes; a baseline assessment of resources (e.g. seabed resources); and the development of appropriate models. Such data sets and models would provide the scientific input needed for the assessment and governance of the marine sector. They would also allow appropriate environmental indicators to be developed and used in determining trends, e.g. impacts of climate change. **The challenge posed by climate change is dealt with under the Discovery Research Measure (Section 3.5)**

Environmental Quality and Protection

In accordance with international conventions to which Ireland is a party (e.g. OSPAR Convention, 1992), Ireland is expected to carry out regular assessments of the quality of the marine environment including water, sediments and biota. Ireland is also obliged under the Water Framework Directive to achieve good ecological and chemical status in its waters by 2015. The achievement of this objective requires implementation of a national research and monitoring programme for water quality in transitional, coastal and marine waters. A key element in this process is the development of appropriate ecological objectives and targets, supported by indicators. This national monitoring and assessment programme will be carried out co-operatively by several agencies including the EPA, Marine Institute, River Basin Districts, RPII and local authorities.

Protecting Marine Biodiversity

The maintenance of biodiversity in Irish waters demands effective regulation backed by coherent programmes of scientific research. The richness of our marine biodiversity can be measured by the range of habitats, the number of species and their genetic variety. In accordance with the National Biodiversity Action Plan, as well as other UN and EU legislation, Ireland needs to implement a prioritised programme of marine species and habitat mapping and surveying. Based on this programme, Ireland will adopt specific provisions in our spatial planning and resource management for the conservation of marine biodiversity. The maintenance of biodiversity also provides a potential resource for biodiscovery and marine eco-tourism, and conserves Ireland's marine heritage for future generations.

Enhanced Monitoring Capability

Ireland can build on the investment made in marine research infrastructure, e.g. research vessels, laboratories and communications technology, to achieve a more efficient and effective marine monitoring system. Ireland has already built expertise in microelectronics, sensors and data management, which provides further opportunities to develop automated systems for environmental quality monitoring in freshwater catchments and marine and coastal areas. In addition, there is the requirement, as listed above, for monitoring and management of the marine environment. The Marine Environment Research Programme 2007–2013 will combine these elements to create Public Private Partnerships to develop novel products and services. These provide an opportunity for business development and can support the enhancement of Ireland's capability in marine environment research and monitoring.

Integrated Management and Advice

The availability and reliability of marine environmental data is critical to assessing and managing the marine environment and promoting sustainable development. Existing and new data sets on key marine environmental variables need to be integrated, made accessible, and presented in formats that can be readily understood by all stakeholders. The review and analysis of such marine data sets will enable us to assess spatial and temporal changes at national and regional levels and to develop further insights into, and understanding of, marine ecosystems. These insights can form the basis for better policy advice and for management of marine resources.

4.1.3 2020 Vision

2020 VISION

By 2020, Ireland will have healthy marine ecosystems that sustain and support a dynamic maritime economy. As part of its commitment to generating and applying knowledge for social and economic benefit, Ireland will have in place an integrated policy and regulatory system to ensure the sustainability of marine ecosystems while allowing for the rational use of marine resources.

National marine policy will be driven by an overarching goal to have healthy marine ecosystems that sustain indigenous biodiversity and provide for existing and new uses of marine and coastal resources.

Ireland will be fully compliant with the requirements of EU marine legislation and international conventions to which it is a contracting party, and will be able to demonstrate, through the compilation and regular publication of a suite of appropriate environmental assessments, the maintenance of a high quality marine environment.

Ireland will have developed a marine brand identity, with a high quality environment and robust economy. This brand will form part of a marketing programme for the seafood, tourism and other marine sectors.

4.1.4 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Support the implementation, on a multi-agency basis, of environmental legislation, e.g.:
   > Water Framework Directive;
   > Proposed Marine Framework Directive;
   > OSPAR Convention (1992);
   > Environmental Impact Assessment Legislation (EIA & SEA Directives); and
   > IMO Convention.

2 Support the sustainable development of marine resources and sectors through:
   i) Establishment of a system of marine spatial planning and the introduction of a comprehensive system of ICZM;
   ii) Identification of environmental indicators and development of sectoral Codes of Practice; and
   iii) Measurement and mitigation of environmental impacts.

3 Enhance our understanding of marine and coastal ecosystems as a basis for environmental policy and sustainable resource management.

4 Support environmental and resource management and protection strategies, which will underpin an expanding marine based tourism and leisure sector.

5 Protect, maintain and, where necessary, enhance marine biodiversity.

6 Integrate data sets, carry out assessments, improve data availability and apply this science-based knowledge in policy-making and ecosystem management.

7 Develop stronger national collaborations (e.g. between lead agencies and research performers) and improved capabilities, methodologies and technologies for marine environmental monitoring.

4.1.5 RTDI Requirements/Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 4.1 Research Requirements & Key Outputs for the Marine Environment to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Support the implementation, on a multi-agency basis, of environmental legislation.	**Water Framework Directive** > Set reference conditions for coastal and transitional waters > Carry out an inter-calibration of monitoring methodologies to ensure a standardised interpretation of ecological quality with EU member states > Further develop ecological classification tools & indicators > Analyse current pressures and impacts on water quality and their future trends > Develop and implement scientific monitoring tools to provide the data from key sectors (e.g. aquaculture, tourism and fisheries) necessary for development and implementation of sectoral 'Programme of Measures'	> Ireland published its River Basin Plans, including Programme of Measures, by June 2009 and is in a position to meet the main environmental objectives by 2015 in coastal and transitional waters in compliance with WFD (2000/60/EC) > Intercalibration of monitoring methods successfully completed > Set of ecological classification tools & indicators developed and in use > Monitoring programmes in place and data accessible to all stakeholders
	EU Marine Strategy > Research guidelines for implementation of the ecosystem approach in EU waters > Set Environmental Quality Objectives appropriate for Irish waters > Develop risk-based management techniques and use of scenarios for natural variability and human impacts > Research methodologies to quantify the value, including non-market value, of marine resources > Collaborate with other EU member states in co-ordinated marine monitoring activities	> Ireland is in a position to shape the evolution of the EU Marine Strategy and any consequent legislation, e.g. Marine Framework Directive > Conservation and management plans for human activities in the marine sector > Environmental Quality Objectives (EQOs) for Irish waters developed and in use > Adaptive management systems developed and in use
	Environmental Impact Assessment (EIA and SEA) > Develop methodologies for screening and scoping plans and programmes > Develop indicators to assess the cumulative impacts of individual marine developments > Design and implement programmes to monitor the impacts of marine developments in order to identify unforeseen adverse effects on the environment	> Ireland is compliant with the progressive implementation of relevant EU Directives (e.g. SEA Directive—2001/42/EC). > Key staff trained and the SEA methodology developed and adopted by state agencies for marine sectors.

continued

Table 4.1 Research Requirements & Key Outputs for the Marine Environment to 2013

Objectives 2013	RTDI Requirements	Key Outputs
	OSPAR Convention > Develop monitoring tools and quality objectives and standards for the broader OSPAR area > Carry out thematic and holistic assessments of the state of the marine environment > Improve methods to monitor and control hazardous substances in the marine environment IMO Convention > Develop research and monitoring programmes to assess the environmental impacts of shipping, including the potential impacts of ballast waters at Irish ports	> Ireland is in a position to meet the OSPAR target (Article 6) of a joint assessment of the marine environment by 2010 > Irish ports and shipping sector has developed systems for the management of ballast water and adapts to meet IMO environmental guidelines
2 Support the sustainable development of marine resources and sectors through : i) Establishment of a system of marine spatial planning and the introduction of a comprehensive system of ICZM;	> Develop the most appropriate methodologies for the preparation of a strategic multi-sectoral marine spatial plan in line with the developing requirements of the EU Maritime Policy and OSPAR > Provide scientific input and co-ordinate the development of ICZM tools to meet local, national and EU requirements and obligations > Design and interpretation of ICZM protocols > Build spatially referenced databases of marine resources and activities	> Network of inshore and offshore SACs established by 2010 > ICZM protocols developed and in use in key areas > ICZM plan for Ireland developed and incorporated in costal zone planning > Methodologies, objectives and targets for marine spatial planning > Databases available and accessible to all stakeholders
ii) Identification of environmental indicators and development of sectoral Codes of Practice; and	> Develop sustainability targets and environmental indicators for key marine sectors > Research and develop Codes of Practice in collaboration with sectors > Develop expertise in carrying capacity modelling for aquaculture > Develop conceptual models for species/habitat interactions, e.g. in fisheries management > Develop adaptive management systems for marine sectors	> Codes of Practice in use for main industry sectors, including aggregates, aquaculture, energy, fisheries, ports and shipping, and tourism > Set of environmental indicators to manage the development, and measure impacts, of the use of marine resources
iii) Measurement and mitigation of environmental impacts.	> Focused research on factors controlling the development, transport and impacts of Harmful Algal Blooms (HABs) > Basic research on environmental quality stress factors such as zooplankton, particulate load, dissolved oxygen etc. > Research on ecosystem effects of fishing	> HAB forecasting models in use to ensure shellfish safety > Appropriate conservation limits and practical mitigation measures adopted > Early warning systems for harmful species (zooplankton) > Science-based regulation of inputs to the marine environment

continued
Table 4.1 Research Requirements & Key Outputs for the Marine Environment to 2013

Objectives 2013	RTDI Requirements	Key Outputs
3 Enhance our understanding of marine and coastal ecosystems as a basis for environmental policy and sustainable resource management.	> Collect and collate adequate data (physical, chemical and biological) to establish baseline characteristics (including the dynamics) of marine and coastal environments	> Key data sets and databases in place and accessible to all relevant stakeholders
	> Develop a comprehensive suite of physical circulation models for marine and coastal waters	> Circulation models of marine and coastal waters, at appropriate spatial scales, developed and in use
	> Establish knowledge of temporal and spatial variations in primary and secondary productivity in Irish waters	> Improved understanding of potential impacts of climate change*
	> Establish a suite of appropriate climate change indicators and assessment tools, e.g. models to enable the identification of climate change impacts/trends on the marine ecosystems and resources*. This could include ocean acidification as a related issue of emerging significance	> Impacts of climate change considered in strategic planning of marine resource development*
	> Improve the understanding of coastal erosion and develop appropriate responses *(*See Section 3.5)*	> National coastal erosion and flood risk mapping and modelling system in place *(* See Section 3.5)*
4 Support environmental and resource management and protection strategies, which will underpin an expanding marine based tourism and leisure sector.	Based on existing coastal management initiatives at various locations around the coastline (e.g. 3rd level research projects), establish an inclusive partnership pilot project to inform the development of an Intergrated Coastal Zone Management (ICZM) strategy for Ireland. This should include: > Analysis of current coastal management practice in Ireland and abroad > Analysis and GIS mapping of current usuage and trends at pilot sites (large and important bays for commercial fishing, tourism & leisure including beaches, aquaculture and landside development) > Analysis of key data on water quality, flora, fauna etc. > Analysis of carrying capacities for each activity > Analysis of conflicting resource uses > Stakeholder consultation on needs and experience (through establishment of user forums) > Opportunity mapping (GIS) > Objective setting in agreement with stakeholders > Analysis of environmental impacts & socio-economic benefits > Establishment of user research & public education programmes on ICZM at a number of pilot sites Within the context of the Water Framework Directive, develop environmental indicators for rivers, lakes and coastal areas to support tourism	> Integrated scientific insight into current coastal management practices, planning processes, carrying capacities and user conflicts > Informed input to future government policy on licensing and regulation of the foreshore > Informed input to regional, local and area waterside planning > Heightened public awareness and understanding of coastal processes, environmental issues and use of the coastline for economic activities > Informed input to management of tourism enterprises, e.g. angling and beaches

continued

Table 4.1 Research Requirements & Key Outputs for the Marine Environment to 2013

Objectives 2013	RTDI Requirements	Key Outputs
5 Protect, maintain and, where necessary, enhance marine biodiversity.	> Enhance surveys and research on marine biodiversity, through the implementation of a prioritised programme of surveys, mapping and assessment of marine species and habitats > Develop a national marine biodiversity database > Develop conservation objectives and targets for marine SAC Management Plans > Produce conservation plans and define the status of threatened and vulnerable species and habitats.	> Marine aspects of the National Biodiversity Plan implemented > Marine biodiversity database available to all stakeholders > Conservation plans and objectives available for all marine SACs > Status of threatened and vulnerable species known and conservation plans in place
6 Integrate data sets, carry out assessments, improve data availability and apply this science-based knowledge in policy-making and ecosystem management. *(*See sections on Marine Technology and Knowledge & Information Management).*	> Publish regular State of the Marine Environment reports, incorporating a suite of standard environmental performance indicators > Establish integrated data management capabilities to extract greater value from routine monitoring activities > Apply new technologies to data management and data visualisation > Apply new analytical tools to marine environmental data	> Improved data accessibility and transparency > Improved data interpretation, resulting in better management advice > Ecosystem approach to management of marine resources adopted
7 Develop stronger national collaborations (e.g. between lead agencies and research performers) and improved capabilities, methodologies and technologies for marine environmental monitoring.	> Implement agreed marine monitoring programmes and co-ordinated surveys as part of a multi-agency plan for the marine environment > Develop a suite of environmental objectives, standards and indicators for use in marine environmental assessment and trend studies; including establishment and maintenance of long-term data sets > Improve methodologies for detection and quantification of priority contaminants in water, sediments and biota > Apply new technologies to marine environmental monitoring	> Regular reports on the state of the marine environment published, incorporating a suite of standard environmental performance indicators and key long-term environmental trends > Novel monitoring tools and sensors in use

4.1.6 RTDI Capacity/Capabilities

Marine environmental research draws on a wide range of disciplines within the research community and is carried out within the state, third-level and private sectors.

Current Research Capacity

Third-level Sector

Within the third-level sector, approximately 25 research groups carry out marine environmental research. Together, these research groups comprise approximately 160 researchers in marine environmental research (Table 4.2). The research focus of these groups/researchers covers a wide range of areas, reflecting the broad nature of the topic.

Table 4.2 Overview of Current Marine Environment Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
NUIG UCC UCD CIT DIT WIT TCD GMIT	10 Large Groups 8 Medium Groups 7 Small Groups	161	> Marine conservation, ecology, biodiversity and ecosystem functioning > Anthropogenic and natural processes controlling marine biodiversity > Water quality assessment and modelling > Molecular ecology > Seabirds and marine mammals > Sediment toxicity & eco-toxicology > Habitat mapping, deep ocean research > Near shore and oceanic modelling > Biological oceanography, bacterial community structure/biodiversity > Aerosol and cloud physics, surface ocean-atmosphere interactions > Management of fisheries resources > Remote sensing/optical properties of marine waters > Pollution and functioning of aquatic systems > Climate change - impact modelling, sea level rise, biodiversity > Sea level change. > Coastal management, remote sensing, geomorphology > Environmental and analytical chemistry > Endocrine Disrupting Compounds (EDCs) > Radiation biology and environmental toxicology > Wind/Wave/SST data analysis

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, a research group may focus on more than one theme and are larger than indicated here. The total number of researchers in the groups identified is approximately 250.

