The Scottish Government

Scotland's Marine Atlas

INFORMATION FOR THE NATIONAL MARINE PLAN

OVERALL ASSESSMENT KEY

Clean and Safe

Topics

- Hazardous substances
- Radioactivity
- Eutrophication
- Oil / chemical spills
- Beach litter
- Bathing water microbiology
- Shellfish water microbiology
- Algal toxins

Status Assessment

- Many concerns
- Some concerns
- Few or no concerns
- Lack of evidence / robust assessment criteria
- Many local concerns
- Some local concerns
- NP Not present

Trend Assessment 2005-2009

- Improvement
- Deterioration
- No overall trend discernible

Healthy and Biologically Diverse

Species

- Plankton
- Cetaceans
- Grey seals
- Harbour seals
- Seabirds
- Commercial fish and shellfish
- Demersal fish
- Sharks / rays
- Occasional visitors
- Non-natives
- Water birds

Habitats

- Intertidal rock
- Intertidal sediments
- Subtidal rock
- Shallow and shelf subtidal sediments
- Deep sea

Area maps - habitat types

- Intertidal rock
- Intertidal sediment
- Subtidal rock
- Shallow subtidal sediments
- Shelf subtidal sediments
- Deep-sea habitats

Habitat information overlays bathymetry data on area maps

Status Assessment

- Many concerns
- Some concerns
- Few or no concerns
- Lack of evidence / robust assessment criteria
- NP Not present

Trend Assessment 2005-2009

- Improvement
- Deterioration
- Stable
- NAA No Area Assessment
- NT No trend information available

Productive

Economic Activity

- Aquaculture - finfish
- Aquaculture - shellfish
- Fishing
- Oil and gas
- Telecommunication cables
- Renewable energy
- Ports
- Shipping
- Waste outfalls
- Waste dredge spoil
- Water abstraction
- Leisure and recreation
- Salmon and sea trout fishing
- Historic environment
- Defence

Area Activity Basis

- % Fish farm gate value
- % Fish farm gate value
- % Catch landing value
- % Production revenues
- % Cable length
- % Mega Watts produced
- % Tonnage of top 16 ports
- % Number of vessels calling at major ports
- % Volume of waste water
- % Actual tonnage disposed
- % Extraction volumes
- % Number of berths available
- % Catches of salmon and sea trout
- Activity not measurable
- Activity not measurable

Level of activity in 2009

- % by value
- % by specific parameter
- Other activities not measurable
- NP Not present
- NA No assessment (covers no data, no robust methodology)
- CC Commercial confidentiality prevents disclosure

Change in pressure 2005-2009

- Increase
- Decrease
- No trend discernible

The Scottish Government

Scotland's Marine Atlas

INFORMATION FOR THE NATIONAL MARINE PLAN

marinescotland

SEPA Scottish Environment Protection Agency

Scottish Natural Heritage
Dualchas Nàdair na h-Alba
All of nature for all of Scotland
Nàdar air fad airson Alba air fad

JNCC Joint Nature Conservation Committee

Recommended citation format: Baxter, J.M., Boyd, I.L., Cox, M., Donald, A.E., Malcolm, S.J., Miles, H., Miller, B., Moffat, C.F., (Editors), 2011. Scotland's Marine Atlas: Information for the national marine plan. Marine Scotland, Edinburgh. pp. 191

The editors would like to acknowledge the enormous effort made by many people in their organisations in the preparation of this atlas.

COPYRIGHTS

Scottish Local Authority boundaries and travel to work areas: Ordnance Survey 2010. Reproduced by permission of Ordnance Survey on behalf of HMSO. © Crown copyright and database right (2011). All rights reserved. Ordnance Survey Licence number 100020540

HydroSpatial and bathymetry: SeaZone 2011. © British Crown and SeaZone Solutions Limited, 2011. Products Licence No. 122006.004

Bathymetry: The Scottish Association for Marine Science (SAMS), based on GebcoCE and GTOPO30 datasets

Broadscale habitat map: produced by JNCC © UKSeaMap 2010 project

Seabird colony data: © JNCC/Seabird Monitoring Programme

Historic Scotland images: © Crown Copyright, Reproduced courtesy of Historic Scotland. www.historicscotlandimages.gov.uk

OSPAR regions: OSPAR Commission

Water Framework Directive Area Advisory Groups, water abstraction sites and industry outfall sites: Scottish Environment Protection Agency (SEPA)

River network: Centre for Ecology and Hydrology © NERC

ICES squares: Danish Institute for Fisheries Research (DIFRES)

Surf beaches: www.magicseaweed.com

Dive sites: www.divesitedirectory.com

Marinas, sailing areas and routes: Royal Yachting Association 2010

Oil and chemical spills: Advisory Committee on Protection of the Sea (ACOPS)

National Renewables Infrastructure Plan (NRIP) sites and ship building yards: Scottish Enterprise

National grid infrastructure: Scottish and Southern Energy (SSE) and Scottish Power Power Systems (SPPS)

Telephone cables: Global Marine Systems and BT Telecom

Coastal Waste Water Treatment Works: Scottish Water

© Crown copyright 2011

ISBN 987-0-7559-8254-7

The Scottish Government
St Andrew's House
Edinburgh
EH1 3DG

Cover designed by Marine Scotland

Produced for the Scottish Government by RR Donnelley B63651 03/11

Published by the Scottish Government, March 2011

Overall Assessment key

II Copyrights

III Contents

V Ministerial Foreword

001 Overall Assessment

020 Chapter 1 Introduction

024 Chapter 2 Physical Characteristics

024 The Scottish Scene
026 Weather and Climatic Conditions
028 Currents and Circulation
032 Temperature, Salinity and Ocean Acidification
036 Waves and Sea Level

038 Chapter 3 Clean and Safe

038 Introduction
040 Water Framework Directive Classification of Transitional and Coastal Waters
042 Hazardous Substances
048 Biological Effects of Contaminants
052 Oil and Chemical Spills
054 Radioactive Substances
056 Microbiological Contamination
058 Biotoxin Monitoring in Scotland
060 Eutrophication
064 Dissolved Oxygen in the Clyde and Forth Estuaries
066 Marine Litter
068 Silver in Intertidal Mussels
069 Underwater Noise

070 Chapter 4 Healthy and Biologically Diverse

070 Introduction
072 Protected Areas
076 Intertidal Rock
078 Intertidal Sediments
082 Subtidal Rock
090 Inshore and Shelf Subtidal Sediments
100 Deep Sea Habitats
104 Plankton
108 Commercial Fish and Shellfish Stocks
114 Demersal Fish Community
116 Sharks and Rays
120 Seals
124 Cetaceans
130 Seabirds
134 Waterbirds
136 Occasional Visitors
138 Non-Native Species in Scottish Waters

140 Chapter 5 Productive

140 Introduction
142 Economic Analysis of Scotland's Core Marine Sector
144 Aquaculture
146 Fishing
150 Salmon and Sea Trout Fishing
152 Leisure and Recreation
156 Historic Environment and Cultural Heritage
160 Coastal Protection and Flood Defence
162 Renewable Energy and Power Cables
166 Carbon Capture and Storage
168 Oil, Gas, Pipelines and Gas Storage
170 Water Abstraction
172 Maritime Transport (Ports and Shipping)
176 Waste Disposal (Dredge Material)
178 Waste Disposal (Waste Water Treatment and Industrial Outfalls)
182 Defence (Military)
184 Telecommunication Cables
186 Marine Management, Education, Research and Development

188 Chapter 6 Climate Change

190 Reference Map

References available on-line at
www.scotland.gov.uk/marineatlas

Data Sources available on-line at
www.scotland.gov.uk/marineatlas

Glossary available on-line at
www.scotland.gov.uk/marineatlas

Scotland's seas shape our nation. We are committed to protecting and managing this precious resource, to meet the needs of nature and people, now and into the future.

Through the Marine (Scotland) Act 2010 we have ensured a more integrated approach to planning for our seas. Marine plans will set out policies for sustainable development of the seas – protecting the environment and promoting economic growth, while also taking social and cultural considerations into account.

The publication of this Atlas is a key step in developing our first national marine plan, for all Scottish waters out to 200 nautical miles. For the first time, the Atlas maps and brings together a wide range of data on the marine environment and the activities that take place in our seas. This represents a unique evidence base to help develop future objectives and inform marine planning and management. This evidence base is an invaluable resource in its own right – and one which we must continue to develop and make as accessible as possible.

The Atlas highlights the breathtaking richness of our seas – from rare species of plants and animals to the income generated by marine industries as diverse as aquaculture and tourism. It draws on well established marine science and monitoring programmes, economic data and a wide range of other sources, demonstrating how they can be interpreted spatially.

The Atlas provides an up-to-date assessment of the current state of Scotland's seas, which will inform the implementation of the Marine Strategy Framework Directive. I hope the Atlas also serves to educate and inform a broad audience, both within Scotland and further afield, as to the beauty and value of our seas.

Richard Lochhead

Richard Lochhead MSP

Cabinet Secretary for Rural Affairs and the Environment

OVERALL ASSESSMENT

SCOTLAND'S VISION IS FOR 'CLEAN, HEALTHY, SAFE, PRODUCTIVE, BIOLOGICALLY DIVERSE MARINE AND COASTAL ENVIRONMENTS, MANAGED TO MEET THE LONG TERM NEEDS OF NATURE AND PEOPLE'

Introduction

Scotland's vision is for 'clean, healthy, safe, productive, biologically diverse marine and coastal environments, managed to meet the long term needs of nature and people'. This assessment of the condition of Scotland's seas has been based on scientific evidence from data and analysis, supported by expert judgement.

© Naomi Moffat

© Brent Harrald

Ocean Processes

Components	State in Scottish Seas
Sea temperature	Sea surface temperature is increasing. The rate of increase over the period 1985 – 2009 has been generally greater than 0.2°C per decade.
Sea level	The average long-term UK trend in mean sea level is estimated as 1.4 mm/year. However the rise is not steady. For example, in the 1990s sea level rose by 3 to 4 mm per year. Rising sea levels adversely affect the low-lying parts of the coast which are vulnerable to flooding and erosion.
Ocean acidification	Since the industrial revolution, the CO_2 absorbed by the oceans has resulted in a decrease in pH of 0.1 units but there are currently no baseline measurements of ocean acidity against which changes in Scottish and wider UK waters can be judged.
Circulation, suspended particulate matter, turbidity, salinity, waves	These processes vary on timescales from a day to years but have shown no significant trend over the past decade, except for a slight increase in the salinity in the northern parts of Scottish seas.

© Sue Scott

Climate Change and Ocean Acidification

The climate shows considerable variation over short and long timescales. However, in recent years there has been a marked increase in the concentration of carbon dioxide (CO_2) in the atmosphere of the Earth and, at the same time, sea surface temperature has risen as have sea levels. Changes in the biological components of the seas have been observed including earlier plankton blooms, a northward movement of some species and a reduction in seabird populations, all of which have been linked to climate change.

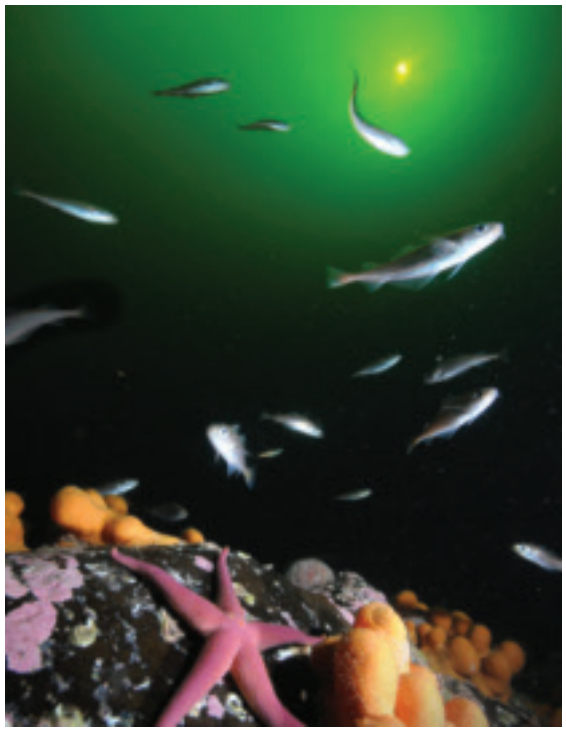
At the same time, the seas are becoming more acidic, the consequences of which, especially for calcareous organisms, could be significant. Reductions in the emissions of greenhouse gases are required and Scotland has set ambitious targets. However, even with such reductions, it is highly likely that further impacts of climate change on the marine environment will be observed.

© SEPA

Clean and Safe

Scotland's seas are mainly clean and safe, although there are some localised areas where there is contamination or hazards to human health. For example, sediments in several harbours and estuaries remain contaminated with hazardous substances, a legacy of past industrial discharges. Water quality in the Forth and Clyde estuaries is compromised by discharges of industrial effluent and treated sewage although effluent treatment has improved resulting in returning populations of residential and migratory fish. The use of historical contaminants such as polychlorinated biphenyls (PCBs) and tributyl tin (TBT) has been banned, and monitoring continues to assess their continued environmental decline.

Information is being gathered on a range of other contaminants, including endocrine disrupters and brominated flame retardants, to assess their environmental impacts. Diffuse inputs of nutrients and bacteria have given rise, respectively, to some localised issues in small east coast estuaries and at bathing beaches. Action plans have been put in place to tackle these issues. Concerns such as marine litter and underwater noise have become more broadly recognised and will be addressed through the operational response to the Marine Strategy Framework Directive. Generally the effects of noise remain unquantified and unknown.



© Sue Scott

Healthy and Biologically Diverse

Scotland's seas support a diverse array of habitats and species and contain nationally and internationally important populations of certain species such as the northern feather star, the burrowing sea anemone, the northern sea fan and cold water corals.

There is evidence that certain habitats have been impacted, for example shallow and shelf subtidal sediments (including burrowed mud habitats). This stems largely from the effects of fishing over large areas of the seabed and more localised impacts from activities such as aquaculture.

The low abundance of some demersal commercial fish species across the west coast of Scotland is a major concern and is being addressed through various initiatives. Improved knowledge of fishing activity and its impact on the marine environment would be beneficial.

Establishment of new fisheries should only be undertaken following careful assessment of the viability and future sustainability of the fishery, especially given the sensitivity of some, particularly deep water, species to fishing and against a background of historic over-exploitation.

Sharks, skates and rays face further declines and are severely depleted all around the coast, although the number of sightings of basking sharks has increased in recent years especially in the Minches and Malin Sea. These declines are largely the consequence of historically unsustainable catches in both target and non-target fisheries and their long-lived, very low fecundity life cycle. Many of these, for example, porbeagle and common skate, can no longer be targeted commercially.

Populations of some seabirds, harbour seals and some fish species have declined. Possible reasons include climate change, a number of different human activities and competition from other species. These declines may be associated with broader changes in the food web. For example, the decline in availability of sandeels has had a major influence on recent changes in seabird numbers on the east coast and in the Northern Isles.

Although, in general, the current assessment for cetaceans suggests there are no specific concerns, this has been made against a background of a very high level of uncertainty and little power to detect concerns if they currently exist.

© John M. Baxter

Productive

Scotland's seas are economically productive. Official figures show that the core marine sector, less the extraction of oil and gas, contributed £3.6 billion of Gross Value Added (GVA) in 2008 (at 2009 prices), about 3.5% of overall Scottish GVA. About 39,800 people were employed, 1.6% of Scottish employment. The extraction of oil and gas had a GVA of £13.3 billion in 2007 (at 2009 prices).

Fishing takes place in all Scottish sea areas but some, such as Hebrides, North Scotland Coast and East and West Shetland, are far more economically productive than others. Aquaculture, both finfish and shellfish, predominates on the west coast and the islands.

Sixteen major ports handle about 98% of all port traffic with liquid bulk, mainly oil and gas, accounting for 69%. There is significant commercial shipping both to ports and for transit through Scottish waters, as well as domestic and international ferry activity. The seas are also used extensively by the Royal Navy and other armed forces, for exercises and operations, sometimes including international partners.

Other activities include cooling water abstraction for power stations and the disposal of treated urban waste water, industrial effluent and dredge spoil. Seabed telecommunications cables carry millions of internet and phone call connections, thereby providing a major communications network.

The seas are also used for leisure and recreation, particularly sailing, angling and other sporting activities. Scotland's historic environment and natural and cultural heritage attract many tourists.

The enormous potential of marine renewable energy generation from offshore wind, waves and tides has started to be harnessed. There is also potential for storage of carbon dioxide under the seabed, in 'carbon capture and storage' schemes.

Pressures

In this assessment, a pressure is a human activity which could lead to an impact, i.e. a change in the condition or state of an ecosystem component. Scotland's extensive marine area is subject to a wide range of pressures. While recognising that there may be cumulative effects, a large number of these individual pressures are at too small a scale to be considered significant at the national level of this assessment. However, some may have local impacts that could threaten rarer species and habitats.

In the 'Activities and Pressures' sections of the following summaries, the aim is to demonstrate both the economic importance of the sea area (through percentages to show how much of the total of that activity in Scottish waters is in that area) as well as to identify pressures and trends. A large amount of activity does not necessarily result in significant pressure on ecosystem components especially where such activities are effectively managed. Conversely, a small amount of activity could result in a significant pressure to a specific ecosystem component if not well managed. Significant pressures have been highlighted separately.

There are two significant pressures on the Scottish marine area which are widespread:

- Human activity contributing to climate change
- Fishing, which impacts on the seabed and species

Fishing is a complex activity. There are various types, each of which exerts a different pressure on the marine environment. Bottom trawlers and scallop dredgers drag their gear across the seabed so potentially damaging it. Pelagic trawlers and long liners fish in the water column, and their gear does not normally touch the seabed. Static nets, pots and creels are lowered onto the seabed and recovered later, although they can drag and damage fragile habitats and species. All types of fishing, of course, remove fish from the sea. As Vessel Monitoring System (VMS) terminals are not compulsory on vessels below 15 m, there are less spatial data available about the activities of this part of the fleet which represents a data gap.

Pressures which are becoming more widely recognised include noise pollution and marine litter. However, the impacts of noise and the longer term effects of the microparticles arising from the breakdown of litter are not well understood. Some pressures may change in scale and location in the future. For example, those associated with offshore oil and gas as new oil and gas fields are discovered and old ones are decommissioned. Also, aquaculture may move offshore to less sheltered waters as technology develops.

New pressures are likely to include those associated with the storage of carbon dioxide deep under the seabed and renewable energy, including offshore wind, wave and tidal power. In particular, further work is required to determine the potential impacts of renewable energy, such as the general effects on shipping, fishing and biodiversity. Possible local concerns beyond these are identified in each summary.

Response

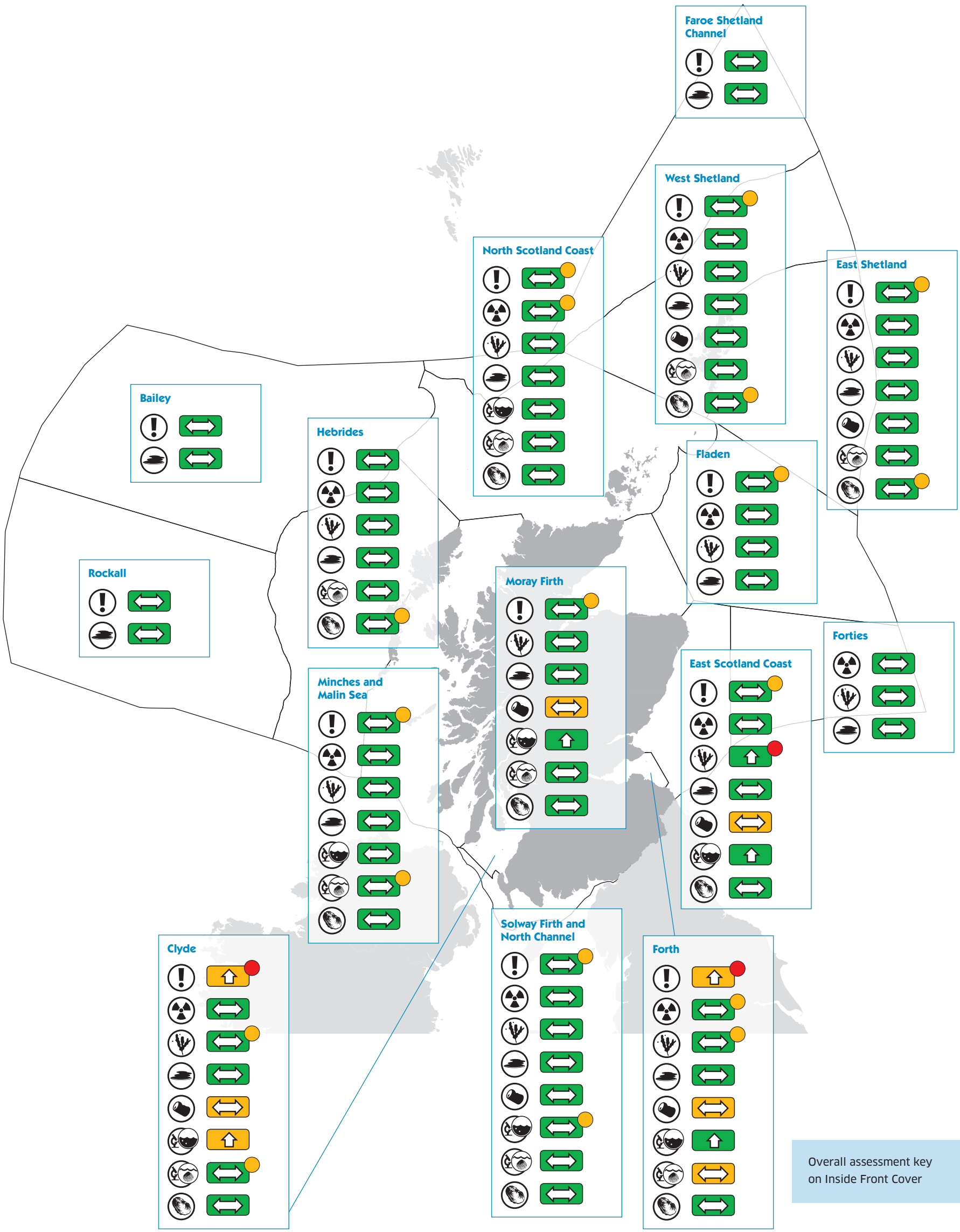
Actions are in place to mitigate the effects of many of the pressures on the marine environment. These actions include education, awareness raising and government activity, such as regulation, licensing, monitoring, management and scientific research.

Marine monitoring programmes assess current status and trends and the effectiveness of mitigation measures, such as pollution control. These programmes also serve to identify gaps in knowledge.

This Atlas is the key science evidence base for the first Scottish national marine plan. The Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009 set the statutory basis for national marine planning in Scottish waters out to 200 nautical miles, and for regional planning potentially out to 12 nautical miles. The marine planning process allows for participation by a wide range of interests in expressing policies for sustainable development - promoting sustainable economic growth which takes account of environmental issues and limits and social and cultural perspectives. The development of marine plans will therefore be an important new method of ensuring opportunities and concerns are identified and action is taken to exploit opportunities and address concerns.

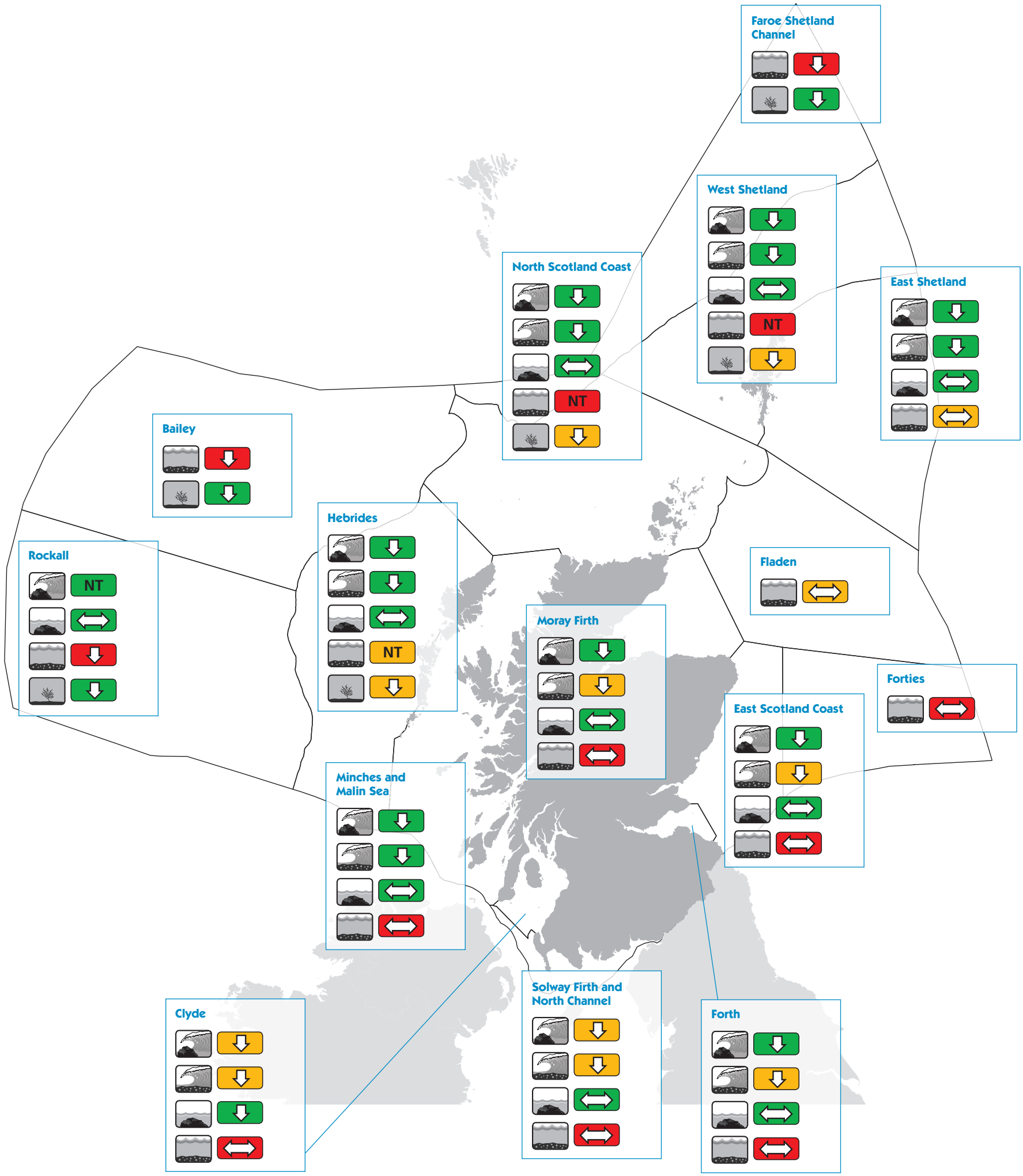
Under the Marine Strategy Framework Directive (MSFD) there is an obligation to take the necessary measures to achieve and maintain Good Environmental Status (GES) for marine waters by 2020. A programme of measures is to be implemented by 2016, which will comprise feasible responses needed to meet the requirements of the Directive. Details of the MSFD GES descriptors are presented in Chapter 1.

OVERALL ASSESSMENT
CLEAN AND SAFE SEAS ASSESSMENT

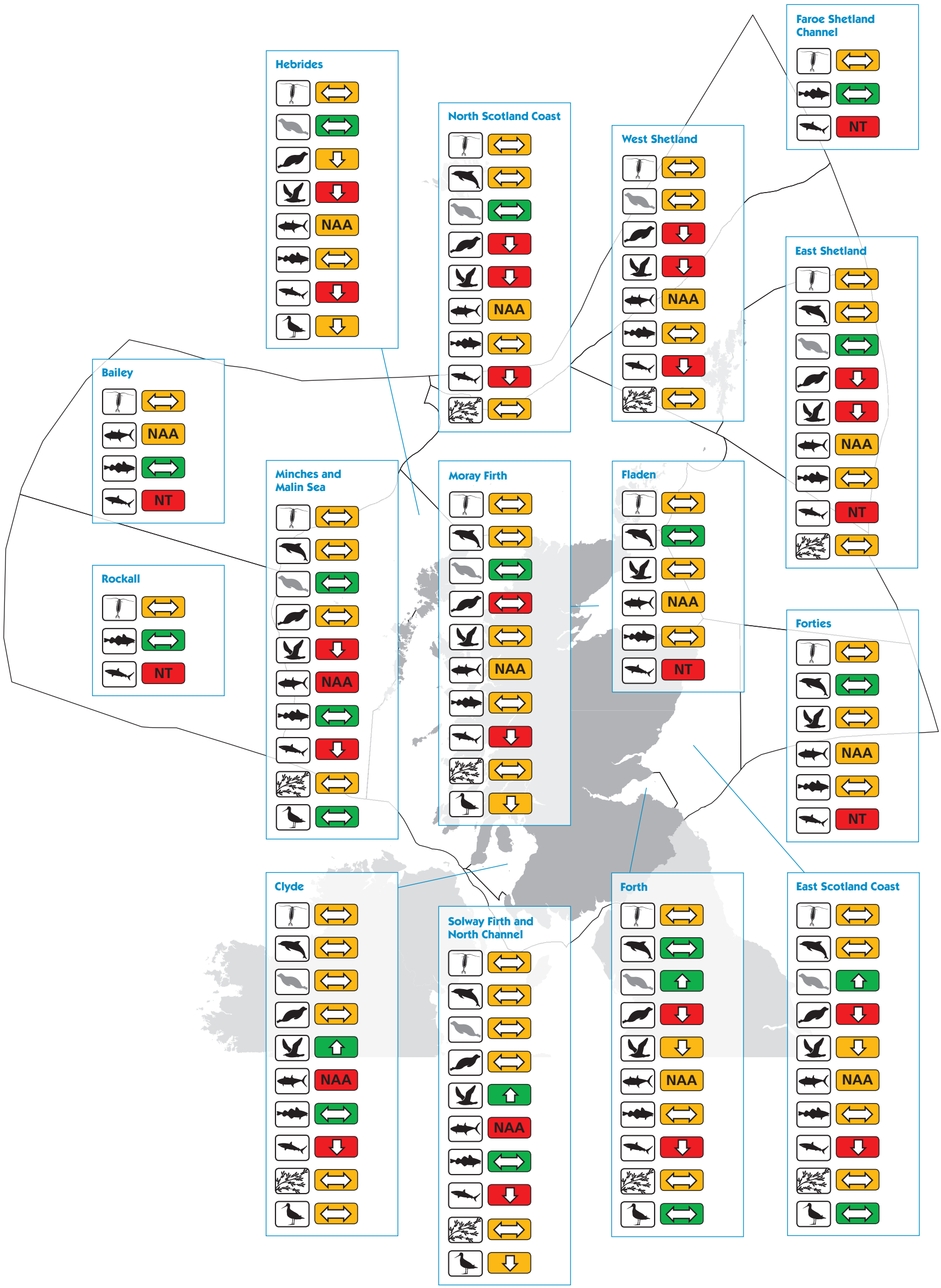


Overall assessment key on Inside Front Cover

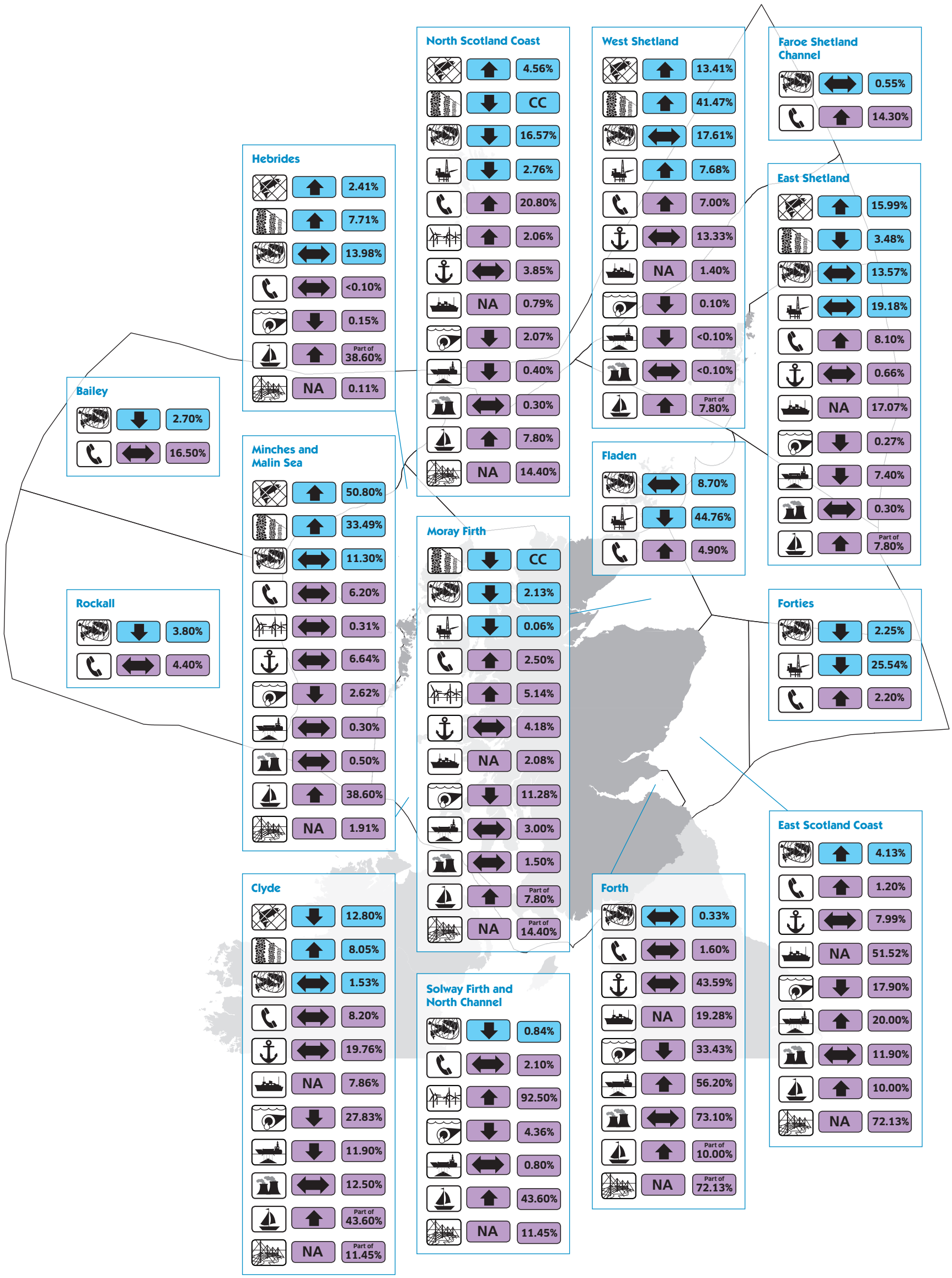
HEALTHY AND BIOLOGICALLY DIVERSE SEAS - HABITATS ASSESSMENT



HEALTHY AND BIOLOGICALLY DIVERSE SEAS - SPECIES ASSESSMENT



OVERALL ASSESSMENT
PRODUCTIVE SEAS ASSESSMENT



OVERALL ASSESSMENT
SOLWAY FIRTH, NORTH CHANNEL AND CLYDE

Characteristics

These two sea areas extend from the English border in the Solway Firth to the upper reaches of the Clyde Estuary in Glasgow and to the Mull of Kintyre. They include the Solway Firth, North Channel and the Clyde, which itself includes the Clyde Estuary, the Firth of Clyde and the Clyde sea lochs. In general the waters are relatively shallow but reach depths of over 100 m in the fjordic sea lochs of the Clyde and in excess of 250 m in Beaufort's Dyke. The areas exhibit a considerable tidal range, illustrated by mesotides (2-4 m) in the Clyde area and macrotides (more than 4 m) in the Solway Firth.

Natural features include large intertidal mudflats and sandflats in the Solway Firth and Clyde Estuary. The areas are important for wintering wildfowl and waders and have extensive mussel beds.

Activities and Pressures

The areas host a wide range of human activities and consequently are subject to a number of pressures.

Aquaculture, particularly salmon and shellfish production, takes place in a number of sea lochs and there is widespread fishing, mainly for *Nephrops* and scallops. There are significant ports, shipping and ferry activities with 20% of Scottish cargo volume passing through the Clyde ports. These are the busiest areas for ferry traffic with key links to various islands and peninsulas, as well as Northern Ireland, accounting for 64% of overall Scottish passenger traffic. Scotland's only Naval base is on the Clyde. The areas are popular for recreational sailing, supporting 44% of Scottish boat berths. There are also popular bathing beaches on the Ayrshire coast.

The Clyde Estuary and Ayrshire coast are relatively urbanised and industrialised compared with other parts of Scotland. This results in discharges from waste water treatment works and industrial effluents to estuary and coastal waters, as well as water abstraction, mainly for power generation. There are seabed telecommunication cables and power cables to Ireland and Northern Ireland and the Robin Rigg wind farm in the Solway Firth.

Pressures resulting from these activities include the introduction of contaminants from industrial effluents and sewage works and dumping of dredge spoil from harbour maintenance. Fishing using trawls and dredges results in the abrasion of the seabed. There are also local effects of aquaculture on seabed ecology.

Caerlaverock

© SNH

HMNB Clyde

© SNH

Ailsa Craig

© SNH

Millport bathing beach

© Keep Scotland Beautiful

Queen Mary 2 at Greenock

© Clydeport PLC

Trawler in the Clyde

© Marine Scotland

Recreational boating and commercial shipping activities have probably led to the introduction of non-native species.

Condition

Clean and Safe
At the area level there are few concerns in relation to hazardous substances, radioactivity, oil and chemical spills and algal toxins. Contaminant loadings to the Clyde Estuary are lower now compared to historical discharges but a legacy of localised contaminated sediments remains. These in turn have caused elevated concentrations of contaminants in mussels in the Clyde Estuary.

Water quality in the Clyde estuary is compromised by discharges of industrial effluent and treated sewage although effluent treatment has improved resulting in returning populations of residential and migratory fish.

The quality of bathing and shellfish waters in the Firth of Clyde is affected by inputs of bacteria from diffuse sources, which increase during periods of high rainfall. Local accumulations of litter are observed on some beaches possibly being transported by the prevailing currents. The source is not always possible to identify.

Healthy and Biologically Diverse
The status of habitats within the areas is mixed. Intertidal habitats (rock and sediments) are deteriorating. In relation to rocky intertidal habitats this is due to invasion of non-native species, in particular wireweed. Shallow subtidal sediments are relatively degraded while shallow, subtidal rocky habitats appear to be in a better state. In general, mobile species such as cetaceans, seals and seabirds also show a mixed picture but overall are stable at the area level. In contrast, the reduced populations of commercial fish are a major concern. The introduction and establishment of a number of invasive non-native species, for example, intertidal wireweed (*Sargassum muticum*) and the subtidal carpet sea squirt (*Didemnum vexillum*), first found at Largs in 2009, is very concerning.

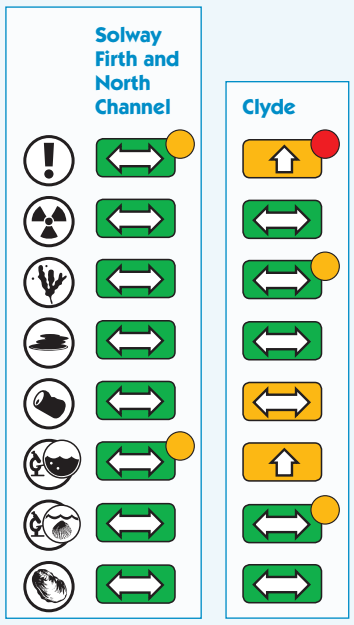
Response / Forward Look

Many of the concerns associated with these areas result from historical practices and management approaches. Enhanced scientific knowledge, improved regulation and greater environmental awareness have resulted in significant reductions in inputs of contaminants and improvements in water quality.

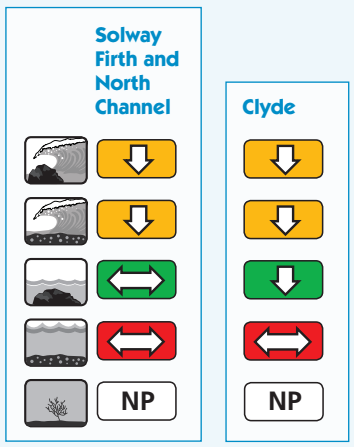
Pressure on coastal and inshore habitats is increasing from industry such as the proposed Hunterston power station (with a possible change in cooling water requirements), aquaculture and recreational activities. The areas have a significant resource to support the generation of marine renewable energy, mainly offshore wind and tidal. Growth of the industry and development of associated infrastructure, including seabed cables, is anticipated. Further work will be required to understand the effects on seascapes and landscapes, communities, tourism and recreation.

Increasing shipping activity, possible new container facilities at Hunterston, and recreational sailing will risk the further introduction of non-native species. Underwater noise associated with industrial and recreational activities is expected to increase. There is also the possibility of increased ferry traffic to Northern Ireland with facilities in Loch Ryan due to expand.