A further 30 groups are either a) involved in small-scale marine environmental research; b) currently applying their research skills/capabilities to niche areas of relevance to the marine environment; or c) have skills/technologies with potential applications to marine environmental research within the context of the identified RTDI requirements (Table 4.3). Many of these are in emerging areas such as advanced detection and analytical methods, environmental biotechnology and advanced sensor systems.

Table 4.3 Additional Marine Environment Research Capacity and Potential in the Third-level Sector

Institute	Research Focus	Institute	Research Focus
UCC	> New detection platforms, optical O_2 sensing and respirometry > Environmental toxicology > Wind/Wave/Sea surface temperature data analysis > Water quality monitoring technology > Coastal zone management	CIT	> Endocrine Disrupting Compounds (EDC) analysis > Bioassays for detection of EDCs > Water-borne pathogen analysis
NUIG	> CZM policy and legislation > Environmental legislation	UL	> Deployed sensors > Estuarine plant ecology
UCD	> Microbial water quality > Remote sensing and the measurement of optical properties of marine waters	IT Carlow	> Advanced analytical /surveillance technologies > Biosensors > Microbial metal resistance
TCD	> Water quality modelling, coastal design > Sensor nodes for water quality monitoring	Sligo IT	> Analytical chemistry > Marine, ecology, biology and biodiversity
DCU	> Environmental sensors, analytical chemistry > Digital Image Analysis-marine sediment profiling > Environmental monitoring and modelling > Environmental biotechnology	DIT	> Radiation biology and environmental toxicology (toxicity of sediments)
GMIT	> Climate change impacts on fish and invertebrate distribution and population dynamics	Athlone IT	> Ecotoxicological and cytoxicological assessment of xenobiotics > In vivo and in vitro assessment of EDCs
WIT	> Separation science > Estuarine research, bioremediation > Novel detection/analytical methodologies > Telemetry	Limerick IT	> Environmental sensing systems (petroleum hydrocarbons, EDCs)

State Sector

A number of state agencies and government departments are actively involved in marine environmental research and monitoring and have the capacity to contribute to the future RTDI requirements:

> Marine Institute staff (~ 20 staff) carry out research programmes that include both Irish and internationally funded research projects (e.g. habitat mapping and trophic status assessment methods), and partner third-level institutes in a number of NDP Marine RTDI-funded projects (e.g. HABS research).

> Department of Environment, Heritage & Local Government (National Parks & Wildlife Service) has research expertise in the area of marine biodiversity and conservation.

> Enterprise Ireland has expertise in the area of Integrated Coastal Zone Management.

> Staff in the Environmental Protection Agency (EPA) carry out monitoring work in estuarine and near shore waters.

> Met Éireann have research expertise in the fields of marine weather forecasting and modelling and climate change modelling.

> Radiological Protection Institute of Ireland (RPII) staff monitor and carry out research relating to radioactive substances in the marine environment.

In addition, staff in a number of coastal local authorities collaborate in research relating to coastal protection and ICZM.

Industry

A small number of marine environmental consultants (both companies and individuals) participate in nationally and internationally funded research programmes and have expertise in a number of areas that can be applied to the identified RTDI requirements. Areas of expertise within these companies include invasive species, biodiversity, environmental surveying and monitoring, taxonomy, water quality and inshore and offshore modelling.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 4.4. Also included in Table 4.4 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 4.4 Competencies Required to Meet Future Research & Innovation Requirements for the Marine Environment

Objectives 2013	Competencies Required	Assessment
1 Support the implementation, on a multi-agency basis, of environmental legislation.	> Environmental assessment	S
	> Risk assessment techniques and scenario modelling	G
	> Development/adaptation of sustainability, environmental and conservation targets and indicators	R
	> Design and implementation of monitoring programmes for activities and developments	R
	> Socio-economics (assessment of value)	G
2 Support the sustainable development of marine resources and sectors through: i) Establishment of a system of marine spatial planning; ii) Identification of environmental indicators and development of sectoral codes of practice; and iii) Measurement and mitigation of environmental impacts.	> Fundamental marine sciences	S
	> Marine spatial planning and ICZM	G
	> Data handling, analysis and management (including GIS)	R
	> Development of management systems/codes of practice	R
	> Carrying capacity models	G
	> Development/adaptation of sustainability, environmental and conservation targets and indicators	R
	> Ecosystem modelling	G
	> Remote monitoring and prediction of HABS	R
	> Assessment of fisheries-environment interactions	R
3 Enhance our understanding of marine and coastal ecosystems as a basis for environmental policy and sustainable resource management.	> Fundamental marine sciences	S
	> Physical modelling	R
	> Offshore and coastal dynamics and coastal processes	R
	> Development/adaptation of climate change indicators	R
4 Support environmental and resource management and protection strategies, which will underpin an expanding marine based tourism and leisure sector.	> Environmental assessment	S
	> Socio-economics (assessment of value)	G
	> Data handling, analysis and management (including GIS)	R
	> Carrying capacity models	G
	> Development/adaptation of sustainability, environmental and conservation targets and indicators	R
5 Protect, maintain and, where necessary, enhance marine biodiversity.	> Fundamental marine sciences	S
	> Habitat mapping	S
	> Species identification and taxonomic skills	G
	> Data handling, analysis and management	R
	> Development/adaptation of sustainability, environmental and conservation targets and indicators	R

continued

Table 4.4 Competencies Required to Meet Future Research & Innovation Requirements for the Marine Environment

Objectives 2013	Competencies Required	Assessment
6 Integrate data sets, carry out assessments, improve data availability and apply this science-based knowledge in policy-making and environmental management.	> Indicator-based environmental assessment > Data handling, analysis and management > Data visualisation	R R R
7 Develop stronger national collaborations and improved capabilities, methodologies and technologies for marine environmental monitoring.	> Development/adaptation of sustainability, environmental and conservation targets and indicators > Data handling and analysis > Advanced detection and analysis methodologies > Advanced monitoring technologies (e.g. deployed sensors)	R R R G

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

There is clearly a large body of researchers in all sectors (state, third-level and private) involved in many aspects of marine environmental research. However, much of the research effort is fragmented and although disciplines and skills may be present within research teams, they need to be targeted and applied to specific RTDI requirements in order to meet the overall objectives. Furthermore, a number of research groups within the third-level sector carry out research that, although not directly marine-related, has potential for application to the marine sector. This is particularly the case in emerging areas such as advanced detection and analytical methods, environmental biotechnology and advanced sensor systems. Coherent research programmes would provide the catalyst to orient the focus of many of these teams towards the RTDI requirements for the marine environment.

Gaps exist in areas such as ecological modelling, taxonomy, advanced monitoring technologies and the application of socio-economics to marine resources (including non-market value). Competencies exist in the areas of marine spatial planning and ICZM. However, the practical application of these tools is weak.

Current Strengths	Require Strengthening	Gaps
> Fundamental marine sciences > Habitat mapping > Environmental assessment	> Design and implementation of monitoring programmes for activities and developments > Data handling, analysis, management and visualisation (including GIS) > Development of management systems/codes of practice > Indicator-based environmental assessment > Development/adaptation of sustainability, environmental and conservation targets and indicators > Development/adaptation of climate change indicators > Remote monitoring and prediction of HABS > Assessment of fisheries-environment interactions > Physical modelling > Offshore and coastal dynamics and coastal processes > Advanced detection and analysis methodologies	> Marine spatial planning and ICZM > Carrying capacity models > Ecosystem modelling > Species identification and taxonomic skills > Advanced monitoring technologies (e.g. deployed sensors) > Socio-economics (assessment of value) > Scenario modelling

Figure 4.1 Research Competencies Required to Meet 2013 Objectives for Marine Environment

4.1.7 Prerequisites for Achieving Objectives

There a number of prerequisites for the successful delivery of the 2013 Objectives for the marine environment research programme:

> A National Marine Policy, aligned to and consistent with EU Marine Policy, together with a coherent set of sectoral policies that recognize the critical role played by the marine and coastal environment;

> Adoption of marine spatial planning tools, building on the available legislative systems;

> Implementation of an agreed national, multi-agency, marine environmental monitoring programme and marine spatial planning;

> Stakeholder and public awareness, understanding and appreciation of the intrinsic value of the marine and coastal environment;

> A new generation of marine scientists and engineers supported by appropriate training programmes and career structures; and

> Availability of state-of-the-art platforms, equipment/instrumentation and laboratory infrastructure, e.g. sensors and telemetry systems.

4.2 Knowledge & Information Management Research Programme

4.2.1 Introduction

The transformation of data into information and then on into knowledge is a process that we must manage effectively to ensure that maximum value is gained from research investment. In this document we use the term 'Knowledge and Information Management' to describe those activities that make this transformation process possible.

In order to achieve this transformation, the many sources of data must be linked physically and by a common language, so that information becomes readily accessible. Once this is done, computation resources, analytical tools and human expertise can be applied to create knowledge products for use by a wide range of interests.

Many organisations are actively involved in the collection of marine data. In the past, the approach taken internationally has been to archive copies of data in marine data centres. These centres then took responsibility for reporting to organisations such as the International Council for the Exploration of the Seas (ICES). Recent advances in communications technology, together with issues relating to the currency of data, the duplication of archives and funding, have led to the emergence of a more distributed approach to information management. This sees individual organisations maintaining data that they have collected and making it accessible on-line or off-line through on-line data catalogues. This change in practice in relation to the management of data makes achievable the goal of having readily available knowledge products, irrespective of where the users, or the data sources used to create the products, are located.

The challenge that now faces Ireland is the establishment of effective mechanisms to allow for ease in the discovery of, and access to, data. To meet this challenge, there is a national need for investment; development of policies; and the co-ordination of expertise, data and technologies.

4.2.2 Current Status

There are a number of distinct data holdings that collectively represent the national marine data asset. A number of ongoing research, monitoring and management programmes highlight the need for the management and co-ordination of these data sets. The relevant organisations, programmes and data sets are summarised in Tables 4.5 and 4.6.

Efforts to integrate data holdings have only started recently, with inter-agency projects such as the Marine Data Exchange project, this is being conducted by the Marine Institute with the GSI, the EPA and UCC participating as project partners. The project is linking the spatial data catalogues in each organisation in order to move toward a national Marine Data Exchange Service. At the same time, the Ordinance Survey of Ireland (OSI) are conducting a pilot project to establish a national spatial data catalogue.

Table 4.5 Irish Organisations with Significant Marine Data Holdings

Department of Communications, Marine and Natural Resources (DCMNR) DCMNR is the central government department with responsibility for the Marine. It is responsible for regulatory enforcement and licensing of commercial marine activities and holds data on, for example, fish landings, aquaculture licenses and foreshore leases and licenses. Much of the monitoring work carried out by the MI is on behalf of DCMNR. Data is submitted to the EU.
Petroleum Affairs Division (PAD) PAD is a line division of DCMNR and its remit is to license private enterprise to conduct petroleum and hydrocarbon exploration and production (E&P). An online inventory containing information on hydrocarbon exploration and development data from offshore Ireland, as well as summary information on individual wells and surveys, is operated by PAD. It is available from www.informatic.ie/paddi.
Geological Survey of Ireland (GSI) The GSI is the National Earth Science Agency. The GSI produce a range of products including maps, reports and databases and acts as the knowledge centre and project partner in all aspects of Irish geology. The GSI works in collaboration with the Marine Institute in the Irish National Seabed Survey programme and manages the data produced by that programme.
An Bord Iascaigh Mhara (BIM) BIM collects data relating to commercial fisheries and aquaculture. This includes economic data relating to marine activities. Data is exchanged with central government, ICES, the EU and other assessment bodies.
Marine Institute (MI) The Institute carries out a variety of monitoring and research programmes, including operation of the national weather buoy network, management of two national research vessels, nutrient monitoring, biotoxin monitoring, contaminants monitoring, fisheries stock assessment, sea lice monitoring, and salmon tagging. Data is submitted to national and international organisations. An online inventory of marine data sets and projects is available from www.marinedataonline.ie.
The Environmental Protection Agency (EPA) The EPA participates in the National Marine Monitoring Programme and has responsibility for implementation of the Water Framework Directive, including assessment of transitional waters.
National Parks and Wildlife Service (NPWS) The NPWS (Department of the Environment, Heritage and Local Government – DoEHLG) conduct and commission surveys of marine habitats and species in support of its remit to designate and manage conservation sites (NHAs, SACs and SPAs).
Third-level Sector A number of Irish universities and Institutes of Technology participate in a range of research programmes at national and international level. The data produced by these programmes is managed on an ad-hoc basis and is not reported or retained centrally.
Radiological Protection Institute of Ireland (RPII) RPII have a marine monitoring programme in place since the early 1980s. It involves the routine sampling and testing for radioactivity in fish, shellfish, seaweed, sediments and seawater. Both DCMNR and MI staff are also involved in this work. Sampling data is available from their website (www.rpii.ie) and results are published.

Within the Third-level and public sectors, Grid consortia provide research organisations with access to data and appropriate computational resources across the country. The National Centre for High-end Computing has recently been established, with the support of Science Foundation Ireland (SFI), to provide a national High-End Computing (HEC) resource. Within the HEC research community, the marine domain is increasingly regarded as providing large-scale civilian computational problems for investigation.

Increasingly, geo-spatial technologies are being applied to the marine area. The Marine Institute has developed a Marine Data Warehouse based on the internationally developed Marine Data Model. This model provides a geo-referenced schema for all marine related data. Nationally, SFI have established the National Centre for Geo-computation as a centre of excellence at NUI Maynooth.

Table 4.6 Programmes Driving the Management and Co-ordination of Marine Data

E-Government Services Programme (DCMNR) The E-Government Services Programme, being conducted by the Department of Communications, Marine and Natural Resources, is streamlining the process of conducting business in the marine sector. Through a range of projects, including the Integrated Fisheries Information System (IFIS), DCMNR are providing customer services to stakeholders, reducing lead times and simplifying processes.
Ocean Explorer Programme (Marine Institute) Through its Ocean Explorer Programme, funded by the Information Society Fund, the Marine Institute has been delivering a number of services including a metadata catalogue to provide an inventory of research data, projects, and collaborators; a data repository of oceanographic and related marine information; and a set of on-line services that provide discovery tools, simple analysis and data delivery.
EU Data Collection Regulation (ICES/DCMNR/MI/BIM/Industry) The EU Data Collection Regulation (1543/2000), introduced by DG Fisheries, is driving the standardisation and co-ordination of fisheries stock assessment data. The Directive covers a range of parameters, including stock data, discard data and socio-economic data. The Marine Institute co-ordinates Irish reporting activities on behalf of DCMNR.
Water Framework Directive & The National Marine Monitoring Programme (DoEHLG/EPA/MI) The Water Framework Directive, currently in a data-gathering phase, is establishing baseline data sets for the future monitoring of water quality in Irish rivers, lakes, estuaries and coastal areas. The EPA estimates that some thirty-six monitoring programmes will be required, with participation from five state agencies and local authorities.
The Irish National Seabed Survey (GSI/MI) The Irish National Seabed Survey, being led by the Geological Survey of Ireland (GSI) in partnership with the Marine Institute, has completed Phase 1 of operations. This five-year programme (outlined in the Seabed & Resource Mapping section) has generated a very large core data set, together with a number of ancillary data sets. These are being managed principally by the GSI, with support from the Marine institute and the third-level sector.
The Irish Spatial Data Infrastructure The Irish Spatial Data Infrastructure (ISDI) is an initiative being led by the Department of the Environment, Heritage and Local Government. The ISDI is developing a national strategy for the management of data of all types with a spatial component.
The Information Society (Department of An Taoiseach) The Information Society agenda is promoting the use of ICT to enable the provision of government services. The development of public service information infrastructures, such as the Public Services Broker (Reach Agency), is providing focal points for data integration activities.
INSPIRE (INfrastructure for SPatial InfoRmation in Europe) This EU programme is endeavouring to make more and better spatial data, including marine related data, available for Community policy making and implementation in Member States at all levels. It focuses particularly on information needed to monitor and improve the state of the environment. The proposed approach to implementation (2009–2013) is based on infrastructures for spatial information established and operated by the Member States. Within Ireland, the ISDI project will develop this infrastructure.

4.2.3 Key Opportunities and Challenges

How can Knowledge products enable decision support?

The provision of decision support systems will be a key deliverable in the establishment of a knowledge management infrastructure. Such systems will underpin the assessment and management of marine resources and activities. For example, within fisheries management the approach has changed from consideration of a single species, e.g. cod stocks in the Irish Sea, to the so-called 'ecosystems approach' where the interaction between multiple species and habitats is considered. This approach aims to achieve sustainable development by assessing interactions and cumulative effects of specific actions, with a view to maintaining fully functional ecosystems. The key to this approach is the ability to turn disparate data sources into the information and knowledge required to support effective management decisions. It requires data from a wide spectrum of disciplines, themes and organisations to be packaged, structured and made accessible to support integrated analysis.

In order to provide this, a number of technology strands will have to be brought together, namely:

> Data Discovery and Retrieval Tools—allowing data in diverse organisations to be searched and brought together as required;

> Data Mining and Warehousing Tools—allowing specific data patterns to be searched for, and discreet sets of data from multiple sources to be queried together; and

> Visualisation Tools—allowing users view the data interactively, in both a spatial context and a modelled representation.

How best can the management of Marine Data be co-ordinated?

Given the dispersed nature of marine-related data, how best can activities taking place in public bodies, central government, private companies and third-level research institutes be co-ordinated? Mechanisms for identifying opportunities to re-use data collected elsewhere and sharing of technical resources will need to be identified. Technical issues to be addressed include publicising data already available, agreement on standards for data exchange, and approaches to maintaining historical archives.

What new technologies provide opportunities for Knowledge Management?

Because of parallel developments in other sectors, Ireland is likely to be well positioned to take advantage of a number of emerging technologies that can be applied to evolving research opportunities in the marine sector. An example is High-end Computing (HEC) centres. Given the very large volumes of data arising from marine research streams and sensors, including satellite and aerial remote sensing, the development of mechanisms to process and turn this data into knowledge in real- or near-real time will be of great importance to research programmes in the marine sector.

What new research opportunities will require a Knowledge Management infrastructure?

A number of emerging research opportunities (outlined in more detail in other parts of this document) will drive the requirement for significant knowledge management strategies in their own right. Proposed research in the following areas is likely to lead to the generation of large data sets requiring the use of new technologies as already discussed. Examples of such areas are:

> Biotechnology/Biodiscovery

> Seabed & Resource Mapping

> Cabled Underwater Networks

> Ocean Circulation and Climate Change Modelling

What legislative and policy initiatives will drive improved Knowledge products?
New approaches to data management, at national and international levels, are evolving through recognition of the need to reduce data duplication, improve efficiencies and increase return on investments made in data collection. The EU Directives on Re-use of Public Sector Information and INSPIRE (see Table 4.6) are two such approaches. Within this context, spatial information is seen as having particular advantages, given the potential to use it as a base for integration across a variety of disciplines.

4.2.4 2020 Vision

2020 VISION

By 2020, Ireland will be a leader in scientific knowledge management with information on Ireland's marine resources effectively managed, easily accessible and routinely used to support national and international policy and management decisions.

4.2.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Develop a National Coastal and Marine Information Service, in order to:
   > Deliver key demand-driven information services targeted to the specific needs of stakeholders and sectoral groups;
   > Provide data and information for policy development and regulatory activities;
   > Develop the capacity and expertise required to integrate data and information in order to improve the quality of scientific advice;
   > Provide a single mechanism for capturing and reporting on the availability of marine data holdings; and
   > Ensure that relevant data generated by research projects is passed, where appropriate, into use in monitoring and management programmes.

2 Promote an effective marine knowledge infrastructure and policy at a national level.

3 Identify and develop emerging technologies that will support knowledge and information management objectives in the marine sector.

4 Establish data management standards for new national strategic research programmes.

5 Ensure a high profile for marine data sets when data and information policy and legislation are being framed at national and international levels.

4.2.6 RTDI Requirements/Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 4.7 Research Requirements & Key Outputs Related to Knowledge and Information Management to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Develop a National Coastal & Marine Information Service in order to: > Deliver key demand-driven Information Services targeted to the specific needs of stakeholders and sectoral groups; > Provide data and information for policy development and regulatory activities; > Develop the capacity and expertise required to integrate data and information in order to improve the quality of scientific advice; > Provide a single mechanism for capturing and reporting on the availability of marine data holdings; and > Ensure that data generated by research projects is passed, where appropriate, into use in monitoring and management programmes.	Integrated Data Management Programmes that focus on the development of frameworks for the integration of data from multiple sources—areas to be addressed include diverse data types, varying spatial resolutions, varying temporal resolutions, currency, archival, large volumes, semantics & ontologies Data Discovery Programmes for the selection of appropriate standards, identification of technical approaches, and the selection of appropriate protocols Data Exchange Programmes to develop methodologies for the exchange of marine data between multiple organisations leveraging on existing programmes and mechanisms such as the REACH public service broker Geo-spatial Analysis Research programmes are required in the areas of hydrography, catchment management, local and global climate change, habitat modelling, and security & threat management	> New inter-agency information services that target the needs of specific stakeholders and are linked in a single information portal > Data and information on Ireland's marine resources, managed by a diverse range of organisations, is easily accessible by all stakeholders > Improved quality of information delivered in support of policy development, including relevant archives of marine data being made accessible to support improved service delivery and generation of value-added products > Data collected under national research and monitoring programmes is documented, with descriptive metadata, and made available via the Coastal & Marine Information Service > Data resulting from research programmes is integrated with data from routine monitoring programmes to support generation of value-added products and services
2 Promote an effective marine knowledge infrastructure and policy at a national level.	Policies and Best Practice: Programmes to respond to the rapid pace of change in the areas of data capture, dissemination and distribution are needed. A national review of policies and best practices in these areas is required. Such research will underpin the delivery of new data centred services and products and resolve issues such as IPR	> The need for national standards to support the management and dissemination of marine data is supported by all relevant organisations/bodies > A policy clarifying the rights and responsibilities relating to ownership, custody and distribution of national marine data sets is in place

continued

Table 4.7 Research Requirements & Key Outputs Related to Knowledge and Information Management to 2013

Objectives 2013	RTDI Requirements	Key Outputs
3 Identify and develop emerging technologies that can support knowledge and information management objectives in the marine sector.	**Data Mining** Programmes will assess how the practice of automatically searching large stores of data for patterns can be applied to environmental and physical data **Data Visualisation** Research areas that need investigation include 3D visualisation, sampling of large-scale data sets to allow timely rendering, firmware and hardware, and processing of algorithms for data transformation and display **Bioinformatics** Research programmes will support investigations in the areas of biotechnology and biodiscovery. These will investigate how best to provide information systems for such areas where large amounts of data are processed in an iterative fashion **High-end Computing** Investigate the use of techniques for parallel problem solving, coupled with computers operating at, or near, the current highest operational rate possible. This includes the areas of High Performance Computing and Grid Computing	> Increased capacity to analyse large data volumes, through use of high-performance computing facilities and improved quality of information services > Improved ability to model and describe data relating to the 3-dimensional marine environment > Enhanced interfaces are available to support visualisation and interpretation of complex marine data sets by researchers, legislators and policy makers > Improved dissemination tools are available to support delivery of information needed by researchers, legislators and policy makers
4 Establish data management standards for new national strategic research programmes.	**Data Discovery** **Data Exchange** **Integrated Data Management** **Policies and Best Practice**	> Assessments completed to determine the scale and scope of the data resource to be managed and the associated costs and benefits > National standards agreed for marine data storage and archiving. > National standards agreed for marine metadata, data exchange and discovery > Research data is collected to common standards, facilitating integration with operational programmes > Marine data is accessible and more readily available for access and exchange between stakeholders
5 Ensure a high profile for marine data sets when data and information policy and legislation are being framed at national and international levels.	**Policies and Best Practice**	> Approaches and mechanisms for implementation of the INSPIRE Directive in relation to the marine sector have been established and agreed > Mechanisms for the inclusion of marine data within the national Irish Spatial Data Infrastructure have been agreed and are operational

4.2.7 RTDI Capacity/Capabilities

Current Research Capacity

Third-level Sector

In the third-level sector, two research groups are currently directly involved in marine-related knowledge and information management research. Together, these groups comprise approximately 10 researchers in marine knowledge and information management research (Table 4.8). Although many other marine research groups manage data generated through research projects, they are considered as IT users rather than innovators.

Table 4.8 Overview of Current Marine Knowledge & Information Management Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
UCC NUIG	2 Large Groups	10	> GIS > Modelling > Data management > Data visualisation

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 50.

In addition, a large number of research teams throughout the third-level sector have expertise/technologies in the broader field of knowledge and information management. A recent on-line survey of IT departments in the third-level sector identified 13 research groups, comprising over 100 researchers, with potential to contribute to the identified RTDI requirements (Table 4.9).

Table 4.9 Research Focus of Third-level Institutes with Potential to Contribute to Marine Knowledge and Information Management Research

Institute	Research Focus	Institute	Research Focus
UCC	> Integrated Data Management > Data Discovery > *Data Mining* > *Data Exchange* > *Marine Data Archival* > *Policies & Best Practice* > *Geo-spatial Analysis* > *Data Visualisation*	NUIM	> Geo-spatial Analysis > Bioinformatics > (Data Mining) > (Data Visualisation) > (High-end Computing) > (Data Discovery)
Letterkenny IT	> Geo-spatial Analysis > *Data Discovery* > *Integrated Data Management* > *Data Visualisation*	NUIG	> Data Exchange > High-end Computing > (Integrated Data Management) > (Data Visualisation) > (Data Mining) > (Marine Data Archival) > (Bioinformatics) > (Data Discovery) > (Policies & Best Practice)

continued

Table 4.9 Research Focus of Third-level Institutes with Potential to Contribute to Marine Knowledge and Information Management Research

Institute	Research Focus	Institute	Research Focus
TCD	> Data Visualisation > *Geo Spatial Analysis*	IT Tralee	> Radio Frequency Systems & Traceability
IT Sligo	> Data Visualisation > *Data Mining*	DIT	> Spatial Data > Interactive Digital Media
DCU	> Computational Modelling > Statistical Modelling Applications		

Note: (Topics in italics indicate secondary research focus or expertise). **N.B.** This is a non-exhaustive list. Other groups/institutes may have similar/additional skills/technologies.

State Sector

Where research and innovation capacity is required, state agencies normally utilise capacity that exists within the third-level sector. Direct research and innovation capacity in the state sector is normally the result of specialised requirements arising from operational programmes. Instances of such expertise in the marine area include:

> The Geological Survey of Ireland—specialist knowledge in the field of dense data management and interpretation has been built up from the Irish National Seabed Survey.

> The Marine Institute—research and innovative approaches have been taken in examining the issues surrounding data management, data exchange, geo-spatial analysis and marine related data modelling as a result of the Ocean Explorer programme funded by the Information Society.

> The Environmental Protection Agency—requirements from programmes such as the Water Framework Directive are driving research. The EPA conducts such research in conjunction with research performers through the Environmental Research, Technological Development and Innovation (ERTDI) programme of the NDP.

Industry

A small number of private companies and individuals offer marine IT-related services and are involved in nationally and EU funded research programmes. Areas of expertise within these companies include data management, GIS and data visualisation.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 4.10. Also included in Table 4.10 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community; both in a general sense and, more specifically, in the marine field.

Table 4.10 Competencies Required to Meet Future Research & Innovation Requirements Related to Knowledge & Information Management

Objectives 2013	Competencies Required	Assessment General	Assessment Marine
1 Develop a National Coastal & Marine Information Service in order to: > Deliver key demand-driven Information Services targeted to the specific needs of stakeholders and sectoral groups; > Provide data and information for policy development and regulatory activities; > Develop the capacity and expertise required to integrate data and information in order to improve the quality of scientific advice; > Provide a single mechanism for capturing and reporting on the availability of marine data holdings; and > Ensure that relevant data generated by research projects is passed, where appropriate, into use in monitoring and management programmes.	> Data discovery > Data exchange > Integrated data management > Geo-spatial analysis	R S R S	R R G R
2 Promote an effective marine knowledge infrastructure and policy at a national level.	> Data discovery > Integrated data management > Policies and best practice	R R G	R G G
3 Identify and develop emerging technologies that can support knowledge and information management objectives in the marine sector.	> Data mining > Geo-spatial analysis > Data visualisation > Bioinformatics > High-end computing	S S S R R	R R G R R
4 Establish data management standards for new national strategic research programmes.	> Data discovery > Data exchange > Integrated data management > Policies and best practice	R S R G	R R G G
5 Ensure a high profile for marine data sets when data and information policy and legislation are being framed at national and international levels.	> Data discovery > Data exchange > Policies and best practice	R S G	R R G

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

Although general strengths exist nationally in relation to many of the competencies outlined in Table 4.10, the application of these skills to marine issues is vital for meeting the 2013 Objectives. Important areas in which gaps exist include integrated data management and policies and best practice (Figure 4.2). Areas that require strengthening include high-end computing, data exchange and data mining. Building competencies in these areas is vital for the successful delivery of many of the research programmes within the Industry, Discovery and Policy Support Measures.