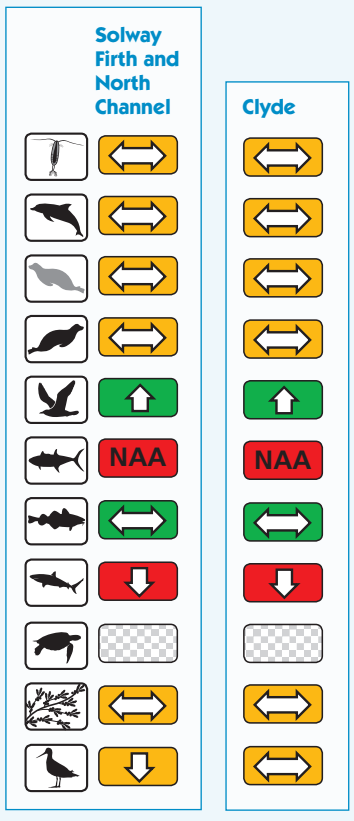
Clean and Safe



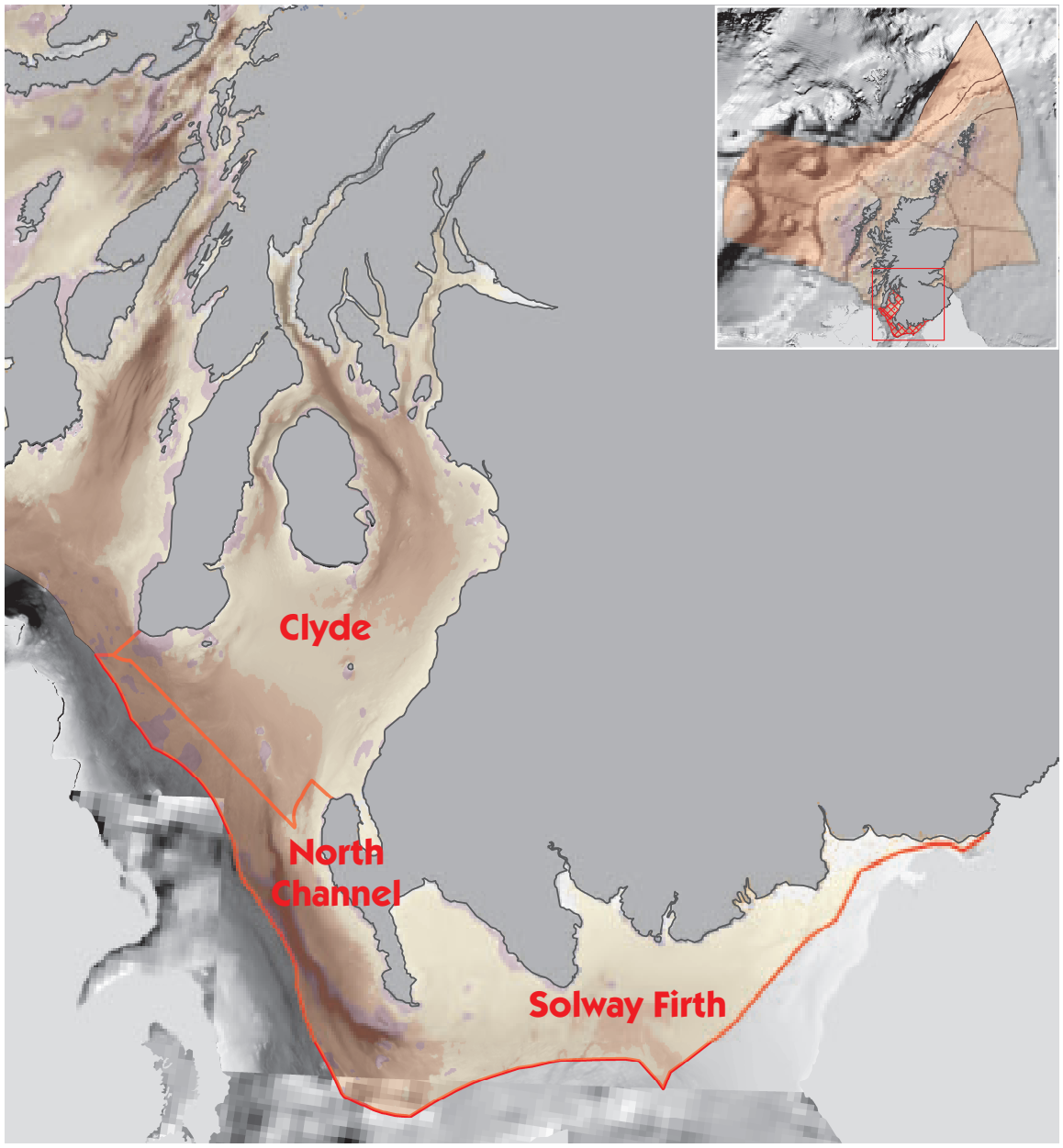
Habitats



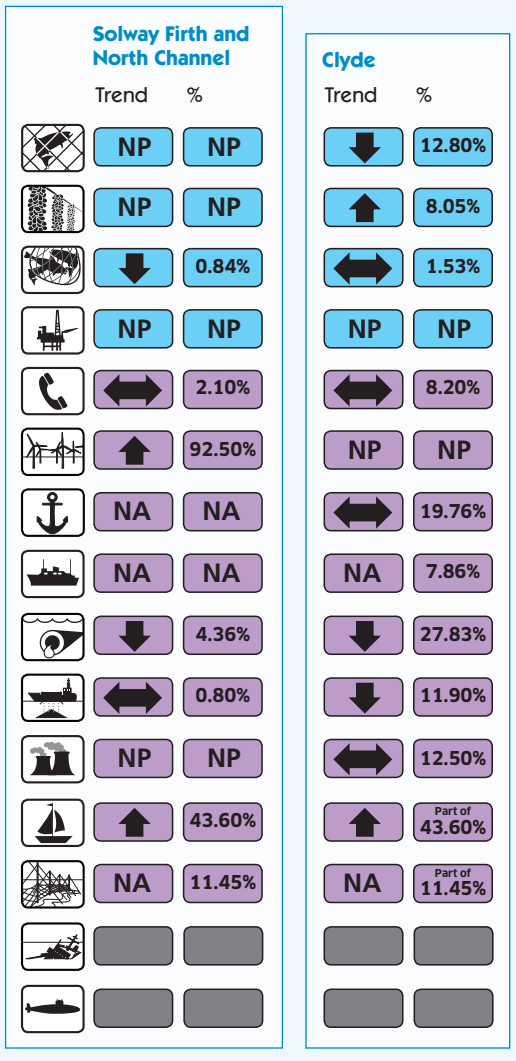
Species



Overall assessment key on Inside Front Cover



Productive



Solway Firth and North Channel

Surface area	3,923 km²
Maximum depth	265 m
Minimum depth	0 m
Average depth	55 m

Clyde

Surface area	4,092 km²
Maximum depth	151 m
Minimum depth	0 m
Average depth	40 m

Area based on high water mark Albers Equal Area Projection. Depths based on 1 arc-minute ETOPO bathymetry.[1]

OVERALL ASSESSMENT
MINCHES AND MALIN SEA

Characteristics

The area extends north from the Mull of Kintyre to Cape Wrath incorporating the sea area between the Scottish mainland and the Western Isles. The seabed is coarse sands, gravel and rock. The coastline of the Scottish mainland is dissected by many fjordic sea lochs which are sheltered from wave action. In contrast, fjardic sea lochs such as Loch Maddy with its complex of basins, tidal rapids and lagoons, are found on the east coast of the Western Isles. Sandy bays are present in many parts of the area. One of Scotland's amphidromic points (where the tidal range is almost zero) is found off Islay.

A large range of habitats supports a great diversity of wildlife. Notable features include cold water coral reef structures near Mingulay, Firth of Lorn pockmarks (seabed craters), sea pen beds, *Nephrops* grounds and areas important for marine mammals and seabirds.

Activities and Pressures

The inshore bays and sea lochs are important for aquaculture (50% by value of finfish production and 34% of shellfish) along with inshore commercial fisheries for mainly *Nephrops*, scallops, lobster and crab, providing important support for local rural economies. There are important fishing ports such as Ullapool and Lochinver.

The various island communities are serviced by a network of ferry routes that are also important for tourism. The scenic landscape, sheltered waters and accessibility make the area attractive for recreational sailing, with around 39% (figure includes Hebrides) of all sailing boat berths in Scotland. Wildlife tourism and recreational diving are also popular.

The Minches are used as a sheltered shipping route and the Raasay Deep, near Skye, is used as an exercise area by submarines. Glensanda on Loch Linnhe is a major stone export quarry. There are a large number of power cables on the seabed carrying electricity to the islands.

Pressures on the marine area as a result of these activities include the effects of fishing (particularly from trawlers and dredgers). There are also local effects of aquaculture on seabed ecology, and localised pressure on coastal landscapes and wildlife from tourism.

Plockton

© David Donnan

Ferry to Iona

© SNH

Skye Bridge

© Transport Scotland

Sailing in the Minches

© The Green Blue

Mull

© SNH

Fish farm, Loch Torridon

© John M. Baxter

Condition

Clean and Safe
At the area level, there are few or no concerns for many of the components assessed (hazardous substances, radioactivity, eutrophication, oil/chemical spills, algal toxins and microbiology of bathing and shellfish waters). Concentrations of most contaminants are low in sediments and mussels. There are relatively few land based sources of contaminants, and while concentrations of copper and zinc are elevated under some fish farm cages there is no evidence of up take by local mussels.

Significant blooms of the phytoplankton species responsible for production of Amnesic Shellfish Poisoning (ASP), Diarrhetic Shellfish Poisoning (DSP) and Paralytic Shellfish Poisoning (PSP) were detected in the west coast in 2009 resulting in the closure of commercial shellfish harvesting areas for DSP and PSP toxins.

Healthy and Biologically Diverse
Habitats are in relatively good condition, although there are concerns about the condition of shallow subtidal sediments impacted by trawling.

Some commercial fish species have declined considerably from levels that may be considered reasonable for a healthy ecosystem, although declines in demersal species appear to have been halted. Some seabird species have also declined. As elsewhere, most sharks and rays are in decline although there have been increased sightings of basking sharks in recent years. Plankton, cetaceans and seals are stable at the area level.

The sea lochs contain a range of important habitats and communities and include some internationally important examples such as the highly unusual serpulid worm (*Serpula vermicularis*) aggregations only found in Loch Creran and Loch Teacius where they are protected.

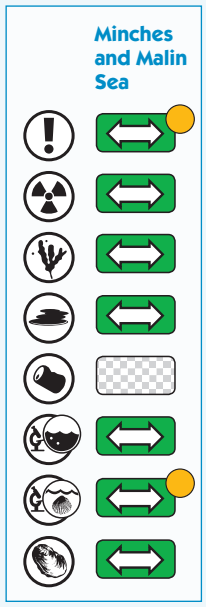
Response / Forward Look

The area is one of the most scenic in Scotland and is home to a variety of habitats and species. Consequently, future economic expansion of marine recreation and wildlife tourism is expected and it is possible this may be accompanied by increased environmental pressures. There will be a need to protect the biological diversity and address the condition of demersal fish and shark and ray populations.

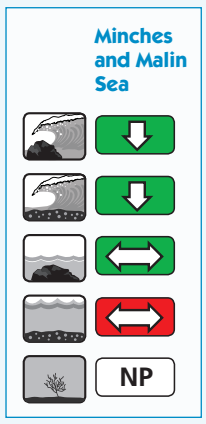
The area has a significant resource to support the generation of marine renewable energy, offshore wind, waves and tidal. Growth of the industry and development of associated infrastructure, including seabed cables, is anticipated. Further work will be required to understand the effects on seascapes, landscapes, communities, tourism, recreation and cultural heritage.

This area is also expected to remain one of the most important areas in Scotland for aquaculture which could potentially change in location and scale as technology allows it to move to more exposed waters.

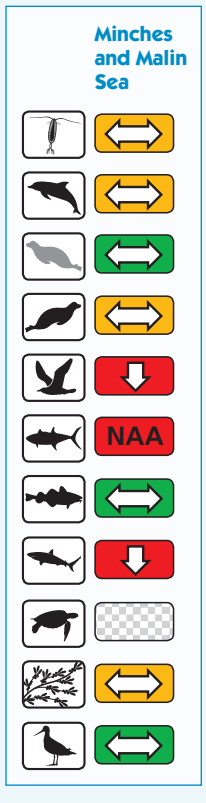
Clean and Safe



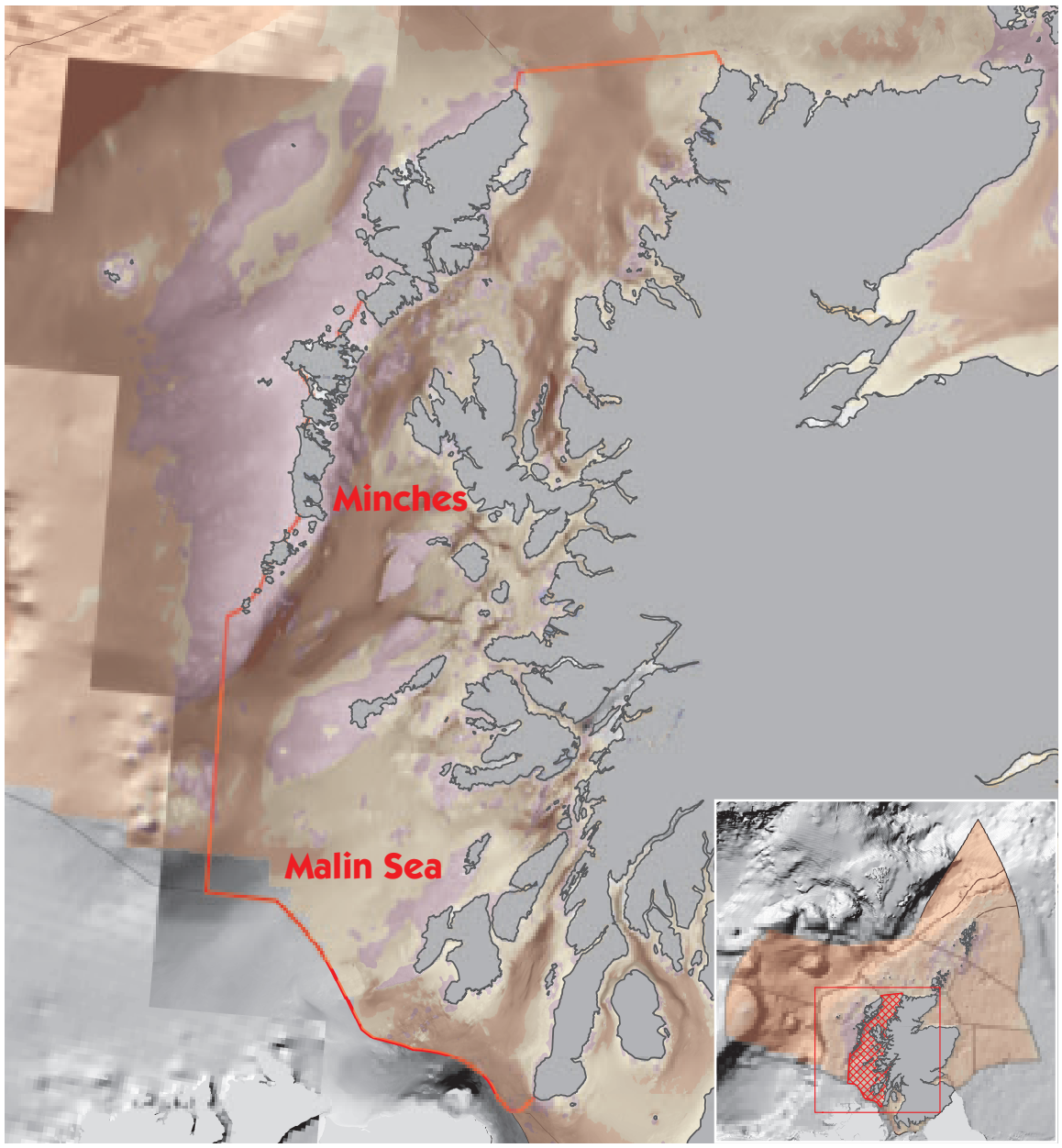
Habitats



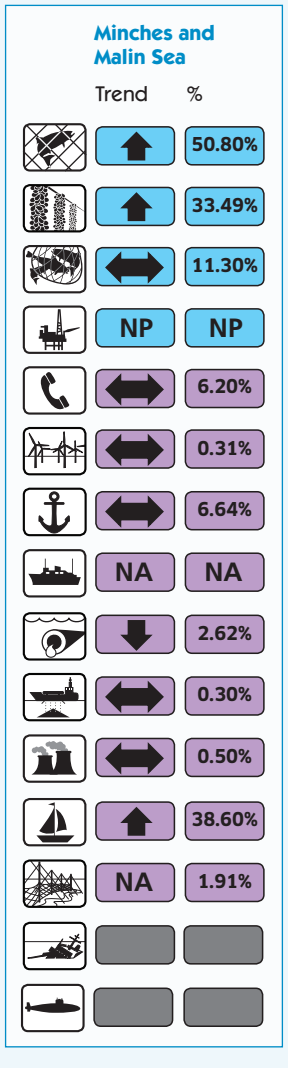
Species



Overall assessment key on Inside Front Cover



Productive



Minches and Malin Sea

Surface area	30,007 km^2
Maximum depth	307 m
Minimum depth	0 m
Average depth	64 m

Area based on high water mark Albers Equal Area Projection. Depths based on 1 arc-minute ETOPO bathymetry.[1]

OVERALL ASSESSMENT
HEBRIDES

Characteristics

This area is defined by the western coast of the Western Isles and extends out to the edge of the continental shelf. The coastline is predominantly rocky and exposed but with some more sheltered sandy bays between and on islands. Deep waters lie at or just beyond the continental shelf edge bringing important ecological communities within Scottish waters, including deep water fish species and oceanic marine mammal populations.

Areas of particular interest include St Kilda, a world heritage site for its cultural and natural heritage, seabird colonies of international importance and the Monach Isles, home to the second largest grey seal colony in the world.

The clarity of the water encourages seaweeds to grow to greater depths than elsewhere around the coast. This is especially evident on some of the more offshore islands, kelp for example is found at depths in excess of 45 m around St Kilda, compared to around 5-10 m off the North Sea coast.

Activities and Pressures

The Hebrides sea area has some of the most remote rural and coastal communities in the UK. The economies of these communities often rely upon fishing (14% by value of the landed catch in Scottish seas and in excess of 10% of total employment being from the fisheries sectors in the Uists and Barra) and aquaculture (8% of Scottish shellfish production). Inshore fisheries are mainly focused upon shellfish. However, there are important fishing grounds to the west of the area, beyond St Kilda, for both demersal fish species, such as anglerfish, and for pelagic species, especially mackerel, and these are typically exploited by vessels from the Scottish east coast or from other European countries. The area is important for military exercises and deepwater shipping routes also pass through this area.

Pressures on this marine area are largely related to those from fishing by trawlers and dredgers. More is known about the pressures from the larger demersal and pelagic vessels operating mainly in deeper waters to the west and towards the continental shelf edge, and this part of the fishery is subject to closer management and scrutiny. Otherwise, this is currently one of the least pressurised areas around Scotland.

St Kilda

© SNH

Plumose Anemone, St Kilda

© SNH

Causeway in the Uists

© SNH

Grey seal

© SNH

Fishing boats in the Uists

© SNH

Tanker off the Outer Hebrides

© P. Warrener, Marine Scotland

Condition

Clean and Safe
There are no significant concerns as regards radioactivity, eutrophication, microbiological contamination, oil/chemical spills or algal toxins. Limited information is available for the status of hazardous substances. Shellfish water quality is generally good, and there are no designated bathing waters in the area. Elevated cadmium levels have been found in some fish species from deeper waters although the origins of this are unknown and could be natural.

Healthy and Biologically Diverse
Habitats within the area are in relatively good condition overall but the effects of trawling and scallop dredging on benthic habitats and the capture of non-target species in fishing operations is a cause for some concern, especially in deep waters where restoration could take many decades or centuries.

Seabirds are showing some declines. Grey seal populations are stable with no significant concerns. Harbour seals are showing signs of decline but not as great as seen in the Northern Isles and east coast of Scotland.

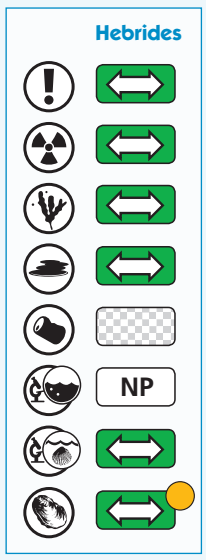
Response / Forward Look

Fishing pressure from mobile demersal fishing continues to decline. Improvements to the demersal fish community have been observed but there is a lag in realising the potential benefits of the reduction of the fishing pressure on fish populations and benthos. Aquaculture will remain an important industry and could potentially change in location and scale as technology allows it to move to more exposed waters.

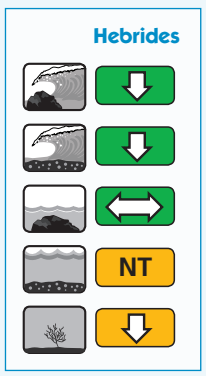
The area has a significant resource to support the generation of marine renewable energy, offshore wind, waves and tidal. Growth of the industry and development of associated infrastructure, including seabed cables, is anticipated. Further work will be required to understand the effects on seascapes, landscapes and cultural heritage as well as for the cetacean populations in the area.

There are undeveloped hydrocarbon reserves in the north of the area. These may be exploited as the oil price rises and new technology is developed, so bringing additional pressures to the area. Tanker traffic to the west of the Hebrides presents environmental risks with low frequency of occurrence but with the possibility of significant consequences should an accident occur.

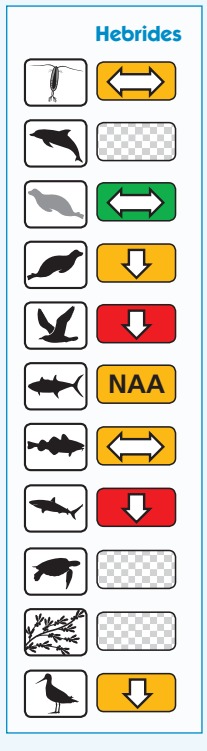
Clean and Safe



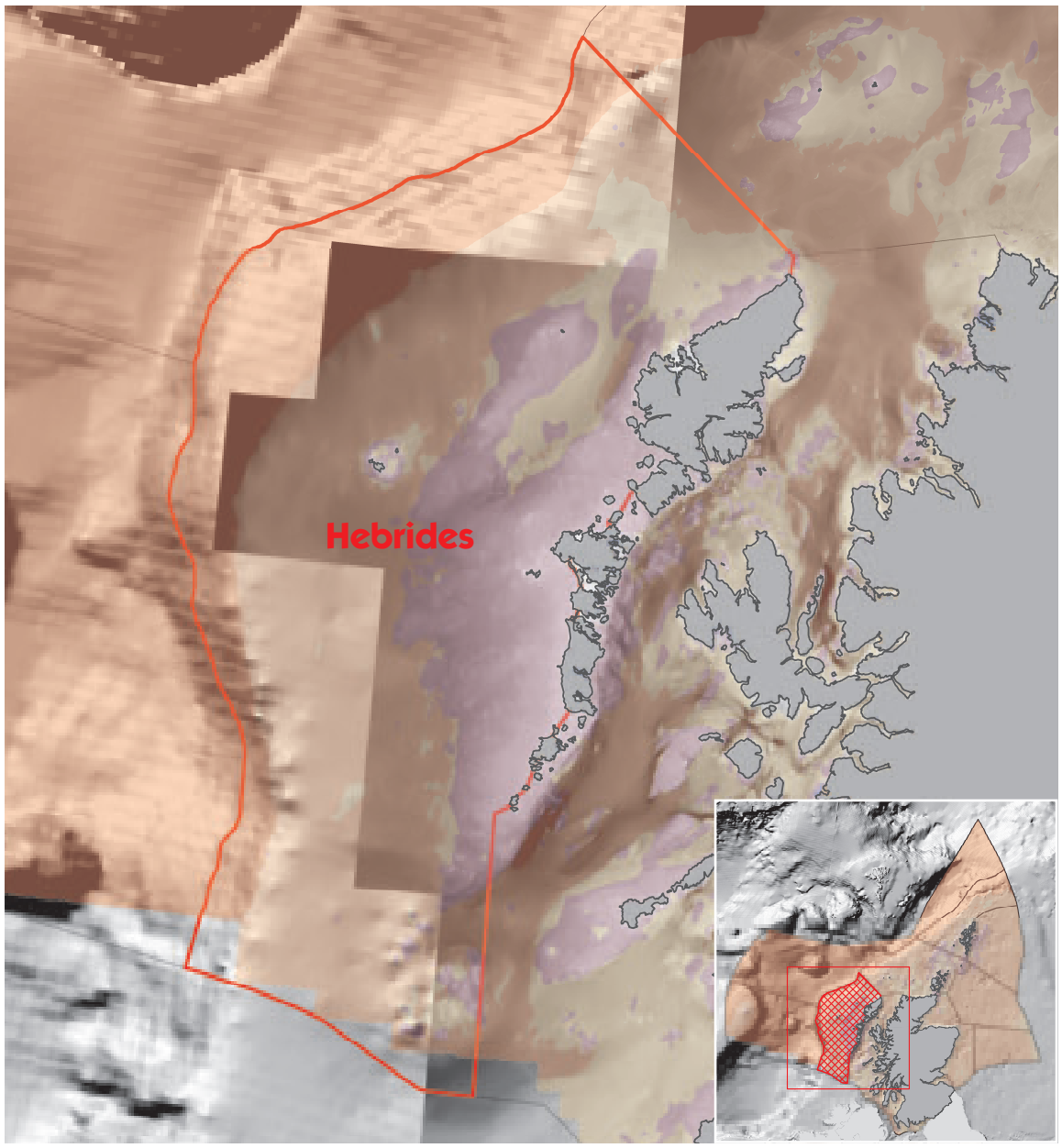
Habitats



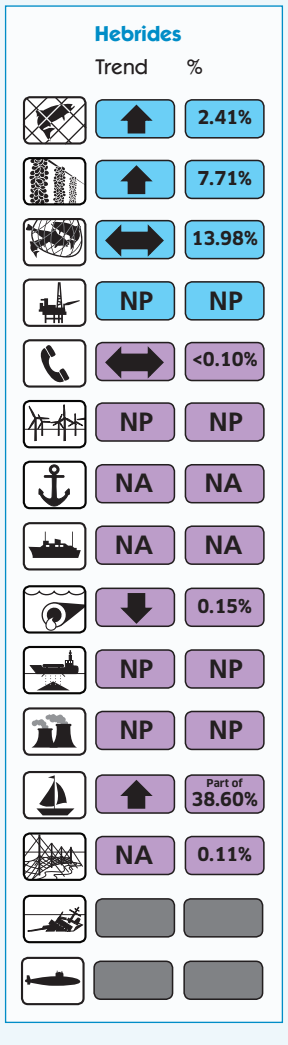
Species



Overall assessment key on Inside Front Cover



Productive



Hebrides

Surface area	41,135 km^2
Maximum depth	1,357 m
Minimum depth	0 m
Average depth	190 m

Area based on high water mark Albers Equal Area Projection. Depths based on 1 arc-minute ETOPO bathymetry.[1]

OVERALL ASSESSMENT
ROCKALL, BAILEY AND FAROE SHETLAND CHANNEL

Characteristics

These three sea areas incorporate much of Scotland's western and northern offshore region. They include deep water and are the only truly oceanic areas within UK seas. Deep waters remain at the frontier of marine exploration which means that knowledge of these areas is more limited than elsewhere.

These areas encompass Rockall which has negligible coastline and no soft intertidal sediments. In places deep water trenches exceed 2,000 m. The North West Rockall Bank is recognised for its geological formations and marine communities, as are other sea mounts, banks and ridges.

Activities and Pressures

The remote nature of these areas means there are few human activities and pressures relative to those in areas closer to centres of population. There are some important fishing grounds that support fisheries for both demersal and pelagic species (4% by value of the landed catch in Scottish seas in Rockall; 3% in Bailey and less than 1% in Faroe Shetland Channel), but the remoteness and water depth mean that few if any small vessels operate here.

Transatlantic shipping transits these areas although the data available do not quantify this. These sea areas have about 35% (by length) of all the active telecommunications cables within Scottish seas.

Pressures are mainly associated with trawling damage to the seabed. The installation and maintenance activity associated with telecommunications cables can cause short-term changes to the seabed sediments and possibly habitat damage.

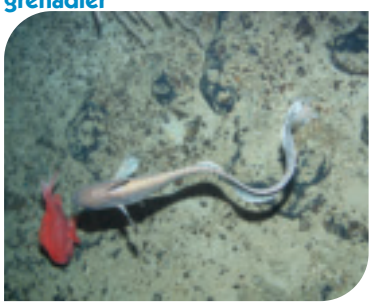
Rockall

© P. Warrener, Marine Scotland

FRV *Scotia*

© Marine Scotland

Orange roughy and roundnose grenadier



© JNCC

Fangtooth, deep water fish

© Marine Scotland

Fishing near Rockall

© P. Warrener, Marine Scotland

False boarfish and corals

© JNCC

Condition

Clean and Safe
Data are not available for all the parameters used to assess whether the seas are clean and safe. This is due to the remoteness of the area and the relative lack of inputs from land. Few or no concerns have been found in relation to the components assessed, which include oil/chemical spills and hazardous substances. Information on hazardous substances is limited to deep sea fish. Elevated levels of cadmium have been found which exceed the maximum dietary levels for humans. However, these fish are very unlikely to be eaten by humans and the origins of the cadmium are possibly natural. Low concentrations of both polychlorinated biphenyls and polybrominated diphenyl ethers have been detected in fish from depths of 1,500 m. Since there are no local inputs of these chemicals, the most likely source is from atmospheric deposition.

Healthy and Biologically Diverse
There are only very small amounts of intertidal and shallow subtidal rock (on Rockall itself) but these represent some of the most wave exposed habitats in the UK. Some deep sea habitats and their associated species have been impacted by trawling. Although detailed information is not available for many of the species groups, assemblages of demersal fish appear to be less diverse and smaller in size than before exploitation of this area began.

Notable features include the recently discovered cold water coral reefs on the 'Darwin Mounds' where there is evidence that deep water trawling has caused some damage to the reefs. It could take decades or centuries for these to fully recover.

The various banks and seamounts attract important fish assemblages including some species that have only recently been exploited, such as the orange roughy (*Hoplostethus atlanticus*) which are already showing worrying declines in their abundance. The commercial orange roughy fishery is currently closed to EU vessels. Rockall, Bailey and Faroe Shetland Channel also host a rich diversity of cetaceans, including oceanic species which probably migrate through these waters seasonally.

Response / Forward Look

Changes in plankton populations are expected because of climate change and ocean acidification. There is some indication that ocean acidification is occurring more rapidly than further inshore and this may be having a significant effect on phytoplankton.

There are undeveloped hydrocarbon reserves on the eastern edge of Bailey as well as recently licensed exploration blocks within Faroe Shetland Channel. Increased activity of this nature presents potential environmental risks with low frequency of occurrence, but they could carry serious consequences.

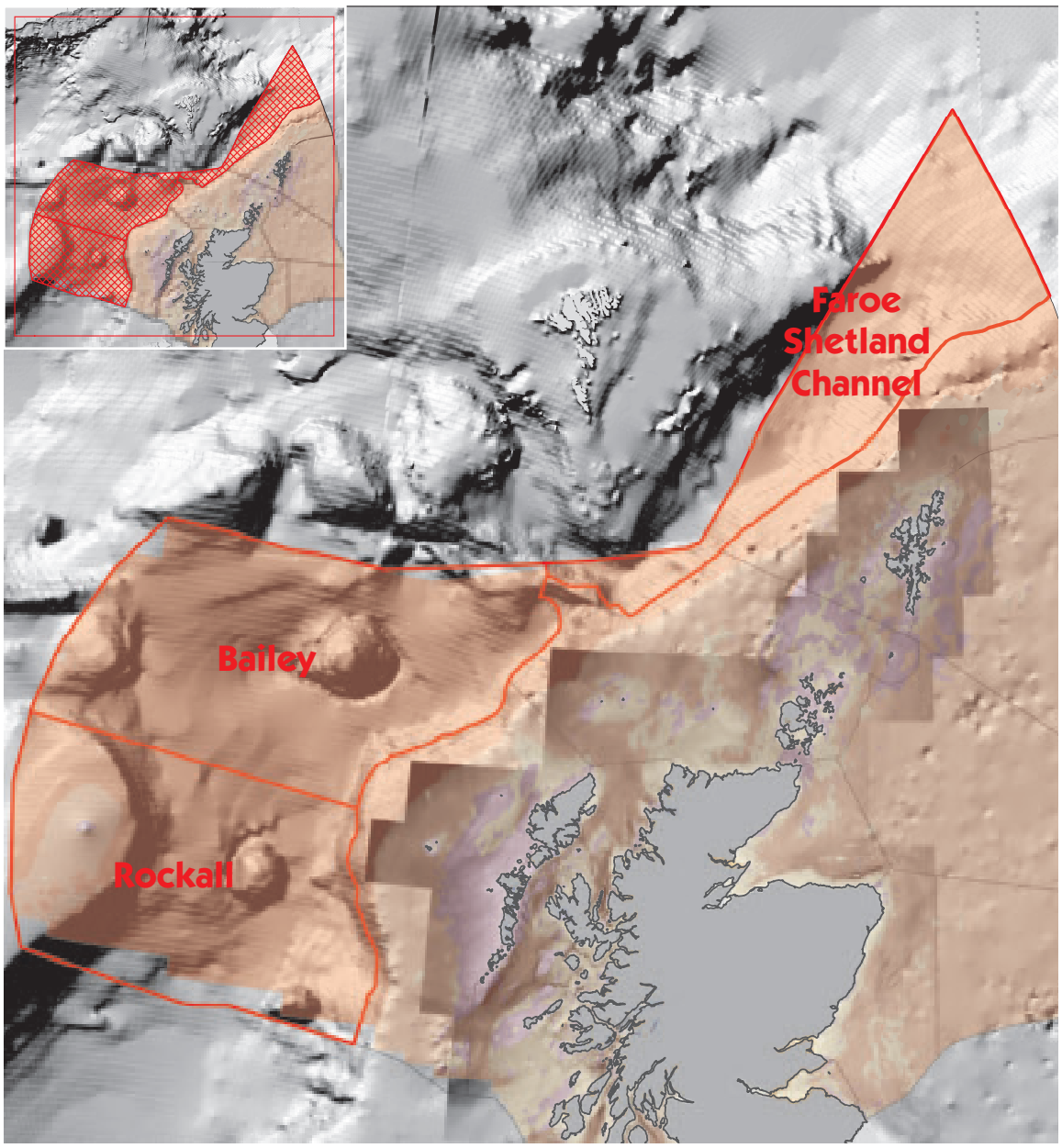
ROCKALL, BAILEY AND FAROE SHETLAND CHANNEL

Clean and Safe

	Rockall	Bailey	Faroe Shetland Channel
	⟷	⟷	⟷
	⟷	⟷	⟷
	NP	NP	NP
	NP	NP	NP
	NP	NP	NP

Habitats

	Rockall	Bailey	Faroe Shetland Channel
	NT	NP	NP
	NP	NP	NP
	⟷	NP	NP
	↓	↓	↓
	↓	↓	↓



Species

	Rockall	Bailey	Faroe Shetland Channel
	⟷	⟷	⟷
	NP	NP	NP
	NP	NP	NP
	NP	NP	NP
		NAA	
	⟷	⟷	⟷
	NT	NT	NT
	NP	NP	NP

Productive

	Rockall Trend	Rockall %	Bailey Trend	Bailey %	Faroe Shetland Channel Trend	Faroe Shetland Channel %
	NP	NP	NP	NP	NP	NP
	NP	NP	NP	NP	NP	NP
	↓	3.80%	↓	2.70%	⟷	0.55%
	NP	NP	NP	NP	NP	NP
	⟷	4.40%	⟷	16.50%	↑	14.30%
	NP	NP	NP	NP	NP	NP
	NP	NP	NP	NP	NP	NP
	NA	NA	NA	NA	NA	NA
	NP	NP	NP	NP	NP	NP
	NP	NP	NP	NP	NP	NP
	NP	NP	NP	NP	NP	NP
	NA	NA	NA	NA	NA	NA
	NP	NP	NP	NP	NP	NP

Rockall

Surface area 65,218 km²
Maximum depth 2,638 m
Minimum depth 0 m
Average depth 1,455 m

Bailey

Surface area 74,553 km²
Maximum depth 2,293 m
Minimum depth 71 m
Average depth 1,360 m

Faroe Shetland Channel

Surface area 42,684 km²
Maximum depth 2,392 m
Minimum depth 341 m
Average depth 1,275 m

Overall assessment key on Inside Front Cover

Area based on high water mark Albers Equal Area Projection. Depths based on 1 arc-minute ETOPO bathymetry.[1]

OVERALL ASSESSMENT
NORTH SCOTLAND COAST AND WEST SHETLAND

Characteristics

These two sea areas extend from Cape Wrath on the mainland to where the sea north-east of Shetland meets the international boundary. It includes the northern coast of the Scottish mainland as well as the rocky, wave exposed coastlines of western Shetland, Fair Isle and Orkney together with the mosaic of habitats in the northern isles of Orkney. Most of these are exposed to the full force of the Atlantic. Strong tidal currents are found in areas such as the Pentland Firth where Atlantic water exchanges with the North Sea. In contrast, there are sheltered inlets such as Yell Sound and Sullom Voe in Shetland, and Scapa Flow in Orkney, which are important both for local biodiversity and economic activity.

The areas have been a centre of cultural importance throughout history. This is illustrated by prehistoric settlements and modern wartime features. Submerged settlements and landscapes are becoming apparent through the application of modern surveying methodologies.

Activities and Pressures

The nature of the coastline and the water conditions around the Orkney and Shetland coasts provide ideal conditions for aquaculture: 18% by value of all Scottish finfish (mainly salmon) production and 42% of shellfish (mainly mussels) production occurs in Shetland. This is an important industry for these island communities. Commercial fishing is also important with 17% by value of total landed catch in North Scotland Coast and 18% in West Shetland.

The oil and gas industry is significant for these areas, accounting for about 10% by value of all production from Scottish seas. Europe's largest oil terminal is at Sullom Voe, West Shetland and there is a smaller terminal on Flotta, Orkney. The areas handle about 17% by volume of all Scottish cargo (mainly in the form of oil) but only 2.5% of calling ships.

Locations within the areas offer potential for renewable energy production. The European Marine Energy Centre's test sites for wave and tidal power are in Orkney, as well as the sites of the world's first commercial wave and tidal lease agreements. The natural, cultural and historic heritage of Orkney and Shetland attract large numbers of visitors and generate significant contributions to the local economy. This includes considerable diving activity at sites mainly within Scapa Flow on the WWI German Fleet. These areas, together with East Shetland, Fladen and Moray Firth, share about 8% of all Scottish recreational sailing berths; these being mainly in Orkney, Shetland and the Moray Firth.

Skara Brae, Orkney

© Historic Scotland

Fair Isle

© Peter Scott, Scottish Viewpoint

EMEC test site, Orkney

© EMEC 2011

Churchill Barriers, Orkney

© Historic Scotland

BP Clair Platform, West Shetland

© BP

Sullom Voe terminal, Shetland

© Shetland Islands Council (Ports and Harbours Operations)

The main pressures come from trawling damage to the seabed, local effects of aquaculture on seabed ecology and localised effects of surface oil sheens caused by oil leakage from the sunken wrecks.

Condition

Clean and Safe

At an area level, there are no significant concerns for many of the parameters assessed (hazardous substances, eutrophication, radioactivity, oil/chemical spills, algal toxins and microbiology of bathing and shellfish waters). There are, however, some small localised effects, such as radioactivity near the nuclear facility at Dounreay on the north coast of the Scottish mainland, and continuous oil leakage from sunken warships in Scapa Flow. Imposex, caused by TBT from anti-fouling paints, was a concern in Sullom Voe, but these impacts have declined.

Significant blooms of the phytoplankton species responsible for production of Amnesic Shellfish Poisoning (ASP), Diarrhetic Shellfish Poisoning (DSP) and Paralytic Shellfish Poisoning (PSP) were detected in Shetland in 2009 resulting in the closure of commercial shellfish harvesting areas for DSP and PSP toxins.

Healthy and Biologically Diverse

Habitats within the areas are in relatively good condition and there are no significant concerns. There are, however, concerns for some shallow subtidal sediments, mainly as a result of the impact of scallop dredging.

Breeding seabird numbers of some species have shown a long-term decline, most probably as a result of a shortage of key prey species such as sandeels associated with changes in oceanographic conditions.

Harbour seals have declined significantly in the past 10 years and this is a cause for considerable concern. In contrast, grey seals have increased in numbers over the same time. Populations of some commercially-exploited fish species are depleted, especially demersal species such as cod.

Response / Forward Look

The areas, particularly around the Pentland Firth and Orkney waters, have a significant resource to support the generation of marine renewable energy, offshore wind, waves and tidal. Growth of the industry and development of associated infrastructure, including seabed cables, is anticipated. Further work will be required to understand the effects on seascapes, landscapes and cultural heritage. This will be underpinned by a marine spatial plan pilot in these waters, which will identify priorities for development and management.

Decommissioning of offshore production facilities will be more prominent in the future. The scale and location of oil and gas exploitation in the areas may change as a result of the development of new technologies and oil price rises. While this will bring new pressures to these areas, monitoring records from Sullom Voe show that careful management can result in such development with virtually no detectable long-term marine impacts.

Aquaculture will remain an important industry and could potentially change in location and scale as technology allows it to move to more exposed waters.

Scapa Flow has been identified as a development opportunity to accommodate container traffic.

Clean and Safe

	North Scotland Coast	West Shetland
Pollution	⇔ ●	⇔ ●
Radioactivity	⇔ ●	⇔
Non-native species	⇔	⇔
Oil spills	⇔	⇔
Litter		⇔
Noise	⇔	NP
Extraction	⇔	⇔
Disease	⇔	⇔ ●

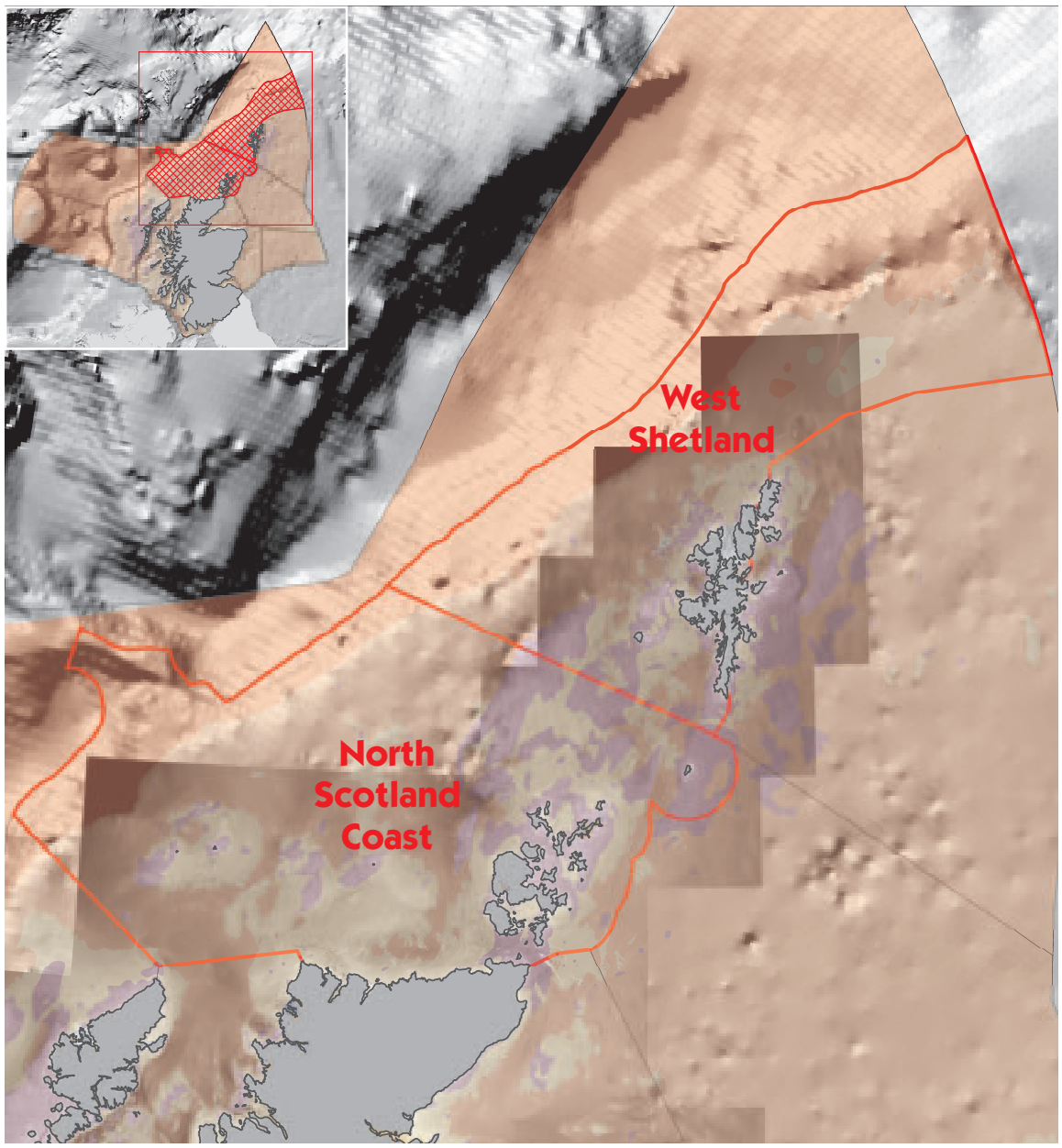
Habitats

	North Scotland Coast	West Shetland
Coastal	↓	↓
Intertidal	↓	↓
Subtidal	⇔	⇔
Seabed	NT	NT
Seagrass	↓	↓

Species

	North Scotland Coast	West Shetland
Cetaceans	⇔	⇔
Seals	⇔	
Otters	⇔	⇔
Seabirds	↓	↓
Waders	↓	↓
Fish	NAA	NAA
Shellfish	⇔	⇔
Sharks	↓	↓
Turtles		
Seaweed	⇔	⇔
Birds		

Overall assessment key on Inside Front Cover



Productive

	North Scotland Coast Trend	North Scotland Coast %	West Shetland Trend	West Shetland %
	↑	4.56%	↑	13.41%
	↓	CC	↑	41.47%
	↓	16.57%	⇔	17.61%
	↓	2.76%	↑	7.68%
	↑	20.80%	↑	7.00%
	↑	2.06%	NP	NP
	⇔	3.85%	⇔	13.33%
	NA	0.79%	NA	1.40%
	↓	2.07%	↓	0.10%
	↓	0.40%	↓	<0.10%
	⇔	0.30%	⇔	<0.10%
	↑	7.80%	↑	Part of 7.80%
	NA	14.40%	NA	NA

North Scotland Coast

Surface area	46,057 km²
Maximum depth	1,066 m
Minimum depth	0 m
Average depth	155 m

West Shetland

Surface area	34,834 km²
Maximum depth	603 m
Minimum depth	0 m
Average depth	216 m

Area based on high water mark Albers Equal Area Projection. Depths based on 1 arc-minute ETOPO bathymetry.[1]

OVERALL ASSESSMENT
EAST SHETLAND, FLADEN AND MORAY FIRTH

Characteristics

These three sea areas extend south from the eastern side of Shetland to the Moray Firth. They include an extensive offshore area characterised by flat sandy seabed with occasional pockmarks (seabed craters), and small inshore firths often with sandbanks, mud flats and sandy beaches. Areas of the coastline are rocky and internationally important seabird colonies are present, for example at Noss and Hermaness in Shetland and Duncansby Head on the east coast mainland.