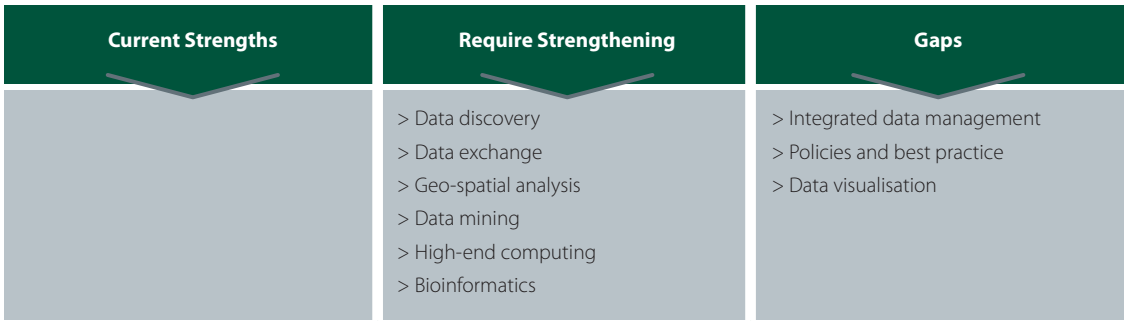


Figure 4.2 Research Competencies Required to Meet 2013 Objectives for Knowledge & Information Management

4.2.8 Prerequisites for Achieving Objectives

> Stakeholder Co-ordination

A National Stakeholder Group to co-ordinate marine data management activities is required. Without such a group there is likely to be a fragmented approach to data management, resulting in a lack of data integration.

> High-end Computing Facilities

Given the volumes of data, and the nature of some of the problems to be analysed (including, but not limited to bioinformatics, climate change models and pollution prediction models), large computational resources will be required. These are discussed in detail in the Infrastructure Supporting Programme section of this document.

Computational resources will require intellectual capacity to support its use by research teams. In effect, this means that there is a need for centres of expertise in particular scientific domains with the capacity to utilise High-end Computing facilities. These centres of expertise will work with individual research teams seeking to model particular problems.

> Policies and Best Practice

Given the rapidity of change in the area of data capture, management and distribution, a review of policies and best practice in the areas of data management, dissemination and use are required. This is needed to underpin the delivery of new data services and resolve issues such as intellectual property rights.

4.3 Policy, Socio-Economic & Legal Research Programme

4.3.1 Introduction

The marine sector has received increasing policy attention in recent years. Its development as an economically active[34], commercially viable, and environmentally and socially sustainable sector is in keeping with some of the most important objectives of European and Irish economic (competitiveness and growth), social (social inclusion and cultural diversity) and environmental (biodiversity and sustainability) policies.

Consequently, it is essential that the outputs from research and innovation in the marine sector support policy development that is, in turn, underpinned by an appropriate legislative and regulatory framework. This framework should be based on the best available socio-economic data and analysis. The dynamic nature of the marine sector means that it is essential to keep developments in the sector under constant review.

4.3.2 Key Opportunities and Challenges

Competitiveness and Moving up the Value Chain

The competitive economic climate has resulted in many industries in the marine sector coming under severe economic and commercial pressure in recent years, e.g. aquaculture, fish processing and water-based tourism. A better understanding of these pressures has implications for the regional distribution of economic activity in Ireland and the overall competitiveness of the economy.[35] In addition, many of the weaknesses that exist, particularly in the traditional or the more mature sub-sectors associated with the marine, can be attributed to poor business models. This includes issues such as the absence of effective organisation structures, integration of business along the supply chain, lack of appropriate economies of scale, lack of competitive market structures, lack of investment in R&D by firms, and the absence of linkages with the third-level sector. These issues require further research.

Non-market Values

There are important non-market benefits (e.g. quality of life, assimilative capacity, etc) associated with many marine resources. However, the techniques and data to estimate the value (or replacement value) of these resources are not sufficiently developed in Ireland to enable any proper quantitative economic assessment to be made of them. Future European regulatory intervention in the marine sector is likely to

[34] 'Economic 'is used in the sense of 'public' and 'private' goods, as well as 'market' and 'non-market' values.

[35] The following example from the marine sector illustrates the complexity of achieving sustainable and economically viable communities. The objective of achieving greater cost-efficiency and competitiveness requires greater scale in the fish-processing sector. However, this strategy may conflict with the desire to sustain employment in culturally and socially 'rich' coastal communities.

focus strongly on the protection of non-market values and may result in spatial planning along similar lines to that for the landmass. This trend has already started with the application of water management units to coastal areas, under the Water Framework Directive, and recent development of marine protected areas. In this context, heightening the awareness of the non-market values of the sea and demonstrating the true value of the marine resource beyond its capacity to deliver goods and services are challenges for the future.

Sustainable Commercialisation

The development of the marine sector must be understood within the context of its overall value as a public natural resource/asset. In this context, it is important to identify those situations where clear market imperfections exist and where social returns exceed those to private investors. The optimisation of social returns requires that:

> the resource base is fully understood and 'valued' in terms of its biodiversity, quality and contribution to unique socio-cultural communities; and

> enhanced marine monitoring systems be incorporated into marine management and policy advice.

As a result, the cost of protecting the marine resource can be more easily quantified, appropriate legislation more easily drafted and effective policy regimes more easily implemented.

Social and Cultural Capital

The marine sector has important regional socio-economic impacts. Fifty-six percent of employment and 'value-created' by the sector is located outside the most developed regions of the country. The contribution of the marine resource is strongest in what are otherwise lagging regions. Stronger multiplier effects (employment and value-added) apply for the sector in these regions. The marine sector is, therefore, of particular importance to achieving a better regional balance. Coastal communities on the west coast present significant challenges in terms of achieving a better regional dispersion of activity. Communities require a certain scale of economic activity in order to retain essential services and sustain essential physical and social infrastructure (i.e. stock and networks of leaders, risk-takers and entrepreneurs, and their formal and informal communication and support networks). The loss of either form of infrastructure inhibits the remaining activity and undermines competitive activity, which, in turn, leads to further decline. In this way, communities are weakened as the workforce moves out to seek opportunities and employment. Those who move are usually most centrally involved in maintaining the social infrastructure and are an essential factor in driving recovery.

For these reasons, recovery depends on more that just reinstating the numbers of those economically active in an area. The social infrastructure, in the form of social networks and their cultural dynamics, also has to be re-instated. Consequently, the costs associated with regeneration are greater that the costs of maintaining the community in the first instance. Standard models of economic development tend to underestimate the costs of losing economic activity. They fail to recognise that the value of economic activity in an area in danger of undergoing decline is not captured by the commonly used metrics of output, incomes and employment, which use average conditions in the national economy. Communities can be maintained in more cost-effective ways when the activities pursued are well integrated with the local economy. Thus, the development and enhancement of marine-related activities in coastal communities should be given priority. Research is required to identify the most culturally compatible and appropriate methodologies for the valuation of cultural diversity.

Greater Integration with Social Sciences

Since public welfare and the public interest often exceed private welfare and interest, public goods, such as environmental, social and cultural capital, are often central to public debate. Consequently, a well-informed debate on these questions is needed so that public welfare and social cohesion are maximised. In addition to the contribution of the public to such debates, the knowledge and insights of lawyers, economists, and political and social scientists are required. They help to identify and quantify many public goods associated with the marine. Their contribution, and that of the public, will best ensure the full understanding of the resource base; including its inextricable association with the unique socio-cultural communities that depend on it.

A key issue for Ireland's marine development is the low profile of the culture of the sea and the absence of a policy culture that promotes the sea. In order to advance and enhance a culture of the sea and a culture of marine policy, and to increase awareness of the culture of marine-dependent communities, research in the social sciences field is required.

Governance, Legislation and a Commercial Ethos in the Public Service

One of the priorities for marine research and innovation is to support the role of government by bringing forward sound research and scientific advice to meet international, national and regional commitments, and to provide evidence and an analytical framework for policy choices. In addition, an active programme of policy research would provide opportunities for Ireland to shape future developments, in order to ensure that an appropriate governance and regulatory framework evolves to support innovation. It is widely recognised that such an approach is needed in Europe to support the growth of the knowledge economy. The overall requirement for research activities in this area should be to establish a knowledge base for efficient and responsive regulation and policy development.

The innovation-supporting reform of governance requires new fora for public consultation and discussion about major innovations and the direction of technological change[36]. Achieving greater competitiveness requires the transformation of knowledge-creation and information management into tangible products and legislation and regulation and policy that is more appropriate. Since the public sector is a major player in these areas, a significant re-configuration towards a more customer-driven and market-conscious ethos and practice is required.

Specific consideration needs to be given to Ireland's participation in the work of international organisations (ICES, OSPAR and UNESCO's advisory body on the law of marine scientific research) and the fact that we have yet to implement the 1982 United Nations Law of the Sea Convention and several other international agreements. Within national legislation and regulation, there is a need to research the law and policy underpinning:

> Marine spatial planning;

> Integrated coastal zone and ocean management;

> Foreshore use; and

> Research, enterprise, and the commercial development of the marine sector.

[36] These may include consensus conferences and foresight programmes.

Integration of Irish Marine Policy with European/International Policy

Ireland's marine law and policy reflects developments within these areas in the European Union (e.g. the Common Fishery Policy). In many cases, national legislation responds to developments in European law, e.g. in relation to sustainable development, food safety and navigational safety. Consequently, there is a need to regularly review developments in European and international law and provide advice on the implementation of European Community policies in Ireland, including:

> Proposed European Marine Strategy Directive

> Common Fisheries Policy

> EU Maritime Policy

> Energy Policy

> Maritime Transport Policy.

4.3.3 2020 Vision

2020 VISION

By 2020, there will be a much greater national awareness of both the market and non-market value of the marine resource. Greater synergies among the productive sectors utilising the resource will exist. This will result in an increased overall contribution of marine resources to Irish regional, social and economic development.

The outputs of marine related research and innovation will be employed to deliver on the broader social, environmental and public policy requirements that are unique to the marine area. Marine research will support and inform policy development, and, in turn, an appropriate legislative and regulatory framework will underpin new policy.

4.3.4 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013.

2013 OBJECTIVES

1 Achieve an understanding of issues relating to the competitiveness of the Irish marine sector.

2 Ensure the availability of high quality socio-economic data for all marine sectors through collaboration with the relevant data collection agencies.

3 Develop an understanding of the changing skills and labour and supply and demands needs of the sector.

4 Develop/adapt techniques that will allow the identification and, where possible, quantification of the non-market benefits associated with marine resources.

5 Promote an awareness of these non-market benefits and incorporate understanding of them into future policies for the development of the sector.

6 Establish a knowledge base for efficient and responsive regulation and policy development.

7 Achieve a balance between regulation and development policies in order to maximise sustainable economic development.

8 Develop a better understanding of the culture of marine-dependent communities.

4.3.5 Key Research Programme Outputs

The key outputs from a Policy, Socio-Economic and Legal Research Programme are:

> A definition of the factors that determine the marine sectors competitiveness;

> High quality marine related socio-economic data;

> Techniques to identify and quantify non-market benefits of Ireland's marine sector; and

> A knowledge base that supports policy development.

4.3.6 RTDI Capacity/Capability

The government, and in particular DCMNR, has a central role in the definition, formation and implementation of marine legislation, regulation and policy to underpin the sustainable development of the marine sector. It is supported by independent research agencies and the third-level sector. These include the Marine Institute, the Economic and Social Research Institute (ESRI), the Marine Law and Ocean Policy Centre (NUI-Galway) and the Policy Centre (TCD); as well as other institutions and consultants.

5 Infrastructure Supporting Programme (2007-2013)

The Infrastructure Supporting Programme identifies the need for specific priority marine infrastructures to enable the delivery of the objectives of the research programmes outlined in the Marine Knowledge, Research and Innovation Strategy for Ireland 2007–2013. The following specialist marine research infrastructures have been identified:

Introduction

Research infrastructures are specialist facilities and/or resources that provide essential services to research communities in the public, academic and private sectors for basic and applied research. Examples include research vessels, instrumentation and sampling equipment, libraries, databases, *in-situ* and mobile observation systems, high capacity and high-speed communications networks, and high-level computing facilities. They may be 'single-sited', 'distributed' or 'virtual'. Research infrastructures are essential tools for the development of leading-edge research in scientific and technological fields. They can foster new science and partnerships and have a significant economic, social and environmental impact. In essence, they are the essential tools without which science cannot progress.

Over the last decade, Ireland has made very significant strides in closing an historic marine research infrastructure deficit. The provision of a multi-disciplinary research vessel fleet, the establishment of the National Ocean Data Buoy and preliminary tide gauge networks, and the initiation of a National Seabed Survey have greatly benefited Irish marine science. They have facilitated the development of new knowledge-based niche products and services, contributed to a better understanding of the Irish marine environment, and enabled stronger engagement in international research and development programmes.

To further progress and address the opportunities and challenges identified in the period 2007–2013 under the Marine Knowledge, Research & Innovation Strategy for Ireland a suite of specialised research infrastructures has been identified (Table 5.1). These are specifically linked to the priorities set out in the Strategy under the three research measures. The availability of, and access to, these specialist marine infrastructures will position Irish science and industry at the cutting-edge in marine science, technology and industrial development. In pursuing the ambitious objectives of this Strategy there will be a critical need for specialist laboratory infrastructure and facilities.

Table 5.1 Marine R&D Infrastructure Requirements 2007–2013

Infrastructure Requirements 2007–2013	Industry Research Measure	Discovery Research Measure	Policy Support Research Measure
Seabed & Resource Mapping	***	***	***
High-End Computing Capacity (Access)	**	***	**
Test & Demonstration Facilities for Marine & Coastal Observatories and Monitoring Technologies	**	***	**
Deep Sea Observatory	*	**	**
Robotic Platforms	**	***	**
Extension of Ocean & Coastal Monitoring Network	***	*	***
Research Vessel – Ship Time	***	**	***
National Equipment Pool	*	*	***
Test Facilities for Offshore Energy	n/a	***	*
Specialist Laboratories & Facilities	***	***	***

*** Critical ** Very important * Relevant

This infrastructure will provide essential support in areas where: (a) there are real opportunities for scientific and commercial development; and (b) there is already an existing core of Irish expertise (e.g. microelectronics, marine science, information & communications technologies, biotechnology and environmental sensors). It will also further advance Ireland's marine research and innovation capabilities, particularly in the areas of marine sensor development, marine biotechnology, ocean energy and marine environmental management. Finally it will facilitate Irish researchers and industry to participate in international research and development programmes and develop new knowledge-based marine products and services.

5.1 Seabed & Resource Mapping

The requirements for future seabed and resource mapping were considered by a foresight panel convened as part of the National Marine Foresight Exercise (see Appendix A & B). Consequently, as with the research programmes in the Industry and Discovery Research Measures, a 2020 Vision, 2013 Objectives, RTDI Requirements and Outputs have been defined for Seabed & Resource Mapping. The principal outputs (e.g. data and data outputs) from a seabed & resource mapping programme (defined below) will contribute significantly to the infrastructure needs of the marine sector.

5.1.1 Introduction

Ireland's seabed area is 10 times its land area and although significant resources are known to exist in, on, and over this seabed area, these resources and the morphology of the seabed itself have not been completely assessed and mapped. Considering the current and increasing number of legislative requirements and obligations across state and semi-state sectors, and the need to further encourage groundbreaking research and innovation, integrated mapping of the seabed under a cohesive national strategy and management approach is crucial. Such mapping will greatly assist in the management and sustainable utilisation of our marine resources.

Over the period 2000–2006, Ireland has developed a world-leading reputation for seabed mapping, including methodologies, human capacity, know-how and physical infrastructure. This has been accomplished through the successful implementation of the Irish National Seabed Survey (INSS), which has already mapped 87% of the Irish continental marine area, producing over 300 paper-based charts and a total of 5.5Tb of digital information stored on the INSS database.

Consistent with the national goal of developing a knowledge-based economy driven by a world-class reputation for research and innovation, the INSS database and associated expertise has already leveraged earnings in excess of €5m for leading-edge Irish research and services associated with integrated seabed mapping and geosciences. As interest in deep ocean research and observation systems grows within the EU, there is great scope for Ireland to increase future earnings in this area; given that we have already averaged €2m+ per annum in 2004 and 2005.

Although significant outputs and benefits have already accrued from the INSS and other marine programmes to date, there remains a crucially important body of work to follow—mapping

commercially valuable inshore, and other, waters outside the original scope of the INSS. Leaving them unmapped could negatively affect the development potential of the marine resource and potentially expose Ireland to significant challenge under diverse legislative obligations.

In order to tackle these legislative requirements and obligations efficiently and cost effectively, a more integrated approach to marine data collection, storage, integration and utilisation is required across state and semi-state sectors. Accordingly, Government approved the next phase of the INSS (INFOMAR). This major programme aims to address these requirements through an integrated programme of data acquisition, assessment, research, data integration and added-value.

5.1.2 Key Opportunities and Challenges

The number and range of stakeholders impacted by the deliverables of INFOMAR will increase significantly by virtue of the fact that the proposed mapping activity is focused in areas with multiple users (e.g. fishing, leisure, aquaculture, renewable energy) that may be subject to extensive development and environmental regulation.

An extensive stakeholder process was conducted to identify priority areas for mapping. This has resulted in the identification of 26 priority bays and three coastal areas (Figure 5.1). Mapping of these areas got underway in mid-2006.

Figure 5.1 Future Seabed Mapping Priorities Identified by Stakeholders[37]

[37] INFOMAR STRATEGY submitted to DCMNR May 2005

In addition to the direct benefits associated with mapping the priority inshore areas, major national benefits can also be derived from an expanded focus and enhanced capabilities related to fully developing the potential of the INSS database. In particular, there are opportunities to be targeted in the marine data integration field—where Ireland has the potential to be a significant world player—and in the areas of added-value research and commercial services.

INFOMAR will deliver the cost effective solutions for Government that are demanded by:

1 A significant and diverse range of national legislation and EU Directive obligations;
2 The information requirements to underpin national policy and governance associated with wisely developing the major potential of our significant marine resources; and
3 The opportunity to maximise the leadership position that Ireland has achieved to date by enhancing the focus and effort devoted to data management and integration, thus ensuring the delivery of optimal value chain outputs to Ireland.

All of which call for the provision of:

1 A prioritised suite of integrated marine mapping surveys; and
2 The delivery of integrated knowledge products, services and competencies.

The INFOMAR strategy was drafted after a detailed preparatory phase that included commissioned research, independent assessment, and extensive consultation with stakeholders.

The INFOMAR strategy recommended the establishment of three core programme elements, which will be supported by a range of identified mechanisms:

1 Data Acquisition, Data Management and Interpretation—to contribute to the management of activities and resources in Irish inshore areas by completing a comprehensive mapping and data interpretation programme for priority areas followed by completion of remaining areas;
2 Data Exchange and Integration—development of processes and procedures to establish an Inter-Agency National Marine Data Discovery and Exchange Service; and
3 Value-added Exploitation—to deliver a range of value-added opportunities linked to user demands, commercial markets and external funding sources (e.g. 7th Framework Programme).

Funding and resourcing of INFOMAR will focus primarily on data acquisition, management and interpretation. Funding the remaining programme components through other means will present a challenge. The data asset will provide the necessary leverage to unlock RTDI funds from a range of sources including the EU, National RTDI Programmes and the private sector. A key element of INFOMAR is the provision of basic information to enable the development of beneficial decision support tools and other products.

5.1.3 2020 Vision

2020 VISION

By 2020, Ireland will have completed baseline mapping of the Irish seabed area. Through the application of state-of-the-art techniques and the development of integrated data management and interpretation, Ireland will be internationally recognised as a leader in seabed mapping and resource evaluation. Information gathered will be used for the generation of critical decision support tools for policy makers.

Building on this reputation and utilising the expertise and experience gained, new commercial opportunities will develop, linked to consultancy and data interpretation. Irish expertise will be sought-after in international marine resource research and development projects.

5.1.4 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Provide baseline data to contribute to the evaluation and management of marine resources in priority inshore areas in support of the adoption of integrated costal zone planning, coastal protection and management approaches.

2 Undertake an evaluation of priority resources and protected habitats, e.g. gas hydrates, oil and gas, marine aggregates, fisheries and deep-water corals, to support the development of appropriate management and regulatory approaches.

3 Be internationally recognised as a strong research performer in the areas of marine survey, habitat mapping and resource evaluation, enabling the development of international collaborative research opportunities that will add value to nationally held data sets.

5.1.5 RTDI Requirements/Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives are presented below.

Table 5.2 Research Requirements & Key Outputs for Seabed & Resource Mapping to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Provide baseline data to contribute to the evaluation and management of marine resources in priority inshore areas in support of the adoption of integrated costal zone planning, coastal protection and management approaches. *(*See Marine Environment Research Programme, Section 4.1).*	> Future (next 5-10 years) mapping activities to be focused on priority areas as identified in Figure 5.1 > Baseline mapping > Data analysis, integration & visualisation > Habitat classification > Environmental baseline measurement > Develop technology and expertise to deliver customised decision support tools and solutions	> Bathymetry data > Hydrographic maps > Seabed classification maps > Habitat maps > Inshore management plans > Input to development of international standards > Decision support tools driven by policy and/or commercial clients
2 Undertake an evaluation of priority resources and protected habitats, e.g. gas hydrates, oil and gas, marine aggregates, fisheries and deep-water corals, to support the development of appropriate management and regulatory approaches.	> Continue priority mapping to provide data for the quantification of priority resources > Develop and apply new tools and methods for data interpretation > Develop an accessible online resource database	> Resource management plans > Input to the development of regulatory frameworks > Online seabed resource database
3 Be internationally recognised as a strong research performer in the areas of marine survey, habitat mapping and resource evaluation, enabling the development of international collaborative research opportunities that will add value to nationally held data sets.	> Significant national programme of value added research on data acquired including: • Geophysical analysis • Biological processes • Physio-chemical processes • $C0_2$ sequestration • Oceanography and climate change	> Expansion of national capacity and capabilities > International research and business opportunities in seabed surveys, habitat mapping and resource management > Participation in European Programmes

5.1.6 RTDI Capacity/Capabilities

Current Research Capacity

Third-level Sector

Six research groups in five third-level institutes are currently actively involved in seabed and resource mapping research. Together, these groups comprise approximately 32 researchers in seabed and resource mapping research (Table 4.12). The research focus of these groups covers areas such as acoustic data interpretation, deep ocean ecosystem research (including cold-water corals), aggregate resource mapping, advanced mapping technologies and ocean floor dynamics. Much of the ongoing research work in the third-level sector is, in some way, linked to the Irish National Seabed Survey (INSS); e.g. using acquired data for seabed mapping and habitat classification.

Table 5.3 Overview of Current Seabed & Resource Mapping Related Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
NUIG UCC UL UCD DIAS	5 Large Groups 1 Small Group	32	> Marine geology and geophysics > Aggregate resource mapping > Deep ocean research > Habitat mapping > Geobiology > Crustal tectonics > Marine and petroleum geology > Sedimentary geodynamics > Marine robotics for seabed mapping > Marine seismics > Marine electromagnetics > Rheological and geodynamic modelling > Sea floor/slope stability > Deep-water ecosystems/past climate change

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 85.

A further 8-10 research groups and a number of individual researchers (approximately 50-75 researchers in total) have relevant skills and research interests that can be applied to the future RTDI requirements for seabed and resource mapping. Much of this expertise could be applied to the RTDI requirements of Objective 3 (adding value to acquired data), with research groups focused on topics such as understanding benthic processes, physical oceanography and modelling, fisheries, biodiversity and climate change.

State Sector

Since the inception of the INSS, the Geological Survey of Ireland (GSI) and the Marine Institute have built up considerable seabed mapping expertise, e.g. in geophysics, hydrography and data management. At present there is approximately 20 staff (GSI & Marine Institute) actively involved in seabed mapping. This expertise can contribute to the ongoing seabed mapping requirements in support of the 2013 Objectives.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 5.4. Also included in Table 5.4 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 5.4 Competencies Required to Meet Future Research & Innovation Requirements Related to Seabed & Resource Mapping

Objectives 2013	Competencies Required	Assessment
1 Provide baseline data to contribute to the evaluation and management of marine resources in priority inshore areas in support of the adoption of integrated costal zone planning, protection and management approaches.	> Seabed mapping > Hydrography > Habitat classification > Marine spatial planning and ICZM	S R R G
2 Undertake an evaluation of priority resources and protected habitats, e.g. gas hydrates, oil and gas, marine aggregates, fisheries and deep-water corals, to support the development of appropriate management and regulatory approaches.	> Seabed mapping > Hydrography > Habitat classification > Marine spatial planning and ICZM > Data management, integration and visualisation > Socio-economics/cost-benefit analysis	S R R G R G
3 Be internationally recognised as a strong research performer in the areas of marine survey, habitat mapping and resource evaluation, enabling the development of international collaborative research opportunities that will add value to nationally held data sets.	> Seabed mapping > Hydrography > Habitat classification > Geophysics > Fundamental marine sciences > Understanding climate change processes and mitigation	S R R S S R

* **S** – Current Strength; **R** – Requires Strengthening; **G** – Gap Area.

The considerable expertise that has been built up over the period of the INSS, primarily within the state sector (Marine Institute and GSI), is clearly a strength that can contribute significantly to the ongoing mapping requirements needed to meet the 2013 Objectives. The acquisition of seabed mapping data is, however, just the first step in achieving these objectives. Appropriate management and utilisation of this data is vital, and there are a number of RTDI competencies that need to be strengthened to optimise use of the current data set and any future acquired data. For example, management and integration of the data with other data sets (e.g. fisheries and environment) is a big challenge. Although much expertise in hydrography and habitat classification has been built up over the course of the INSS, further strengthening is required—particularly, given Ireland's reliance on the UK Hydrographic Office for navigational charts. The interpretation of seabed survey data to produce habitat classification maps is currently the subject of ongoing research within the third-level sector. Further strengthening in this field is required.

A national programme of value-added research using seabed-mapping data can draw on a wide range of researchers within the third-level sector if research programmes are accurately defined. Although there are clear strengths within the third-level sector in some of the fundamental marine sciences needed to achieve this, e.g. zoology and microbiology, other discipline such as marine chemistry are, perhaps, not as well represented. An understanding of climate change processes and mitigation measures are also areas that require strengthening.

Finally, exploitation of seabed resources cannot proceed in the absence of a structured management regime and a cost-benefit analysis. There is little expertise in Ireland in the practical application of marine

spatial planning and Integrated Coastal Zone Management. Cost-benefit analysis of seabed resource exploitation is also considered a research gap.

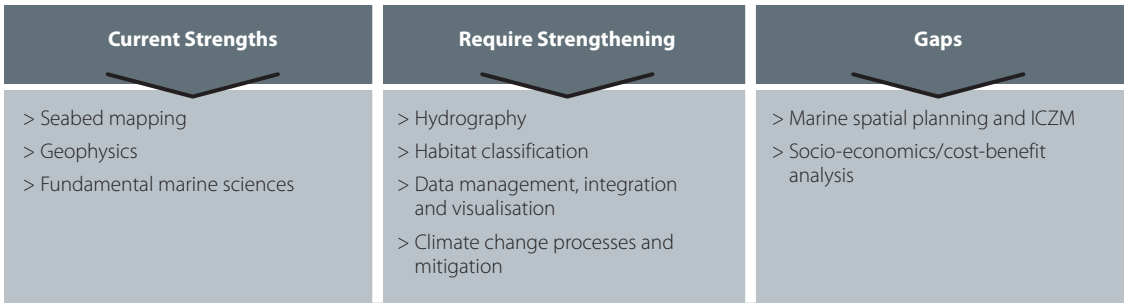


Figure 5.2 Research Competencies Required to Meet 2013 Objectives for Seabed & Resource Mapping

5.2 High-End Computing Capacity (Access)

In order to support the programmes proposed in this Strategy, a basic prerequisite for the research and commercial sectors is access to High-End Computing facilities. Such facilities are defined as 'computers operating at, or near, the current highest operational rate possible, coupled with techniques for parallel problem solving'. High-End Computing facilities have associated data storage, processing, visualisation and retrieval systems. This is necessitated by the very large volumes of data emanating from marine research streams utilising sensors and satellite and aerial remote sensing, and the requirement to process and turn these data into knowledge in real-or near-real time.

High-End Computing capacity is required across many sectors and disciplines to meet national Research and Innovation aspirations. Marine sector requirements can be facilitated through access to the National Centre for High-End Computing. This exists in embryonic form, with support from Science Foundation Ireland, and as it evolves into a National Facility it could be accessed and utilised by the marine sector through a grid computing facility.

A Marine High-End Computing Facility would provide:

> Access to supercomputers and ancillary services for data management, visualisation and analysis;

> Trained specialists to develop and run existing modelling systems and provide advice and services to the research community in the public and private sector; and

> Enhanced linkages to cabled observatories, test-bed facilities, permanent monitoring networks and continuous sensor streams.

The High-end Computing Facility would be used to support a number of research areas including:

1 Seabed & Resource Mapping

Very large data sets are generated from the digital multi-beam survey operations carried out in the National Seabed Survey. The manipulation and mining of these data sets requires advanced computational capacity and capabilities to support the delivery of a wide range of products and services. These include:

> Modelling deep seismic data;

> Evaluation of gas hydrate resources;

> Modelling gravity/magnetic data;

> Modelling oceanographic data;

> Tidal predictions;

> Investigation of seafloor processes;

> LIDAR (Light Detection and Ranging) waveform analysis;

> Deep ocean habitat mapping;

> Seabird & cetacean distribution maps;

> Hydrodynamic modelling for pollution;

> Geohazard identification; and

> Quantification of seaweed resources.

2 Bioinformatics

The Marine Biodiscovery Research Programme and associated Biotechnology Research Programme provide new challenges for adding value to the investment made in marine data acquisition. Bioinformatics capability will require the integration and analysis of complex interactive data sets from a wide range of sources and activities, including marine taxonomy, metagenomic analysis, synthetic chemical data sets, cell biology readings and clinical trials. High-end computing capabilities are an important supporting infrastructure for the future development of activities in this field.

3 Environmental, Climate Change and Circulation Modelling

Climate change is one of the greatest environmental, social and economic threats facing the planet. Global monitoring activities will grow exponentially over the next decade. The ability to incorporate complex marine data sets into models will greatly improve the resolution of marine and coastal climate change scenarios and predictions. Met Éireann runs and part-funds the Community Climate Change Consortium for Ireland (C4I) project. This project runs ocean and atmospheric models, in collaboration with CosmoGrid (a network of distributed computing resources in Ireland), to examine the impact of climate change at a regional level on Ireland and surrounding coastal areas.