Major inflows of Atlantic water into the North Sea through the Pentland Firth and Fair Isle Channel transport nutrients and plankton to the North Sea.

Activities and Pressures

These areas are the most economically important for oil and gas with 65% of oil and gas produced and 59% of seabed pipelines. Nineteen percent of calling ships visited ports here although only 5% of Scottish cargo was handled. In recent years the Moray Firth area has been a focus for renewable energy development, with the Beatrice Windfarm Demonstrator Project. Onshore facilities are adapting to service this growth industry. Sixteen percent of telecommunications cables are on the seabed, in these areas.

Commercial fishing is important and widespread with 14% of total landed catch by value coming from East Shetland. The Fladen Ground is also important with 9% of total catch value, especially for *Nephrops*. Much of the Scottish demersal and pelagic fishing fleets operate here. Aquaculture is also a prominent industry in East Shetland accounting for 16% of Scottish salmon production.

Local wildlife tourism has developed. In particular, trips in the Moray Firth to view the most northerly population of bottlenose dolphins as well as the accessible seabird colonies are especially popular. These areas, together with North Scotland Coast and West Shetland, share about 8% of all Scottish recreational sailing berths; these are mainly in Orkney, Shetland and the Moray Firth.

Pressures resulting from these activities include possible localised contamination from oil and gas activity and dumping of dredge spoil from harbour maintenance. Trawling results in the abrasion of the seabed and there are local effects of aquaculture on seabed ecology in the north of the areas. There is also localised pressure on coastal landscapes and wildlife from tourism.

Beatrice Windfarm Demonstrator Project

Noss, near Bressay, Shetland

© SNH

Lerwick Harbour, Shetland

© SNH

Bottlenose dolphins

© SNH

Cromarty Firth

© SNH

Pelagic fishing boat

© P. Warrener, Marine Scotland

Condition

Clean and Safe
At an area level, there are few or no concerns for many of the components assessed (hazardous substances, eutrophication, radioactivity, oil/chemical spills, algal toxins and microbiology of bathing and shellfish waters). Some concerns have been seen at a local level, for example concentrations of copper and zinc are elevated under marine caged fish farms in East Shetland, and beach litter is a concern in the Moray Firth area.

Significant blooms of the phytoplankton species responsible for production of Amnesic Shellfish Poisoning (ASP), Diarrhetic Shellfish Poisoning (DSP) and Paralytic Shellfish Poisoning (PSP) were detected in Shetland in 2009 resulting in the closure of commercial shellfish harvesting areas for DSP and PSP toxins.

Healthy and Biologically Diverse
Intertidal habitats within the areas are in relatively good condition and improving. The shallow subtidal sediments in the Moray Firth are relatively impoverished as a result of demersal fishing activity.

In recent years seabird breeding success in Shetland has decreased significantly. Changes in the marine environment, affecting the availability of fish prey, such as sandeels, are thought to be primarily responsible for this. Harbour seals have declined in the areas although the decline in the Moray Firth population appears to have been arrested, whilst grey seal numbers have been increasing but there are signs that the population is now levelling off.

Response / Forward Look

The scale and location of oil and gas exploitation in the areas may change as a result of the development of new technologies and oil price rises. Decommissioning of offshore production facilities will be more prominent in the future. Development of carbon dioxide storage is expected to support carbon capture and storage.

The areas have a significant resource to support the generation of marine renewable energy, mainly offshore wind. Growth of the industry and development of associated infrastructure, including seabed cables, is anticipated. Further work will be required to understand the effects on seascapes, landscapes and cultural heritage as well as for the cetacean populations in the areas.

Fishing is likely to continue to be an important industry for the foreseeable future, although careful management will be required to ensure future sustainability against a background of historic over-exploitation. Marine recreational activities are expected to increase, a significant proportion of which will be marine wildlife tourism. Management of this growth industry will be required to minimise impacts on wildlife and habitats.

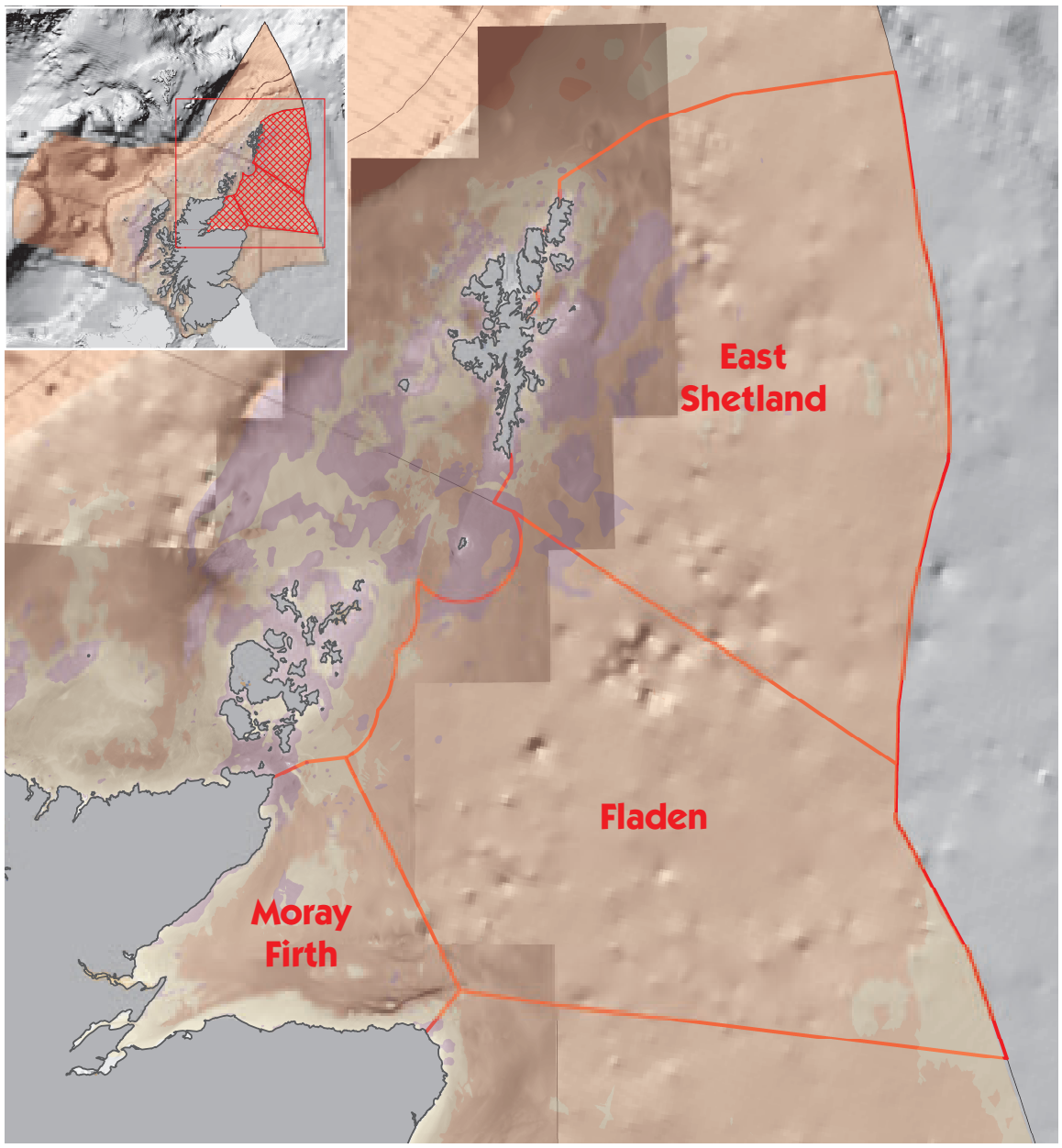
Aquaculture will remain an important industry and could potentially change in location and scale as technology allows it to move to more exposed waters.

Clean and Safe

	East Shetland	Fladen	Moray Firth
	⇔	⇔	↑
	⇔	⇔	
	⇔	⇔	⇔
	⇔	⇔	⇔
	⇔	NP	⇔
	NP	NP	↑
	⇔	NP	⇔
	⇔		⇔

Habitats

	East Shetland	Fladen	Moray Firth
	↓	NP	↓
	↓	NP	↓
	⇔	NP	⇔
	⇔	⇔	⇔
	NP	NP	NP



Species

	East Shetland	Fladen	Moray Firth
	⇔	⇔	⇔
	⇔	⇔	⇔
	⇔	NP	⇔
	↓	NP	⇔
	↓	⇔	⇔
	NAA	NAA	NAA
	⇔	⇔	⇔
	NT	NT	↓
	⇔		⇔
		NP	↓

Productive

	East Shetland Trend	East Shetland %	Fladen Trend	Fladen %	Moray Firth Trend	Moray Firth %
	↑	15.99%	NP	NP	NP	NP
	↓	3.48%	NP	NP	↓	CC
	⇔	13.57%	⇔	8.70%	↓	2.13%
	⇔	19.18%	↓	44.76%	↓	0.06%
	↑	8.10%	↑	4.90%	↑	2.50%
	NP	NP	NP	NP	↑	5.14%
	⇔	0.66%	NP	NP	⇔	4.18%
	NA	17.07%	NA	NA	NA	2.08%
	↓	0.27%	NP	NP	↓	11.28%
	↓	7.40%	NP	NP	⇔	3.00%
	⇔	0.30%	NP	NP	⇔	1.50%
	↑	Part of 7.80%	NA	NA	↑	Part of 7.80%
	NA	NA	NP	NP	NA	Part of 14.40%

East Shetland

Surface area 37,991 km²
Maximum depth 168 m
Minimum depth 0 m
Average depth 117 m

Fladen

Surface area 37,193 km²
Maximum depth 231 m
Minimum depth 53 m
Average depth 114 m

Moray Firth

Surface area 10,137 km²
Maximum depth 213 m
Minimum depth 0 m
Average depth 54 m

Overall assessment key on Inside Front Cover

Area based on high water mark Albers Equal Area Projection. Depths based on 1 arc-minute ETOPO bathymetry.[1]

OVERALL ASSESSMENT
FORTIES, EAST SCOTLAND COAST AND FORTH

Characteristics

These three sea areas extend south from Rattray Head to the English border. They include the east coast and the Forth and Tay estuaries adjacent to the main centres of population as well as the Forties offshore area. Subtidal sediments are dominant although rocky areas associated with diverse benthic habitats are found adjacent to the coast in some areas. The coastline lacks the complexity of the west coast but includes major firths, sea cliffs and stretches of rocky coastline interspersed with long sandy beaches. Extensive mud and sand flats systems are present in the Forth and Tay estuaries.

Activities and Pressures

These areas are important for oil and gas with 26% by value of all production from the Forties area and 26% of seabed pipelines between them, the Forties pipeline being a central hub for delivery ashore from several fields. The only oil refinery in Scotland is at Grangemouth.

There are many important ports. The Forth handles 44% by volume of all Scotland's cargo and 19% of calling vessels. East Scotland Coast handles 8% of cargo but receives 51% of calling vessels. The significant port activity means that 76% of all Scottish dredge spoil disposal is generated here. There is also a large amount of treated urban waste water and industrial effluent disposal. Water abstraction, mainly for power generation, accounts for 73% of total abstraction by volume in the Forth and 12% in East Scotland Coast.

Aberdeen supports the North Sea oil and gas industry, as well as ferry services to the Northern Isles. A freight ferry link to continental Europe operates from Rosyth, which is also an important ship repair dockyard, often used by naval vessels.

Commercial fishing is important accounting for 7% by value of total catch in Scottish waters. There are key fish landing ports at Fraserburgh and Peterhead, which service most of the Scottish vessels over 10 m in length. There is a large inshore fleet of smaller vessels operating mainly from Pittenweem in the Firth of Forth and Eyemouth.

Recreational activities, including sailing, bathing beaches, diving and wildlife tourism, are popular mainly because of the close proximity to centres of population.

Pressures resulting from these activities include possible localised contamination from oil and gas activity and dumping of dredge spoil from harbour maintenance. Trawling results in the abrasion of the seabed. There is also localised pressure on coastal landscapes and wildlife from tourism.

Aberdeen Harbour

© Aberdeen Harbour

Forth bridges, Forth

© P & A Macdonald / SNH

Bass Rock

© Lorne Gill, SNH

Forvie Nature Reserve

© Lorne Gill, SNH

Forties oil platform

© Apache Corporation

***RRS Discovery*, Dundee**

© Discovery Heritage Trust

Condition

Clean and Safe
At an area level, there are few or no concerns for many of the components assessed (hazardous substances, radioactivity, oil/chemical spills, algal toxins and microbiology of bathing and shellfish waters). However, elevated but decreasing concentrations of hazardous substances are detected in the Forth Estuary.

Water quality in the Forth estuary is compromised by discharges of industrial effluent and treated sewage although effluent treatment has improved resulting in returning populations of residential and migratory fish.

High nutrient inputs from agricultural run-off have resulted in the Ythan Estuary being designated as a 'problem area' for eutrophication and the catchment area as a Nitrate Vulnerable Zone. Measures are in place to reduce these inputs. Similarly, Montrose Basin has been identified as a 'potential problem area' due to elevated nutrients in the South Esk River. Little information is available for the Forties area. Beach litter poses some concerns in the Forth and Tay Estuaries.

Healthy and Biologically Diverse
Intertidal habitats and subtidal rock within the areas are in relatively good condition. In general, subtidal sediments are in poor condition because of considerable pressure from both inshore and offshore fishing activities.

Harbour seals are in a depleted state and continue to decline whereas grey seal numbers are increasing. Most commercially-exploited fish populations are also in a depleted state.

Response / Forward Look

The scale and location of oil and gas exploitation may change as a result of the development of new technologies and oil price rises. Decommissioning of offshore production facilities will become more prominent. Future development of carbon dioxide storage is expected and there is a possibility of exploiting geothermal energy sources under the Firth of Forth. Possible new electricity generation capacity at Longannet, Cockenzie and Boddam could change water abstraction requirements.

There is a significant resource to support the generation of marine renewable energy, mainly from offshore wind. Growth of the industry and development of associated infrastructure, including seabed cables, is anticipated. Further work will be required to understand the effects on seascapes, landscapes and cultural heritage as well as for the cetacean populations. Some smaller coastal ports will provide increasing support during development and operation phases of the renewable energy industry. The Forth has been identified as a possible site to accommodate additional container traffic, which may require associated dredging.

Fishing will continue to be an important industry for the foreseeable future although careful management will be required to ensure future sustainability given the history of over-exploitation in these waters. There is a presumption against finfish farming in these areas.

Closer to the coast, close proximity to centres of population could mean there will be an increase in marine recreation.

Clean and Safe

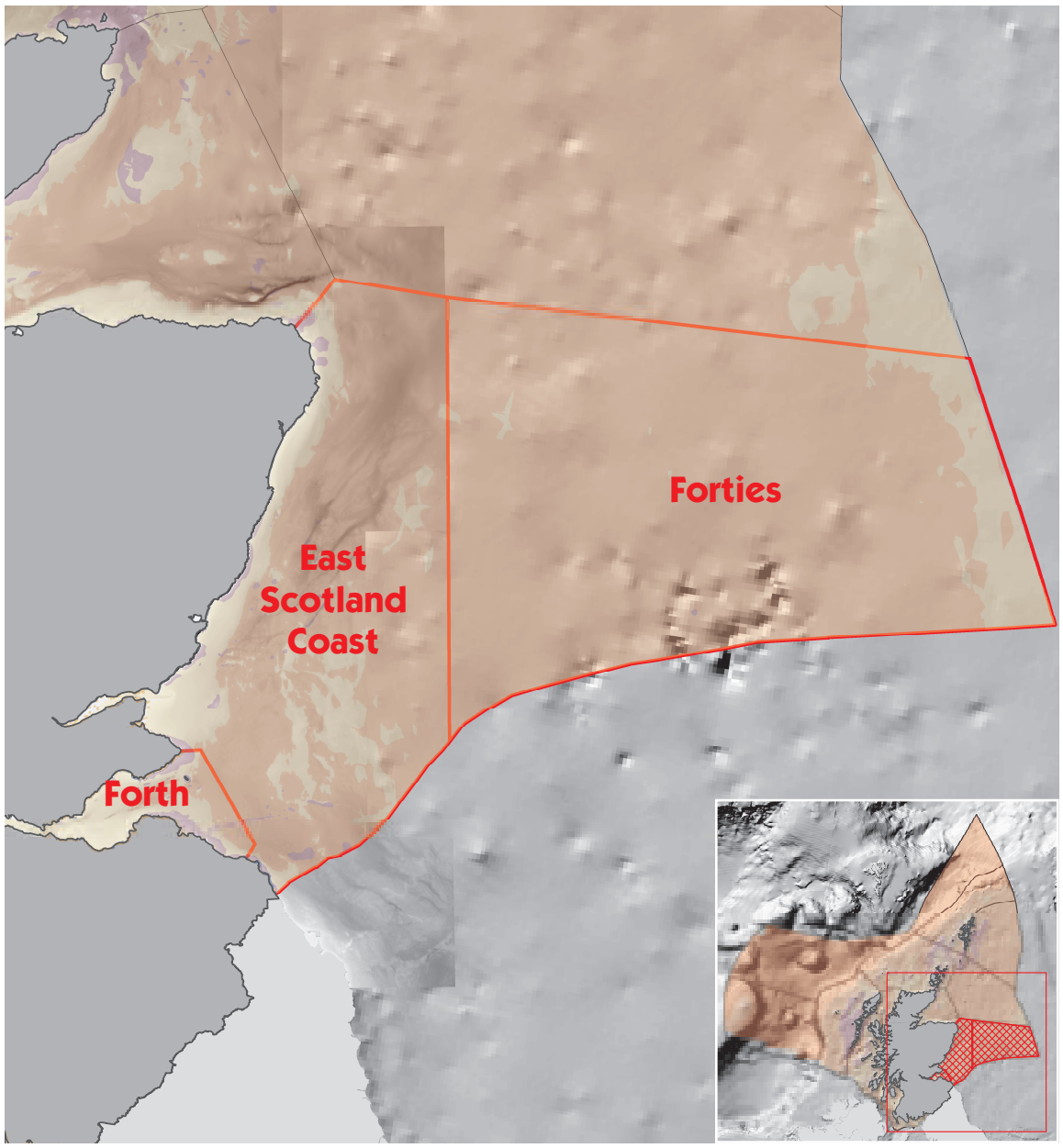
	Forties	East Scotland Coast	Forth
		⇔	↑
	⇔	⇔	⇔
	⇔	↑	⇔
	⇔	⇔	⇔
	NP	⇔	⇔
	NP	↑	↑
	NP	NP	⇔
		⇔	⇔

Habitats

	Forties	East Scotland Coast	Forth
	NP	↓	↓
	NP	↓	↓
	NP	⇔	⇔
	⇔	⇔	⇔
	NP	NP	NP

Species

	Forties	East Scotland Coast	Forth
	⇔	⇔	⇔
	⇔	⇔	⇔
	NP	↑	↑
	NP	↓	↓
	⇔	↓	↓
	NAA	NAA	NAA
	⇔	⇔	⇔
	NT	↓	↓
		⇔	⇔
	NP	⇔	⇔



Productive

	Forties Trend	Forties %	East Scotland Coast Trend	East Scotland Coast %	Forth Trend	Forth %
	NP	NP	NP	NP	NP	NP
	NP	NP	NP	NP	NP	NP
	↓	2.25%	↑	4.13%	⇔	0.33%
	↓	25.54%	NP	NP	NP	NP
	↑	2.20%	↑	1.20%	⇔	1.60%
	NP	NP	NP	NP	NP	NP
	NP	NP	⇔	7.99%	⇔	43.59%
	NA	NA	NA	51.52%	NA	19.28%
	NP	NP	↓	17.90%	↓	33.43%
	NP	NP	↑	20.00%	↑	56.20%
	NP	NP	⇔	11.90%	⇔	73.10%
	NA	NA	↑	10.00%	↑	Part of 10.00%
	NA	NA	NA	72.13%	NA	Part of 72.13%

Forties

Surface area	24,663 km²
Maximum depth	218 m
Minimum depth	42 m
Average depth	84 m

East Scotland Coast

Surface area	14,987 km²
Maximum depth	143 m
Minimum depth	0 m
Average depth	60 m

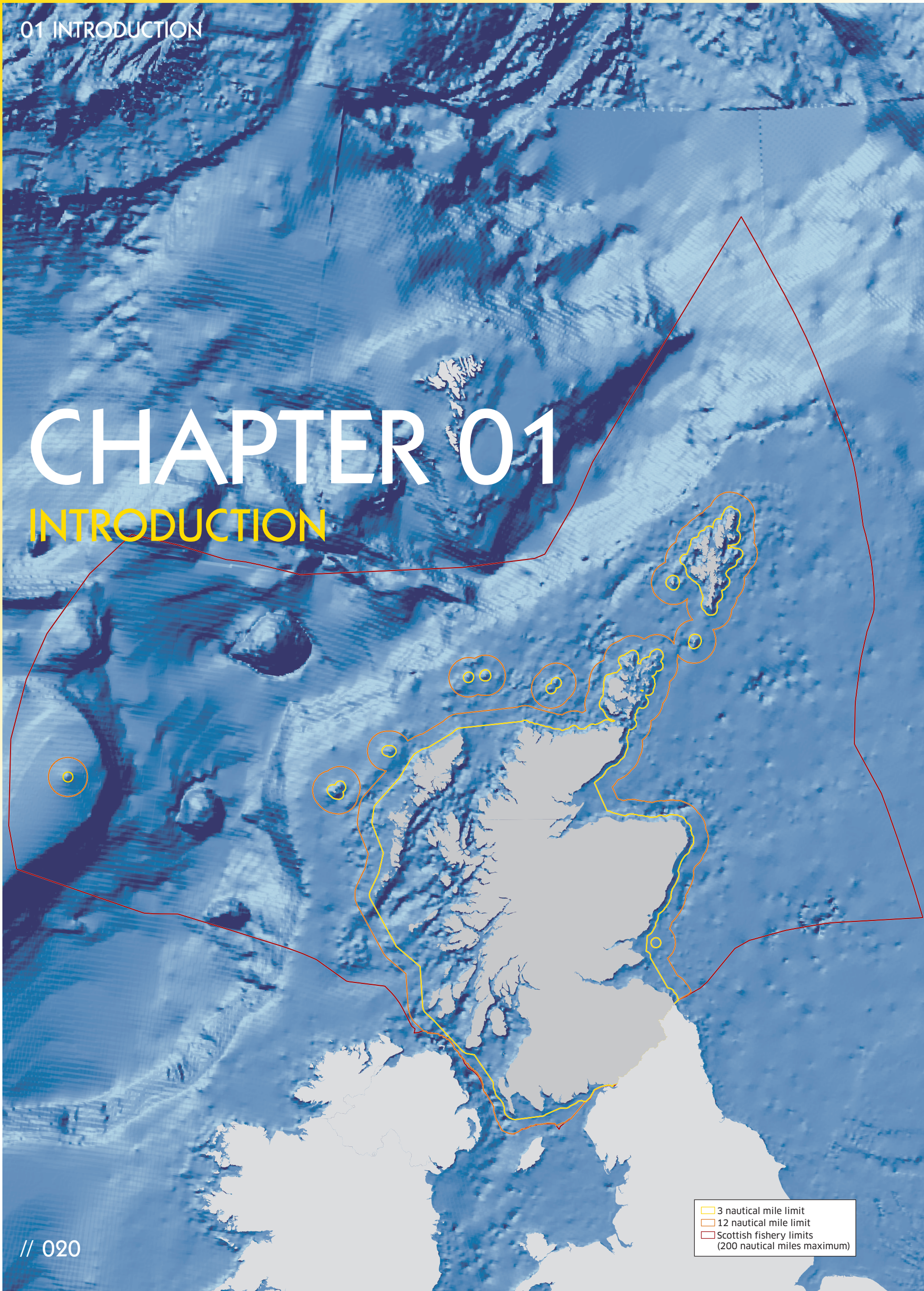
Forth

Surface area	1,528 km²
Maximum depth	61 m
Minimum depth	0 m
Average depth	30 m

Overall assessment key on Inside Front Cover

Area based on high water mark Albers Equal Area Projection. Depths based on 1 arc-minute ETOPO bathymetry.[1]

CHAPTER 01
INTRODUCTION



Aim of Scotland's Marine Atlas

The first '*Marine Atlas*' presents data spatially to assist with the introduction of marine planning. It does so based around the elements of the government's vision for the sea: **clean and safe, healthy and biologically diverse and productive**. The Atlas presents the assessment of condition and summary of significant pressures and the impacts of human activity required for the national marine plan. It also represents a contribution to the initial assessment required for the Marine Strategy Framework Directive (MSFD)[1] by July 2012.

Area covered and scale of data

The Marine (Scotland) Act 2010[2] and the Marine and Coastal Access Act 2009[3] provide for marine planning of Scottish waters out to 200 nautical miles and give new marine conservation responsibilities. So this Atlas presents data over this whole area, including for policy areas which are reserved to Westminster, to ensure that policies developed in the national marine plan are informed by the fullest data possible. The Atlas refers to a variety of boundaries and spatial scales:

- 200 nautical miles – the maximum limit for fisheries and renewable energy powers. Marine planning and nature conservation powers can extend further.
- 12 nautical mile territorial sea – limit of Scotland as defined in the Scotland Act.
- 3 nautical miles - the limit to which Water Framework Directive measures have been implemented in Scotland.

Data can be aggregated to different scales for different purposes, so its presentation has to consider the purpose. This Atlas presents data at the most relevant scale available to illustrate the main issues for national marine planning.

There is provision for future marine plans to be developed for Scottish marine regions. These regions have yet to be decided. However, the 15 sea areas used in this Atlas, based on areas previously adopted for certain environmental monitoring programmes, are likely to be of a similar scale as marine regions.

The data from these 15 areas can be presented regionally and also reasonably aggregated to form a national picture and to develop information for the two main areas required for the MSFD initial assessment: the Greater North Sea (Area II) and the Celtic Seas (Area III) which are existing sea areas used by OSPAR (the Oslo Paris Convention for the Protection of the North East Atlantic)[4].

How this Atlas has been compiled

The Atlas has taken *Scotland's Seas: Towards Understanding their State*, published in 2008[5], and developed its contents to provide a spatial assessment where possible. Much effort has been taken to map data sets and present graphs around them. It is recognised that there are some areas where this is not yet possible so the provision of spatial data suitable for marine planning will be an evolutionary process. A data annex available online, lists the various data sources used for this Atlas.

The preparation of the Atlas has been a collaborative effort. Marine Scotland led the work on chapters 2, 5 and 6, with SEPA in the lead for chapter 3 and SNH, with assistance from JNCC, leading chapter 4. Each contributor also developed the appropriate part of the overall assessment. A valuable contribution was also provided by the Marine Alliance for Science and Technology Scotland (MASTS)[6] to all work. The Agri-Food & Biosciences Institute; Centre for Environment, Fisheries & Aquaculture Science; Countryside Council for Wales; Department for Environment, Food and Rural Affairs; Environment Agency; National Oceanography Centre; Natural England and Northern Ireland Environment Agency all reviewed Atlas material.

A variety of data sources have been used. The key data sets are from the range of established monitoring programmes undertaken by the various contributing organisations for their main responsibilities, for example, to meet legal obligations. For much of the productive seas data, existing data from regularly published government statistics have been used. Most data have required some re-working to be presented at the level of the sea areas used.

Data used for *Charting Progress 2* (CP2)[7], published in July 2010, have also been heavily relied on here. CP2 was the second assessment of the UK seas and involved the same contributing Scottish scientists as this Atlas. This Atlas draws on the four CP2 Feeder Reports adding more detail where necessary and appropriate to map Scottish seas.

To make the Atlas easily accessible and to focus on portraying information spatially, the material has been restricted to summaries and short text, complimented by images and graphs. For many topics, further information is available from a variety of sources and these are referenced. Full references are available in an online annex.

The overall assessment

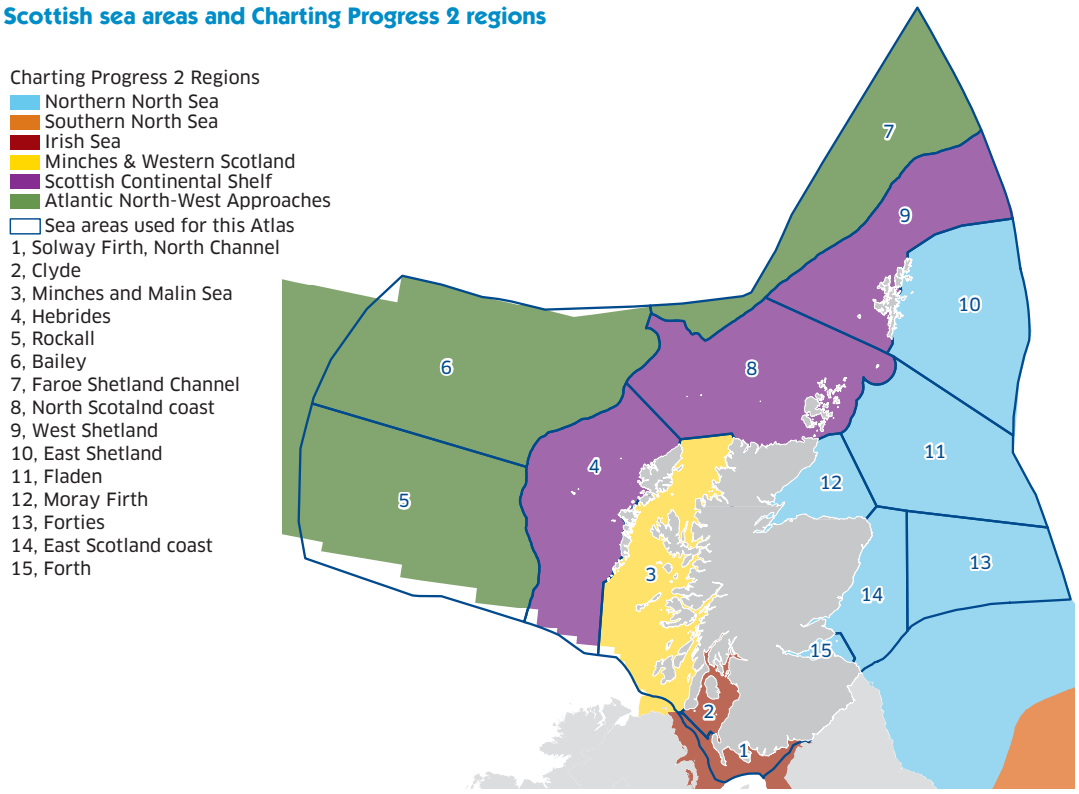
This is presented based around the elements of the vision for the seas. A red/orange/green traffic light approach has been used for the range of parameters assessed for 'clean and safe' and 'healthy and biologically diverse' seas. For 'productive' seas the amount of each activity per sea area is based on either value (where known) or amount of activity.

Responsibility for key marine policy areas

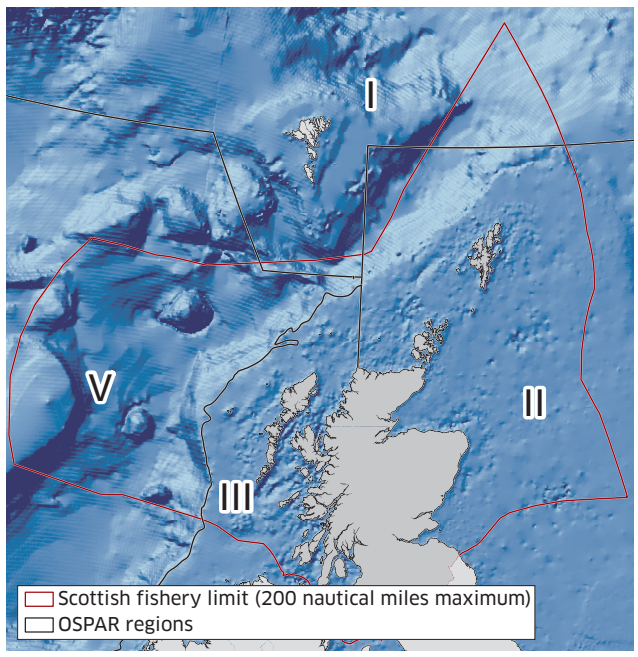
Policy area	0-12 miles	Offshore (*)
Marine Planning	Devolved	Executively devolved
Fishing	Devolved	Devolved
Aquaculture	Devolved	Executively devolved
Renewable energy	Executively devolved	Executively devolved
CCS	Devolved	Reserved
Nature conservation	Devolved	Executively devolved
Ports and harbours	Devolved	Not applicable
Land-based discharges	Devolved	Not applicable
Historic heritage	Devolved	Reserved
Marine licensing	Mainly devolved	Mainly executively devolved
Oil and gas	Reserved	Reserved
Shipping	Reserved	Reserved
Defence	Reserved	Reserved
Telecommunications	Reserved	Reserved

Executively devolved – Scottish Government administers the activity but the Scottish Parliament has no powers to change the legislation.
(*) Offshore is to the median line, 200 miles or further, where applicable

Scottish sea areas and Charting Progress 2 regions



OSPAR sea regions of the North East Atlantic



Facts about Scottish seas

Coastline length (LW mark)* 18,002 kms	**Coastline length (HW mark)*** 18,672 kms	**Inhabited islands**** 118	**Uninhabited islands** in excess of 800
HW mark to territorial sea baseline (internal waters) (approx) 34,810 kms²	**Territorial sea baseline to 12 nautical miles (Territorial waters) (approx)** 53,638 kms²	**12m limit to 200 nautical mile fishery limit (approx)** 380,546 kms²	**Total sea area inside 200 mile fishery limit (approx)** 468,994 kms²
Total UK sea area to 200 mile limit 764,678 kms²	**Scottish sea area as % of UK sea area** 61%	**Scotland land area (to mean low water)** 80,060 kms²	**Sea area : land area ratio** 5.85 : 1

Source: * Scottish Government - created from OS Boundary Line 2007 and OS Mastermap: coastline length at minimum scale 1:10,000. ** General Register Office for Scotland based on 2010 postcode data

Descriptors for determining GES under MSFD

	Good environmental status (GES) descriptor	Chapter with relevant information
(1)	**Biological diversity** is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions	2, 4
(2)	**Non-indigenous species** introduced by human activities are at levels that do not adversely alter the ecosystems	4
(3)	Populations of all **commercially exploited fish and shellfish** are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock	4
(4)	All elements of the **marine food webs**, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity	4
(5)	**Human-induced eutrophication** is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters	3
(6)	**Sea floor integrity** is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected	2, 4
(7)	Permanent **alteration of hydrographical conditions** does not adversely affect marine ecosystems	2
(8)	**Concentrations of contaminants** are at levels not giving rise to pollution effects	3
(9)	**Contaminants in fish and other seafood** for human consumption do not exceed levels established by Community legislation or other relevant standards	3
(10)	Properties and quantities of **marine litter** do not cause harm to the coastal and marine environment	3
(11)	**Introduction of energy**, including underwater noise, is at levels that do not adversely affect the marine environment	3

Indicative list of characteristics, pressures and impacts in MSFD Annex III

Characteristics	Chapter with relevant information
Physical and chemical features	2, 3
Habitats types	2, 4
Biological features	2, 4
Other features (e.g. chemicals and specific characteristics)	2, 3
Pressures and Impacts	
Physical loss	4, 5
Physical damage	4, 5
Other physical disturbance	3, 4, 5
Interference with hydrological processes	3, 4, 5
Contamination by hazardous substances	3, 4, 5
Systematic and/or intentional release of substances	3, 5
Nutrient and organic matter enrichment	3, 4, 5
Biological disturbance	3, 4, 5

Ecosystem goods and services

The concept of ecosystem goods and services is based around the cycle of events that link human societies and their wellbeing with the environment. The concept is an attempt to make apparent the value and importance of functioning ecosystems in providing essential support for human society.

The extent of the benefits received from ecosystems and the possible consequences of damaging them are slowly being understood, having been examined as part of the *Millennium Ecosystem Assessment*[8].

Marine habitats and their diversity of organisms provide a range of ecosystem services and benefits of significant value to Scotland. The goods and benefits accrue both directly and indirectly to much of society. Well established benefits include:

provisions (P) – for example, food (fish, shellfish); genetic resources (used in aquaculture); industrial inputs (blue biotechnology, bio-catalysts, medicines); fertiliser and bio-fuels (from seaweed);

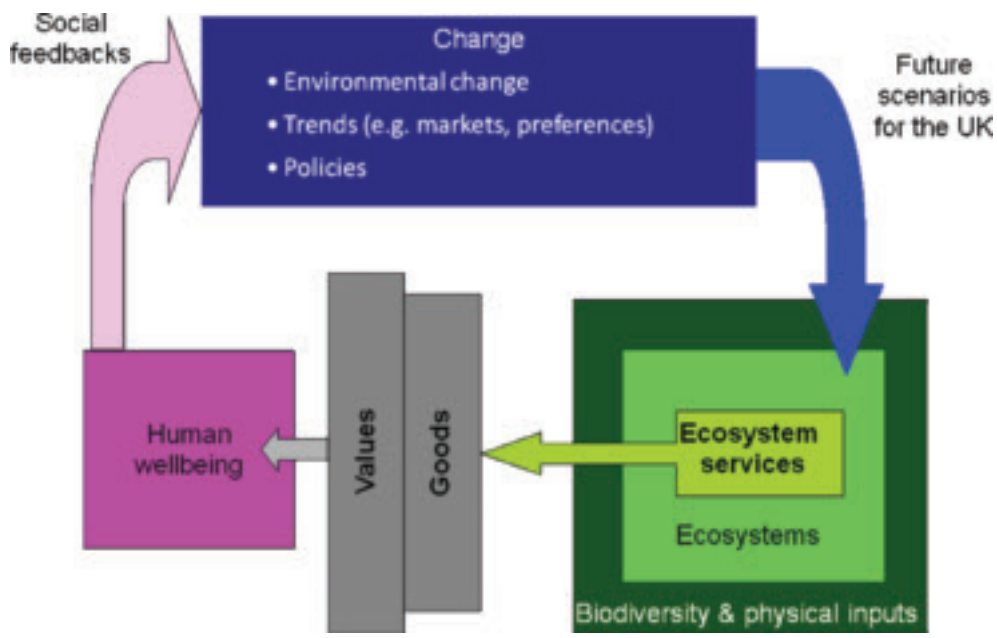
regulation (R) – for example, the reduction of climate stress (through carbon and other greenhouse gas regulation by the seas); flood and coastal protection; pollution regulation (through waste removal, breakdown and detoxification); disease and pest control; and

non material benefits (N) – for example, leisure and recreation opportunities; a focus for engagement with the natural environment; physical and mental health benefits; cultural heritage and learning experiences.

At the time of writing, a UK *National Ecosystem Assessment* (NEA) is being prepared[9] which will go some way to valuing ecosystem services including those provided by the marine environment. The link between ecosystem services, the goods they provide and the value to people is illustrated in the schematic diagram.

This Atlas provides an economic valuation of a range of productive uses of the sea and the value of some goods, for example, fish caught or farmed. It does not provide an analysis and valuation of ecosystem services.