The need for sophisticated ecosystem modelling to support the 'ecosystem approach' to environmental management (e.g. EU Marine Strategy) and the ability to assess 'what if' scenarios related to marine resource development (in fisheries, aquaculture, shipping, energy and tourism, etc) would benefit from access to enhanced computational resources.

The increasing complexity of environmental data sets, coupled with a continuous stream of environmental data from in-situ and autonomous environmental sensors, demands a new approach to data storage, quality control, processing, visualisation and output formats, and computational capabilities that are beyond the operational scope of many institutional computer systems.

5.3 Test & Demonstration Facilities for Marine & Coastal Observatories and Monitoring Technologies

Initially driven by 'big science' drivers such as climate change and plate tectonics studies, there is now a significant and growing level of international activity in the development and deployment of an array of novel observation and monitoring systems; notably in the US, Canada, Japan and a number of European countries. These systems involve the synthesis and application of technologies in areas such as photonics, sensing and ICT, and result in entirely new scenarios for coastal and marine observation and monitoring. A vision is emerging, internationally, of networks of systems that are both feasible and cost effective, and which will become ubiquitous in environmental monitoring over the next decade.

An example of this is the EU Global Monitoring for Environment and Security (GMES) initiative, which plans to establish a European capacity in earth observation and environmental monitoring based on remote sensing and *in-situ* observations (e.g. ocean/coastal data buoys, seabed observatories). An important component of this will be the marine observation system that the European Commission is considering fast tracking over the period 2007–2013. Recent events, such as the 2004 tsunami in the Indian Ocean, have further emphasised the need for an operational European Ocean Observing System with active links across the Atlantic to the USA and Canada.

This new class of technologies and methodologies will directly and significantly affect and benefit:

> weather forecasting (including storm and coastal flooding warnings);

> safe navigation;

> harmful algal bloom warnings;

> circulation and climate modelling;

> input to the fisheries and aquaculture sectors by facilitating the 'ecosystem approach' to resource management; and

> the development of enhanced tools (including ICZM) to support the water-based tourism sector.

In addition to improved environmental data, the establishment of coastal and marine observation and monitoring systems provides opportunities for equipment/sensor designers and manufacturers, and services industries providing value-added services (e.g. forecasting services). They will be very important tools for realising the developmental objectives of the programmes proposed in the Discovery Research Measure.

Autonomous sensor networks and cabled observatories with power availability and reliable broadband communications represent the future of freshwater, coastal and marine observation and monitoring systems and very large markets for components and systems will emerge over the next decade.

Ireland has already begun the process of applying new technology-based methodologies, through the establishment of the National Ocean Data Buoy and Tide Gauge Networks and the Harmful Algal Blooms Database and Monitoring System. Our strategic location on the western seaboard of the European Union (emphasised, for example, in the European Seafloor Observatory Network Report, see below) provides Ireland with an opportunity to be an important player in this emerging knowledge-based, high-tech area.

To facilitate and support Irish participation and benefit from future developments in coastal and marine observation and monitoring systems, two initiatives are proposed:

1 SmartBay

In order to accelerate the capability for development of advanced marine technologies in Ireland and to inform and enhance a range of activities of strategic significance to a wide variety of agencies and stakeholders in marine sector industries, a catalytic national innovation project, **SmartBay**, has commenced. This will be an inter-disciplinary and inter-agency project, in a major multi-use bay in the west or south-west of Ireland, designed to test and demonstrate new marine technologies and to pilot their application to a wide range of monitoring and management applications; including coastal zone management, habitat mapping, electronic charting and navigation, and algal bloom forecasting. The component technologies will include:

> a fibre-optic cable from shore to an underwater hub;

> a variety of instrument nodes and sensor packages;

> a calibration site/facility;

> multi-beam digital map and geotechnical survey of the area;

> deployment of a moored buoy, and possibly drifting buoys; and

> navigation and telemetry infrastructure.

Figure 5.3 Elements of the 'Smart Bay' Concept (Canadian Centre for Marine Communications, 2004)

This infrastructure will be available to researchers and industry to:

> Test new concepts in instrument design;

> Field test and demonstrate new products prior to marketing;

> Integrate these new technologies with the innovative methodologies for resource management that are being developed and applied in fisheries, aquaculture, shipping, tourism and leisure, etc.; and

> Attract significant international funding to what will be a unique infrastructure facility.

SmartBay has direct links, and is an essential precursor, to active Irish participation in the design, installation and operation of continental shelf and deep-ocean cabled observation systems. The schedule for developing **SmartBay** is outlined in Table 5.5.

Table 5.5 Schedule for SmartBay Implementation

Steps/Tasks	Time Scale	Benefits/Deliverables
1 Identification of SmartBay site in association with user community	2006	Agreement with user community (shipping, fisheries, aquaculture, tourism and technology sector) on site location and specific infrastructure requirements
2 Comprehensive baseline assessment and seabed/environmental survey	2006	Integrated foundation data set for chosen site
3 Establishment and testing of cabled hub infrastructure (including data collection platforms)	2007 – 2008	Provision of national and international test site for advanced coastal observation and monitoring technologies
4 Initiation, operation and installation of sensor packages	2008 – 2013	Accelerated commercialisation of advanced sensor and sensor system technology International partnerships and technology transfer

2 Deep Sea Observatory – Cabled Network

The establishment of a cabled Deep Sea Observatory on the Irish Continental Shelf, as an extension of the SmartBay concept, will provide an essential scientific tool for deep-sea research and observation and add to our understanding of deep-sea ecosystems.

In addition, the cabled Deep Sea Observatory would serve a similar function to SmartBay in providing a deep-sea test facility for researchers and, in particular, industry to test new concepts in instrument and sensor design, optoelectronic, and wireless and other communication technologies and to field-test and demonstrate new products prior to marketing. A proactive national decision in respect to this initiative will place Ireland in a strong position for EU contributory funding for what the Commission regard as a strategic European priority.

The European Seafloor Observatory Network —ESONET

In 2004, the EU-funded ESONET project (The European Seafloor Observatory Network) provided a vision of a European Seafloor Observatory Network and identified nine pote ntial locations. One of these locations, the Porcupine Abyssal Plain, is off th e west coast of Ireland . Ireland is currently leading a follow-up feasibility study and cost benefit analysis (ESONIM) on the establishment of a seabed observatory in the Porcupin e Seabight.

In early 2006, the Commission propose to fund a €7 million Network of Excellence on Seabed Observatories as a step towards the establishment of an operational European Seabed Observatory System. The EU, through its GMES initiative and 7th Framework Programme (2007–2013), is considering fast tracking el ements of the European Ocean Observing Network and it is anticipated that supporting grant -aid will become available for research and demonstration projects.

5.4 Extension of Ocean and Coastal Monitoring Network

Over the past five years, Ireland has developed important elements of an ocean and coastal monitoring network.

> The Marine Institute, in collaboration with Met Éireann, the UK Met Office and DCMNR, has established an **Irish Marine Data Buoy Network** of five strategically placed data buoys. The Data Buoy Network, which currently focuses on meteorology, provides on-line information for weather forecasts, shipping bulletins and gale and swell warnings. The network is being up-graded to collect oceanographic data, including currents and temperature at depth.

> **The Harmful Algal Blooms (HABs) Database** provides up-to-date information on HABs in shellfish growing areas around Ireland. The HABs database is not strictly oceanographic in its nature but will soon incorporate temperature data as part of the routine data output to shellfish producers. The phytoplankton and toxin chemistry components of the database are truly operational, providing data that permits sound decision-making on whether harvesting of shellfish is permitted or not on a day-to-day basis.

> **The National Tide Gauge Network** is a Public Private Partnership providing on-line information on tide levels at five strategic harbours around the Irish coast. The data provided is essential for port management, hydrographic mapping, maritime safety, sea-state forecasts and research and development.

Further extension of the geographical coverage of the ocean and coastal monitoring network, expansion of data collection parameters, enhancement of data management and modelling capabilities, and further development of data products are required.

5.5 Research Vessel – Fund to Access Ship Time

The Marine Institute operates the national marine research fleet (RV *Celtic Explorer* and RV *Celtic Voyager*), on behalf of the Irish Government and the Irish marine research community, on a charter basis. Government agency users (including the Marine Institute) pay a fee for use of the ships. These fees come from annual operational budgets or from earned research grants. The funding of ship time poses a problem for academic researchers who do not normally have a ship charter allocation in their research budgets. It also poses problems for co-operation in International R&D Programmes (e.g. EU) where ship time is either 50% funded (with an upper cap) or expected as part of the Member State contribution to the co-operative research.

The Marine Knowledge, Research & Innovation Strategy proposes to address this issue by including a dedicated competitive R&D Research Vessel Funding Programme. This Programme, similar to that operated in other countries, would make grant-aid available to researchers on a competitive (annual) basis, enabling them access to ship time as part of institutional and co-operative international marine research programmes.

Supporting access to research vessels via competitive funding of RV ship time will:

> Maximise the utilisation of world-class infrastructure on strategic national projects consistent with the objectives of the Marine Knowledge, Research and Innovation Strategy;

> Maximise value for money and return on investment by the state in national infrastructure;

> Significantly improve competitiveness of Irish research groups in applying for strategic and high profile EU and international funding;

> Increase the general perception (brand) of Ireland as a significant international player in marine science, with knock-on benefits;

> Maximise the contribution that research performers in the third-level sector can make to various national marine scientific programmes as outlined in this Strategy; and

> Enhance the 'brand' image of Ireland as a strong research performer and knowledge economy player globally by contributing to international scientific and ocean governance undertakings.

5.6 National Equipment Pool

The Marine Institute operates a National Equipment Pool for specialised marine research equipment on an informal basis. This includes Marine Institute equipment and other equipment that owners place, for an agreed maintenance fee, under the care of the facility. In the future, the intention is to operate the pool on a commercial basis with charges levied for:

> design and build of equipment;

> modification of equipment;

> provision of equipment operators (if applicable);

> engineering calibration of instruments (if applicable);

> scientific calibration of instruments (if applicable); and

> transport and usage of the equipment.

The establishment of more formal arrangements will enable the Marine Institute to play a key role in the 'mechanics' of Marine RTD, optimise equipment and resource usage, and facilitate inter-institutional co-operation. It will also support the developmental objectives of the advanced technologies component of the Discovery Research Measure and provide a valuable service to technology developers in industry.

5.7 Robotic Platforms

A wide, and growing, range of marine activities requires the use and intervention of robotic and semi-robotic platforms, e.g. remotely operated vehicles (ROVs). These activities include oil and gas exploration and development, deployment and inspection of underwater cables, installation and monitoring of instrument packages, and marine biodiscovery. It is anticipated that these systems—ROVs, autonomous underwater vehicles (AUVs), towed systems, manned submersibles, floats and buoys—will continue to evolve and reduce in price as a result of developments in other areas of science (e.g. materials, nanotechnology, power systems & ICT).

Ireland has no ROV or other vehicle capable of operating in waters greater than 200m. Even this limited capability is currently sourced through the hiring of equipment from specialist contractors. In order to take advantage of growing opportunities to develop commercial products and services in this niche area, and to service existing and planned instrument platforms, research projects and potential salvage operations, it is proposed to acquire a mid-range ROV, (rated to 4000m) capable of supporting research, development, survey, and search and salvage operations. The system should be capable of carrying a significant payload including cameras, scanning sonar, side-scan sonar, profiling sonar, sub-bottom profiler, transponders and manipulator and skid.

5.8 Test Facilities for Offshore Energy

Following the early design and testing stages, the critical requirement for ocean energy prototype development is to demonstrate the performance and operational capabilities of devices in a 'real' environment. The phased **Renewable Ocean Energy Programme**, developed by SEI and the Marine Institute (launched in 2006), outlines a series of measures to support the emergence of a commercially successful wave energy industry in Ireland. It has also led to the establishment of an enhanced **Centre of Excellence in Ocean Energy Research** and a developing programme of research and development aimed at underpinning Ireland's ambitions to be among the world players in this emerging technology sector. Achievement of these objectives is dependant on access to a supporting infrastructure, in the form of wave tank facilities and a fully equipped test-bed facility for ocean energy research and development.

In line with the measures proposed in the Renewable Ocean Energy Research Programme (Section 3.4), a two-step approach is proposed in respect to the provision of test facilities. The first stage, completed in early 2006, involved putting in place an interim marine test site in Galway Bay to assist offshore energy device developers to deploy and test scale devices in a near-operational environment. This will enhance the capability of Irish device developers to meet the need for visible operational demonstration of their devices in what is a competitive international arena for this emerging technology. Expanded wave tank facilities will also support developers through this phase.

Following the successful conclusion of the first phase of the programme, a second stage test site will be required, for the testing of full-scale production devices. The facility will be in an operational open-ocean environment and will include a cabled grid connection.

5.9 Summary

The specialist marine research infrastructures identified above are essential if Ireland is to achieve the aims and objectives outlined in the Marine Knowledge, Research and Innovation Strategy (2007–2013). They represent a very significant and long-term financial investment in the national marine science and technology infrastructure. Some of the requirements may be amenable to Public Private Partnerships and they will act as 'research and technology enablers', facilitating the development of niche knowledge-based products and services. They will also provide a powerful 'attractant' to the type of joint Public Private research partnerships with international and multinational companies (e.g. in the medical, pharma, energy and senor technology sectors) that will be an essential feature of Ireland's economic development over the next decade. Specific opportunities are already evident for potential funding from the EU Framework Programme.

In addition to new investments, the ongoing maintenance of existing state-of-the-art marine research infrastructure—such as the ocean-going *Celtic Explorer*, and the Ocean Data Buoy Network—and the completion of National Seabed Survey (INFOMAR) are essential. The availability of this infrastructure has already brought Ireland and Irish researchers to the forefront of marine research and has facilitated participation in prestigious international and regional (European Union) research and development programmes. The proposed new infrastructure, to be established over the period 2007–2013, will further advance Ireland's marine research and innovation capabilities, facilitate participation by Irish researchers and industry in international research and development programmes, and facilitate development of new knowledge-based marine products and services.

Appendix A: Developing a Marine Knowledge, Research & Innovation Agenda (2007-2013)

Background

The Marine Institute is the national state agency charged with the co-ordination of marine research and development in Ireland. The Institute operates under the aegis of the Department of Communications, Marine and Natural Resources and in accordance with its remit is required to:

> Identify and advise on the co-ordination and implementation of national RTDI priorities in the marine sector; and

> Engage in foresight and planning activities for the marine sector, for the purpose of advising on the formulation and implementation of policy, research and development initiatives (Service Level Agreement 2003).

In June 2004, the Marine Institute agreed in consultation with the DCMNR to undertake the preparation of a new National Marine Research and Innovation Strategy for the period 2007-2013 over an 18-month period, to deliver on the following key actions:

1 A **national foresight exercise** to create a shared vision for the development of the marine sector to 2020.

2 Preparation of a **clearly defined** National Marine Knowledge, Research & Innovation Strategy for the period 2007-2013 through engagement in a wide-ranging consultation process with the public and private sector and the general public.

3 Achievement of a **greater national awareness** of the value of the marine resource and **better synergies** among the productive sectors utilising the resource, resulting in an acceleration of the overall contribution of marine resources to Irish regional, social and economic development.

The following process was adopted for the preparation of a new Marine Knowledge, Research and Innovation Strategy for Ireland (2007-2013).

Figure A1 Process of Preparing a Marine Knowledge, Research & Innovation Strategy for Ireland (2007-2013)

Phase I Preparatory Phase

To inform the process a number of preparatory reports/studies were commissioned.
A number of these have been published as part of a new Marine Foresight Publications Series. A full list of preparatory reports is outlined below:

> A report highlighting the contribution of the global marine sector to the international economy & market trends to 2020. Douglas-Westwood Ltd. (2005). *Marine Industries Global Market Analysis*. Marine Foresight Series 1.

> A report identifying climate-induced impacts, and necessary related actions, that Foresight/Stakeholder Groups need to take into account in preparing future R&D plans and programmes. Boelens *et al*. (2005). *Climate Change: Implications for Ireland's Marine Environment and Resources*. Marine Foresight Series 2.

> A report identifying the potential economic benefits of renewable ocean energy and a roadmap for its development. Marine Institute and Sustainable Energy Ireland (2005). *Ocean Energy: Analysis of the Potential Economic Benefits of Developing Ocean Energy in Ireland. A Summary Report*. Marine Foresight Series 3.

> A socio-economic assessment of the marine sector. Marine Institute (2005). *Ireland's Ocean Economy & Resources*. Marine Foresight Series 4.

> An evaluation of the experience and lessons learned from the 1999-2003 Strategy *'A Marine Research, Technology, Development and Innovation Strategy for Ireland'* (Marine Institute, 1998).

In addition, the following in-house assessments were carried out:

> Identification of Current and Future Third-level Research Capacity;

> Marine Industries Database and SWOT; and

> 2020 Draft Scenarios.

Phase II National Marine Foresight Exercise

In March–April 2005, the Marine Institute hosted a series of **Marine Foresight Meetings**, bringing together 29 international experts and 90 Irish experts representing the public, academic and commercial sectors. The panels were tasked with taking a forward look at the opportunities and challenges facing the marine sector, and identifying future scenarios, objectives and research and innovation requirements necessary to achieve the identified scenarios.

The following Foresight Panels (see Appendix B) were convened:

> Shipping & Maritime Transport;

> Energy (Oil & Gas and Offshore Renewables) and Offshore Resources;

> Water-based Tourism and Leisure;

> Sea Fisheries;

> Aquaculture, Seaweed and Seafood;

> Marine Environment & Sustainable Development; and

> Marine Technology.

There were a number of plenary sessions involving the chairs and facilitators of all panels. Dr Tom Higgins chaired the plenary sessions.

The Institute would like to thank all of those who gave their time and expertise to this important exercise. In particular, the Institute would like to acknowledge the panel chairpersons, facilitators and rapporteurs. A list of the Foresight Panel Members is contained in Appendix B.

Phase III Identification of Research Requirements

Building on the scenarios and objectives developed in the foresight process, draft research requirements were identified under three main headings:

> Industry Research Measure;

> Discovery Research Measure; and

> Policy Support Research Measure.

Phase IV Stakeholder Consultation

A stakeholder consultation process was initiated following the foresight process. The objective of the stakeholder process was to obtain feedback on the objectives and the research requirements that had been identified. The consultation process has consisted of:

> Inter-agency meetings to further define and refine research requirements;

> Briefings with Industry Representative Groups;

> Consultation with Third-level Institutions; and

> A stakeholder Meeting in Dublin Castle 12th July 2005 (over 300 invitees). The formal stakeholder consultation process ran to the 22nd July. Feedback and comments on identified research requirements were submitted to stakeholders@marine.ie

Further consultation on the Strategy took place up to June 2006. A list of consultative meetings is presented in Appendix C.

Appendix B: Marine Foresight Panels

Marine Foresight Team

Strategy Lead and Co-Chair of Marine Foresight Exercise Ms Yvonne Shields

Yvonne Shields is Director of Strategic Planning and Development at the Marine Institute with responsibility for the following programmes: NDP Marine RTDI Programme, Foresight & Planning, International Co-operation, Information Services and Development, Industry and Third-level Liaison, Marine Technology and Marine Tourism & Leisure.

Yvonne designed and chaired the Marine Foresight Exercise, managed the delivery of the Marine Foresight Reports and drafted and developed the Marine Knowledge, Research and Innovation Strategy for Ireland 2007-2013. Yvonne is a Council Member of both the Irish Research Council for Science, Engineering and Technology (IRCSET) and the Irish Energy Research Council whilst also serving as a member of the Advisory Board, Martin Ryan Marine Science Institute, NUIG.

CO-CHAIR
Ms. Yvonne Shields

Strategy Coordinator **Ms Jenny O'Leary**

Jenny O'Leary is Foresight and Planning Officer with the Marine Institute. She is responsible for research and data collection activities associated with ongoing analysis and planning for strategic research initiatives and programmes. Jenny played a key role in co-ordinating the overall delivery of the Marine Knowledge, Research and Innovation Strategy 2007-2103. She was responsible for generating research data, co-ordinating the Marine Foresight Exercise and collating the outputs, managing and co-ordinating stakeholder input to the strategy and the publication of the Marine Foresight Series and strategy reports.

Advisor and Marine Foresight Co-Chair **Dr. Tom Higgins**

Tom Higgins is an economist (UC Berkeley and UCD) and private consultant with senior public sector management experience in science, technology and innovation. He has published and lectured widely on these topics, including two books. Dr Higgins has advised Government Departments in Ireland, Europe, Japan and the US, as well as the European Commission on science and technology investment policies and strategic planning for R&D and has chaired EU advisory groups on R&D evaluation methodologies. He is currently advisor to the Minister for Communications, Marine and Natural Resources and the Department, the Higher Education Authority and the Department of Enterprise, Trade and Employment on science and technology issues. Tom acted as co chair for the Marine Foresight Exercise and advised on key strategic elements of the Marine Knowledge, Research and Innovation Strategy 2007-2013.

CO-ORDINATOR
Ms. Jenny O'Leary

CO-CHAIR
Dr. Tom Higgins

Marine Technology Panel

Chair **Professor Dermot Diamond,**
Director of the SFI Adaptive Information Cluster, Dublin City University.

Facilitator **Mr. Eoin Sweeney,**
Manager, Technology Programme, Strategic Planning & Development Services, Marine Institute.

> **Mr. Eamonn Doyle,** Principal Consultant, ESRI Ireland
> **Mr. Gregory O'Hare,** Head of Computer Science, University College Dublin
> **Dr. Mark White,** CEO, Nowcasting International Ltd., Co. Clare
> **Dr. Andy Shearer,** Astrophysics & Scientific Computing Group, NUI, Galway
> **Dr. William Donnelly,** Head of Research & Innovation, Waterford Institute of Technology
> **Prof. Heather Ruskin,** Associate Professor in Computer Applications, Dublin City University
> **Mr. John Clare,** Country Operations Officer, Fujitsu Services, Co. Dublin
> **Prof. Raymond Gosine,** Dean & Professor, Faculty of Engineering & Applied Science, Memorial University, Newfoundland, Canada
> **Mr. Colm Butler,** Principal Director, Department of An Taoiseach, (Head of Information Society Fund)
> **Dr. Scott Rickard,** Department of Electronic & Electrical Engineering, University College Dublin
> **Mr. John Wallace,** Managing Director, Informatic Software Ltd., Co. Clare
> **Mr. Henry B. Sisk,** Director, Sicon Ltd.
> **Mr. Cliff Funnell,** Cliff Funnell Associates, West Sussex, UK
> **Mr. Dermot Honan,** IT Innovation Centre Solutions & Architecture Manager, Intel Ireland
> **Mr. John Evans,** Manager of Information Services & Development, Strategic Planning & Development Services, Marine Institute
> **Mr. John Breen,** Assistant Director of Business and Technology, Department of Communications, Marine & Natural Resources
> **Mr. Paul Phelan**, Consultant

CHAIR
Professor Dermot Diamond

FACILITATOR
Mr. Eoin Sweeney

Aquaculture, Seaweed & Seafood Panel

Chair **Mr. Shay Garvey,**
General Partner, Delta Partners, Dublin.

Facilitator **Mr. Michéal Ó Cinnéide,**
Director, Marine Environment & Food Safety, Marine Institute.

> **Mr. Gabriel de Labra Chas,** Co-Manager AquaReg, Galicia, Spain

> **Dr. Reid Hole,** Corporate Director of Food Safety, Nutreco B.V., Norway

> **Mr. Mark Norman,** Taighde Mara Teo, Co. na Gaillimhe

> **Mr. James Ryan,** Aquaculture Industry Consultant, Mayo

> **Dr. Niall McDonough,** Manager, Centre for Marine Resources and Mariculture (C-Mar) Queen's University Marine Laboratory

> **Dr. Sebastian Belle,** Executive Director, Marine Aquaculture Association, USA

> **Dr. Henry Lyons,** Head of Development, Institute of Technology, Tralee

> **Dr. Stefan Kraan,** Manager, Irish Seaweed Centre, National University of Ireland, Galway

> **Dr. Lars Horn,** Director, Research Council of Norway

> **Dr. Ronan Gormley,** Head of Prepared Foods, National Food Centre, Teagasc

> **Mr. Don McSwiney,** Senior Development Advisor, Seafood Sector, Enterprise Ireland

> **Mr. Donal Maguire,** Aquaculture Development Manager, Bord Iascaigh Mhara

> **Dr. Dave Jackson,** Section Manager – Aquaculture & Rearing – Aquaculture & Catchment Management Services, Marine Institute

> **Mr. Joe Ryan,** Principal Officer, Department of Communications, Marine & Natural Resources

> **Ms. Josephine Kelly,** Principal Officer, Seafood Policy & Development, Department Of Communications, Marine & Natural Resources

CHAIR
Mr. Shay Garvey

FACILITATOR
Mr. Michéal Ó Cinnéide

Shipping & Maritime Transport Panel

Chair **Mr. Ari Marjamaa,**
Senior Consultant, DNV Maritime Solutions, Norway.

Facilitator **Mr. Glenn Murphy,**
Director, Irish Maritime Development Office, Marine Institute.

> **Mr. Fred Doll,** Managing Director, Doll Shipping Consultancy, UK
> **Mr. Mike Garret,** MDS Transmodal, UK
> **Mr. Fergal Marrinan,** Managing Consultant, Sonas Innovation, Ireland
> **Mr. Chris Fisher,** Fisher Associates (Shipping & Transport Consultants) UK
> **Dr. Alfred J Baird,** Head TRI Maritime Research Group, Napier University Business School, Scotland
> **Mr. Michael Delaney,** Head of Development, Cork Institute of Technology
> **Mr. Paul Packard,** Head of Maritime Industries, Bank of Ireland (Corporate)
> **Mr. Raymond Burke,** Raymond Burke Consulting, Ireland
> **Dr. Frank O'Brien,** Industry Liaison Manager, Strategic Planning & Development Services, Marine Institute
> **Mr. Kieron McCann,** Assistant Principal, Department of Communications, Marine and Natural Resources

CHAIR
Mr. Ari Marjamaa

FACILITATOR
Mr. Glenn Murphy

Water-based Tourism & Leisure Panel

Chair **Mr. Kevin Bonner,**
Chairman, Transition Management, Dublin.

Facilitator **Mr. Kevin O'Connor,**
Coordinator, Donegal County Council.

> **Mr. John Concannon,** CEO, Western Regional Tourism Authority Ltd.
> **Mr. Niall Gibbons,** Director of Corporate Services, Tourism Ireland
> **Professor Andrew Cooper,** Head of Coastal Studies Research Group, University of Ulster, Coleraine
> **Mr. Peter Coyne,** CEO, Dublin Docklands Development Authority
> **Mr. Paddy Boyd,** O'Sullivan Marine Ltd., Co. Dublin
> **Ms. Judith Annett,** Countryside Consultant, Northern Ireland
> **Mr. Eric Huyskes,** Regional Director Ireland, Royal Haskoning, Co. Dublin
> **Dr. Simon Berrow,** Chairman, Irish Whale and Dolphin Group, Co. Clare
> **Mr. Glenn Millar,** Director, Economic Development, British Waterways, Watford, UK
> **Dr. Philip McGinnity,** Fisheries Science Services, Marine Institute
> **Dr. Ken Whelan,** Director, Aquaculture & Catchment Management Services, Marine Institute
> **Ms. Yvonne Shields,** Director, Strategic Planning & Development Services, Marine Institute
> **Mr. Philip Lee,** Managing Partner, Philip Lee Solicitors, Dublin
> **Mr. Simon Haigh,** Quay Marina, Bristol, UK
> **Mr. Michael Guilfoyle,** Assistant Secretary, Department of Communications, Marine & Natural Resources
> **Ms. Anne Wilkinson,** Section Manager, Water-based Tourism & Leisure, Marine Institute
> **Ms. Kilda Taylor,** Department of Communications, Marine & Natural Resources

CHAIR
Mr. Kevin Bonner

FACILITATOR
Mr. Kevin O'Connor

Oil & Gas and Offshore Renewables Panel

Co-Chair **Mr. John Westwood,**
Managing Director, Douglas-Westwood Ltd., UK.

Co-Chair **Mr. Chris Brondson,**
Director, Scottish Energy Environment Foundation.

Facilitator **Mr. John O'Connor,**
Director, HotOrigin, Dublin.

> **Mr. John O'Sullivan,** Exploration Manager, Providence Resources Plc, Dublin

> **Mr. Nick O'Neill,** Director, CSA Group Ltd., Dublin

> **Mr. Chris Hannevig,** Sure Engineering (Europe) Ltd., Dublin

> **Mr. Graham Brennan,** Manager of Renewable Energy RD&D, Sustainable Energy Ireland

> **Dr. Peadar McArdle,** Director, Geological Survey of Ireland

> **Prof. Paul Ryan,** Head of Department of Earth & Ocean Sciences, NUI, Galway

> **Mr. John Breslin,** Manager, Research Vessels Operations, Ocean Science Services, Marine Institute

> **Dr. Tony Lewis,** Hydraulics & Maritime Research Centre, University College Cork

> **Dr. Peter Readman,** Dublin Institute for Advanced Studies

> **Mr. Michael O'Sullivan,** Group Managing Director, Marine Computation Systems

> **Mr. Michael Gillooly**, Director, Ocean Science Services, Marine Institute

> **Dr. Stephen Boldy,** RAMCO

> **Mr. Rory Boyd,** Assistant Principal Officer, Petroleum Affairs Division, Department of Communications, Marine & Natural Resources

> **Mr. Sean Griffin,** Assistant Principal Officer, Department of Communications, Marine & Natural Resources

> **Mr. Bob Hanna,** Chief Technical Adviser (Energy), Energy Division, Department of Communications, Marine and Natural Resources

CO-CHAIR
Mr. John Westwood

CO-CHAIR
Mr. Chris Brondson

FACILITATOR
Mr. John O'Connor

Marine Environment & Sustainable Development Panel

Chair **Dr. Michael P. Crosby,**
Executive Officer, National Science Board (NSB) & Director NSB Officer, USA.