Overall conceptual framework for the NEA showing the links between ecosystems, ecosystem services, goods, values, human wellbeing, change processes and scenarios[9]



Final ecosystem services and corresponding goods and benefits from the marine environment

Final ecosystem service	Goods and benefits
(P) Cultivated seaweeds, cultivated fish, wild caught fish	Food, energy, bio-energy, genetic resources, industrial inputs, fertiliser, recreation and tourism
(P) Kelp forests	Recreation and tourism, fertiliser and industrial feedstock
(R) Climate regulation (greenhouse gases)	Avoidance of climate stress
(R) Hazard regulation – vegetation and other habitats	Coastal protection, erosion protection, avoidance of climate stress
(R) Waste breakdown and detoxification	Pollution control, waste removal, waste degradation, human health, clean food
(P,R) Wild species diversity including microbes	Natural medicine, disease and pest control, genetic resources, wild food, blue biotechnology, recreation and tourism, aesthetics and inspiration, citizenship (responsibility for biodiversity)
(R) Purification (including water quality)	Clean water (for potable use via de-salination, industrial use, recreational use, aquarium use), clean sediments
(N) Places, (including coasts and waterscapes)	Spiritual / religious, cultural heritage, aesthetic / inspirational, security and freedom, neighbourhood development, enfranchisement / social and environmental citizenship
All services	Contribute to physical and mental health and ecological knowledge

Valuing some marine ecosystem goods and services

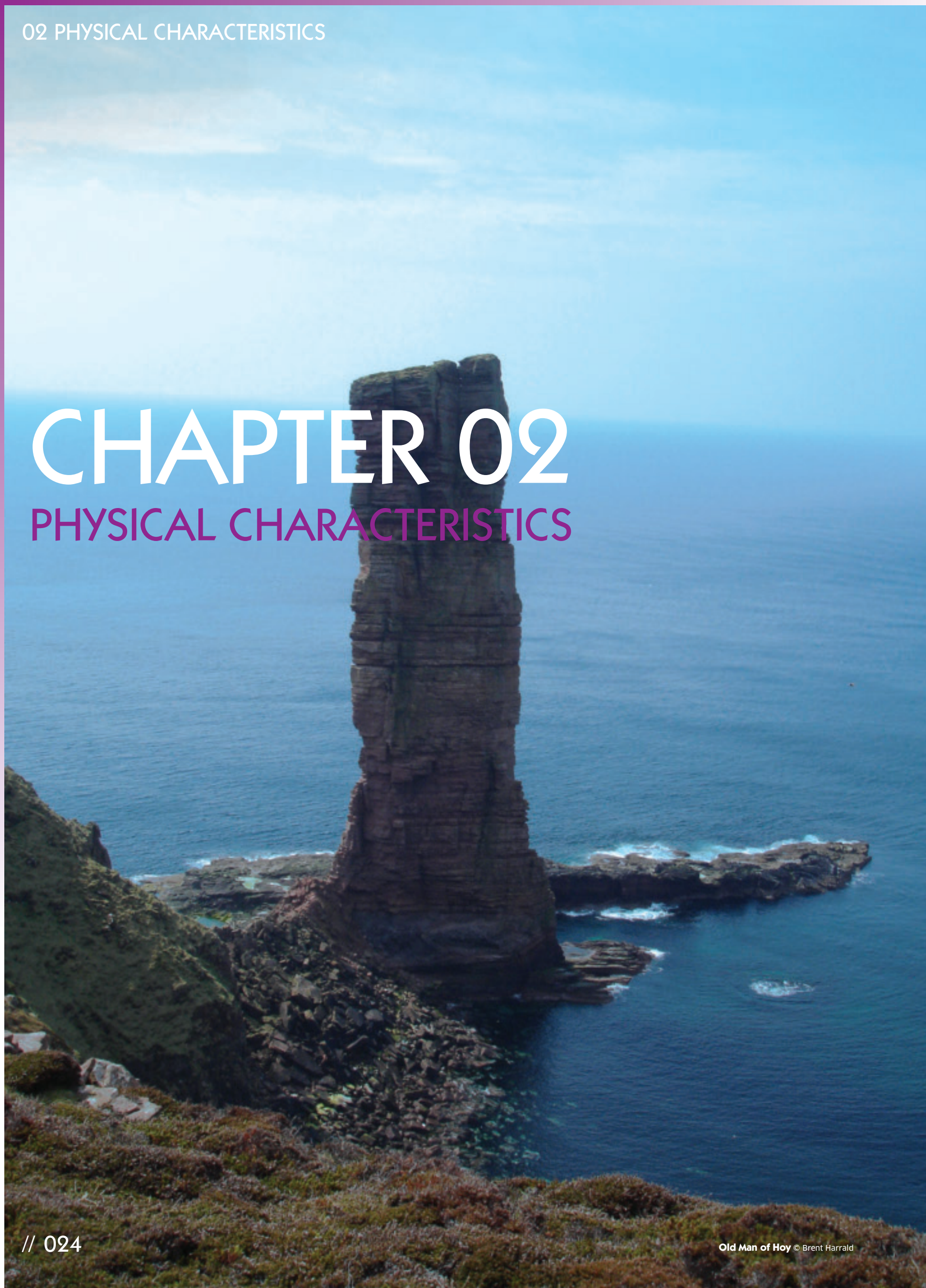
Primary and intermediate processes	Final ecosystem services (ES)	Goods (including input from other capital)	Value of goods (Benefit to people)	ES value (Benefit to people)	Health and Well-being (Benefit to people)
Primary production	Seaweed, cultivated fish	Food	£	£	
	Kelp forests	Fertiliser	£	£	
Nutrient cycling →	Waste breakdown and detoxification →	Pollution control, waste removal →	£	£	
Carbon cycling	Climate regulation	Avoidance of climate stress	£	£	
Ecological interaction	Wild species diversity	Natural medicine	£	£	

← Focus of this Atlas → ← Started in NEA → ← to be developed →

Adapted from UK National Ecosystem Assessment[9]

CHAPTER 02

PHYSICAL CHARACTERISTICS



Old Man of Hoy © Brent Harrald

Bathymetry and selected features of the seas around Scotland

Loch Slapin, Isle of Skye

© Marine Scotland

Gairloch

© Marine Scotland

St Ninian's Isle, Shetland

© Marine Scotland

Puldrite, Orkney

© Sonia Duguid, Marine Scotland

St Kilda

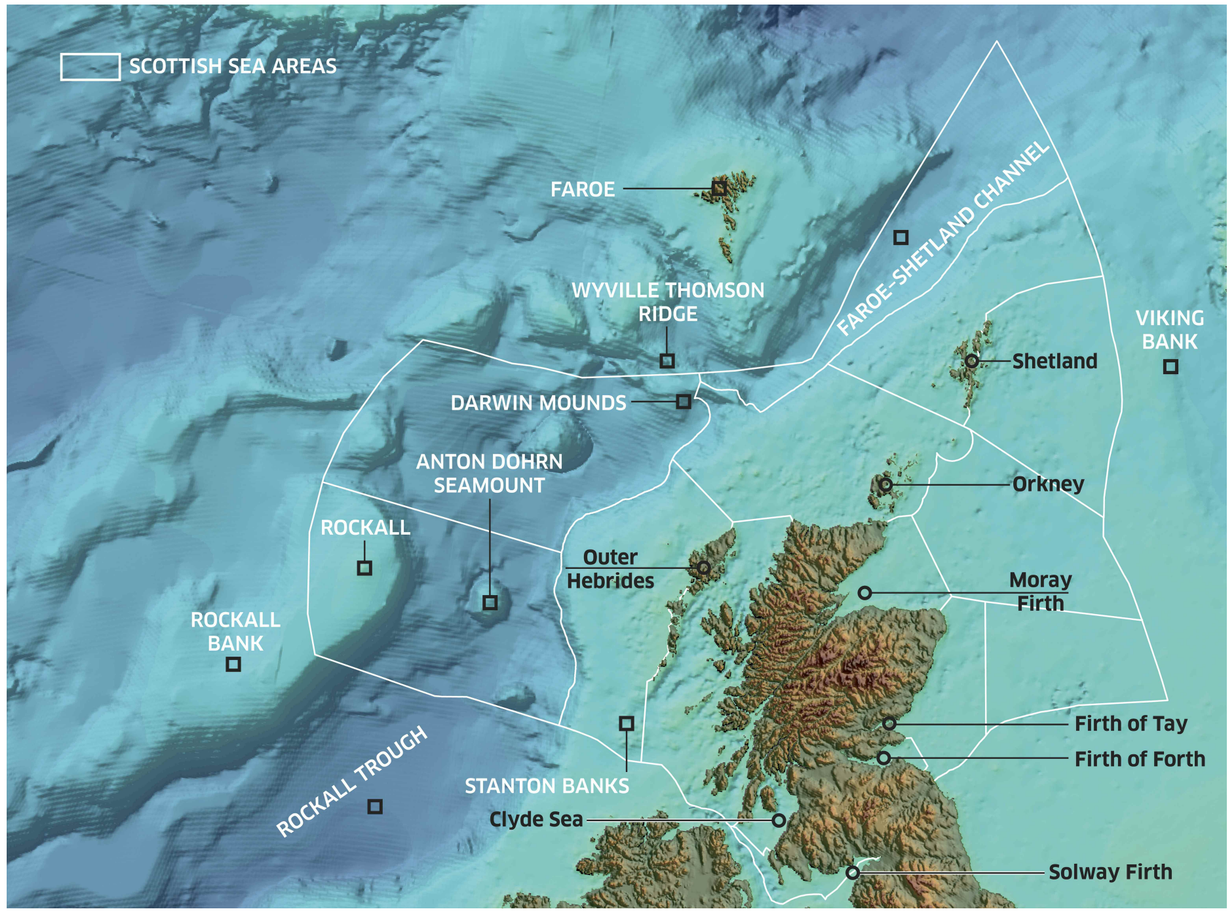
© Brent Harrald

Rockall

© Francis Neat, Marine Scotland

Mull

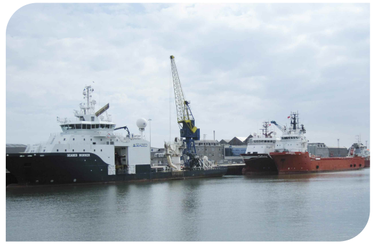
© SNH



Duncansby Head, North Scotland

© George Brown

Aberdeen Harbour



© Marine Scotland

North-East Scotland

© Marine Scotland

Clyde

© SNH

Caerlaverock, Solway Firth

© SNH

Grangemouth, Firth of Forth

© SNH

Stonehaven Bay

© Marine Scotland

The Scottish Scene

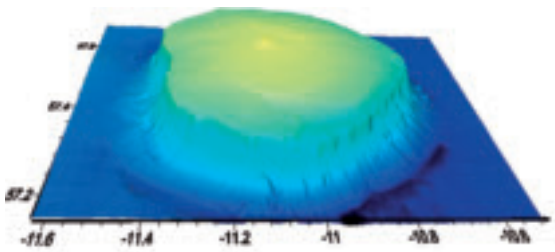
Scotland is a maritime nation with a history that is linked to the seas. Over many centuries, the seas have been a major source of food for the Scottish population, through the consumption of wild fish and shellfish, and they have been important for trade, the movement of people and the early political and governance structure of Scotland.

Industrialisation of Scotland's seas began in earnest with the herring fisheries in the 19th Century. This has gathered pace with increasingly technology-led fishing practices and with the exploitation of offshore oil and gas reserves, mainly in the North Sea, over the last 30-40 years. At the same time, the sheltered sea loch environments, typical of the west coast of Scotland and Shetland, have provided opportunities for the development of aquaculture. This process of industrialisation of Scotland's seas will continue through the development of offshore renewable energy and the exploitation of oil and gas reserves in deeper water towards the edge of the continental shelf. Furthermore, there is likely to be increased tourism and recreational marine activity.

The North Atlantic circulation brings warm surface water past the west of Scotland, improving our climate by warming the prevailing westerly airflow. At the same time, the northward Scottish Coastal Current carries water through the Minches and around the Outer Hebrides and then flows into the northern North Sea, in effect flushing this relatively landlocked sea with new oceanic water. A general southward coastal flow down the east coast completes that pattern of flow around Scotland.

Average water depths vary, but are generally between 50 and 200 m for the shelf seas, the waters being shallower around the south west of Scotland, and typically between 100 and 150 m to the west of the Hebrides and off the north coast. Scotland's offshore environment also includes waters of depths greater than 2,000 m. Little is known about the deep seas around Scotland compared with the shallow shelf seas. In general, less is known about Scotland's seas compared with our knowledge of landward Scotland. What is known however is that Scotland's seas are some of the most diverse on the planet. They are at the confluence of northerly-flowing surface currents and southerly-flowing polar currents and the complex bathymetry to the west causes these to become mixed, bringing nutrients to the surface. These are fed on by plankton communities which form the basis for what could be one of the richest fishing regions anywhere on the globe.

Anton Dohrn Seamount



© Francis Neat, Marine Scotland

The above 3-dimensional representation of the Anton Dohrn seamount was generated from data gathered by means of multiple echo soundings, using 3D visualisation. The longitude and latitude are shown giving the location of the seamount.

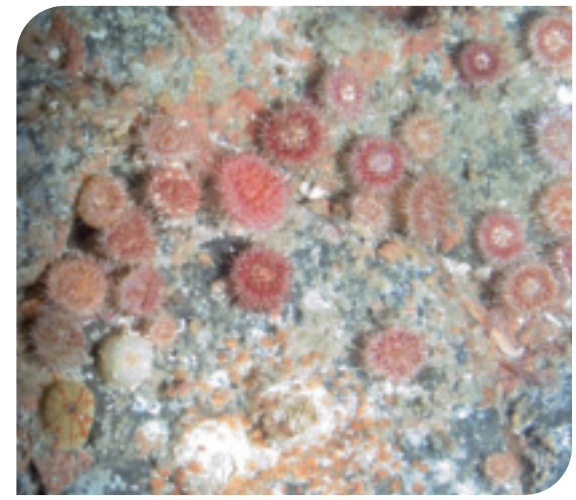
Coastal Zone

In the coastal zone, the coastline varies between deep and narrow sheltered sea lochs on the west coast, shallow bays and estuaries, and long stretches of coastline that have little shelter from waves and storms. Major Scottish estuaries are the Solway Firth, the Clyde Sea, the Moray Firth, the Firth of Tay and the Firth of Forth. The North Sea coastline is predominantly rocky but there are intertidal sediments in the bays and inlets and some extensive stretches of sandy beach. Indeed, some of the largest sandy beaches are on the coasts of Aberdeenshire and Moray. Scotland has some extensive gravel beaches with Spey Bay on the Moray coast being one of the most important gravel beaches in the UK. Raised beaches on Scotland's west coast are also the remnants of an ancient past that illustrate the dynamic nature of the coastline. Spits are one of Scotland's most dynamic coastal landforms. Two examples of this are on the Moray coast at Culbin and Whiteness Head which is currently growing at a rate of 30 m per year. The west coast of Scotland is also typically rocky but has many bays, channels and sea lochs where there can be restricted water exchange with the surrounding seas and high levels of freshwater input from rivers, particularly for the sea lochs with a sill at the mouth of the loch. The coastline of the Western Isles, the north of Scotland and the Northern Isles is also rocky but the extreme length of Scotland's coastline, estimated at 18,840 km, is largely because of the large number of these diverse island coastlines that can transition quickly between rocky shore, sand, gravel and silt because of extreme variability in exposure. The machair landscapes and coastlines of the western Hebrides, which are created from ancient shell sand deposits, are an ecotype that is largely unique to Scotland.

Selected features of the seas around Scotland (see fold-out map)

Feature	Latitude	Longitude
Solway Firth	54.80 N	3.53 W
Clyde Sea	55.87 N	4.94 W
Firth of Tay	56.43 N	2.74 W
Firth of Forth	56.08 N	3.02 W
Moray Firth	57.66 N	3.92 W
Orkney	59.05 N	2.95 W
Shetland	60.31 N	1.29 W
Faroe	62.13 N	6.94 W
Outer Hebrides	57.84 N	7.10 W
Stanton Banks	56.21 N	7.79 W
Viking Bank	60.28 N	2.41 E
Wyville Thomson Ridge	60.11 N	7.67 W
Rockall Trough	56.08 N	11.69 W
Anton Dohrn Seamount	57.47 N	11.08 W
Rockall	57.57 N	13.55 W
Darwin Mounds	59.62 N	7.22 W

Pentland Firth – Dahlia anemone (*Urticina* sp.)



© Pete Hayes, Marine Scotland

Offshore Environment

The offshore environment in Scottish waters ranges from shelf sea areas to deep ocean regions with depths greater than 2,000 m. The continental shelf includes the Malin and Hebrides Shelf Seas, Orkney and Shetland Shelf Seas, and the North Sea. The shelf seas are marked by notable features such as banks (e.g. Stanton Banks, Viking Bank) and deep channels.

The western margin of the continental shelf is marked by a sharp change in depth of seabed at about 200 m. The continental slope is a transition area between two systems– the deeper oceanic waters and the shelf sea waters. The deep oceans have a complex bathymetry that is broken up by steep ridges (e.g. Wyville Thomson Ridge), seamounts (e.g. Anton Dohrn) and banks (e.g. Rockall Bank). The main offshore habitats for the North Sea are large expanses of sand and mud. On the west coast, however, the main offshore habitats are coarse sands, gravel and rock. To the west of the Outer Hebrides and to the north of Scotland the main offshore habitats are expanses of mud, sand and coarse sediment. In the deeper waters to the west and north of Scotland, the main habitats are large expanses of mud and fine clay, but a variety of coarse sediments are found in shallow waters, on banks and seamounts.

West of Lewis – Dead man's fingers (*Alcyonium digitatum*) and a single sea urchin (*Echinus* sp.)

© Pete Hayes, Marine Scotland

Weather and Climatic Conditions

Scotland has a maritime climate that is strongly influenced by the oceanic waters of the North Atlantic and prevailing south-westerly winds. As these winds blow over the regions of the North Atlantic warmed by the North Atlantic Current, they pick up heat which is delivered to Scotland, giving Scotland a relatively mild, wet climate considering its latitude. As such, changes in the strength of the Atlantic Ocean circulation have a significant effect on the variability in the climate of Scotland.

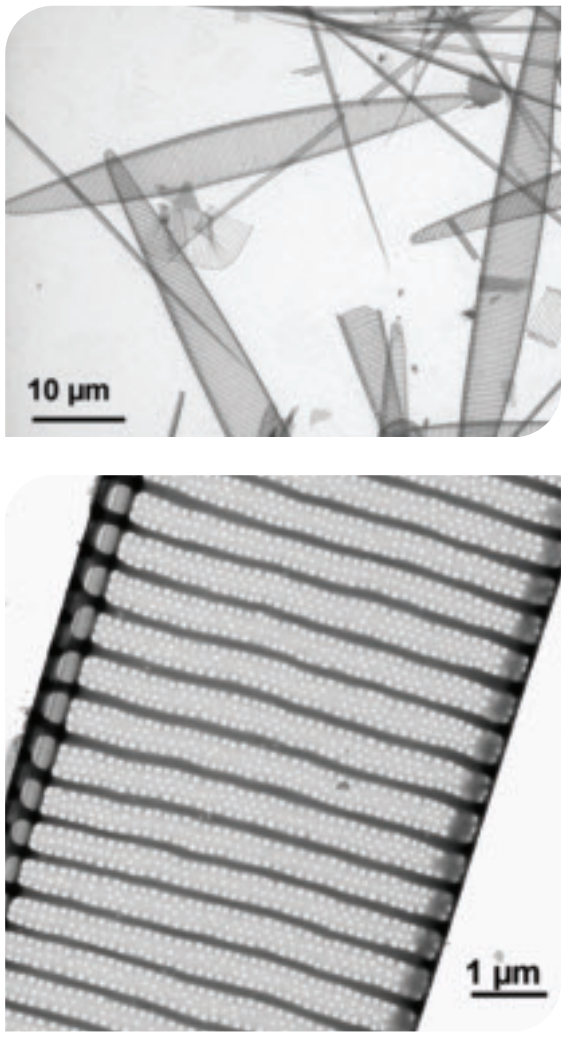
Normally, in the atmosphere over the North Atlantic, a low pressure area is situated in the north, near Iceland, and a high pressure area is situated in the south of the region near the Azores. This pattern of sea-level pressure results in a stream of smaller, secondary depressions, travelling in a north-eastward direction between these two regions. The passage of these depressions accounts for the variable weather experienced in Scotland and although the predominant wind direction is from the south-west, wind direction varies as depressions pass. The depressions are often more intense during winter months bringing gales, which in the windiest places (Western Isles, Orkney and Shetland) can occur up to 30 days each year. Severe winter storms across the British Isles were most prominent in the 1920s, 1980s and 1990s. These severe storms over the UK often related to strong local gradients of pressure as well as to the large scale pressure differences over the Atlantic.

The low lying areas, including the shelf seas, on the west coast of Scotland that are exposed to the Atlantic Ocean tend to have more cloud, less sunshine and be slightly warmer and wetter than the east of Scotland. Mean annual air temperatures in low lying areas are between 7-9°C. However, sea fog (haar) from the North Sea is common in spring and summer, particularly in the Northern Isles and on the east coast. All areas of Scotland have shown an increase in the annual average daily mean temperature between 1961 and 2006, with the increase being slightly greater on the east of the country[1]. A relatively uniform increase has been observed in the average daily maximum temperature across Scotland, apart from in the south-east of Scotland where the change is slightly greater than elsewhere. Average temperatures in Scotland and Northern Ireland have risen by approximately 0.8°C since about 1980.

Rainfall over Scotland is high compared to the UK as a whole. Total rainfall is 113,150 million cubic metres of water per year of which 73% is estimated to runoff into the sea. This equates to approximately 1 million cubic metres runoff per square km of land. Between 1961 and 2006, the average total rainfall in some areas of Scotland increased by between 25 and 50% and average days of rain of ≥ 1 mm decreased by between 12 and 22 days.

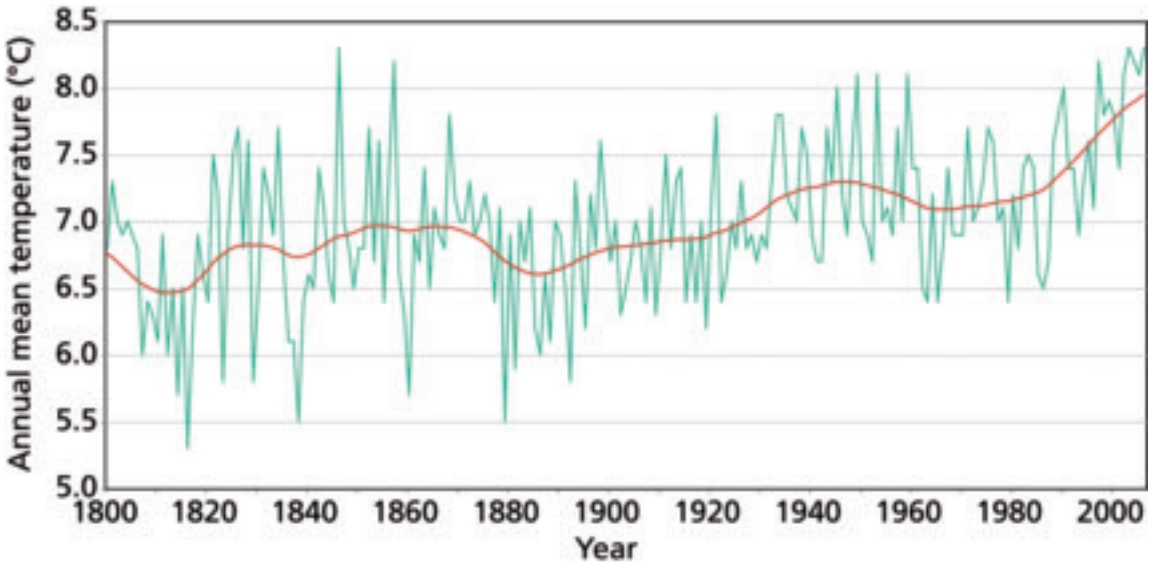
The latitude of Scotland causes large variations in length of daylight throughout the year. Some northern areas receive almost 24 hours daylight in midsummer and just a few hours of daylight at midwinter. The duration of light availability is known to produce a varied response in different phytoplankton species. The short, dark winter days, typical of the north of Scotland, mean that phytoplankton growth is considerably reduced between the months of November and February and very low numbers of plankton are observed in the water column. In contrast, some phytoplankton growth is observed in more southerly latitudes of the UK during the winter period. The extended daylength, which is most exaggerated in the northern waters of Scotland, has been shown to affect the biotoxin production of some phytoplankton routinely detected in Scottish waters such as *Pseudo-nitzschia seriata*.

Transmission electron micrographs of *Pseudo-nitzschia seriata* cells at different magnification



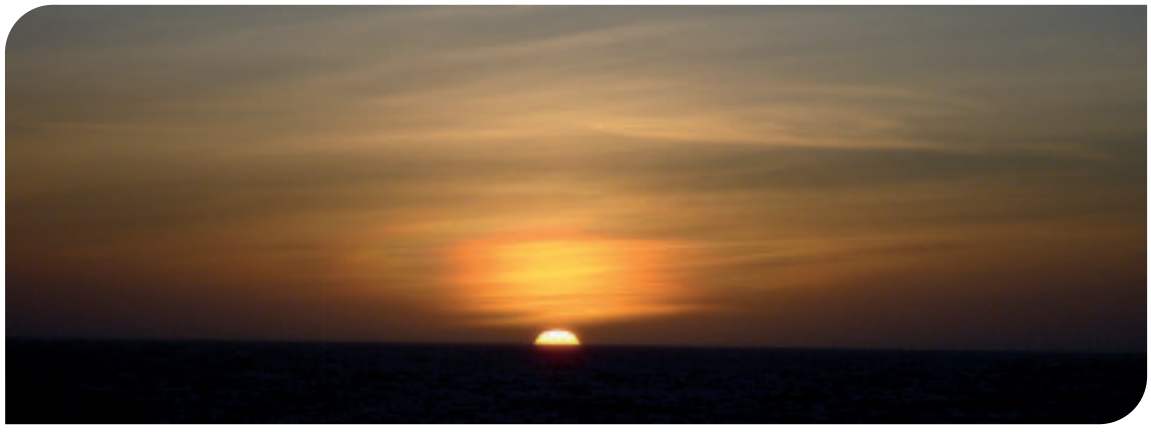
© Eileen Bresnan, Marine Scotland

Annual mean temperature averaged over the Scottish mainland, 1800-2006. The red line emphasises long-term variations



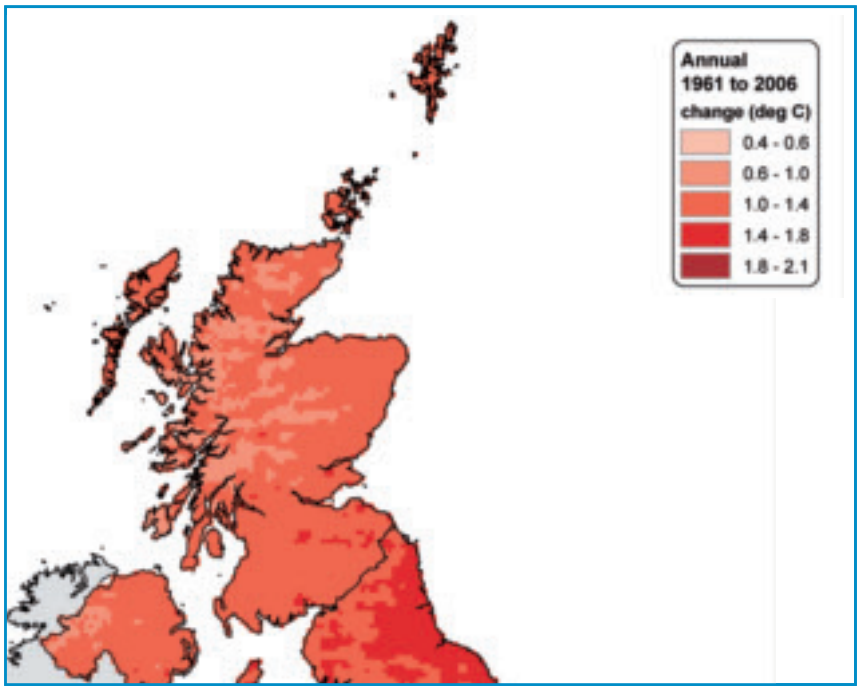
(Source: Met Office, after P. Jones)

Winter sun setting over the Faroe Shetland Channel



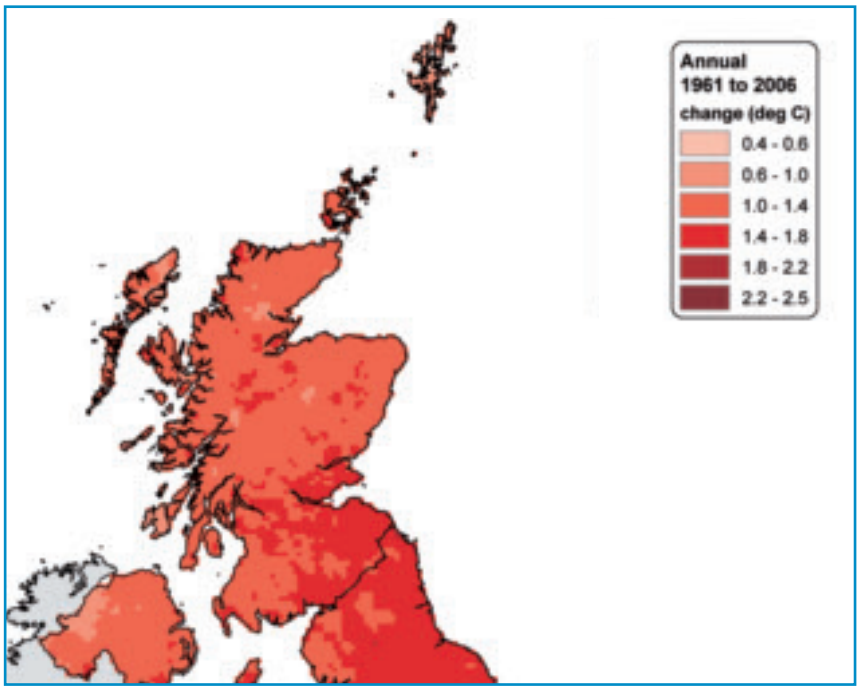
© John Dunn, Marine Scotland

Change in average daily mean temperature (°C) from 1961 to 2006



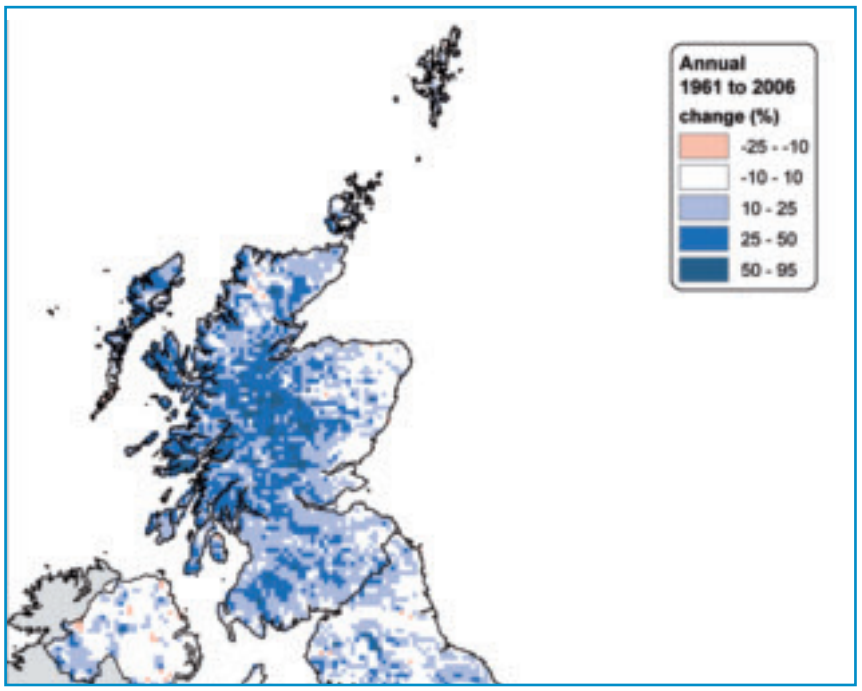
© Crown Copyright

Change in average daily maximum temperature (°C) from 1961 to 2006



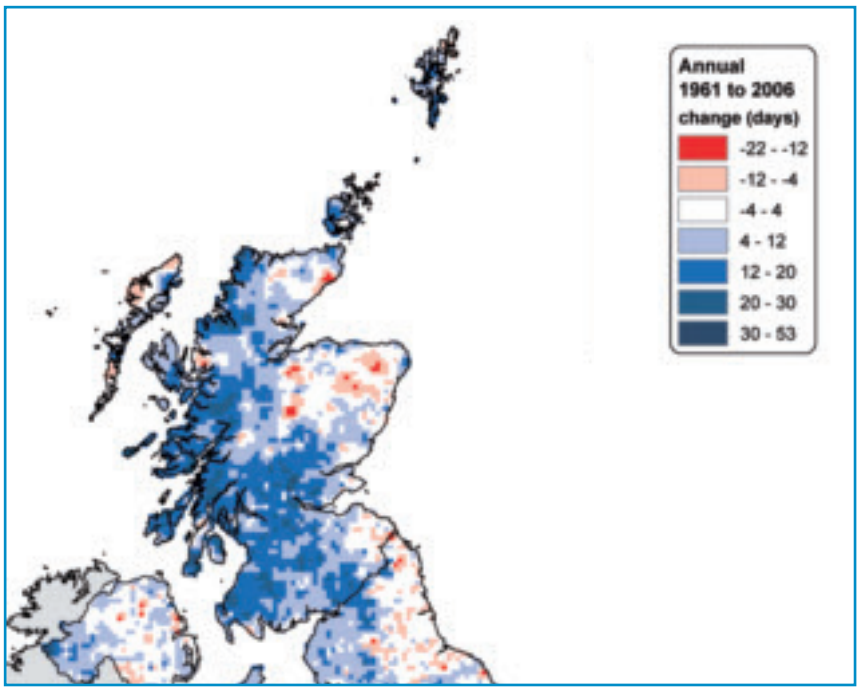
© Crown Copyright

Percentage change in total precipitation amount from 1961 to 2006 based on a linear trend



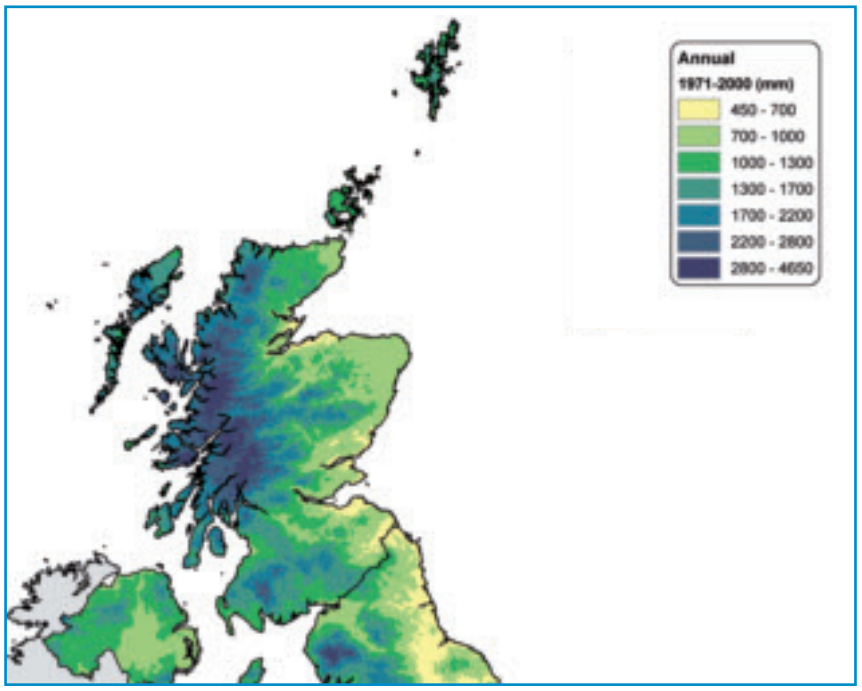
© Crown Copyright

Change in average days of rain ≥ 1 mm from 1961 to 2006



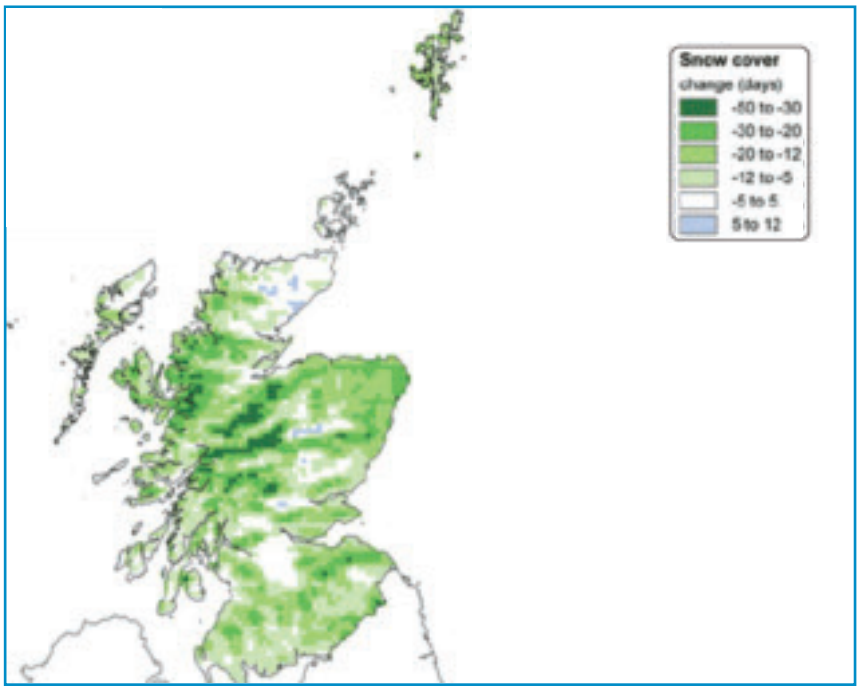
© Crown Copyright

Average total precipitation (mm) from 1971 to 2000



© Crown Copyright

Change in snow cover (in days) each year, from 1961 to 2004[2]



© Crown Copyright, Met Office 2006

Reproduced by permission of the Met Office

Ocean Circulation

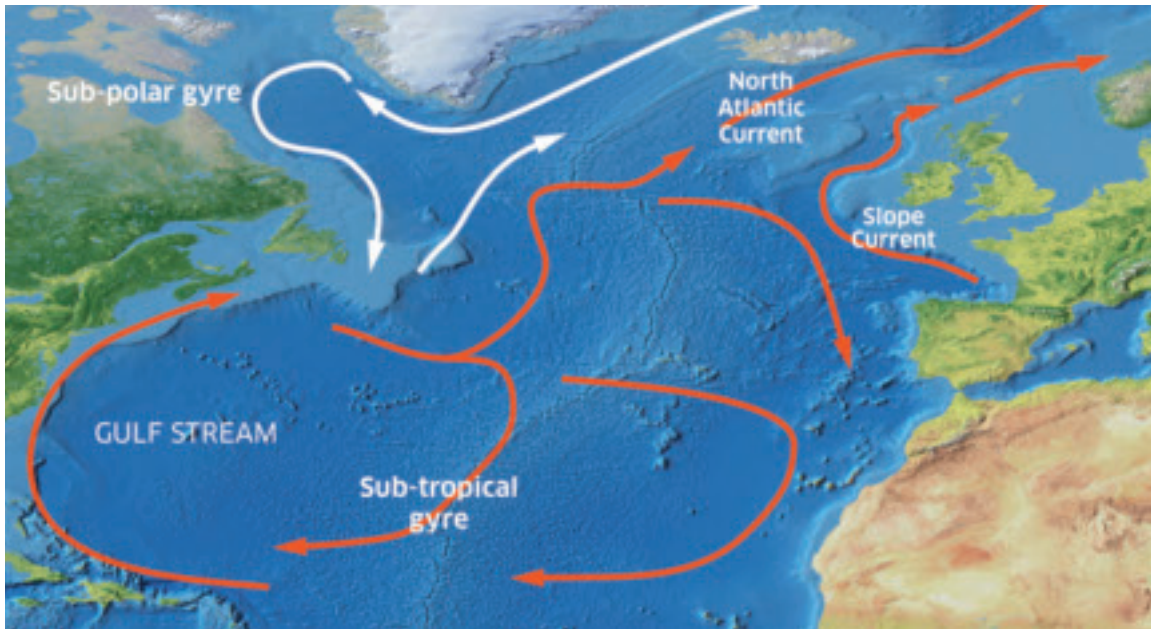
Ocean circulation is the large scale movement of waters in the ocean basins. Currents are driven by a combination of wind, planetary rotation and changes in water density as water evaporates from the sea surface and also as it re-enters from the land as fresh, low density water. The subsurface currents are mainly driven by differences in the density of seawater caused by changes in temperature and salinity. Subsurface currents generally travel at a much slower speed when compared to surface flows.

The surface circulation in the North Atlantic is dominated by two gyres, the southernmost of this is called the subtropical gyre. The current known as the North Atlantic Current (part of the sub-tropical gyre circulation and also sometimes called the North Atlantic Drift) is partly responsible for the mild weather conditions in Scotland relative to other land at similar latitudes in the Northern Hemisphere. (Many people mistakenly refer to the Gulf Stream when describing the current that brings warm waters to Scotland's shores). North Atlantic circulation is partly wind driven and partly driven by the density differences between the warmer, southern water and the cooler, northern water.

Despite the significance of this circulation, current speeds are relatively low compared to those in shallower waters. Currents speeds can be intensified around topographic features so areas such as the Rockall Bank and the edge of the continental shelf have faster currents associated with them. The general pattern of circulation within the North Atlantic is represented schematically in the map (above right).

North Atlantic Circulation

Circulation map representing the general circulation pattern within the North Atlantic. It should be noted that flow is not confined to these arrow tracks. Circulation of warmer saltier water in the sub-tropical gyre are shown by the red arrows with the cooler fresher waters of the sub-polar gyre shown as white arrows.

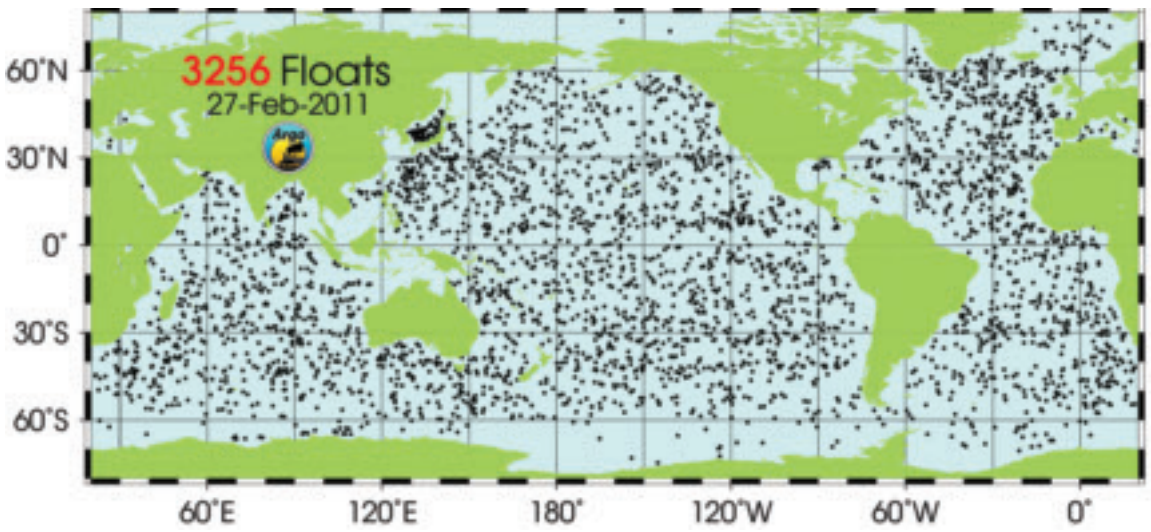


The map does not show the fine detail associated with the complex circulation of water. Currents change over shorter timescales because of complex effects such as mesoscale meanders and eddies, internal tides, internal waves, fronts and storm surges.

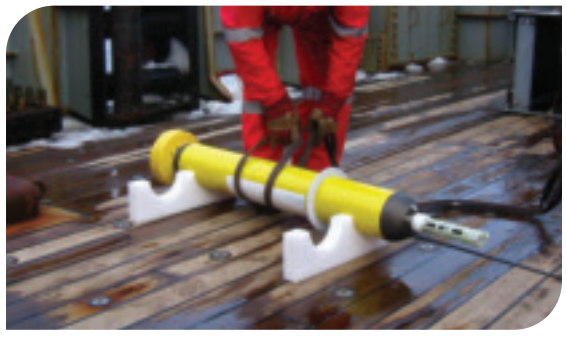
In addition to the North Atlantic Current, a jet-like current, known as the Slope Current, flows in a poleward direction along the edge of the continental slope with speeds in the range of 15 to 30 cm/s, and centred approximately over the 400-500 m depth contour. The waters in the Slope Current are thought to originate from the Iberian region and some of the North Atlantic Water that reaches the Bay of Biscay joins the Slope Current. Also on the continental slope, tides cause a large wave to form on the thermocline and this breaks when it hits the continental shelf causing mixing and nutrients to be brought closer to the surface. These features vary seasonally but are important sources of heat and nutrients, and enhance plankton growth in the waters around Scotland. They form important habitat for fish which are the subject of commercial fisheries.

Gathering Global Data

Scotland, and the wider UK, contribute to developing our knowledge of ocean circulation by supporting global observing systems and by placing data within international databases. Measurements are made using ships, buoys, moorings, aircraft and satellites. One system is Argo which is a global array of approximately 3,000 free-drifting profiling floats that measure the temperature and salinity of the upper 2000 m of the ocean. This allows, for the first time, continuous monitoring of the temperature, salinity and velocity of the upper ocean, with all data being relayed and made publicly available within hours after collection.