Facilitator **Mr. Geoffrey O'Sullivan,**
International Co-Operation/Foresight & Planning Manager – Strategic Planning & Development Services, Marine Institute.

> **Dr. Niamh Connolly,** Executive Scientific Secretary, Marine Board - European Science Foundation, France
> **Dr. Ciaran O'Keeffe,** National Parks & Wildlife Service, Department of the Environment, Heritage and Local Government
> **Mr. Rick Boelens,** Marine Environmental Advisor
> **Dr. Dan Laffoley,** Head of Marine Conservation, English Nature, Peterborough, UK
> **Dr. Larry Stapleton,** Director, Environmental Protection Agency, Ireland
> **Dr. Brendan O'Connor,** Managing Director, Aquafact International Services Ltd
> **Dr. Glenn Nolan,** Section Manager, Oceanographic Services, Ocean Science Services, Marine Institute
> **Mr. Paul Leonard,** Head of Science Unit, Marine & Waterways Division, DEFRA
> **Ms. Siân John,** Business Group Director Environment UK, Posford Haskoning Ltd., UK
> **Mr. Jim Casey,** Engineering Division, Department of Communications, Marine & Natural Resources
> **Dr. Terry McMahon,** Section Manager, Marine Environment & Food Safety, Marine Institute
> **Mr. Caoimhin O'Ruairc,** Department of Communications, Marine & Natural Resources
> **Ms. Mary Lally,** Department of Communications, Marine & Natural Resources

CHAIR
Dr. Michael P. Crosby

FACILITATOR
Mr. Geoffrey O'Sullivan

Sea Fisheries Panel

Chair **Professor Gerd Hubold,**
Director General, BFA (Federal Research Centre for Fisheries), Germany.

Facilitator **Dr. Paul Connolly,**
Director, Fisheries Science Services, Marine Institute.

> **Dr. Harald Loeng,** Head of Oceanography & Climate, Institute of Marine Research, Norway
> **Dr. Joe Horwood,** DEFRA, Chief Fisheries Science Advisor, CEFAS
> **Prof. Tom Cross,** Department of Zoology, University College Cork
> **Dr. Malcolm Beveridge,** Head of Scottish Executive, Faskally Lab. FRS Freshwater Laboratory (EU rep International Atlantic Salmon Research Board)
> **Mr. Jacques Fuchs,** EU Commission
> **Dr. Emer Rogan,** Department of Zoology, University College, Cork
> **Prof. Christopher Frid,** Director Dove Marine Lab, University of Newcastle, UK
> **Dr. Michael Keatinge,** Fisheries Development Manager, Bord Iascaigh Mhara
> **Dr. Stefano Mariani,** Zoology Department, University College, Dublin
> **Cdr. Mark Mellett,** Irish Naval Service
> **Mr. James Lavelle,** Department of Communications, Marine & Natural Resources
> **Dr. Cecil Beamish,** Department of Communications, Marine & Natural Resources
> **Mr. Domhnic Rihan,** Bord Iascaigh Mhara
> **Dr. Colm Lordan,** Fisheries Science Services, Marine Institute
> **Mr. Jason Whooley,** Irish South and West Fish Producers Organisation, Cork
> **Dr. Eamonn Kelly,** National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government

CHAIR
Professor Gerd Hubold

FACILITATOR
Dr. Paul Connolly

Appendix C: Stakeholder Consultative Meetings

Table C.1 Overview of Stakeholder Consultative Meetings 2005-2006

2005	Month
Health Research Board *Re. Marine Biotechnology*	May
Science Foundation Ireland *Re. Biotechnology*	May
Biotechnology Meeting (NUIG, UCC, DCU, IMM, UCD)	May
Office of the Chief Science Advisor to the Government	May
Marine Food RTDI Group	May
Irish Maritime Development Office Advisory Group *Re. Shipping and Maritime Transport*	May
Higher Education Authority Re. Research Infrastructure and Capacity	May
Energy Stakeholders (Third-level Institutes and Private Sector)	May
Teagasc Re. Functional Seafood Research	May
BIM	June
Marine Institute/Third-level Liaison Group (reps of 13 Third-level Institutes)	June
Department of Enterprise, Trade and Employment	June
Irish Shellfish Association *Re. Aquaculture & Seafood Processing*	June
Killybegs Fishermen's Organisation *Re. Sea Fisheries*	July
DCMNR Re. Knowledge Management	July
DCMNR & BIM Re. Fisheries, Aquaculture, Seaweed & Seafood	July
DCMNR Re. Overall Strategy & Stakeholder and planned consultation	July
DCMNR Re. Marine Environment Programme	July
Enterprise Ireland Re. Strategy Overview, Technology Programme,	July
Biotechnology, Ocean Energy and Seafood Processing	July
Irish Fish Producers' Organisation & Irish South and West Fishermen's Organisation *Re. Fisheries & Seafood R&D*	July
DCMNR Re. Overview & Renewable Energy Programme	July

continued
Table C.1 Overview of Stakeholder Consultative Meetings 2005-2006

2005	Month
DCMNR Re. Water-based Tourism & Leisure Programme	July
Stakeholder Meeting in Dublin Castle (over 300 representatives invited)	July
Teagasc, EI, BIM, UCC Re. Functional Foods Research in the Seafood Area	July
DCMNR/PAD Re. Energy (Oil & Gas) and Other Seabed Resources	October
BIM	November
Marine Institute Board	November
Fáilte Ireland Re. Water-based Tourism & Leisure Programme	December

continued
Table C.1 Overview of Stakeholder Consultative Meetings 2005-2006

2006	Month
Department of Enterprise, Trade & Employment	January
DCMNR Secretary General and Senior Management	February
DCMNR Senior Management	March
Marine Food RTDI Group (EI, BIM, Údaras na Gaeltachta, researchers)	March
Department of Transport	April
DCMNR Research Co-ordinator	April
Department of An Taoiseach, Knowledge Management Unit	April
Enterprise Ireland	May
The Economic & Social Research Institute	June

Table C.2 Stakeholders who were consulted as part of the main Stakeholders Meeting (Dublin Castle, 12th July 2005) and associated web/email consultation

Stakeholders Consultation July 2005
AIB Bank
Airtricity Ltd.
Ambient Systems Group
An Taisce
Anglo-North Irish Fish Producers Organisation
Aquaculture and Fisheries Development Centre, UCC
Aquafact International Services Ltd.
AquaTT
Arklow Shipping Ltd.
Arramara Teo.
Athlone Institute of Technology
Atmospheric Science Research Group, NUIG
Bantry Harbour Mussels Ltd.
Biochemistry Department, NUIG
BMW Regional Assembly
Bord Iascaigh Mhara
Brandon Products
Causeway Coast & Glen Heritage Trust
Celtic Atlantic Salmon Ltd.
Central Fisheries Board
Centre for Marine Resources and Mariculture (C-MAR), QUB
Marine Law & Ocean Policy Centre, NUIG
Centre for Renewable Energy, Dundalk Institute of Technology
Clare County Council
Coastal & Marine Resource Centre, UCC
Coastwatch Ireland
Commissioner of Irish Lights
Compass Informatics Ltd.
Connemara Seafoods Ltd.
Conway Institute, UCD
Cork County Council
Cork Institute of Technology
Countryside Consultancy

continued

Table C.2 Stakeholders who were consulted as part of the main Stakeholders Meeting (Dublin Castle, 12th July 2005) and associated web/email consultation

Stakeholders Consultation July 2005
Cruise Ireland Marketing Group
CSA Group Ltd.
DCMNR – Petroleum Affairs Division
Delta Partners
Department of An Taoiseach
Department of Communications, Marine & Natural Resources
Department of Electronic Engineering, NUI Maynooth
Department of Enterprise, Trade & Employment
Department of Environment, Heritage and Local Government
Department of Foreign Affairs
Department of Geology, UCC
Department of Biochemistry, UCD
Development Solutions Consultancy
Donegal County Council
Donegal County Development Board
Drogheda Port Company
Dublin City University
Dublin Docklands Development Authority
Dublin Institute for Advanced Studies
Dublin Institute of Technology
Dublin Molecular Medicine Centre
Dublin Port Company
Dun Laoghaire Harbour Company
Dun Laoghaire Rathdown County Council
Dundalk Port Company
Dunmore East Fishermen's Co-op
Earagail Eisc Teo. (Errigal Fish Company Ltd.)
Electronic & Computer Engineering, UL
Enterprise Energy Ireland
Enterprise Ireland
Environmental Change Institute, NUIG
Environmental Protection Agency

continued

Table C.2 Stakeholders who were consulted as part of the main Stakeholders Meeting (Dublin Castle, 12th July 2005) and associated web/email consultation

Stakeholders Consultation July 2005
ESB International
ESRI Ireland
EUCON
Fáilte Ireland
Fibrepulse Ltd.
Fingal County Council
Fitzpatrick Associates
Food Product Development Centre, DIT
Forfás
Fujitsu Services
Gael Aquatic Enterprises Ltd.
Galway & Aran Fishermen's Co-op
Galway County Council
Galway Harbour Company
Galway Mayo Institute of Technology
Geological Survey of Ireland
Green Tiger Express
Greenore Port Company
Hamilton Shipping
Heritage Council
Hydraulics & Maritime Research Centre, UCC
Iasc Mara Teo.
IBEC
IFA Aquaculture
Informatic Software Ltd.
Inland Waterways Association
Institute of Technology, Carlow
Institute of Technology, Sligo
Institute of Technology, Tralee
International Maritime Studies Institute, National College of Ireland
Ireland West Tourism (Mayo)
Irish Association of Activity Centres

continued

Table C.2 Stakeholders who were consulted as part of the main Stakeholders Meeting (Dublin Castle, 12th July 2005) and associated web/email consultation

Stakeholders Consultation July 2005
Irish Ferries
Irish Fish Processors and Exporters Association (IFPEA)
Irish Fish Producers' Organisation
Irish Fishermen's Organisation
Irish Institute of Master Mariners
Irish International Freight Association
Irish Mainport
Irish Marine Federation
Irish Naval Service
Irish Offshore Operators' Association
Irish Passenger Boat Ferry Operators
Irish Ports Association
Irish Sailing Association
Irish Salmon Producers Group (ISPG) Salmon Exporters
Irish Seal Sanctuary
Irish Seaweed Centre
Irish Ship Agent's Association
Irish South & East Fishermen's Organisation
Irish South & West Fish Producers' Organisation
Irish Surfing Association
Irish Underwater Council
Irish Whale and Dolphin Group
John Barnett & Associates Ltd.
Kerry County Council
Killybegs Fishermen's Organisation
Kilsaran Concrete Ltd.
Kirk McClure Morton
KPMG
Lagan Asphalt Ltd.
Leitrim County Council
Letterkenny Institute of Technology
Life Sciences Department, GMIT

continued

Table C.2 Stakeholders who were consulted as part of the main Stakeholders Meeting (Dublin Castle, 12th July 2005) and associated web/email consultation

Stakeholders Consultation July 2005
Limerick County Council
Limerick Institute of Technology
Louth County Council
Luxcel Biosciences Ltd.
Malahide Marina
Centre for the Environment, TCD
Marine Computation Systems
Marine Federation
Marine Harves
Marine Institute Board Members
Maritime Institute of Ireland
Martin Ryan Institute, NUIG
Mathematics & Statistics Department
Mayo County Council
Meath County Council
Mechanical & Aeronautical Engineering
MTL Ltd.
Muir Gheal Teo
Mullock & Sons.
National Diagnostics Centre, NUIG
National Food Centre, Teagasc
National Maritime College of Ireland
National Parks & Wildlife Service
National University of Ireland, Galway
National Windpower Ireland Ltd.
Nautical Enterprise Centre
New Ross Port Company
Norfolkline
Norse Merchant Ferries
North-Western Regional Fisheries Board
Nowcasting International Ltd.
NUI Maynooth

continued

Table C.2 Stakeholders who were consulted as part of the main Stakeholders Meeting (Dublin Castle, 12th July 2005) and associated web/email consultation

Stakeholders Consultation July 2005
Ocean Energy Ltd.
Oilean Glas Teo.
O'Sullivan Marine
Petroleum Affairs Division
Philip Lee Solicitors
Port of Cork Company
Port of Waterford Company
ProteoBio, Cork Institute of Technology
Providence Resources Plc
R.A. Burke Ltd.
Radiation and Environmental Science Centre, DIT
Radiological Protection Institute of Ireland
RAMCO
Raymond Burke Consulting
Readymix Plc.
Research Councils/HEA
Roadstone Dublin Ltd.
Rockall Marine Ltd.
Rosslare Europort
Royal Haskoning
Rural Tourism Federation
School of Law, University of Aberdeen
School of Science, Letterkenny Institute of Technology
Shannon Development
Shannon Foynes Port Company
Shannon Regional Fisheries Board
Sherkin Island Marine Station
Sicon Ltd.
Sligo County Council
Sonas Innovation
South Dublin County Council
Southern Regional Fisheries Board

continued

Table C.2 Stakeholders who were consulted as part of the main Stakeholders Meeting (Dublin Castle, 12th July 2005) and associated web/email consultation

Stakeholders Consultation July 2005
South West Donegal Chamber of Commerce/ Killybegs Electrical Refrigeration Services Ltd.
South-East Shellfish Co-Op Ltd.
South-Western Regional Fisheries Board
Stena Line Ltd
Sure Engineering (Europe) Ltd.
Sustainable Energy Ireland
Taighde Mara Teo.
Teagasc
Technology, Automation and Productivity, Enterprise Ireland
TecNet
The Embark Initiative
The Loughs Agency
Tourism Ireland
Tourism Research Centre, DIT
Transition Management
Trinity College Dublin
Údarás Na Gaeltachta
University College Cork
University College Dublin
University of Limerick
University of Ulster
University of Plymouth
Veterinary College, UCD
Waterborne Geophysics Ireland Ltd.
Waterford County Council
Waterford Institute of Technology
Waterways Ireland
Wave Energy Research Team, UL
Wavebob Ltd.
Western Development Commission
Western Regional Fisheries Board
Western Regional Tourism Authority Ltd

continued

Table C.2 Stakeholders who were consulted as part of the main Stakeholders Meeting (Dublin Castle, 12th July 2005) and associated web/email consultation

Stakeholders Consultation July 2005
Wexford County Council
Wicklow Port Company
Zoology Department, UCC
Mr. Michael Neylon, Independent Consultant
Mr. James Ryan, Independent Consultant
Dr. Rick Boelens, Independent Consultant
Dr. Tom Higgins, Independent Consultant
Ms. Zena Hoctor, Independent Consultant
Mr. Dermot McNulty, Independent Consultant

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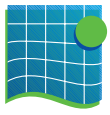

Marine Institute
Foras na Mara