An Argo float



A newly deployed Argo float

Deploying a mooring from the FRV *Scotia*

© Marine Scotland

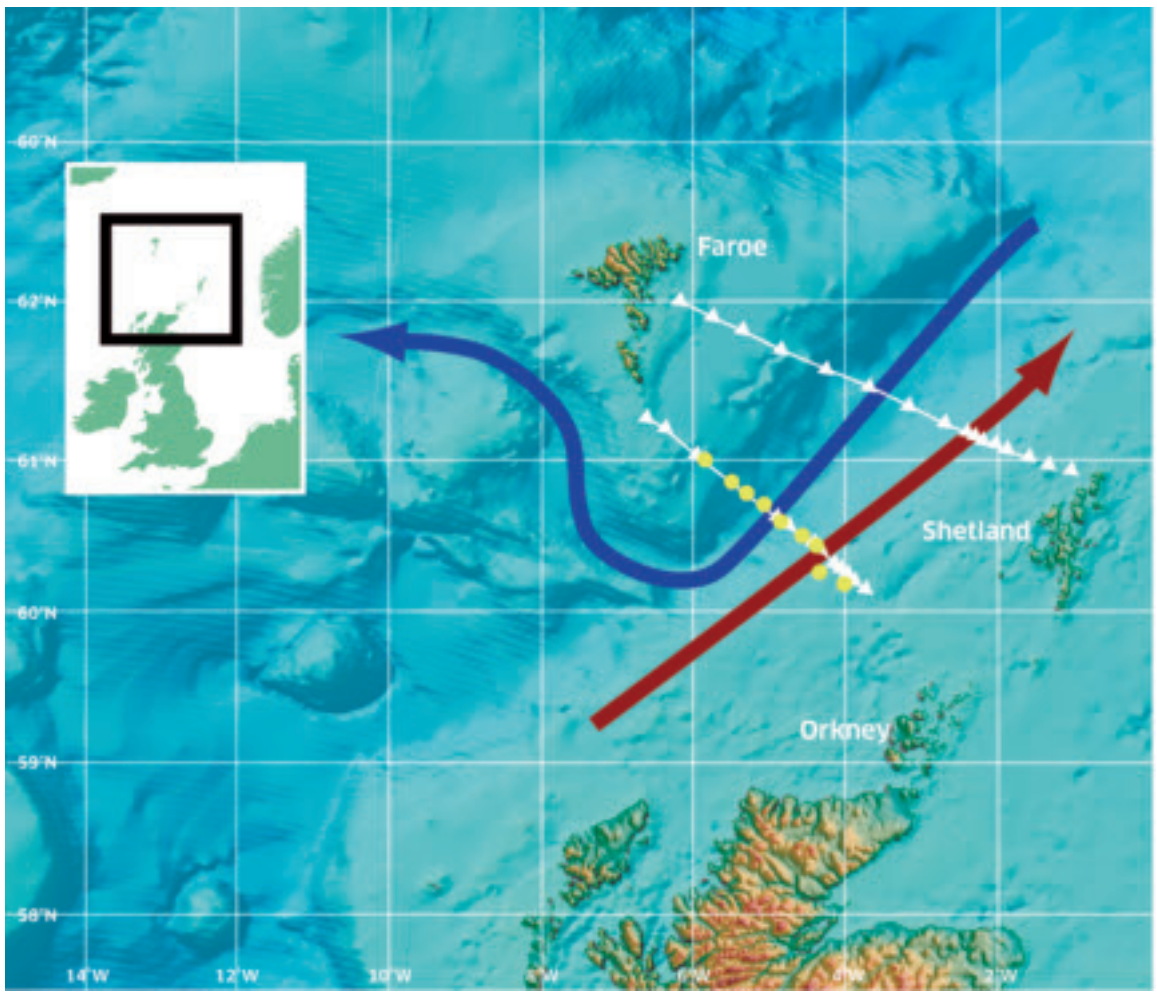
Deeper Waters

In the North Atlantic as well as the surface circulation, there is a flow of deep water returning at depth from the Arctic. Two technical terms often associated with this circulation are the Thermohaline Circulation and, more recently, the Atlantic Meridional Overturning Circulation (AMOC). The AMOC has been the subject of intense study in recent years, because of its significant contribution to climate variability and the possibility that the effects of global climate change will weaken the AMOC, possibly bringing the cold Arctic water further south at the surface and having a cooling effect upon Scotland and Northern Europe.

The return flow of deep water from the Arctic to the North Atlantic is evident from the presence of cold water at depth in the Faroe Shetland Channel (below 400-600 m) that has its origin in the Iceland, Greenland and Norwegian Seas. The presence of both sub-tropical water on the surface and Arctic water at depth brings diverse ecological conditions to Scotland's waters. The cold deep waters from the Arctic, which travel in a south-eastward direction through the Faroe Shetland Channel, are diverted westward by the Wyville Thomson Ridge and eventually spill over into the deep basin of the Rockall Trough. There are also intermittent overflows through deep channels in the Wyville Thomson Ridge that are as yet unquantified.

Monitoring in the Faroe Shetland Channel

The Faroe Shetland Channel, to the north-west of Scotland is an important area as both surface and deep waters flow through the Channel as they move from the one ocean basin to another. Changes in the properties of the deepwater are thought to be related to changes in the surface circulation and the wider scale climatic changes. Two hydrographic sections across the Faroe Shetland Channel have been surveyed for over a century (white triangles) and are situated at a key point to allow these changes to be monitored. The currents flowing through the Channel are also being measured directly using an array of Acoustic Doppler Current Profilers (ADCPs) (●).



Deploying an ADCP

© Marine Scotland

ADCP deployment

© Marine Scotland

Scientists preparing a current meter mooring

© Marine Scotland

ADCP in seabed frame

© Marine Scotland

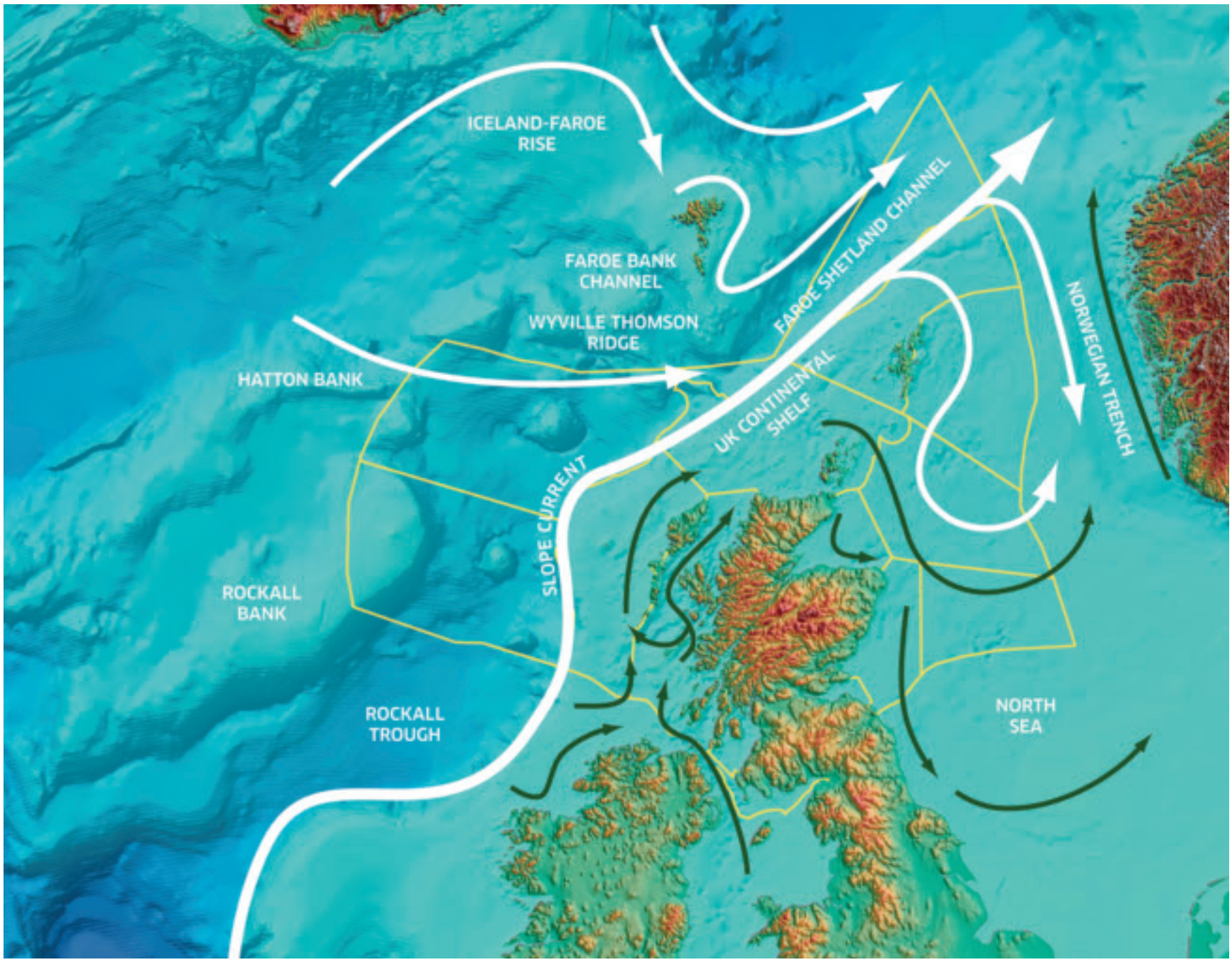
Measuring how fast water is moving

An Acoustic Doppler Current Profiler (ADCP) is used to measure how fast water is moving. An ADCP anchored to the seafloor can measure current speed not just at the bottom, but also at equal intervals all the way up to the surface. The ADCP works by transmitting "pings" of sound at a constant frequency into the water. As the sound waves travel, they scatter off particles suspended in the moving water, and reflect back to the instrument. Due to the Doppler effect, sound waves bounced back from a particle moving away from the profiler have a slightly lowered frequency when they return. Particles moving toward the instrument send back higher frequency waves. The difference in frequency between the waves the profiler sends out and the waves it receives is called the Doppler shift. The instrument uses this shift to calculate how fast the particle and the water around it are moving.

Circulation around Scotland

Circulation map representing the general circulation pattern within the North Atlantic and North Sea areas. It should be noted that flow is not confined to these arrow tracks. Circulation of Atlantic water is shown by the white arrows with coastal circulation represented by the green arrows.

The coastal circulation around Scotland and in the North Sea (green arrows) will show considerable seasonal variation in both strength and positioning, responding mainly to changing patterns of wind. During the summer months some of this circulation consists of frontal jets that are associated with density fronts and will therefore be altered with the loss of stratification during the autumn and winter.



Shelf Sea Circulation

Scotland's position on the UK Continental Shelf means that the seas around Scotland are directly affected by oceanic circulation. The steep bathymetry of the continental slope acts as a barrier between oceanic regions and the shelf sea systems, reducing the amount of water that can travel from the deeper waters of the North Atlantic into the shallower waters on the continental shelf. Processes that cause mixing of oceanic waters and shelf sea waters are complex but have a significant impact on conditions in Scottish waters. Most waters from the North Atlantic that enter the North Sea do so between Orkney and Shetland, around the north east of Shetland and through the deep Norwegian Trench. Tidal currents are predictable and stronger than the non-tidal currents in many areas. Tidal currents cause mixing in the water column and therefore often determine the location and extent to which the water column is stratified into different distinct layers.

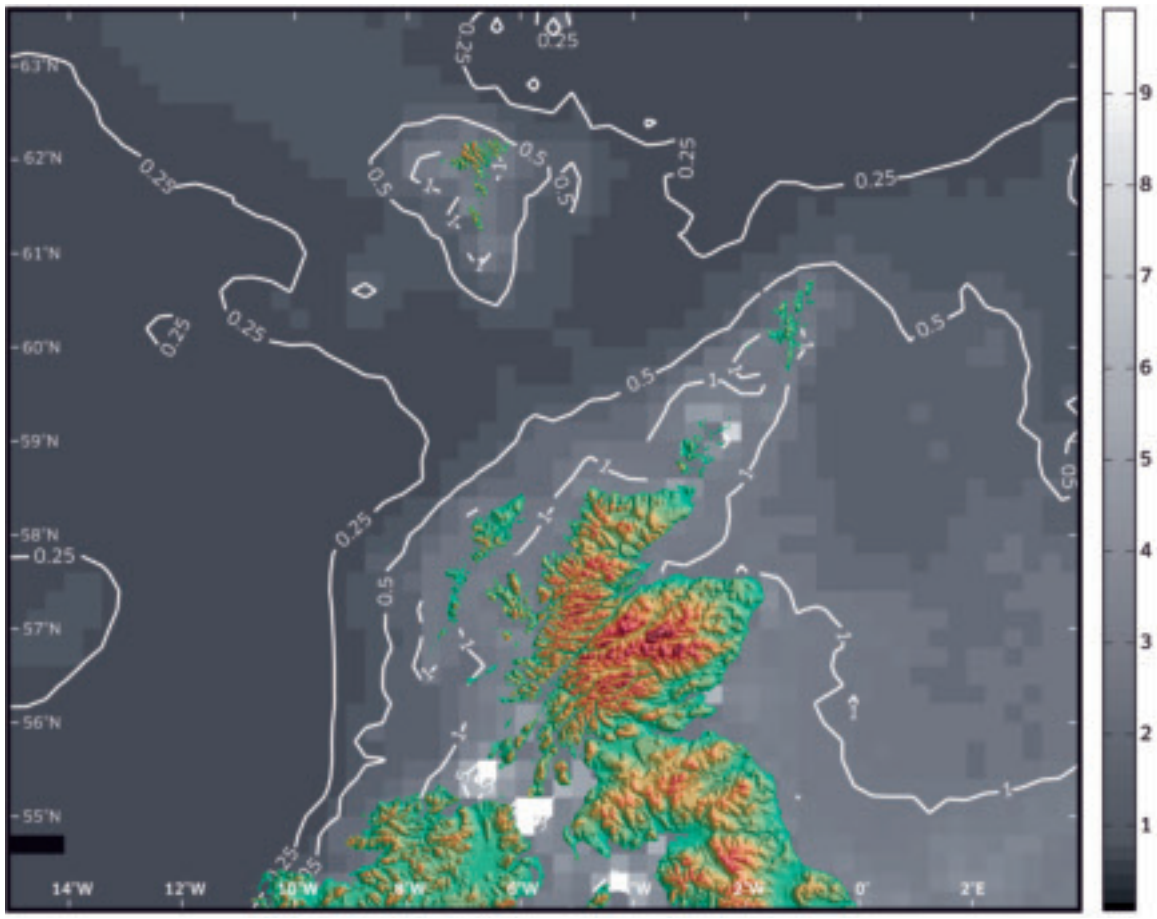
Tidal currents are intensified in localised areas, usually where the flow is constrained by topography. This includes areas such as between Orkney and Shetland, the Pentland Firth, off the Mull of Kintyre and Hebrides where tidal streams can be as high as 3.5-4.5 m/s.

However, when the overall transportation of water around Scotland is considered, the effect of the tides is quite small as tidal currents mainly move water back and forth with little net change in displacement of water. The non-tidal circulation in the North Sea is predominantly anti-clockwise and circulation on the shelf west of Scotland, (the Scottish Coastal Current) is mainly northwards. However this circulation is strongly affected by winds and density-driven coastal currents and jets, which can lead to large changes in currents and even a reversal of this general pattern for short periods.

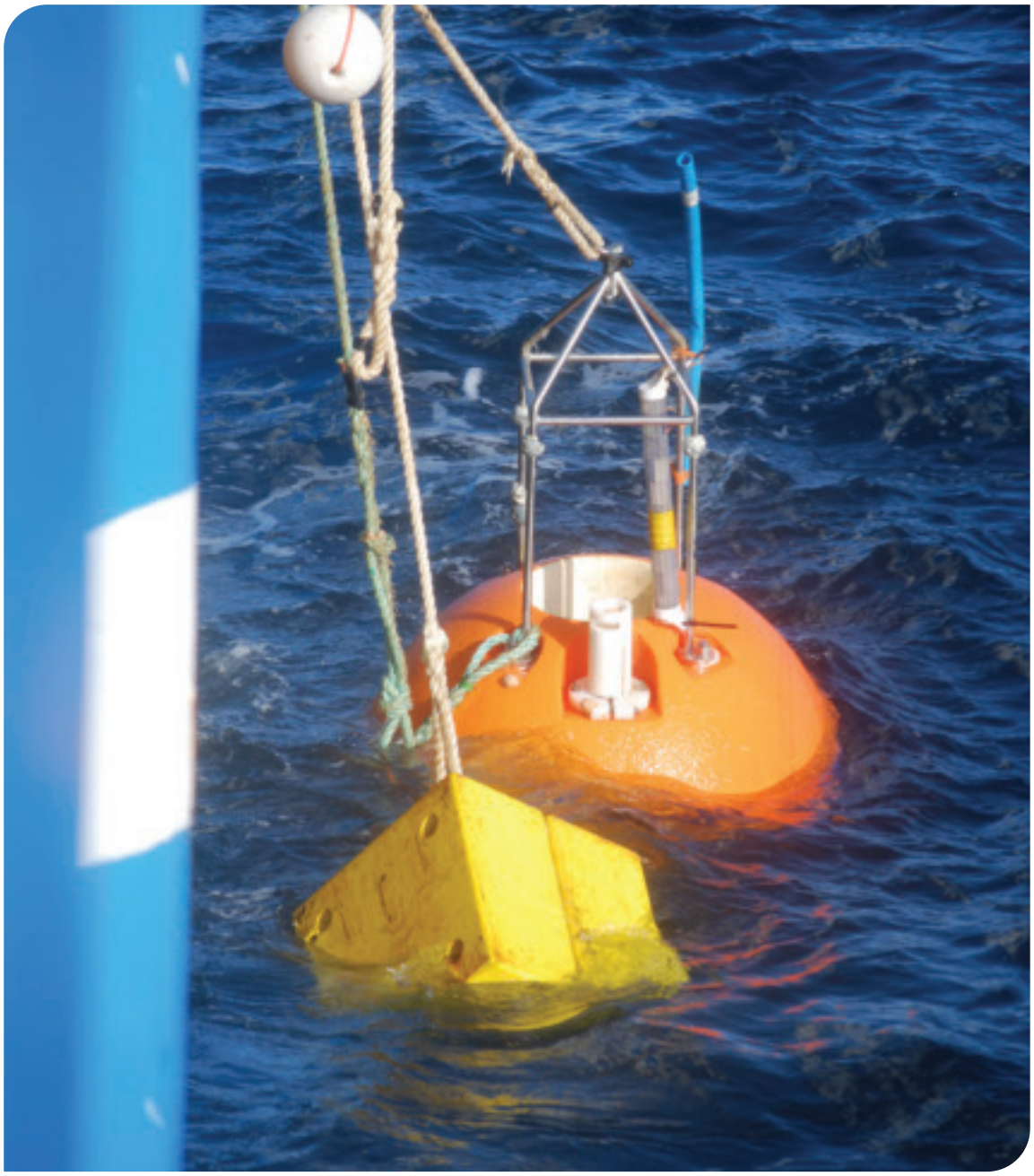
Turbidity and Suspended Particulate Material (SPM)

Seawater contains suspended particulate material (SPM) which comprises mineral particles as well as living and dead plankton. There is an association between SPM and the turbidity of marine waters. Turbidity is highest in coastal areas with large fresh water input (e.g. Clyde Sea and the Forth/Tay river plume). Compared to the southern North Sea, the Scottish North Sea has much lower concentrations of suspended sediment. The turbidity of water influences productivity, as murky waters limit the penetration of light and can inhibit photosynthesis.

Modelled turbidity (mg/l) in coastal waters of Scotland



Source: Mike Heath, University of Strathclyde



© Marine Scotland

© Marine Scotland

© Marine Scotland

© Marine Scotland

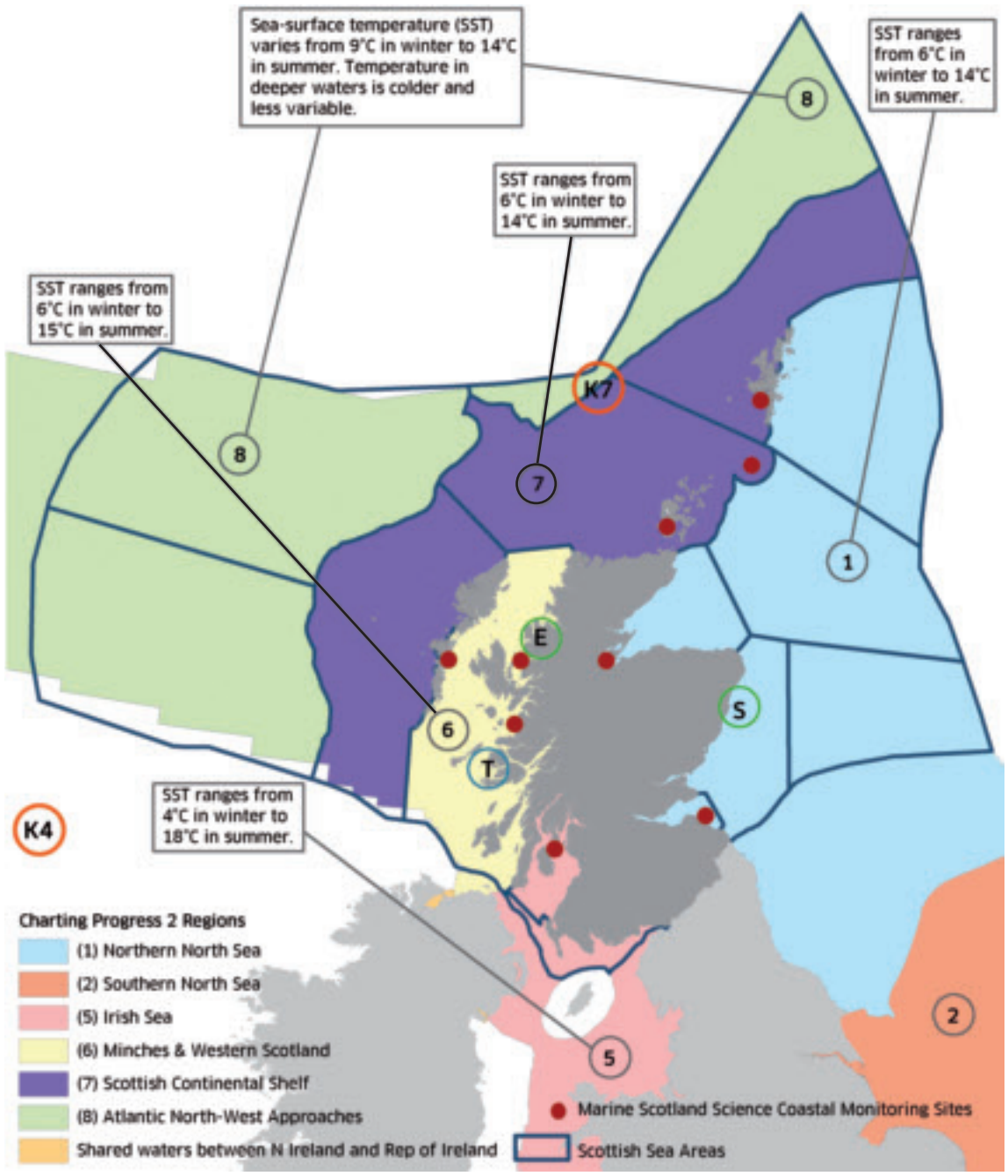
TEMPERATURE, SALINITY AND OCEAN ACIDIFICATION

Temperature

Sea temperatures around Scotland are affected by local climatic conditions (heat flux with atmosphere) and the heat transferred to the shores of Scotland by ocean currents (advective effects). Sea surface temperatures vary with an annual cycle, lagging behind the cycle of atmospheric temperature by around one month.

Average sea temperatures around Scotland reflect the influence of heat transported from oceanic waters. On average, winter temperatures on the west coast of Scotland are higher than those on the east coast. In summer this situation is reversed as waters in the shallower North Sea warm up more quickly, and so summer temperatures on the east coast are higher than on the west coast. The influence of the North Atlantic Current and climate system can also be observed in the long term variability of sea surface temperatures.

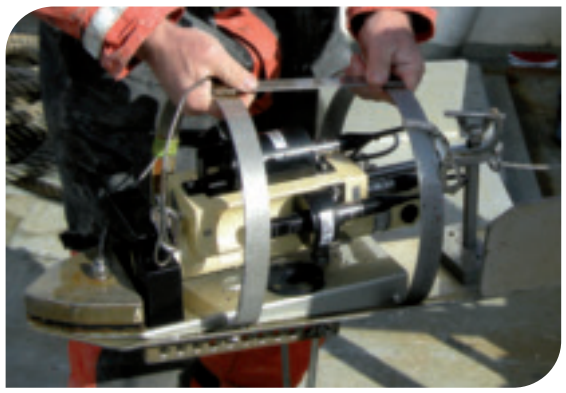
In deeper waters, the circulation patterns have a strong influence on temperatures. Cold Arctic waters fill the deep basins below about 800 m and intermediate waters lie between these and the warmer Atlantic waters above.



Sea surface temperature in the water around Scotland

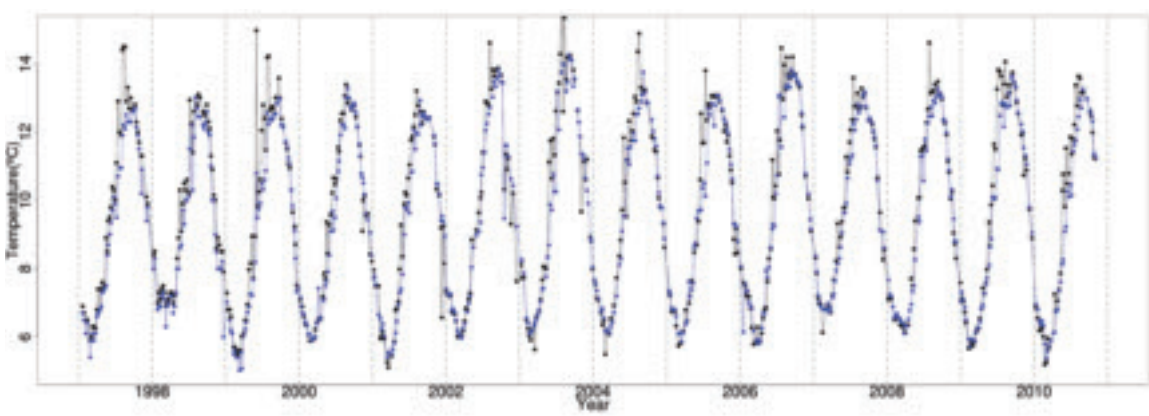
Summer and winter sea surface temperature (SST) by Charting Progress 2 Regions. Specific monitoring sites include Stonehaven (S), Loch Ewe (E), operated by Marine Scotland Science, and the Tiree Passage (T), operated by the Scottish Association for Marine Science. Other data come from a variety of sources including Met Office Marine Automated Weather Stations (e.g. K7 and K4) and the Marine Scotland Science coastal monitoring sites (●).

A towed CTD used to measure, amongst other parameters, temperature at the Stonehaven ecosystem monitoring site



© Marine Scotland

Variation in water temperature off Stonehaven



Water temperature has been measured on a weekly basis at a site 3 km offshore of Stonehaven in the eastern North Sea, south of Aberdeen, since 1997. The station (56°57.8'N 02°06.2'W) is in a water depth of around 50 metres. Temperature is measured at both 1 m (surface; black line) and 45 m (near seabed; blue line). The annual variation shows the minimum occurring during February and the maximum around late August.

The harbour at Stonehaven, the base for the weekly sampling at a site 3 km offshore

© Marine Scotland

Tiree Passage – Temperature

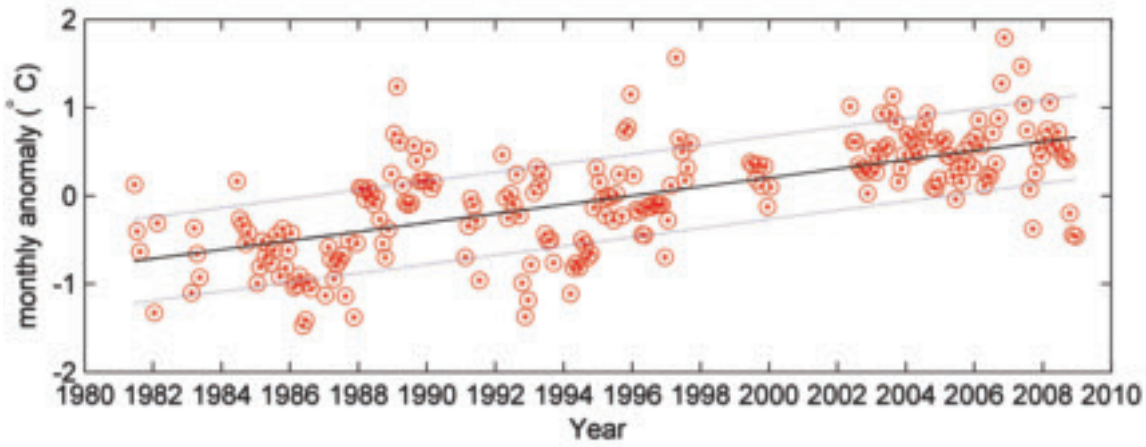
The Scottish Association for Marine Science (SAMS) has been investigating temperature, salinity and flow variability on the European Shelf west of Scotland since 1982. The main time series are from the Tiree Passage mooring (T in map opposite) which has been maintained since June 1981, and a hydrographic section repeated at least annually across the shelf at approximately 56°N since 1975 (The Ellett Line). The overall trend for temperature variability on the continental shelf is of warming at a rate of +0.50°C per decade. In addition it was found that the date of maximum annual temperature has been changing at the rate of 12 days per decade. Given the large inter-annual variation in temperature, a linear trend is a poor predictor of future temperature change. Furthermore, the seasonal timing trend is not indefinitely sustainable, and so neither should be used to predict future changes.

Tiree Passage mooring operated by the Scottish Association for Marine Science (SAMS), Scottish Marine Institute based in Oban

© Mark Inall, SAMS

© Mark Inall, SAMS

Monthly temperature anomaly measured using the Tiree Passage mooring



Sea Surface Temperature

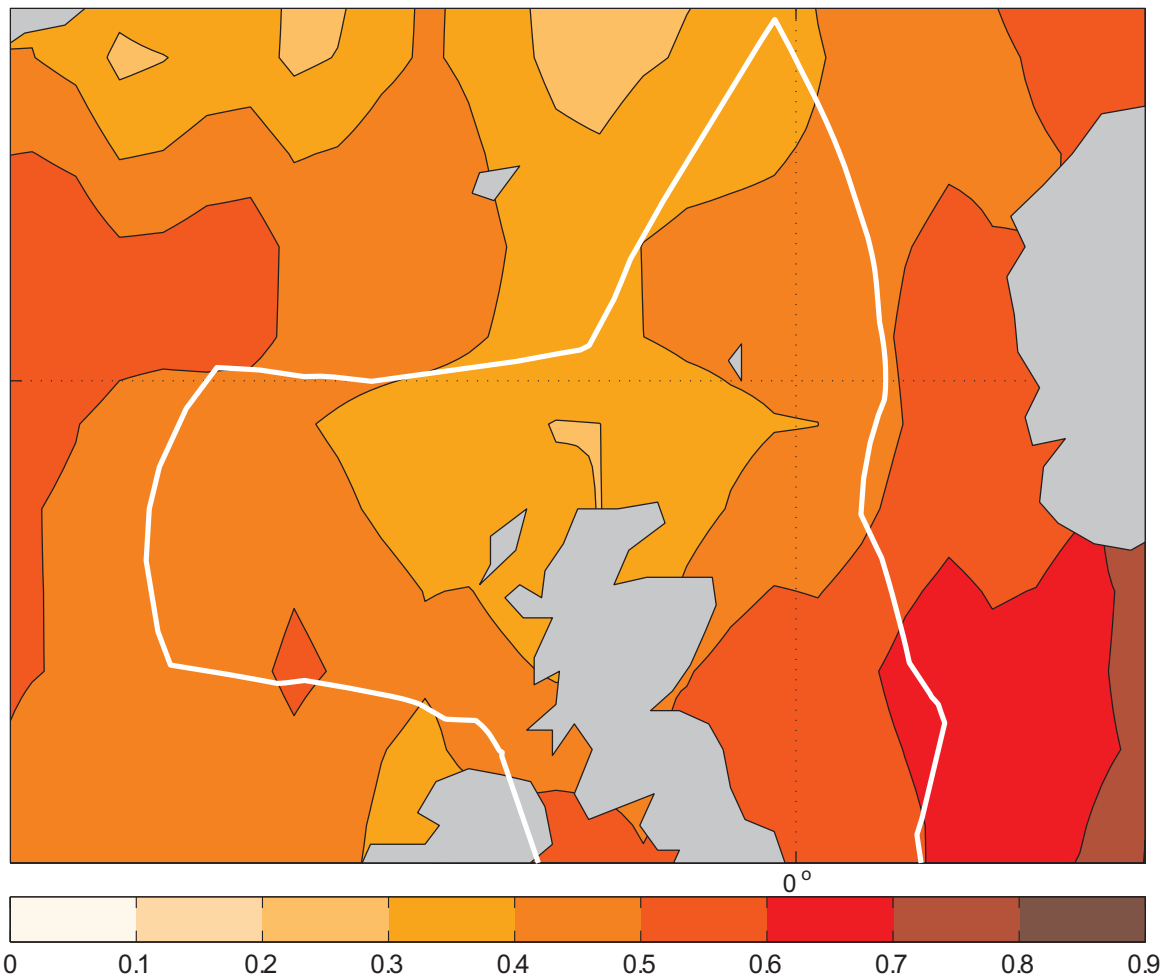
Around the coast of Scotland, and indeed the whole of the United Kingdom, the sea surface temperature is increasing. The rate of increase over the last 25 years (1985-2009) shows geographic variation, but has generally been greater than 0.2°C per decade; to the south east of Scotland the rate over the last 25 years has been 0.5°C per decade.

Minilogger used to record temperature at the Marine Scotland Science coastal monitoring sites

© Marine Scotland

Twenty five year trend in sea surface temperature (°C per decade), calculated over the period 1985-2009.

The dataset is created from a combination of satellite and in situ observations interpolated to provide complete coverage. OISST.v2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their web site at *http://www.cdc.noaa.gov*. (white line = Scottish Fisheries limits)



Salinity

Salinity in the open sea is controlled by the balance between evaporation (fresh water out) and precipitation or run-off from land (fresh water in). In coastal waters, the direct input of fresh water from land run-off and rivers dominates the changes in salinity (figure below for Loch Ewe) and the salinity of many shelf areas is reduced as a result. Areas where fresh water inputs have high influence are the large estuaries and adjacent coastal waters of the Clyde, Solway Firth, Moray Firth, Firth of Tay and Firth of Forth as well as coastal areas on the west coast that receive a lot of fresh water from land runoff and numerous small rivers.

Many west coast Scottish sea lochs have restricted water exchange with the surrounding seas, particularly those with a sill at the mouth of the loch, and this means they can have salinities that differ considerably from those of the open sea.

Salinity can be an important factor determining the ecology of coastal communities. Moreover, depending upon flow rates in adjacent rivers, there will be large variations in salinity in some coastal regions. Since fresh water tends to sit on top of the denser salty water of the open sea, this variation can take place through the water column as well as geographically.

© John Dunn, Marine Scotland

Sampling of water off Stonehaven, North-East Scotland, from the MV *Temora* using a Van Dorn type water bottle to determine nutrient concentrations, salinity and dissolved oxygen.

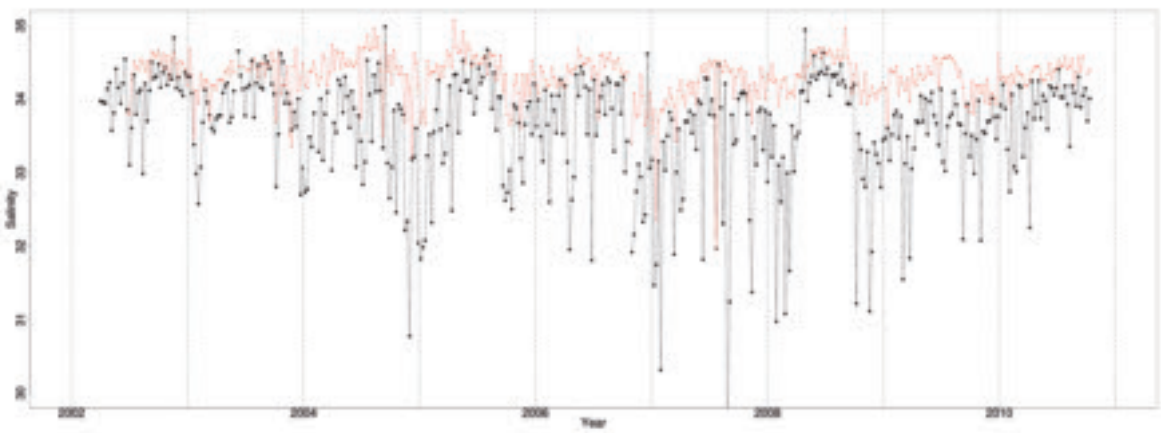
A. Preparation for deployment
B. Deployment
C. Recovery
D. Sub-sampling

© John Dunn, Marine Scotland

© John Dunn, Marine Scotland

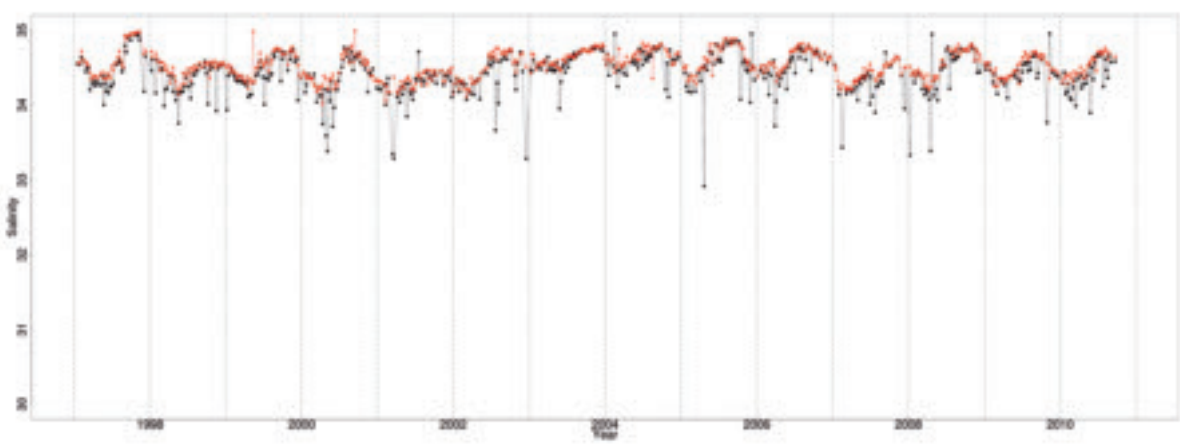
© John Dunn, Marine Scotland

© John Dunn, Marine Scotland



Loch Ewe – Salinity

Variation in salinity measured on a weekly basis at two sites in Loch Ewe in northwest Scotland: Site A (57º50.99'N 05º38.97'W) in water depth of around 40 m where sampling started in April 2002 and Site B (57º50.13'N 05º36.44'W) in water depth of around 15 m where sampling started in June 2000. The surface salinity (—) shows greater variability than observed at 35 m (—).



Stonehaven – Salinity

Variation in salinity measured on a weekly basis at a site 3 km offshore of Stonehaven in the eastern North Sea, south of Aberdeen. The station (56º57.8'N 02º06.2'W) is in water depth of around 50 m. The salinity has been recorded at both 1 m (surface: —) and 45 m (near seabed: —) since January 1997. Annual variation is observed as are periodic large, short term reductions in surface salinity.

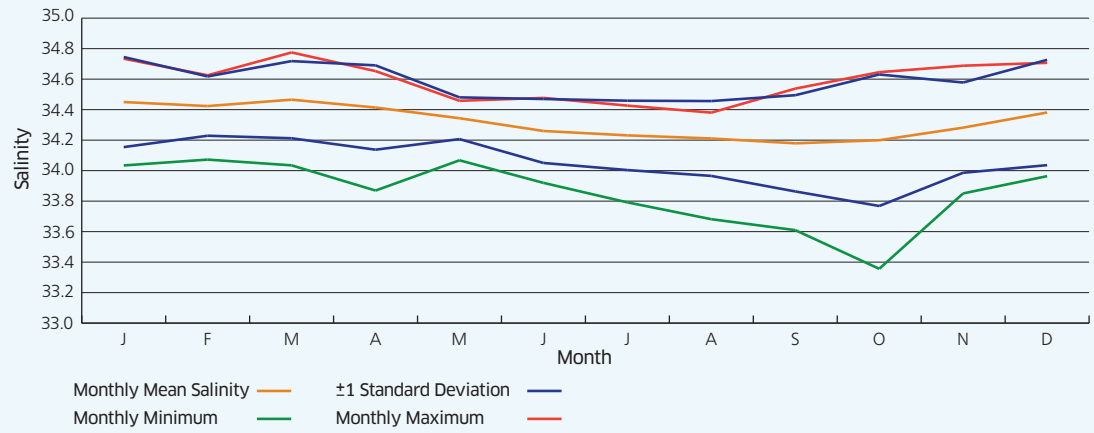
Tiree Passage – Salinity

Accurate salinity time-series are much shorter than those for temperature or currents. Between 2002 and mid-2009, shelf salinities have shown only weak seasonality. Variability peaks in October, and is smallest in May (Figure right).

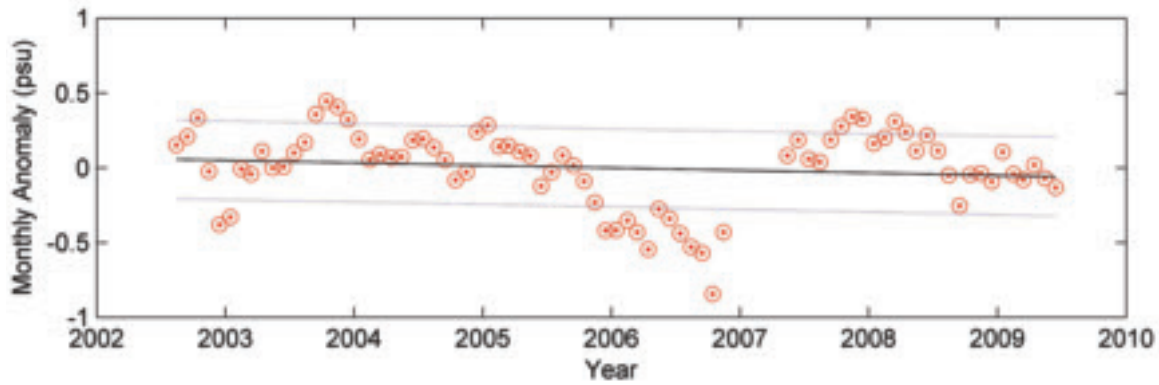
Salinity anomalies (defined as deviations from the long-term average) show strong inter-annual variability. There was a prolonged decline in salinity from 2005 to 2007, suggesting a reduced influence of water from the Atlantic on the shelf during that time (Figure below right).

No single determining factor has been found for the movement of saline Atlantic Ocean waters across the shelf towards the Tiree Passage. Prolonged periods of high North Atlantic Oscillation index (NAO) are found to coincide with periods of raised salinity of shelf waters (NAO: high values of this index correspond to warm, wet and windy conditions over Scotland).

Monthly mean salinity measured using the Tiree Passage mooring



Salinity anomaly measured using the Tiree Passage mooring

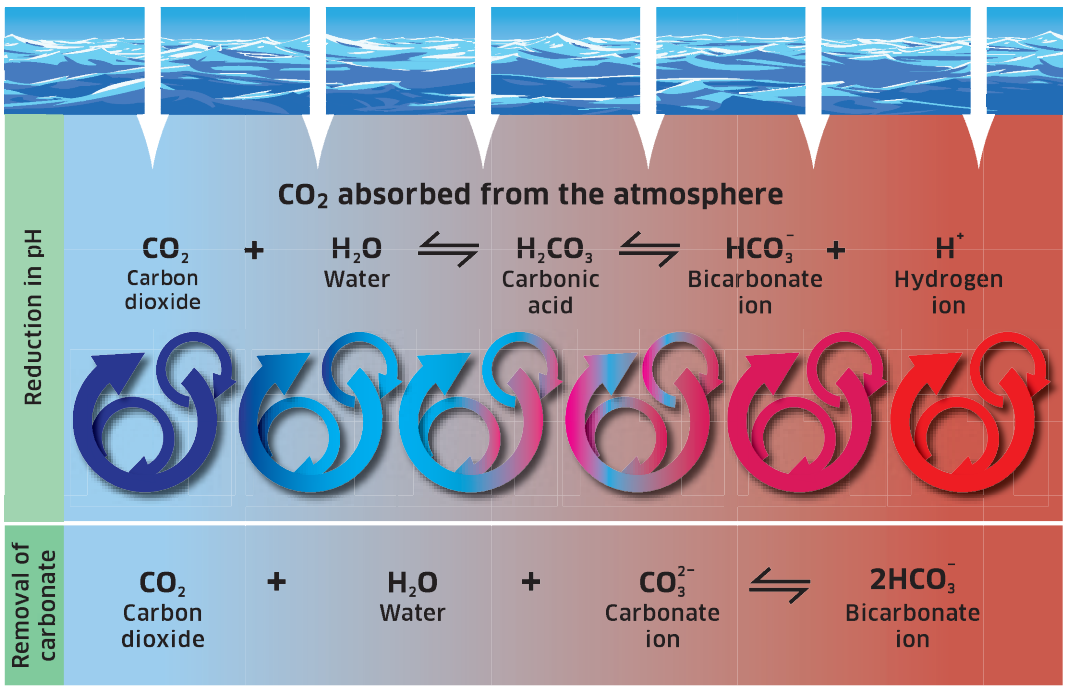


Carbon dioxide and acidification

The oceans have, historically, been a net absorber of carbon dioxide (CO_2). This has reduced the rate of increase of CO_2 in the atmosphere. However, it also makes the oceans more acidic and potentially reduces their capacity to take up CO_2 in the future. Changing the acidity of sea water will have an impact on biogeochemical and ecosystem processes including planktonic calcification, carbon and nutrient assimilation, primary production and physiology. Since the Industrial Revolution, the CO_2 absorbed by the oceans has resulted in a decrease in pH of 0.1 units, but there are currently no baseline measurements of ocean acidity against which changes in UK waters can be judged. It will be some time before accurate judgements can be made about the rate of acidification relative to natural annual and inter-annual cycles.

Ocean acidification may impact the phytoplankton community in various ways. It may influence the calcification rates of some coccolithophore species such as *Emilania huxleyi* (pictured right; collected from a site off Stonehaven, North-East Scotland) as well as competition between phytoplankton groups with different carbon affinities. This includes the diatoms such as *Thalassiosira* (pictured right; sample collected from Loch nam Madadh, North Uist).

The absorption of carbon dioxide by the oceans has the potential to makes them more acidic and reduce the availability of carbonate ions

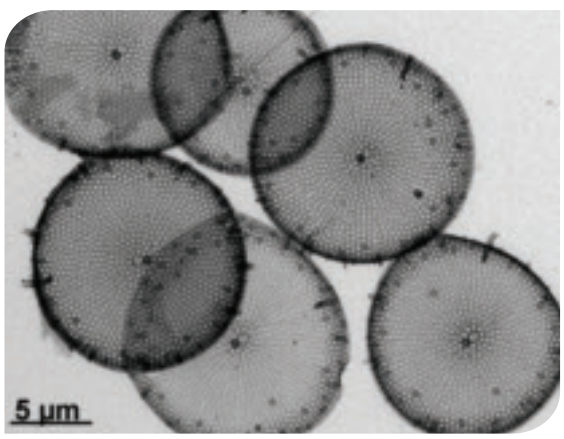


© Marine Scotland

Emilania huxleyi

© Eileen Bresnan, Marine Scotland

Thalassiosira



© Eileen Bresnan, Marine Scotland

WAVES AND SEA LEVEL

Waves

Sea surface waves are mainly caused by the effects of wind on the surface of the sea. Their height is predominantly determined by the fetch (i.e. distance wind has blown over) and length of time of the wind forcing. Some local modification of wave height can be caused by tides. The seabed also influences waves in shallow water as waves will become steeper and higher as they approach the shore.

Within Scottish waters, the wave climate is mainly influenced by conditions in the North Atlantic ocean, where the fetch is long enough to establish large, regular waves known as swell. The north and west of Scotland (Hebrides, Orkney and Shetland) are most exposed to these conditions. On the east coast of Scotland, conditions in autumn and winter may also be rough in the North Sea because the wind direction can lead to a large fetch. Moreover, the Moray Firth is also relatively exposed because of its shoaling bathymetry and exposure to the North Sea.

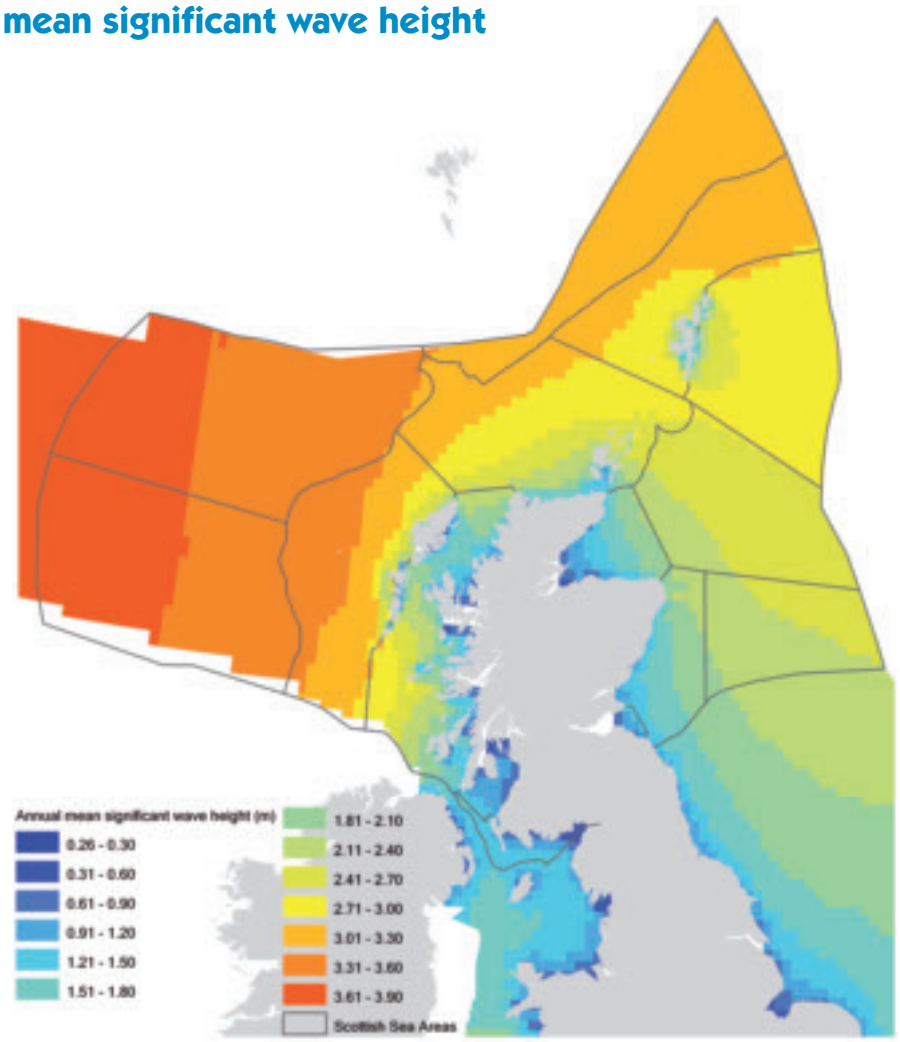
Seas breaking over the breakwater at Aberdeen Harbour

© Marine Scotland

Fishing vessel ploughing through the sea

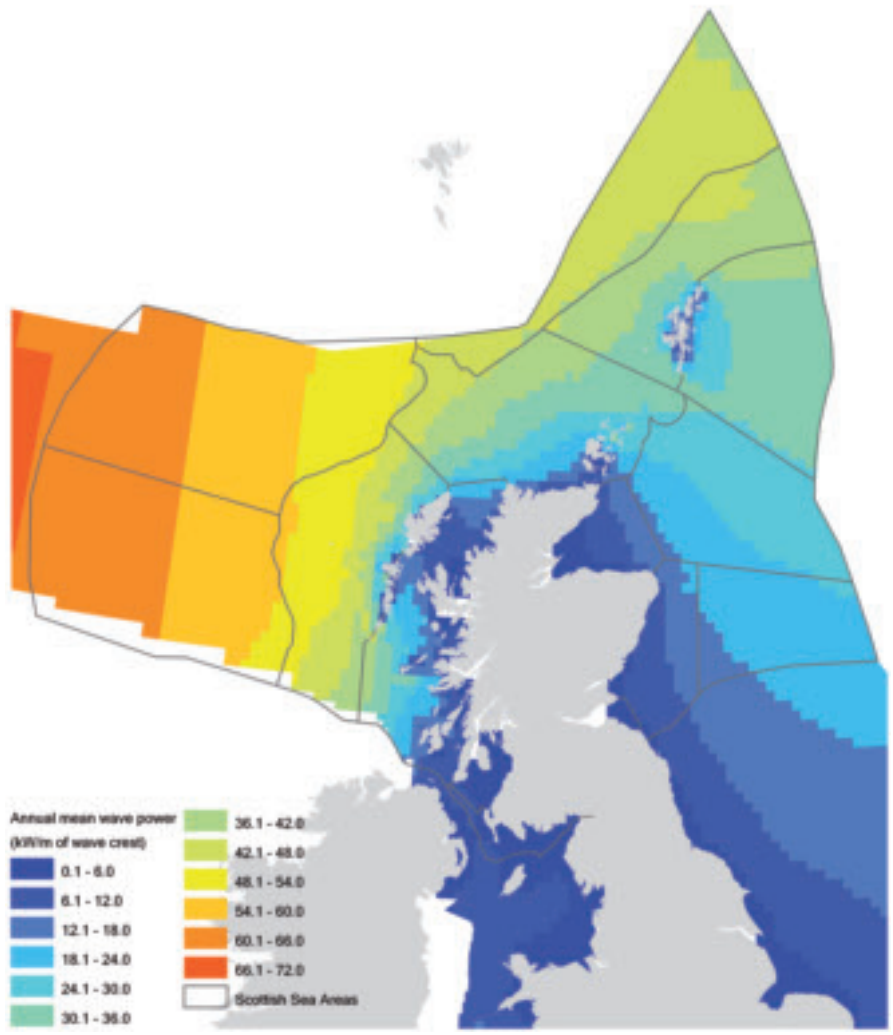
© Marine Scotland

Annual mean significant wave height



Annual mean significant wave height (m) (the average height of the highest $^1/_3$ of waves). The wave height is greatest in the Atlantic, moderate in the North Sea and least in the immediate coastal zone where the values are generally < 1.2 m.

Annual mean significant wave power of wave crest



Annual mean significant wave power (kW/m of wave crest). Typical values in the coastal zone are between 0.1 and 12 kW/m of wave crest.

(Data from the Atlas of UK Marine Renewable Energy Resources, Commissioned by DTI and produced by ABPmer, The Met Office & Proudman Oceanographic Laboratory (2008)., http://www.renewables-atlas.info/)

Sea Level

Sea levels are affected over short timescales by the rise and fall of the tide as well as the effects of storm surges. Over longer timescales, the sea level is affected by global climate change and movements of land masses relative to the Earth's crust.

The principal tidal components are the semi-diurnal (twice daily) tides although in some limited regions the diurnal (daily) tides are significant. The UK Tide Gauge Network, run by the Tide Gauge Inspectorate, records tidal elevations at a number of locations around the UK coast of which 11 are currently operating in Scotland. These measurements, together with those provided by the Scottish Environment Protection Agency (SEPA) Tide Gauge Network, provide a long time series of sea level data. Annual mean sea level is the height of the sea averaged over a year. This removes short term fluctuations caused by waves and tides. Across the UK, mean sea level changes seasonally because of thermal expansion by approximately 10 cm (range), and is at a maximum in late summer.

Trends in sea level vary greatly at different sites. Much of this variation is probably caused by differential rates at which the land on which the tide gauges sit is moving up. This movement is caused by the land continuing to rise after the removal of the weight of ice after the Ice Age.

Impact of Rising Sea Level by Charting Progress 2 Regional Seas (see – Temperature, Salinity and Ocean Acidification section for description of these Regional Seas)

The rate of sea level rise around the UK coast, adjusted for land movements, was about 1.4 mm per year during the 20th Century.

Northern North Sea (Region 1) – rising sea levels are only adversely affecting a small proportion of the coast

Irish Sea (Region 5) – rising sea levels are adversely affecting a large proportion of the low-lying parts of the coast which are vulnerable to flooding and erosion

Minches and Western Scotland (Region 6) – rising sea levels are only affecting a small proportion of the coast

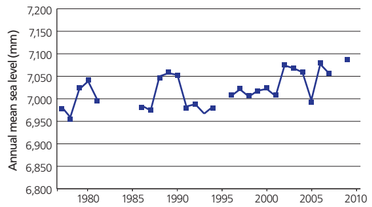
Scottish Continental Shelf (Region 7) – rising sea levels do not pose a significant threat to the coast which is rocky and rising

(Assessment taken from Charting Progress 2: The State of UK Seas; http://chartingprogress.defra.gov.uk)

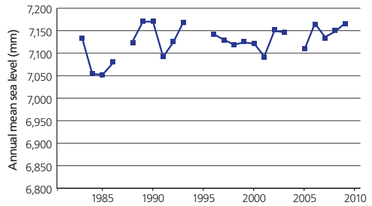
Tidal Range

Tidal range is generally between 4 and 5 m; highest tidal ranges are found in the inner Solway Firth where the mean spring tidal range can be between 7 and 8 m. Tidal range is at a minimum in areas known as amphidromic points. One of these points occurs in Scottish waters between Islay and the Mull of Kintrye; another amphidromic point can be found in the north east of the North Sea. Tidal range decreases with distance offshore from the North East coast.

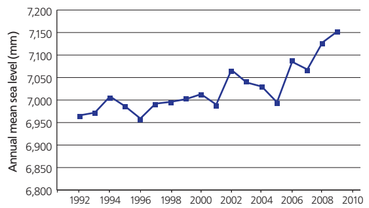
Stornoway (S)



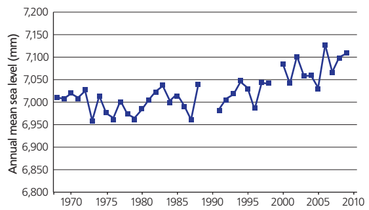
Ullapool (U)



Port Ellen (PE)



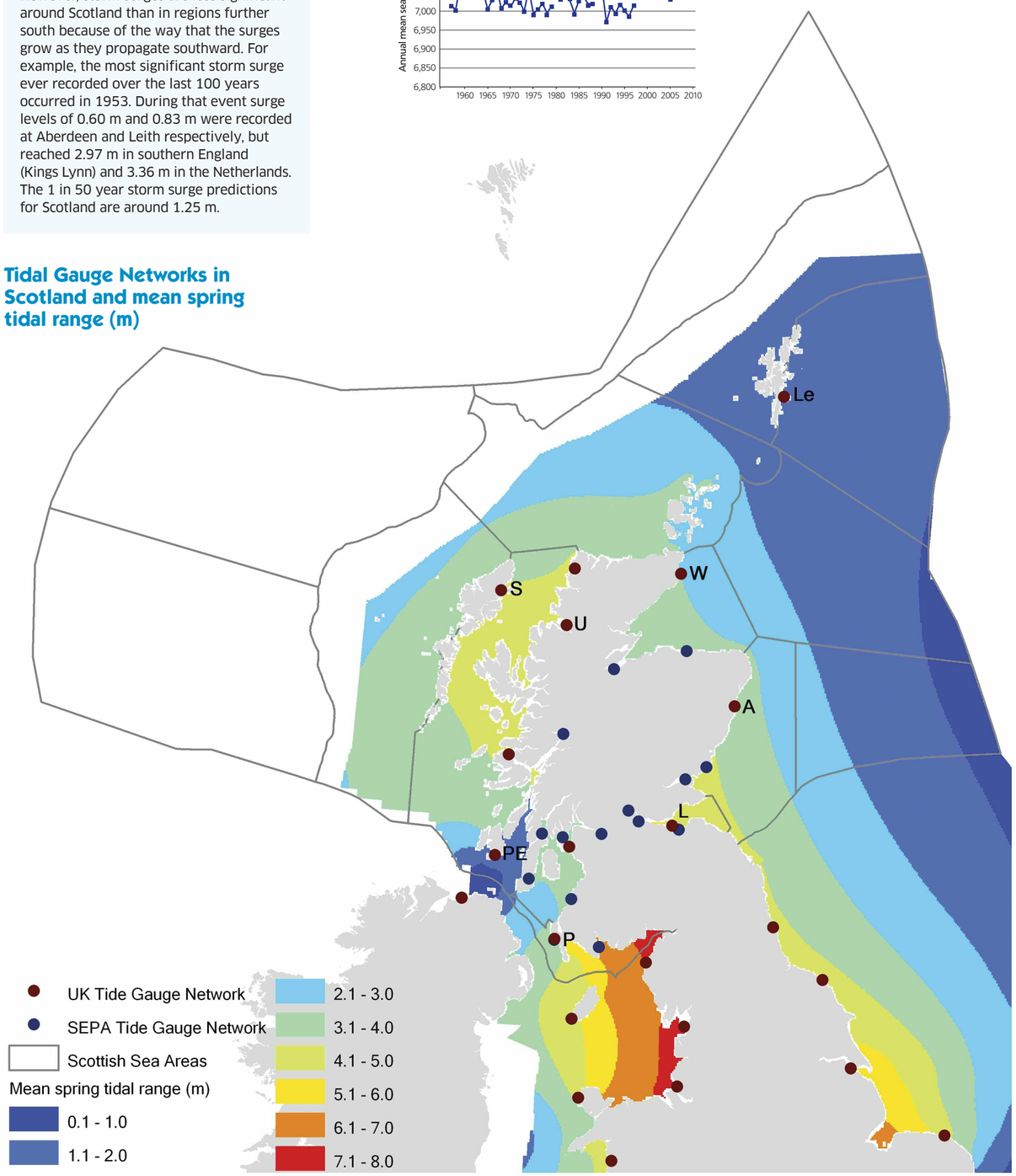
Portpatrick (P)



Tidal Surges

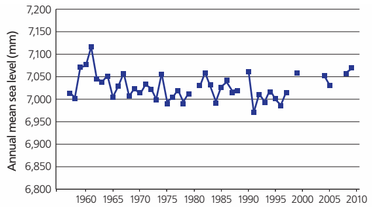
Tidal surges caused by storms do occur in Scotland, and mainly affect the east coast. However, storm surges are less significant around Scotland than in regions further south because of the way that the surges grow as they propagate southward. For example, the most significant storm surge ever recorded over the last 100 years occurred in 1953. During that event surge levels of 0.60 m and 0.83 m were recorded at Aberdeen and Leith respectively, but reached 2.97 m in southern England (Kings Lynn) and 3.36 m in the Netherlands. The 1 in 50 year storm surge predictions for Scotland are around 1.25 m.

Tidal Gauge Networks in Scotland and mean spring tidal range (m)



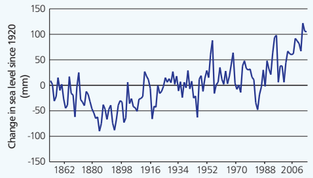
Source for the UK Tidal Gauge Network: Permanent Service for Mean Sea Level (http://www.psml.org/dat/obtaining)

Lerwick (Le)

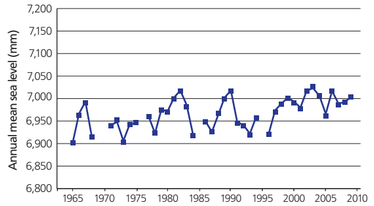


Aberdeen – One of the longest mean sea level time series in the United Kingdom

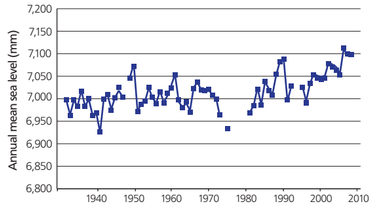
Until the mid-1980s, sea levels in Aberdeen have varied around the 1920 levels. However, for every year since 1985, sea levels have been higher than 1920. On average, in the past two decades, sea levels are more than 60 mm higher than the baseline. Between 2006-08 sea levels have been higher than 1920 by more than 100 mm.



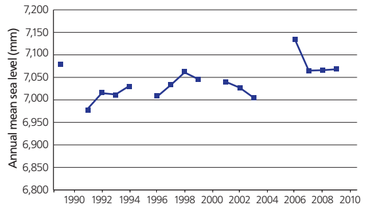
Wick (W)



Aberdeen (A)



Leith (L)

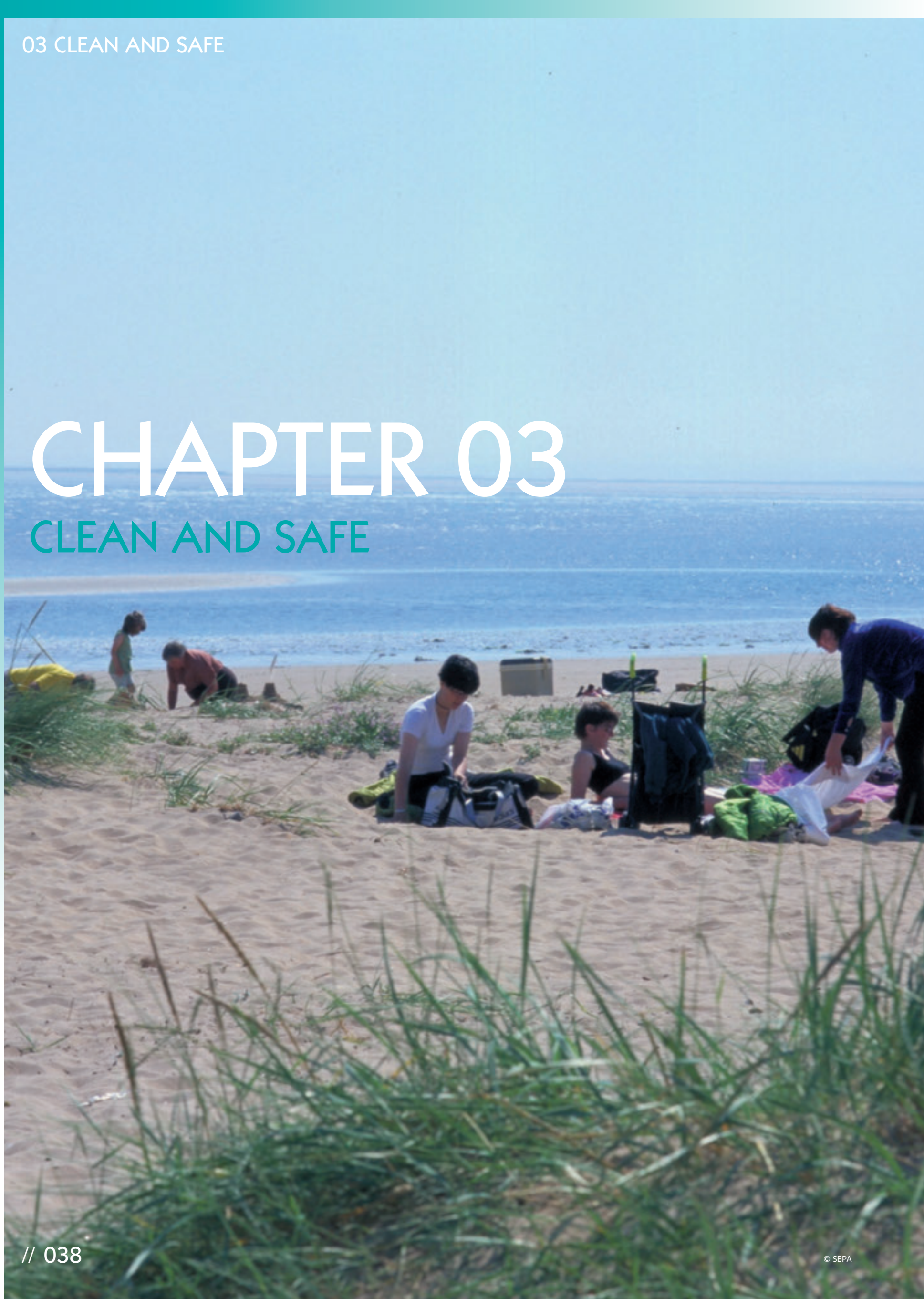


Source for Annual Mean Sea Level plots: Permanent Service for Mean Sea Level, UK.

© Marine Scotland

CHAPTER 03

CLEAN AND SAFE



© SEPA

Introduction

The Clean and Safe chapter provides an assessment of whether Scotland's seas are clean, that is, on levels of contamination, and safe, that is, whether there are hazards to marine life in the sea or to human beings using the sea.

Most contaminants enter estuaries and coastal waters from land-based sources. These inputs can be natural, due to weathering, or due to man's activities. Most discharges from industry or sewage treatment works are from point sources, but agricultural run-off and other inputs can be from more diffuse sources. The impacts of sewage discharges on water quality in Scotland's major estuaries are described, and the impacts of inputs of nutrients on estuaries and coastal waters are considered in relation to the risks of eutrophication. The classification of Scotland's estuaries and coastal water for the EU Water Framework Directive (WFD) are presented.

Contaminant inputs from point and diffuse sources are quantified and reported annually to the Oslo and Paris Commission (OSPAR), and these are described here. Contaminant groups covered include trace metals and organic chemicals used in industry; these are toxic, persistent and bio-accumulable substances such as cadmium, lead, mercury, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and brominated flame retardants (PBDEs). Concentrations of these contaminants in waters, sediments, fish and shellfish are presented, together with an assessment of the behaviour, fate and biological effects of these contaminants, to assess whether Scotland's seas can be considered as clean.

Information is presented on some issues which may be considered as having an impact on whether the seas are both clean and safe, such as marine litter and oil and gas spills. The presence of marine litter on a shore may be taken to indicate that a beach is contaminated and therefore not clean. In relation to safe seas, there is evidence that marine life has been damaged by plastic and other debris in the sea, and the uptake of pollutants by microplastics is thought to present a toxic hazard to marine life. Information on oil and gas spills in relation to the oil and gas industry are presented, along with figures on loss of life at sea in maritime accidents.

Whether Scotland's seas are safe is also considered through the assessment of concentrations of bacteria in waters designated as suitable for bathing or for growing shellfish, and levels of algal toxins are reported and assessed.

The information presented is intended to form the scientific evidence base to inform Scotland's national marine plan. It will also serve to highlight key knowledge gaps and help focus and prioritise the deployment of resources in the future.

It is recognised that the information presented is not totally comprehensive. Areas where there is a need for more information are highlighted. These include the introduction of new chemicals to the environment, new policy areas such as marine planning and renewables, changing priorities and the EU Marine Strategy Framework Directive (MSFD). These new challenges together with the current financial situation mean that current monitoring programmes will need to change to continue to provide the required information. In addition, new ways of working will need to be adopted, including more partnership working, to ensure that management decisions are made using a robust scientific evidence base.

Information Sources

The Scottish Environment Protection Agency and Marine Scotland Science both contribute contaminant data to a national (UK) database (MERMAN). This data is submitted to the International Council for the Exploration of the Sea (ICES) to fulfil the UK's obligation for the OSPAR Coordinated Environmental Monitoring Programme. The data in MERMAN is quality assured and has been used for national assessments such as Charting Progress 2. Scottish data in the MERMAN database was used in this report and the data was assessed using internationally agreed assessment criteria where available.

Data not stored in MERMAN was obtained from the relevant competent monitoring authority.

- The Scottish Environment Protection Agency and Food Standards Agency (Scotland) provided microbiological contamination information collected for the Bathing Waters and Shellfish Waters Directives and EC food hygiene regulations.
- The Food Standards Agency (Scotland) also provided information on biotoxins in shellfish.
- The Marine Conservation Society provided beach litter data from their annual Beachwatch surveys.
- Data on Oil and Chemical spills was taken from The Advisory Committee on the Pollution of the Sea (ACOPS) annual reports.
- Radioactive substances information was provided by the Radioactivity in Food and Environment (RIFE) reports.

WATER FRAMEWORK DIRECTIVE CLASSIFICATION OF TRANSITIONAL AND COASTAL WATERS

What is the Water Framework Directive?

The EU Water Framework Directive (WFD) (200/60/EC) established a new legal framework for the protection, improvement and sustainable use of rivers, lochs, transitional waters, coastal waters and groundwater across Europe in order to:

- prevent deterioration and enhance the status of aquatic ecosystems, including coastal waters (out to 3 nautical miles from the coast in Scotland)
- promote sustainable water use
- reduce pollution, and
- contribute to the mitigation of floods and droughts.

Implementation of the Water Framework Directive

The Water Framework Directive requires the competent monitoring authority to divide surface waters into water bodies and assess the status of these water bodies by assigning them to a class from High to Bad. All water bodies must achieve Good status by 2015. In Scotland, the work required to implement the Directive is being delivered by the Scottish Environment Protection Agency (SEPA), in conjunction with the Scottish Government and other partners, with the timetable for action set out in the Directive and in line with guidance agreed with other EU member states.

Scotland has 457 coastal water bodies and 57 transitional water bodies. Each water body is individually classified using a decision tree, according to its ecological or chemical quality, using a set of "quality elements". Water bodies are classified for ecological quality by comparison to background reference conditions for each quality element. Ecological quality is assessed over a 5-point scale from High Status, through Good, Moderate and Poor to Bad. Chemical quality is assessed through comparison to numerical Environmental Quality Standards set nationally and internationally.

Quality element

Quality elements are key components of the physical, ecological or chemical aspects of a water body that contribute to its overall quality. For example, the ecological quality elements include plankton species, benthic invertebrates, fish populations, seagrasses and saltmarshes.

Classification results

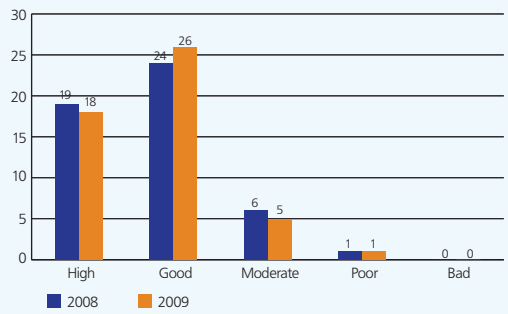
The WFD classification results for 2008 and 2009 are shown as numbers of water bodies in each class for transitional and coastal waters.

Overall, 88% of Scotland's transitional waters and 93% of Scotland's coastal waters had good or high status, although there are a few areas where condition is "less than good" and where improvements should be sought.

Heavily modified water body – Clyde estuary

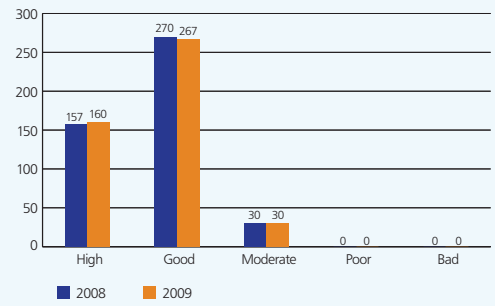
© SEPA

WFD Classification results for transitional waters



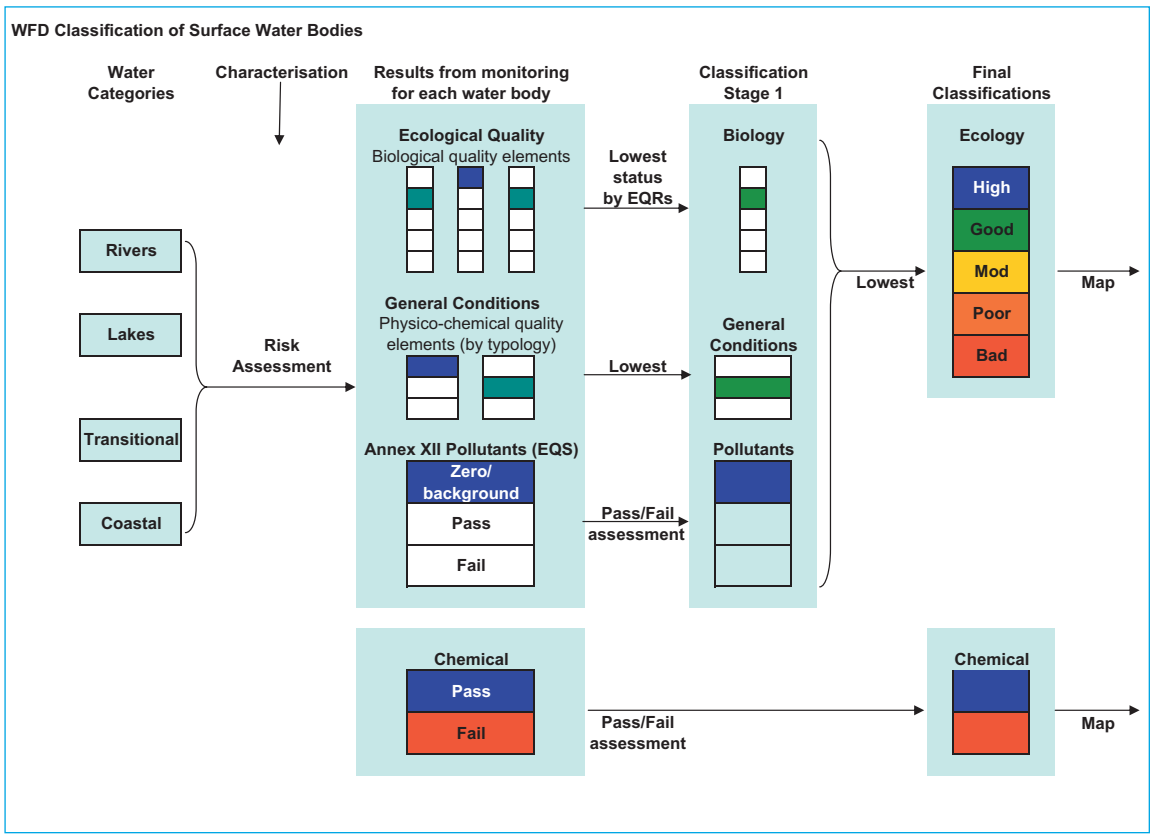
Source: SEPA

WFD Classification results for coastal waters



Source: SEPA

Classification of Surface Water Bodies Decision Tree



© Source: SEPA

Seagrasses

© SEPA

Saltmarsh

© SEPA

WATER FRAMEWORK DIRECTIVE CLASSIFICATION OF TRANSITIONAL AND COASTAL WATERS

Changes between 2008 and 2009

The results for transitional waters show very little change from 2008 to 2009. The results for coastal waters show that the number of water bodies at high status increased slightly, from 157 in 2008 to 160 in 2009. This was due to improvements in some water bodies moving from good to high status as a result of re-assessing nutrient data for the Shetland Islands, but with some apparent downgradings at other water bodies. The downgradings resulted from more data being available. Water bodies default to high status and are monitored on a 1 year in 3 rolling programme. Additional data was collected for rocky shore macroalgae and for benthic invertebrates.

Main cause of the water bodies having moderate or poor status

The only transitional water body at poor status in 2008 and 2009 was the upper Forth Estuary, due to seasonal low oxygen levels related to impacts of organic waste combined with low river flows and reduced mixing.

The 5 transitional water bodies at moderate status include the Forth and Clyde estuaries, also due to seasonal low oxygen levels related to impacts of organic waste combined with low river flows and reduced mixing. Montrose Basin and the Ythan estuary are also at moderate status because of high nutrient inputs leading to elevated macroalgal growth.

Other transitional water bodies at moderate status include Girvan harbour, the middle Forth estuary and the canalised stretch of the Clyde estuary. This is due to morphological impacts where the structure of the water body has been affected by man's activities, such as the construction of harbours, navigation channels or sea defences.

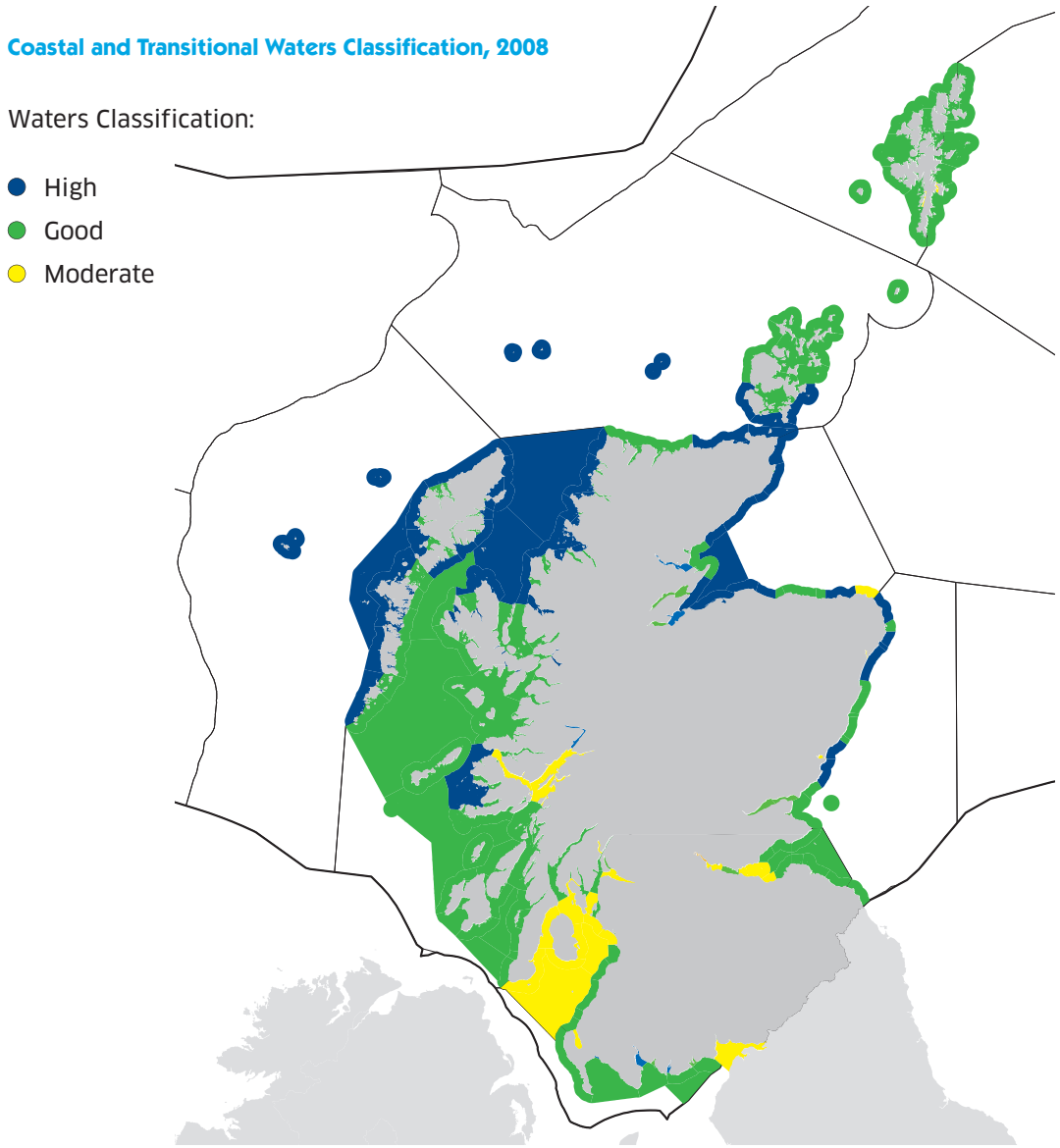
There are 30 coastal water bodies at moderate status. These are mainly downgraded because of the condition of the benthic invertebrate populations. This may be due to organic pollution or trawling pressures.

Action to improve the condition of water bodies

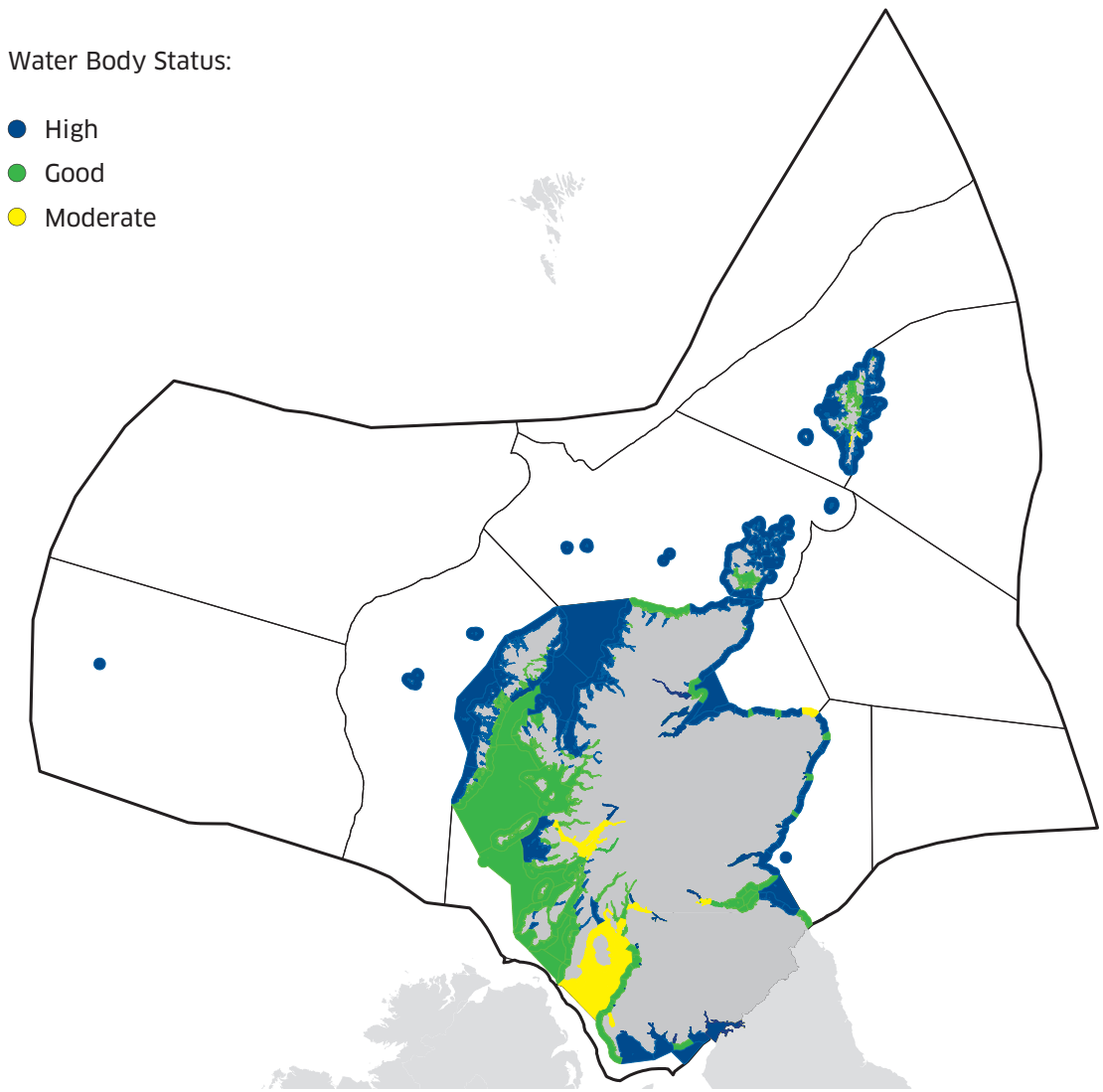
SEPA is working with partner organisations, including Marine Scotland, to improve the condition of downgraded water bodies through changes to current practice, where appropriate. Examples of this approach are reducing fishing pressures to improve the status of benthic populations and action programmes in Nitrate Vulnerable Zones designated under the Nitrates Directive (91/676/EC) to reduce inputs of nutrients from agriculture.

Water bodies affected by physical structures such as harbours and canalisation are described as "heavily modified", and the status of these water bodies is not likely to change over time.

Coastal and Transitional Waters Classification, 2008



Water Body Status for Benthic Invertebrates, 2008



What are hazardous substances?

Substances which accumulate in the environment and impact on wildlife are considered to be hazardous. Substances identified as a particular cause for concern include cadmium, mercury, lead, pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and brominated flame retardants (PBDEs).

Hazardous substances are released to the environment as a result of human activities such as manufacturing, pest control and the burning of fossil fuels. Trace metals may also be released naturally by leaching from rocks and soils. Although the use of some substances has been banned (PCBs and some brominated flame retardants) they continue to be present in the environment as a result of historical use.

The marine environment is the ultimate sink for these substances through direct introduction from marine activities such as dredge spoil dumping, transport via rivers or deposition from the atmosphere by solution at the surface or in rainfall. Inputs of selected substances to the marine environment via rivers and effluent discharges have been quantified for the OSPAR Rivers and Direct Discharges (RID) programme since 1990.

Measuring hazardous substance inputs to Scottish marine waters

Hazardous substance inputs to the marine environment from rivers and effluents are estimated by measuring the concentration in the discharge and multiplying this by the flow to give the load. Inputs are reported by ICES sea areas. These are named SC1, SC2, SC2a, SC2b, SC3, SC4 and SC5 and are shown on the map opposite. If the concentration of a substance in the discharge is too low to be measured the estimated load assumes that the concentration is at the limit of detection. Inputs from the dumping of dredge spoil are measured separately.

Inputs of trace metals from discharges

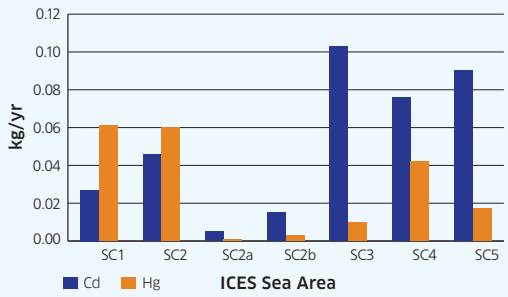
Inputs of cadmium and mercury are often at concentrations too low to be measured so they are estimated from the limit of detection of the analysis. These estimates have decreased as improvements to analytical methods have lowered limits of detection so trends are difficult to quantify. In 2008 it was estimated that between 0.4 and 2 tonnes of cadmium and between 0.2 and 0.3 tonnes of mercury were discharged to Scottish coastal waters. In 2008 approximately 85 tonnes of copper, 35 tonnes of lead and 300 tonnes of zinc were discharged to the sea in Scotland. The highest inputs of all metals were from urban and industrial areas. Inputs of copper, lead and zinc have all decreased since monitoring began in 1990. Lead inputs decreased substantially following the introduction of unleaded petrol in 1988, and inputs of copper and zinc have decreased as a result of improvements to effluent treatment. There is considerable variability in the amount of decrease in different areas. For example, inputs of copper and zinc appear to increase in SC3 in 2000 however this is due to an increase in the number of discharges monitored rather than an actual increase in inputs.

The marine caged fish farm industry is a potential source of trace metals in less populated areas however they are not monitored as there is no aqueous discharge. Since 2007 inputs of copper and zinc from marine caged fish farms have been estimated from the trace metal content of the fish food, the amount used and the amount deposited on the sea bed through waste, plus the amount of copper-based antifoulants used to treat cage nets. These estimates show that fish farms are potentially a substantial source of copper and zinc compared to other inputs in the north and west of Scotland. However the metals released from fish farms are contained in particulate material deposited on the sea bed and it is not known what proportion can be taken up by animals and plants.

Intertidal mussel sampling

© SEPA

Inputs of Cadmium and Mercury to Scottish Sea Areas in 2008



Source: SEPA

Inputs of trace organic compounds

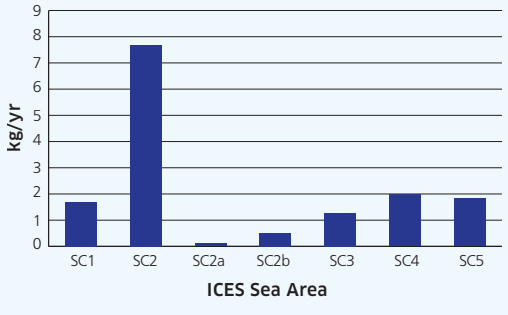
Most trace organic compounds are not soluble in water and are present below the limit of detection in discharges. Inputs of Lindane have been quantified as it is relatively soluble in water and present in measurable concentrations. Lindane (γ-hexachlorocyclohexane (HCH)) enters the environment through its use as an insecticide in a wide range of products. The use of lindane as an insecticide is declining and aqueous inputs to Scottish seas decreased from 225 kg in 1991 to 17 kg in 2008. Current inputs are highest in the Clyde sea area (SC2).

Estimated inputs of Copper and Zinc from the marine caged fish farm industry

ICES Sea Area	Copper t/yr 2007	Copper t/yr 2008	Zinc t/yr 2007	Zinc t/yr 2008
SC2	32.4	39.3	1.9	4.9
SC2a	16.2	32.4	4.0	11.1
SC2b	16.8	21.0	3.8	10.7
Total	**65.3**	**92.8**	**9.6**	**26.7**

Source: SEPA

Inputs of lindane from aqueous discharges to the sea in 2008



Source: SEPA

Trace metals in dredged sediments

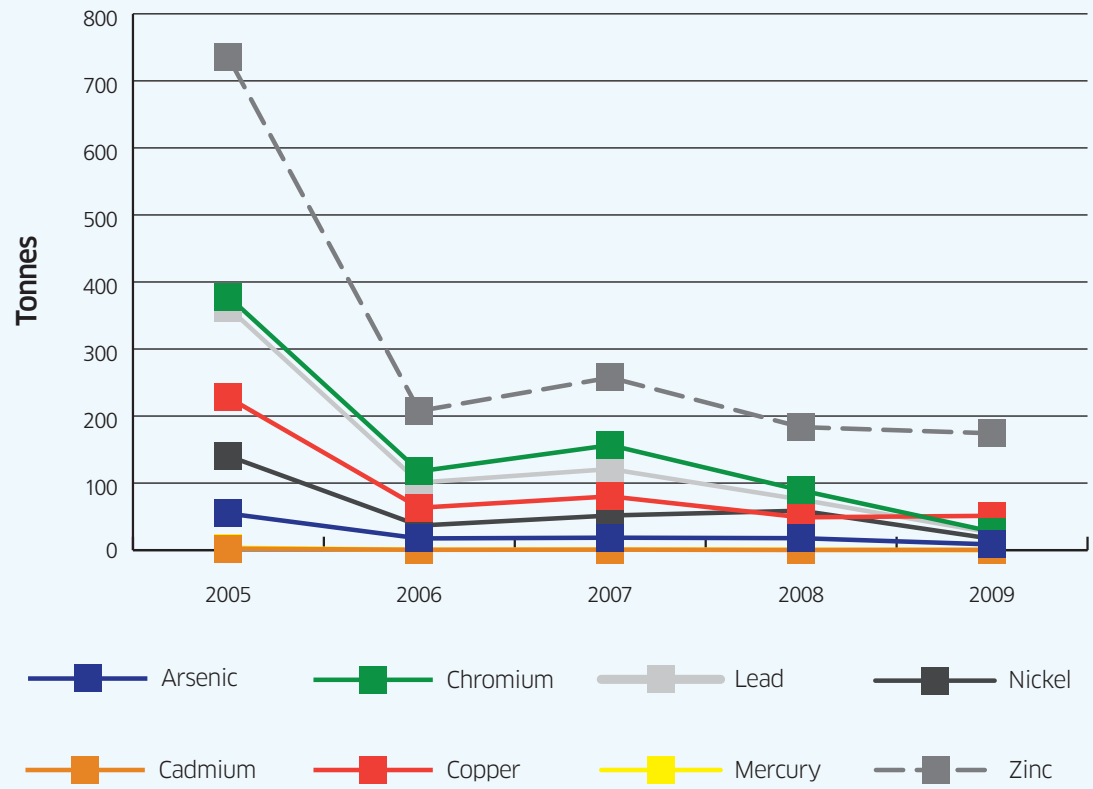
Trace metals in dredge spoil

Trace metal inputs in dredge spoil deposited on the sea bed in Scotland have decreased since 2005 in all areas except the East Scotland coast where inputs of copper and zinc increased in 2009. This increase resulted from the disposal of dredge spoil from Peterhead which contained relatively high concentrations of copper and zinc.

Beaufort's Dyke

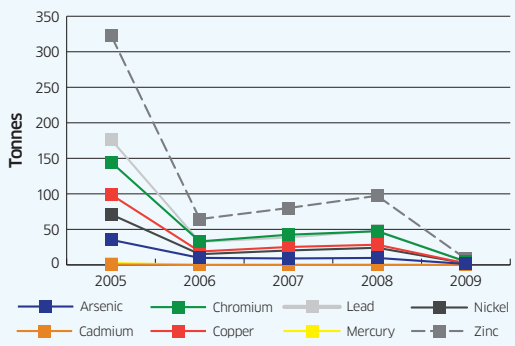
The Beaufort's Dyke, (692 sq.kms), was historically used to dump munitions. Recent underwater TV surveys highlight the abundance and widespread nature of material in the north east corner of the site and also beyond the boundary of the original dumping site. Records show various types of ammunition (shells, ammunition boxes, mines and other debris) within the site and at locations 5.5-9 km away. Some of the munitions contained (and may still contain) phosgene gas that will remain liquid at the pressures and temperatures at this site. The seabed in these locations varies from silty sand to coarser sand, mollusc shells and pebbles and much of the debris is colonised with flora and fauna indicating that it has not been disturbed for some time.

Summary of Tonnages 2005-2009



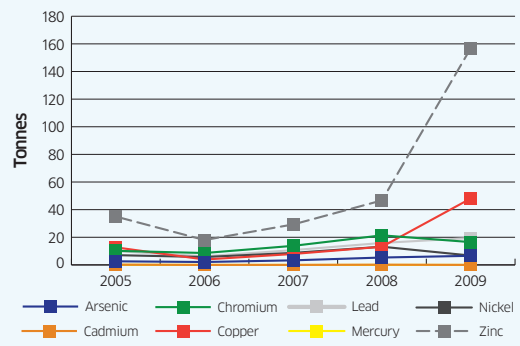
Source: Marine Scotland

Dredged sediment contamination (tonnes) for the Forth (2005-2009)



Source: Marine Scotland

Dredged sediment contamination (tonnes) for the East Scotland Coast (2005-2009)

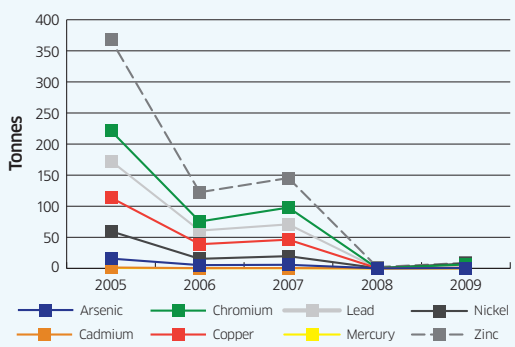


Source: Marine Scotland

Beaufort's Dyke (rippled sand, burrowing anemone)

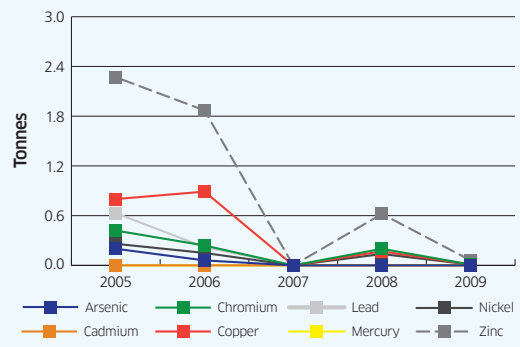
© Marine Scotland

Dredged sediment contamination (tonnes) for the Clyde (2005-2009)



Source: Marine Scotland

Dredged sediment contamination (tonnes) for the Moray Firth (2005-2009)

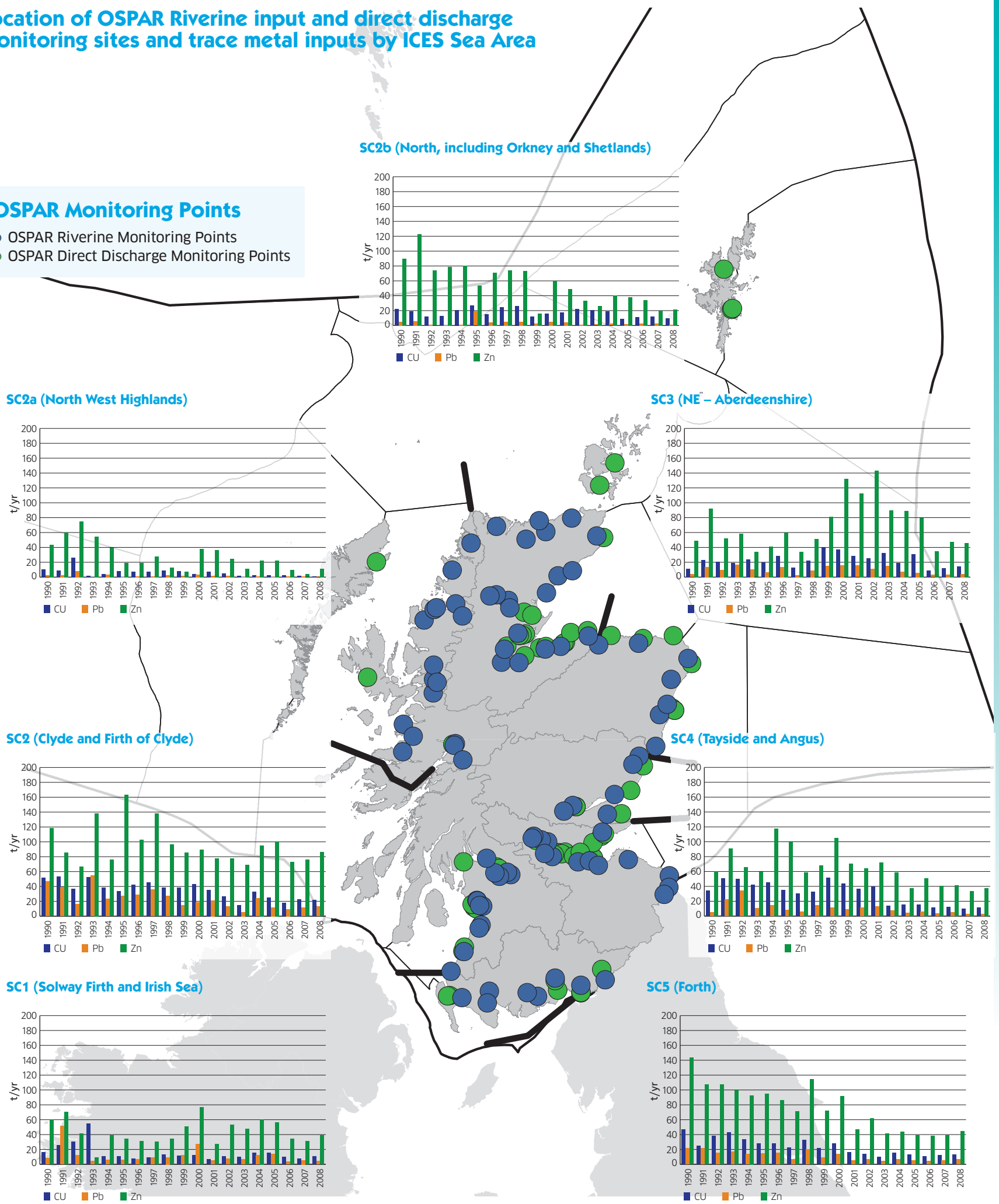


Source: Marine Scotland

Sediment grabbing

© SEPA

Location of OSPAR Riverine input and direct discharge monitoring sites and trace metal inputs by ICES Sea Area



Monitoring contaminants in the marine environment

Contaminants are measured in waters, sediments and biota (mussels and fish) to determine their long term fate. Water soluble contaminants may remain in solution. Less soluble contaminants are more likely to be incorporated onto particulate matter in the water column and deposited on the sea bed. Contaminants may be bio-accumulated, that is, absorbed into animal tissue by ingestion from particulate matter or absorption from solution.

Hazardous substances in water

Hazardous substance concentrations in seawater are compared to internationally and nationally agreed Environmental Quality Standards (EQS). Environmental Quality Standards are set at a safe level below the concentration at which toxicity to sensitive organisms was observed, in laboratory tests.

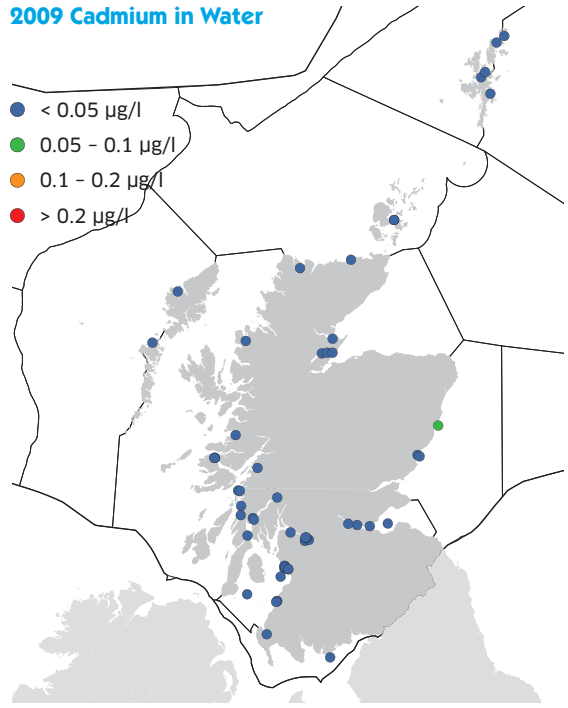
Environmental Quality Standards for dissolved trace metals and lindane in marine waters (µg/l, annual average)

	Environmental Quality Standard µg/l
Cadmium	0.2
Copper	5.0
Lead	7.2
Zinc	40
Mercury	0.05
Lindane	0.02

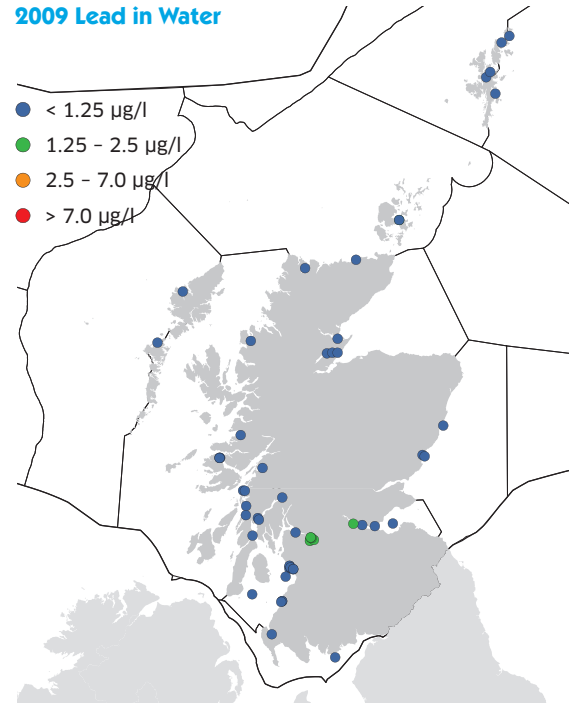
Source: Water Research Centre, UK

Contaminant concentrations in Scottish estuaries and coastal waters are low compared to Environmental Quality Standards. Mercury concentrations are below the limit of detection (10 ng/L), and lindane concentrations are close to the limit of detection. Slightly elevated concentrations of cadmium, copper and zinc occur at sites close to localised inputs, with the highest concentrations in the Clyde and Forth estuaries where the main inputs are located.

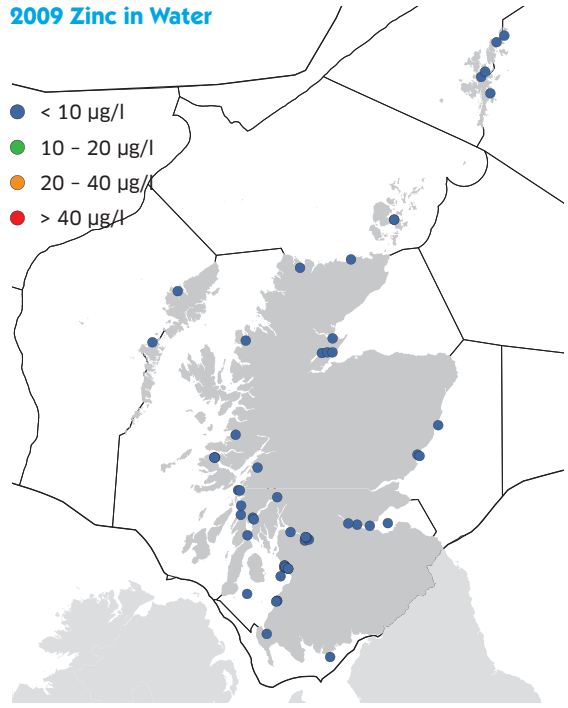
2009 Cadmium in Water



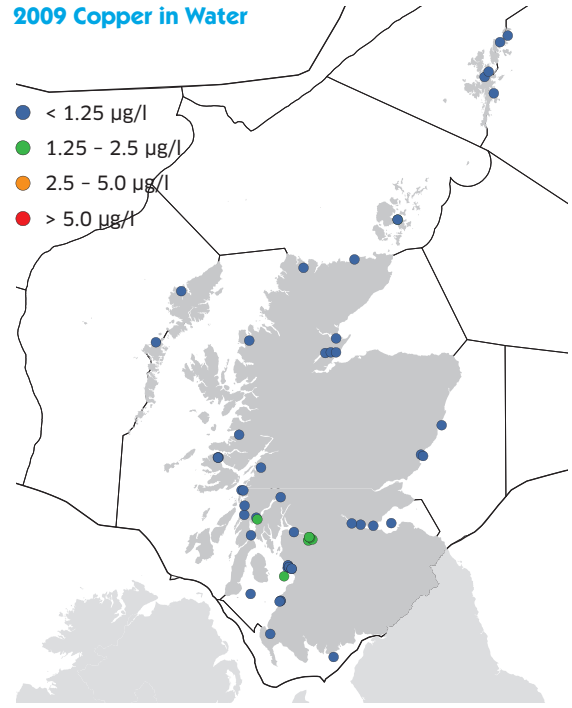
2009 Lead in Water



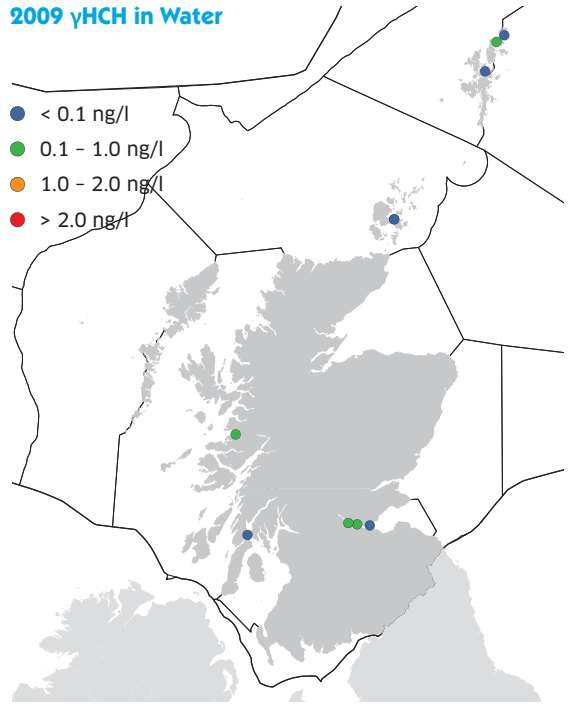
2009 Zinc in Water



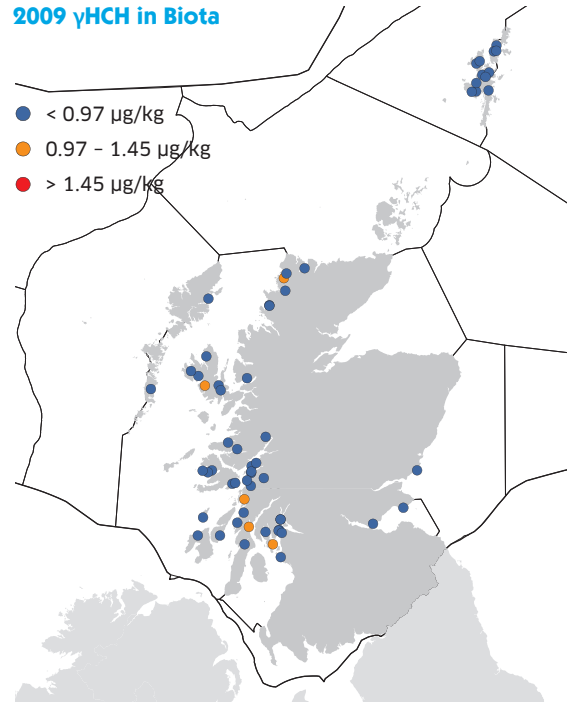
2009 Copper in Water



2009 γHCH in Water



2009 γHCH in Biota



Hazardous substances in sediments and biota

Contaminants in sediments and biota are compared with international standards developed by OSPAR[(1)]. Contaminant concentrations are considered to be low if they are below the Background Assessment Concentration (BAC)[1] and slightly elevated if they are greater than the BAC but less than the Environmental Assessment Criteria (EAC). Contaminant concentrations are considered to be of concern if they exceed the EAC, that is, they may cause adverse biological effects in marine species. Concentrations of trace metals and PAH are considered to be of concern towards other marine species if they exceed the Effects Range Low (ERL)[2] in sediments. Trace metals are of concern towards humans if they exceed the EC maximum acceptable dietary level in biota.

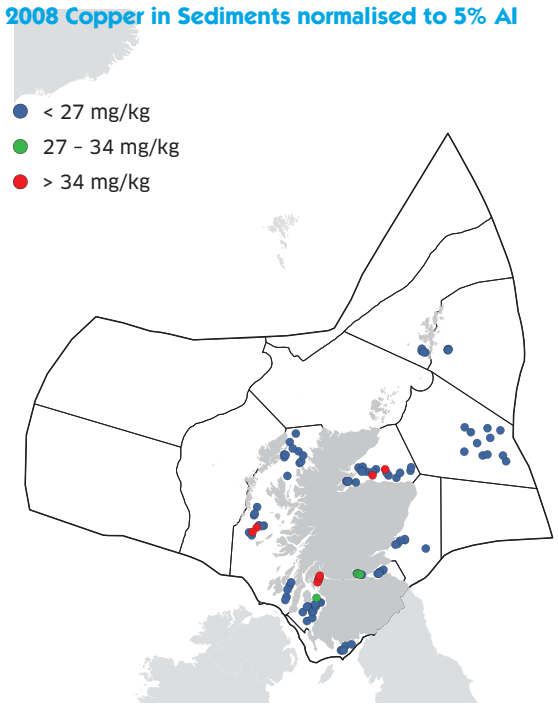
Trace metal concentrations in sediments are expressed as concentrations relative to aluminium and trace organic contaminant concentrations are expressed in concentrations relative to organic carbon to compensate for different sediment types. Trace organic contaminant concentrations in fish livers are expressed in concentrations relative to lipid to allow for differences in fat content.

There are no standards for copper and zinc in biota or for brominated flame retardants (polybrominated diphenyl ethers, PBDEs) in sediments and biota. Therefore the environmental significance of the concentrations found can not be assessed, but spatial comparisons can be made.

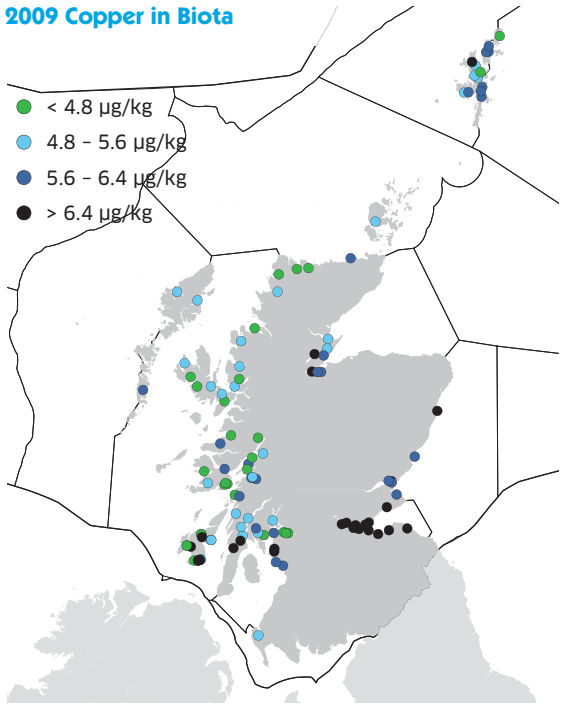
1 BACs were derived from observed background concentrations for naturally occurring substances, and are based on low concentrations which are measurable and close to zero for man-made substances.

2 The Effects Range Low is the 10 percentile concentration of each contaminant above which toxic effects were observed.

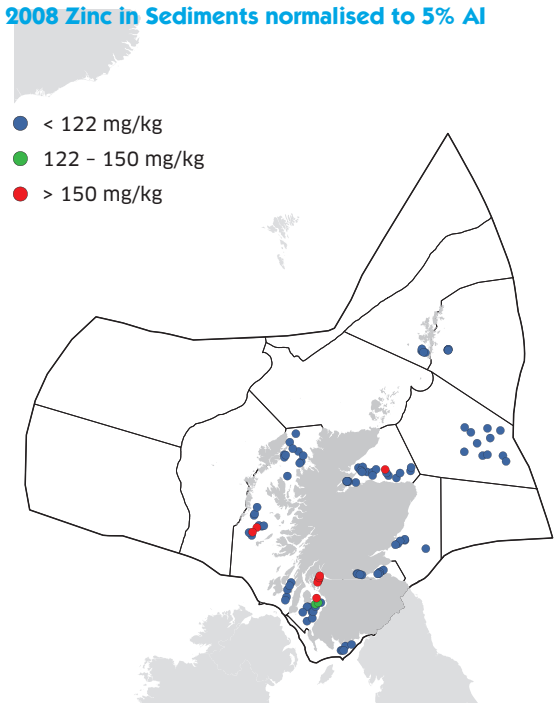
2008 Copper in Sediments normalised to 5% Al



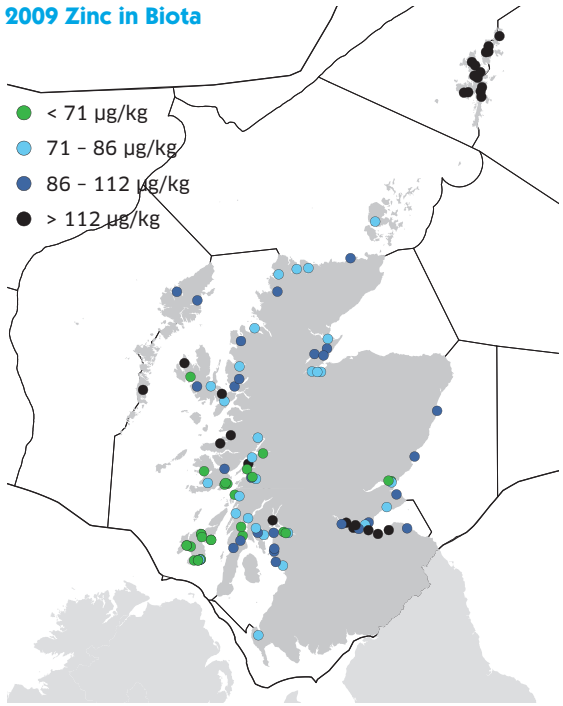
2009 Copper in Biota



2008 Zinc in Sediments normalised to 5% Al



2009 Zinc in Biota



OSPAR assessment criteria for contaminants in sediment, mussels and fish liver

Group	Substance	Sediment			Mussels			Fish		
		µg/kg dry weight normalised to 2.5% TOC			µg/kg dry weight			ug/kg lipid weight		
		<BAC	BAC – EAC	> EAC	<BAC	BAC – EAC[a]	>EAC[a]	<BAC[b]	BAC[b] – EAC[a]	>EAC[a]
PCB	CB153	<0.19	0.19 – 40	>40	<0.6	0.6 – 80	80	<0.1	0.1 – 1,600	>1,600
	CB118	<0.17	0.17 – 0.6	>0.6	<0.6	0.6 – 1.2	1.2	<0.1	0.1 – 24	>24
	CB52	<0.12	0.12 – 2.7	>2.7	< 0.75	0.75 – 5.4	5.4	< 0.08	0.08 – 108	>108

Group	Substance	Sediment			Mussels		
		µg/kg dry weight normalised to 2.5% TOC			µg/kg dry weight		
		< BAC	BAC – ERL	> ERL	<BAC	BAC – EAC	>EAC
PAH	Pyrene	<24	24 – 665	>665	<9	9 – 100	100

Group	Substance	Sediment			Mussels			Fish		
		µg/kg dry weight normalised to 5% Al			µg/kg dry weight			µg/kg wet weight		
		< BAC	BAC – ERL	> ERL	<BAC	BAC – EC	>EC	<BAC	BAC – EC	>EC
Trace Metals	Cadmium	<310	310 – 1,200	>1,200	<1,940	1,940 – 5,000	5,000	<26	26 – 1,000	>1,000
	Mercury	<70	70 – 150	>150	<140	140 – 2,500	2,500	<35	35 – 500	>500
	Lead	<38,000	38,000 – 47,000	>47,000	<1,520	1,520 -7,500	7,500	<26	26 – 1,500	>1,500
	Copper	<27,000	27,000 – 34,000	>34,000						
	Zinc	<122,000	122,000 – 150,000	>150,000						
Pesticide	γ-HCH	<0.13	0.13 – 3.0	>3.0	<0.97	0.97 – 1.45	1.45			

Note: Cadmium and lead are measured in fish liver whereas mercury is measured in fish flesh.
[a] $EAC^{passive}$, calculated from the EAC for sediment.
[b] BAC for fish liver is on a wet weight basis.

Trace metals in biota and sediments

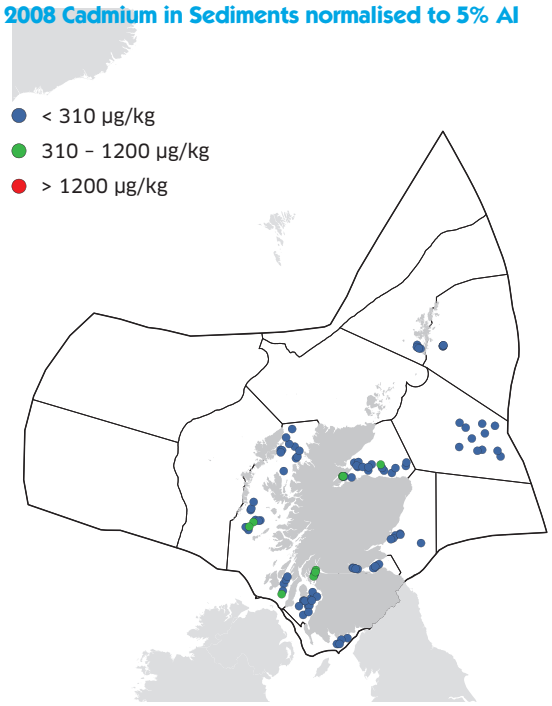
Trace metals are measured in blue mussels (*Mytilus edulis*) and fish, and these data need to be assessed separately. This is because mussels are short-lived, sessile and shore-based, with relatively low fat content, whereas fish are longer-living, mobile and where livers are analysed, have higher fat content. Fish such as dab, plaice and flounder are collected in coastal waters while in deep waters offshore, other species are collected. These differences result in different metal concentrations, and for this reason, different background assessment concentrations are used. Hence while cadmium concentrations are close to background in mussels they are elevated in fish livers at all sites. Lead is close to background in mussels in less populated areas but slightly elevated in the more industrialised areas and in the majority of fish samples. Mercury is close to background in mussels at most sites on Shetland and most sites on the west coast but is elevated on the east coast and several sites on the west coast. Mercury is slightly elevated in all fish except the sample caught in the Moray Firth.

The geographical distribution of copper in mussels is similar to that for lead, although concentrations of copper are much lower. The relatively high concentrations of copper in mussels on Islay may be related to inputs from several distilleries in this area. There are relatively high concentrations of zinc in mussels on Shetland and in the Forth Estuary plus a few isolated sites on the west coast. Discharges of zinc are low in these areas, and the elevated zinc concentrations may be linked to local mineralisation.

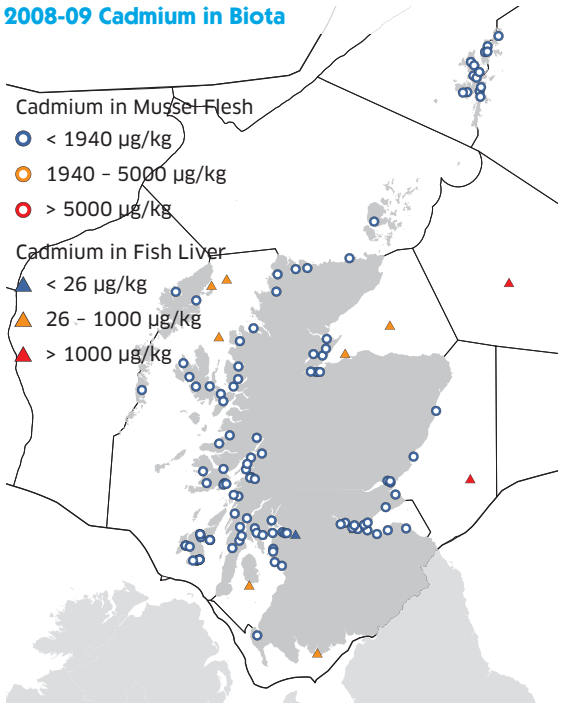
Trace metal concentrations in sediments are highest in the Inner Firth of Clyde where all samples exceed the Effects Range – Low for all metals, except cadmium. Cadmium concentrations are low in sediments compared to other metals and close to background at most sites. Forth estuary and Firth of Forth sediments all exceed the Effects Range – Low for mercury and exceed the Background Assessment Criteria or Effects Range – Low for lead. The trace metal concentration of coastal sediments is low. However, some sites exceeded the assessment criteria when normalised to aluminium, as their aluminium content was low.

The data highlight an interesting contrast in copper and zinc concentrations in mussels and sediments between the Forth and Clyde Estuaries. Concentrations of these metals are higher in sediments in the Clyde than in the Forth, but higher in mussels in the Forth compared to the Clyde. This may be because the Forth is a more turbid estuary due to the stronger tides which mix the sediments into the water column. This will result in particulate bound metals being more available to filter feeders such as mussels.

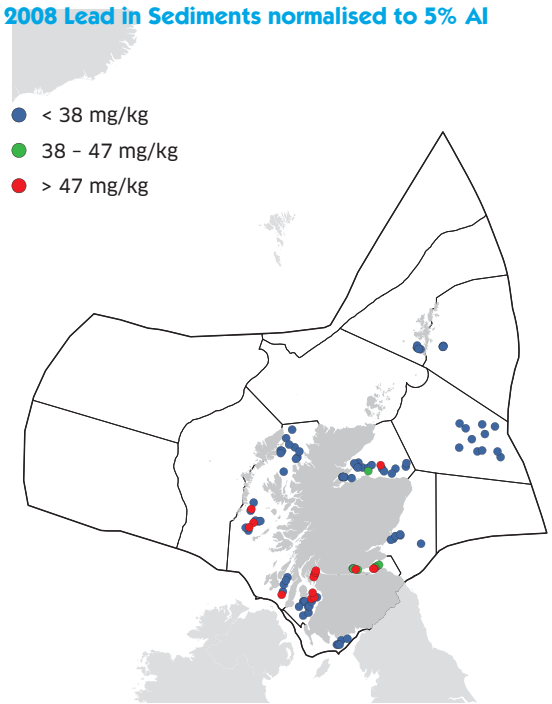
2008 Cadmium in Sediments normalised to 5% Al



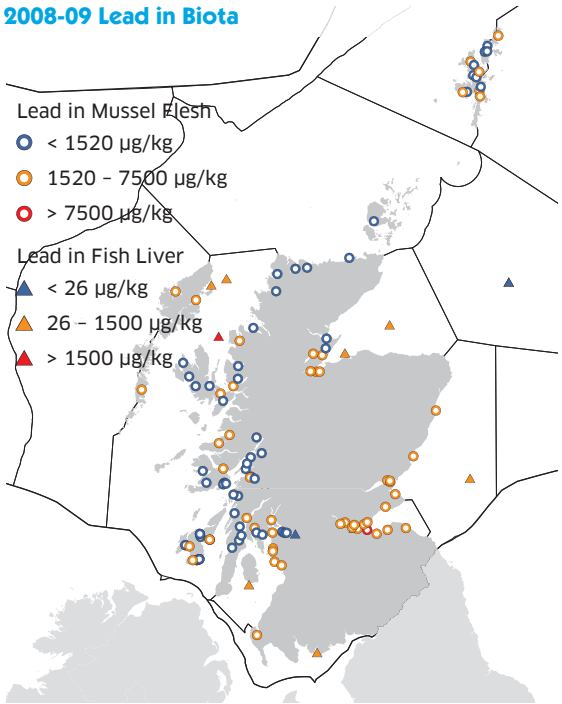
2008-09 Cadmium in Biota



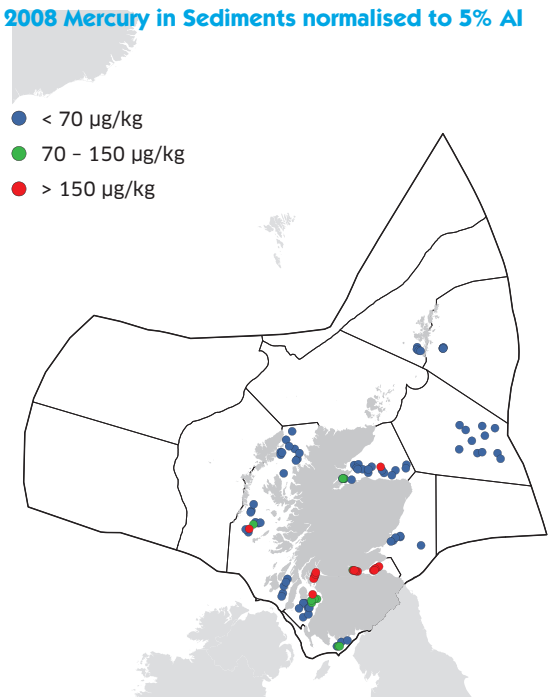
2008 Lead in Sediments normalised to 5% Al



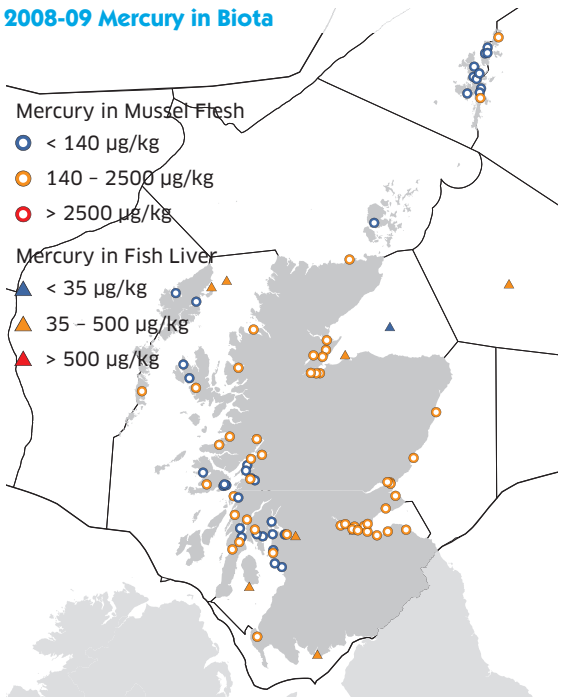
2008-09 Lead in Biota



2008 Mercury in Sediments normalised to 5% Al



2008-09 Mercury in Biota



Trace organic compounds in biota and sediments

Lindane (γ-HCH) concentrations in mussels are low and close to background at the majority of sites. Concentrations are slightly elevated at a few sites in remote areas which may be related to localised inputs.

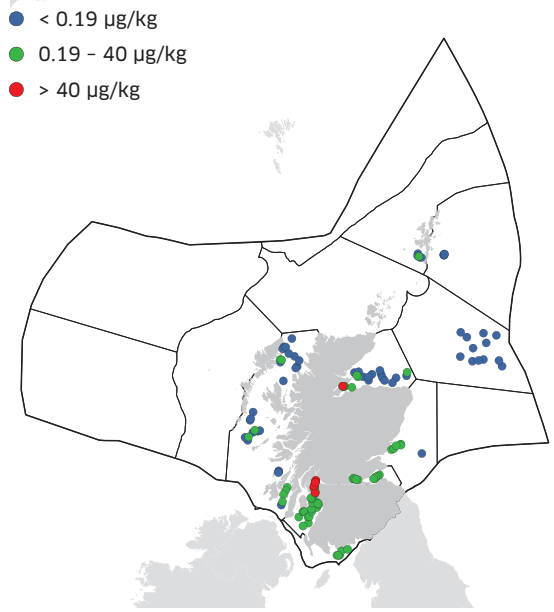
Polychlorinated biphenyls (PCBs) include a range of compounds of varying toxicity. CB153 (the identifying number relates to the number and distribution of chlorine atoms) is the most abundant but one of the less toxic compounds whereas CB52 and 118 are less abundant but more toxic. The least toxic PCB (CB153) is above the BAC at all biota and most sediment sites but below the EAC at all sites. The most toxic PCB (CB118) is present above the EAC in all mussels and is above the EAC in sediments in the Inner Firth of Clyde and some sites in the Forth, Minch Malin and the Moray Firth. CB52 is above the EAC in mussels and one sediment sample in the Firth of Clyde. The overall picture is that PCBs are widespread in sediments and biota but that concentrations are only of concern, that is, adverse biological effects may be observed in marine species, in the Firth of Clyde.

Polycyclic aromatic hydrocarbons (PAHs) also include a range of compounds of varying toxicity. They are described here using pyrene which is easily measurable and has agreed assessment criteria. Pyrene is close to background concentrations in coastal and offshore sediments and in mussels collected in the North West. It is slightly elevated in inshore sediments and mussels located near more populated and industrialised areas. Pyrene exceeds the EAC and is therefore of concern in mussels in the Forth and Clyde estuaries and exceeds the ERL in Firth of Clyde sediments, indicating that adverse biological effects in marine species may be observed in these areas.

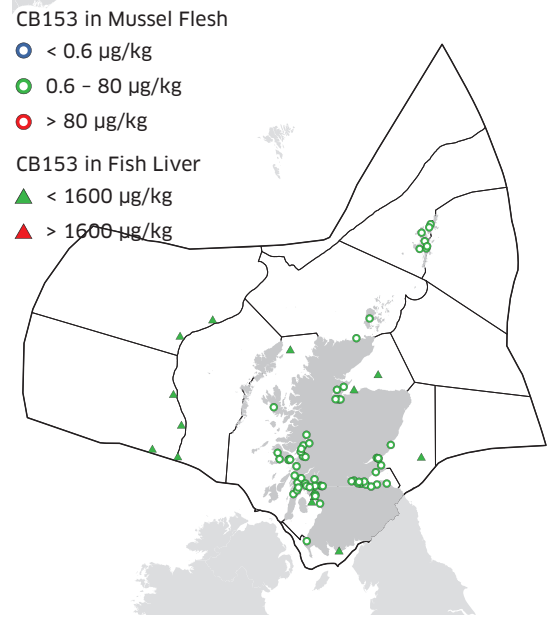
Polybrominated diphenyl ethers (PBDEs) are synthetic compounds used as brominated flame retardants in electronic equipment, textiles and furniture, and these are discharged to marine waters via industrial effluents and waste water treatment works. PBDEs consist of technical mixtures of approximately 20 compounds, of which the most frequently detected in sediment and fish liver is BDE47. PBDEs were not detected in any of the sediments from East Shetland, West Shetland and East Scotland. PBDEs were detected most frequently in sediment and fish from the Clyde region, although even here they were not found in all samples. PBDEs were also detected in three species of deep water fish indicating that they are widespread in the environment. Concentrations in deep water fish were low and comparable to those found in shallow water species from the Minches and Malin Sea region.

Dioxins are a particularly toxic group of organic compounds which are formed as by-products in industrial processes (e.g. during the manufacture of industrial chemicals such as pentachlorophenol and chlorobenzenes, and in paper production). They are also produced during incineration processes, both industrial, including power generation and cement manufacture, and natural (e.g. forest fires). A recent survey indicated that dioxins were present either below the limit of detection or at low concentrations in biota and sediments in the Forth and Clyde Estuaries and in the Firth of Forth.

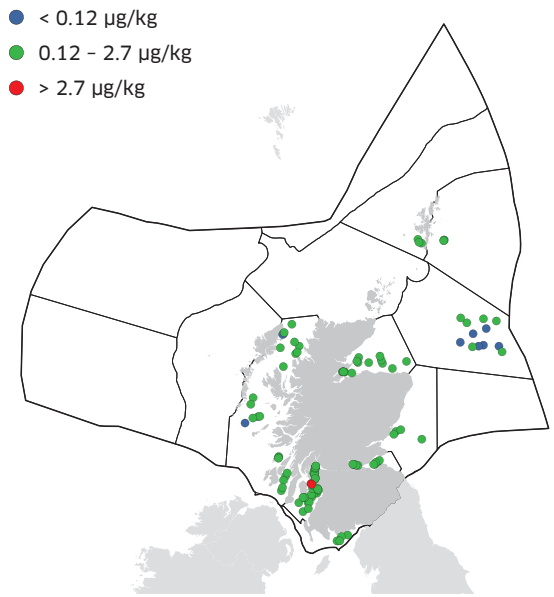
CB153 in Sediments normalised to 2.5% TOC



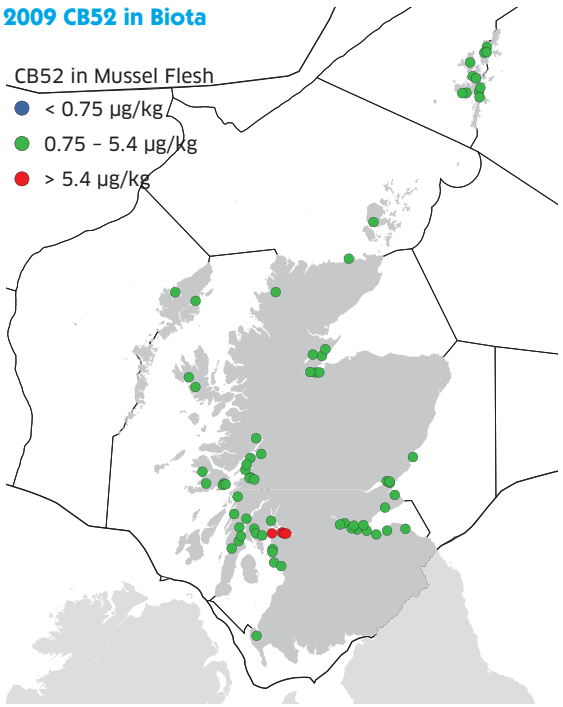
CB153 in Biota



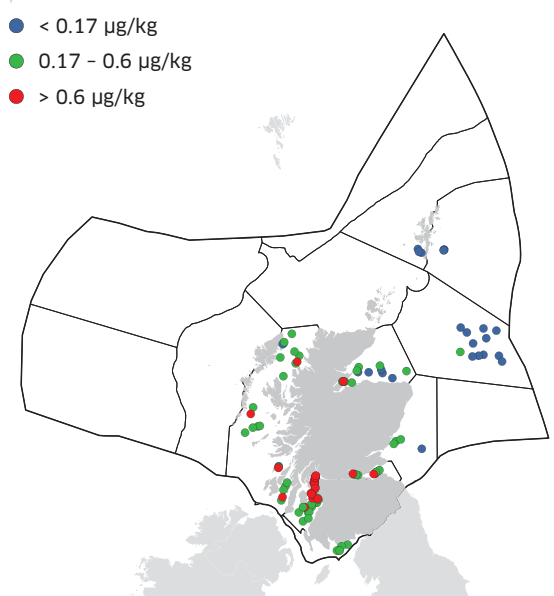
2008 CB52 in Sediments normalised to 2.5% TOC



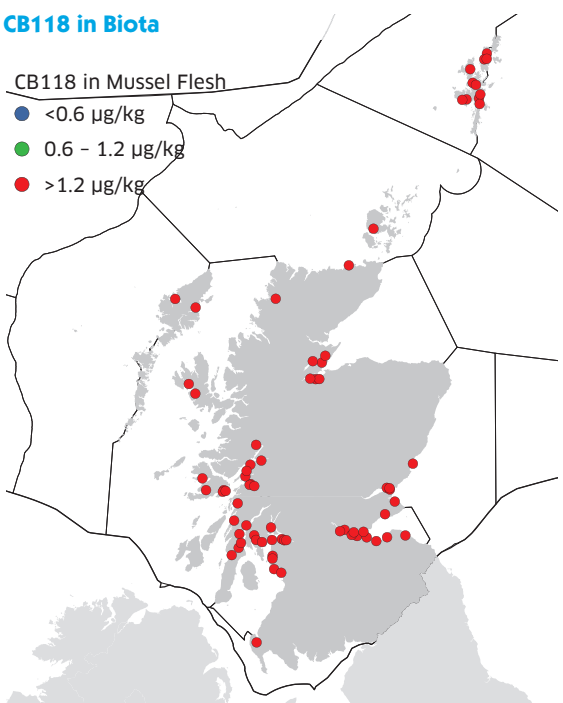
2009 CB52 in Biota



CB118 in Sediments normalised to 2.5% TOC



CB118 in Biota



Impact of hazardous substances in sediments

The biological effect of hazardous substances in sediments is determined by bioassays using the crustacean *Corophium volutator* and the polychaete worm *Arenicola marina*. Both animals live in the sediment, and while *A. marina* ingests sediment, *C. volutator* grazes on sediment particles. In both bioassays, the animals are exposed under controlled conditions to sediment samples, and mortality is measured after 10 days. Toxicity is determined by the number of test organisms which survive in the test sediments compared to uncontaminated control sediment samples.

Mortality of the test organisms was significantly greater than the control sample at two adjacent sites in the inner Firth of Clyde, between Wemyss Bay and Toward Point. The sediments from the Inner Firth of Clyde contained the highest levels of contaminants and the bioassay results indicate that adverse effects of contaminants are possible at these sites, in line with the comments above on contaminant concentrations. However analysis of the benthic community in the sediments does not show any adverse impacts. This illustrates the difficulties in drawing conclusions from laboratory tests and relating these to the marine environment, where the complexity of marine benthic communities is such that these may adapt and develop tolerances to their local conditions. The benthic community is at high or good status at the majority of sites with some at moderate status in the Forth, outer Clyde and Minches and one at poor status in the Forth estuary. It is thought that seabed damage due to fishing and the stresses of natural changes in coastal and estuarine environments, for example salinity, are the causes of downgrading at these sites rather than contaminants.

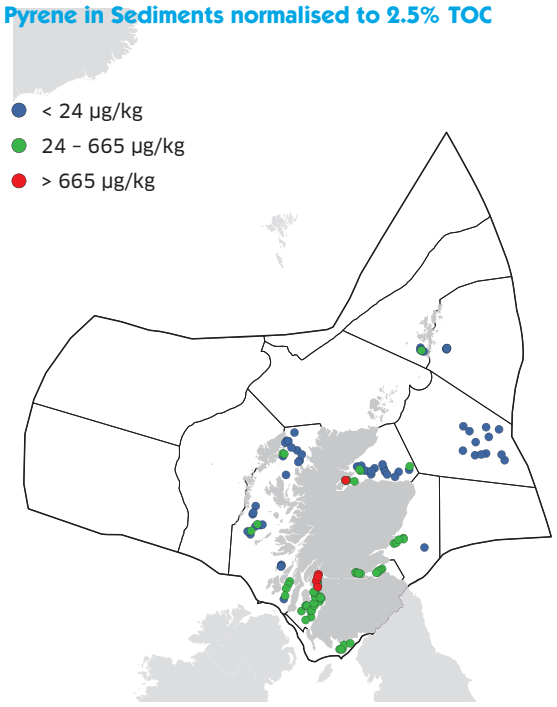
Impact of hazardous substances on fish and shellfish

A range of techniques are used to determine the sub lethal effects of hazardous substances in biota. Contaminant specific techniques include the determination of cytochrome P450 enzymes (specifically EROD [7-Ethoxyresorufin-O-deethylase] in fish exposed to hydrocarbons and imposex in dog whelks exposed to tri-butyl tin. Recent research is investigating the use of genomics to determine the sub lethal impacts of contaminants on mussels. These biological effects techniques are described in more detail overleaf.

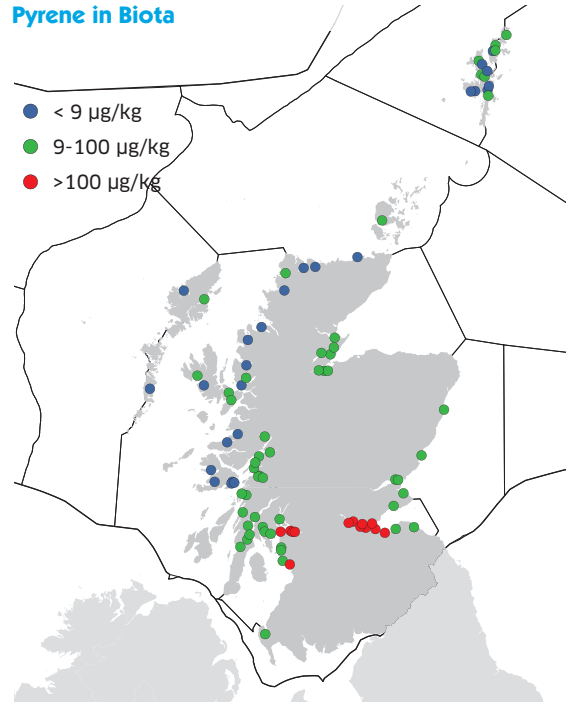
Trends in hazardous substances

Hazardous substance concentrations in water have decreased over time and are now low, reflecting reductions in inputs, which are well controlled. Hazardous substance concentrations in sediments reflect integration over many years, including historical contamination, and remain high in some industrialised estuaries and harbours. Hazardous substance concentrations in mussels are decreasing in response to changes in inputs, but remain elevated for some substances due to their accumulation from contaminated sediments.

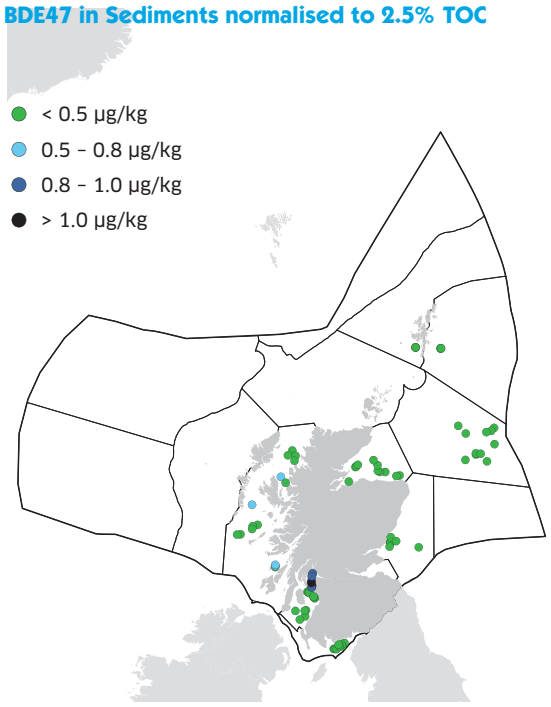
Pyrene in Sediments normalised to 2.5% TOC



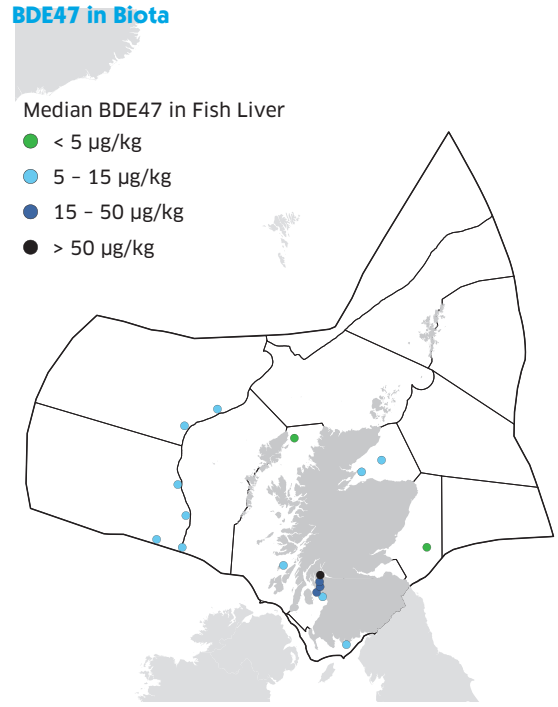
Pyrene in Biota



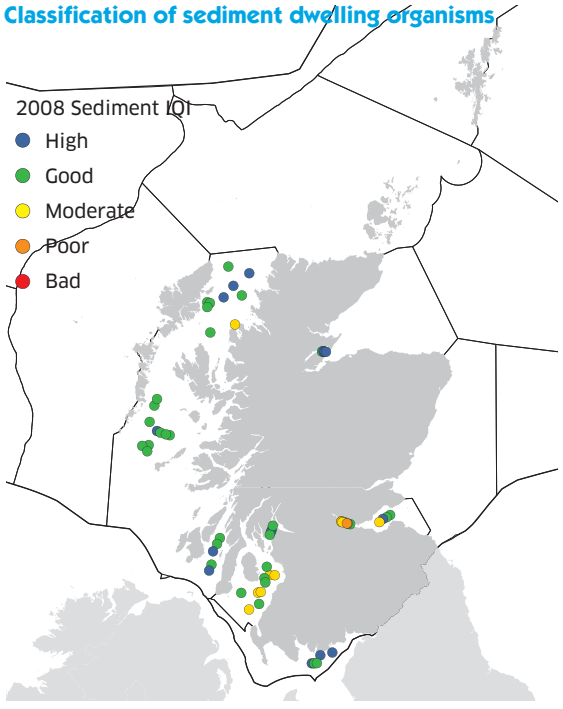
BDE47 in Sediments normalised to 2.5% TOC



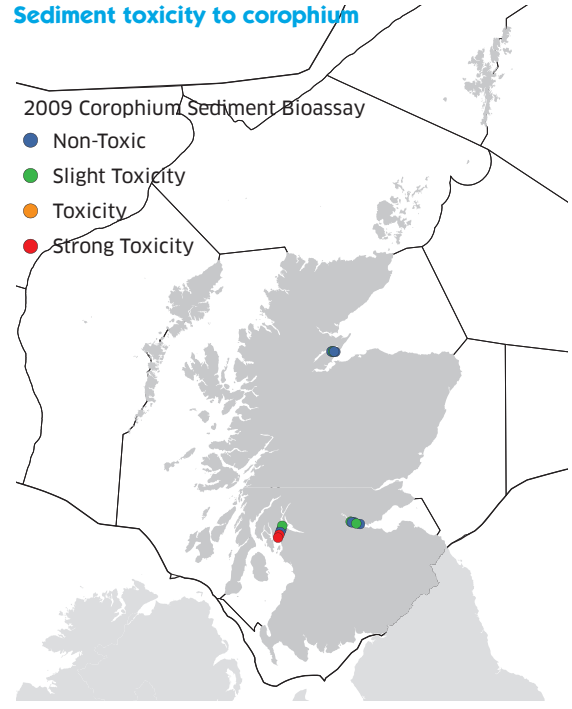
BDE47 in Biota



Classification of sediment dwelling organisms



Sediment toxicity to corophium



BIOLOGICAL EFFECT OF CONTAMINANTS – IMPOSEX

What is imposex?

Imposex is the development of male sexual characteristics (the formation of a vas deferens and growth of a penis) in female dog whelks. The common dog whelk, *Nucella lapillus*, is a marine snail. It is abundant on many rocky shores, where it feeds on barnacles.

Cause of imposex

Imposex is caused by exposure to Tri-Butyl Tin (TBT). TBT entered the marine environment through its use as the active biocide in anti-fouling paints applied to boats' and ships' hulls from the 1970s. The TBT was released by leaching from the ships' hulls and in ports and harbours when old coatings were replaced with fresh paint.

How we measure imposex

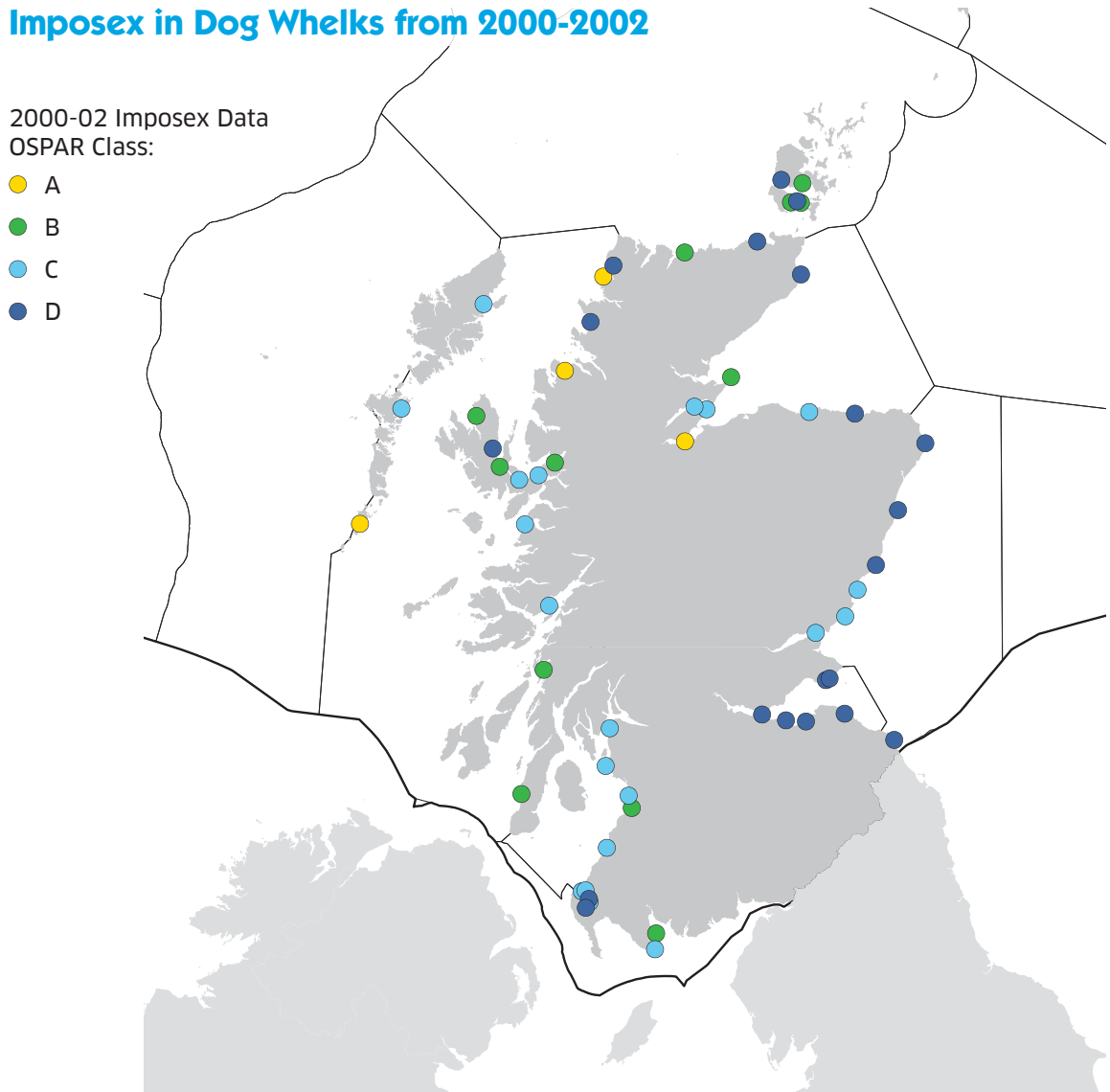
The effect of TBT on the dog whelk population is assessed using the Vas Deferens Stage Index (VDSI). This index is based upon the development of a vas deferens in females and relates directly to the reproductive capability of the dog whelk population. Low levels of imposex appear to cause no significant harm, but at higher levels females may become sterile. This in turn, could result in the loss of populations and seriously affect the shore communities of which they are part. The VDSI is used to classify dog whelk populations from A to F, where A is close to background, D indicates the presence of some sterile females, and F indicates that the dog whelks have died out.

Trends in imposex

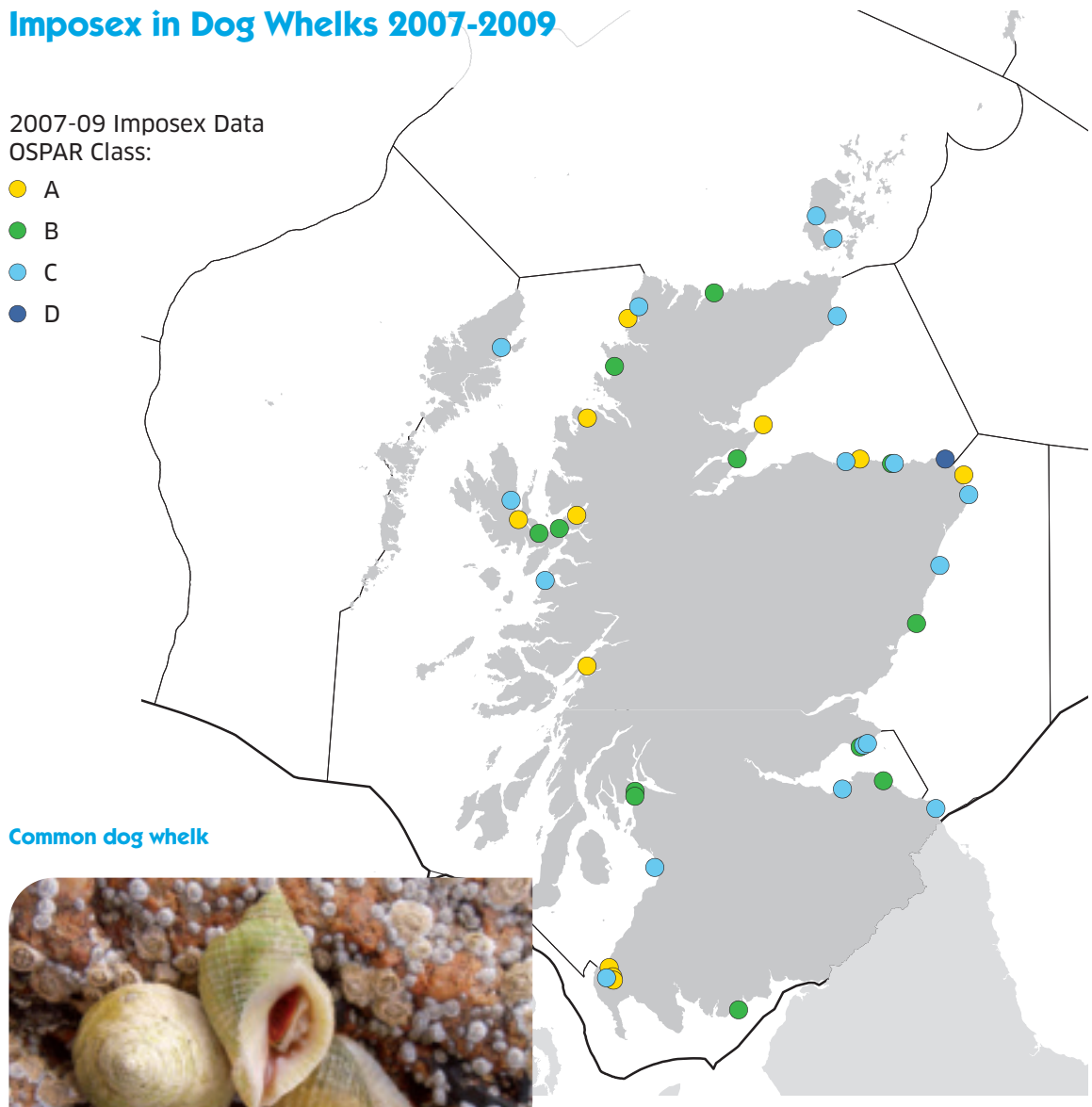
TBT was initially banned for use on boats less than 25m in length in 1988, on all international shipping in 2003, and completely on all boats and ships in 2008.

Since the late 1980s, populations of dog whelks have been sampled, on an 'ad hoc' basis, at over 100 sites around the Scottish coast. In 2002 several sites were Class D but no sites were Class E or F. By 2008 the number of Class D sites had decreased and the number of Class A sites had increased. The overall picture is one of a decrease in the levels of imposex, showing that the ban on TBT has been effective. By the late 2000s, the levels of imposex at many sites had decreased to background so the monitoring programme was reduced. A few local 'hotspots' near point sources of TBT, which yielded high VDSI scores in the late 1980s and 1990s are still evident, but even in these hotspots the severity of imposex has decreased.

Imposex in Dog Whelks from 2000-2002



Imposex in Dog Whelks 2007-2009



Common dog whelk

© SEPA

BIOLOGICAL EFFECT OF CONTAMINANTS – EROD

What is EROD?

EROD [7-Ethoxyresorufin-O-deethylase] is an enzyme found in fish liver which is important in the metabolism of contaminants such as certain polycyclic aromatic hydrocarbons (PAHs) and other structurally similar compounds.

Why do we measure EROD?

The expression and activity of EROD increases in fish exposed to these contaminants through the food they eat, contact with contaminated sediments or via the water column. Although the health effects of high levels of EROD are unknown, the mechanism of enzyme induction produces highly reactive intermediates of certain contaminants which may cause the onset of carcinogenesis, cell death and embryonic mortality.

EROD measurements

EROD in plaice and flounder has been measured annually since 2001 at potentially contaminated and uncontaminated (background) sites throughout Scotland.

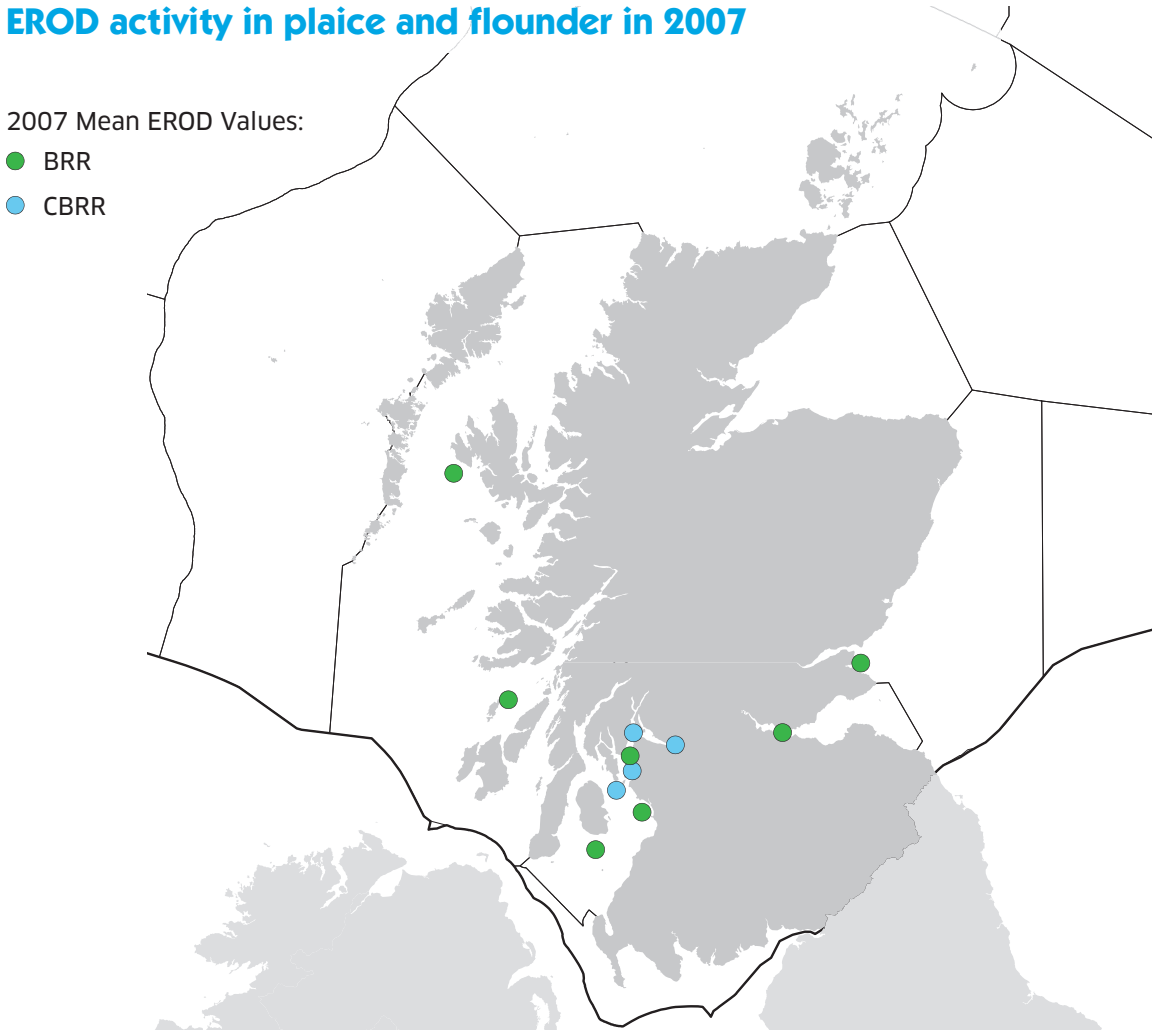
As the health effects of EROD are unknown, the results were assessed from the range of data obtained from 466 observations in plaice (excepting values below the limit of detection and including data from reference sites). The lowest 10th percentile value of 5.26 pmol min^{-1} mg^{-1} (protein) was multiplied by 3.3, 10 and 33 to give the background response range (BRR), close to background response range (CBRR), elevated response range (ERR) and high effect response range (HRR) (see table below).

Due to the relatively small dataset available for flounder EROD activity and the fact that flounder and plaice respond similarly, the response ranges developed for plaice were applied for assessment of EROD data for both species.

Flounder

© Paul Kaye

EROD activity in plaice and flounder in 2007



EROD in plaice

EROD activity in plaice was at the background response range at the reference sites, Broad Bay, Colonsay and Pladda, and did not exceed the close to background range at Irvine Bay, Hunterston and Skelmorlie. The response range in plaice at the Garroch Head site was in the elevated response range between 2001 and 2005, but decreased to the close to background response range in 2006 and 2007.

EROD in flounder

EROD activity in flounder was in the effects response range in the Forth estuary in 2001, reducing to close to background then background response range between 2004 and 2007. EROD activity in flounder in the Clyde estuary (Bowling) did not exceed the close to background response range. The response range in flounder at the St Andrews Bay reference site was close to background in 2001 and 2002, and decreased to the background response range during the remainder of the sampling period.

Trends in EROD

The results show that EROD activity in flounder and plaice caught in the Clyde and Forth has decreased and is now in the close to background or background response range at all sites. This is particularly apparent at one of the most affected sites in the Clyde, Garroch Head where sewage sludge disposal ceased in 1998 and the evidence from EROD data suggests that exposure of plaice in this area to planar organic contaminants has been decreasing consistently since 2001.

There is a clear indication that the EROD response measured at Garroch Head and Holy Loch may be related to a decrease in contaminant availability at these sites. It would be of value to relate these responses to sediment contaminant data over the same sampling period. Furthermore the EROD responses reported here could be used in an integrated assessment framework with chemical contaminant concentration in sediment and biota and with other higher biological effect responses.

Response ranges used for classification of EROD activity in plaice and flounder

Criteria	Assessment calculation of upper range value for each criteria	Assessment criteria range; values as pmol/min/mg protein (LV = lowest value)
BRR	10th percentile value x 3.3	LV – 17
CBRR	10th percentile value x 10	18 – 52
ERR	10th percentile value x 33	53 – 174
HRR	> 10th percentile value x 33	> 175

BIOLOGICAL EFFECT OF CONTAMINANTS – ENVIRONMENTAL GENOMICS

What are environmental genomics?

Genomics is the study of gene sequences. Analytical techniques are being developed to assess the stress response of mussels exposed to contaminants in the marine environment from the expression of gene sequences. The results of a study of the stress response of mussels exposed to contaminants and three sites in the Clyde are described here.

Biochemical response of exposure to contaminants

When animals are exposed to harmful chemicals they respond by producing enzymes that can eliminate the chemical threat. The chemicals bind to a cellular protein known as a receptor. The receptor activates gene sequences that promote the synthesis of the protective enzymes to produce a messenger molecule, messenger RNA (mRNA). The messenger RNA is subsequently translated into the protein sequence of the enzyme.

How can we measure this response?

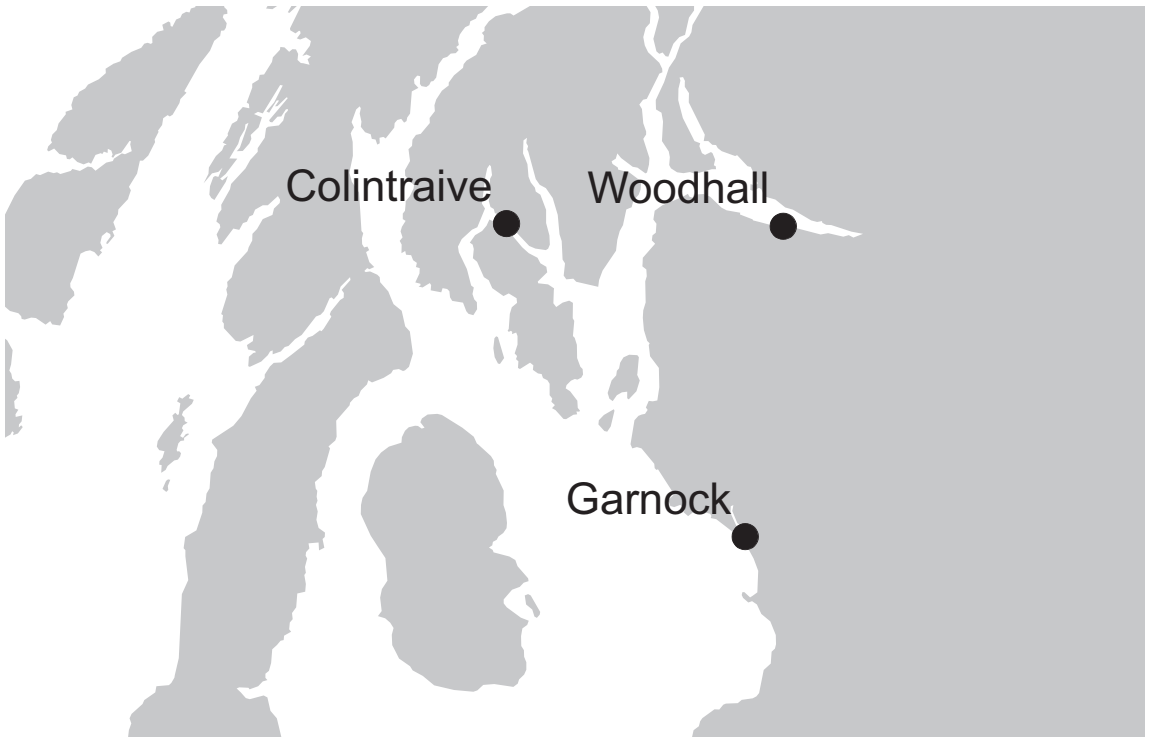
The quantities of mRNAs are very low and chemically they cannot be distinguished one from another. Polymerase Chain Reaction or PCR is used to amplify the signal of specific mRNAs. This method has been described as "molecular photocopying" because it can start with complex mixtures of DNA and quickly produce millions of copies of a single component of that mixture. Monitoring the "molecular photocopying" process in real time allows quantification of the amount of DNA in the starting material. This adaptation is known as Quantitative, Real-time PCR or qPCR for short.

Responses measured

The levels of mRNAs (messenger RNAs) produced by several genes associated with adaptive stress responses to different contaminants were measured. The genes measured included metallothionein, which respond when exposed to metals in the environment, and others such as catalase and glutathione S-transferase, which respond to exposure to trace organics compounds.

Mussels were collected from three sites in the Clyde Sea Area in January 2009, as shown on the map. Tissue from half of the animals was used for chemical determination of metals and organic compounds (polycyclic aromatic hydrocarbons and polychlorinated biphenyls). Tissues from the other half were used to isolate mRNA which was converted by an enzymic method to DNA which in turn was used for qPCR. The levels of 8 different mRNAs or transcripts were measured either in all tissues or in selected tissues.

Location of sampling sites for environmental genomics



Comparison of results

Results are expressed as a ratio relative to the clean reference site at Colintraive. Significant differences were found in transcript levels at the other two sites relative to the Colintraive reference site, particularly at Woodhall where the gene transcripts HSP90 and MT10 in gill and digestive gland were higher.

Comparison of qPCR results of mRNA for each gene relative to Colintraive, showing levels of significance

		Significance of differences in gene transcripts, $p < 0.05$ is significant							
Site	Tissue	MT20II	MT10	Vdg3	HSP90	GST	CAT	P53	Try
Woodhall	Gill	<0.01	<0.001	NS	<0.001	NS	<0.05	NS	ND
	Mantle	NS	ND	<0.05	NS	ND	NS	NS	ND
	DG	NS	<0.05	<0.001	NS	ND	NS	ND	<0.01
Garnock	Gill	NS	NS	NS	NS	NS	NS	NS	ND
	Mantle	NS	ND	<0.05	NS	ND	ND	<0.01	ND
	DG	NS	NS	NS	<0.01	ND	ND	ND	<0.05

Key: DG: digestive gland; NS: not significant; ND: not done

Key to gene transcripts: MT20II, metallothionein-20; MT10, metallothionein-10; Vdg3, Veliger digestive gland 3; HSP90, Heat shock protein 90; GST, glutathione S-transferase; p53 protein 53kDa; Try, serine protease CFSP3. Source: Glasgow Caledonia University

Woodhall

© Thomas Nugent

Colintraive

© Kenneth Hall

What do the results mean?

Each of the genes studied are involved in adaptive stress responses to contaminants, so the implication of transcript values significantly higher than at Colintraive indicate higher levels of biological effects from contaminants than at Colintraive, while significantly lower values indicate less biological effect.

The most obvious finding from this study was that a number of genes in all three tissues were affected at Woodhall, whereas fewer genes and fewer tissues differ at Garnock relative to Colintraive. The higher levels of gene transcripts in metallothioneins at Woodhall suggest effects due to heavy metals, and since both MT10 and MT20 were affected this indicated exposure effects attributable to essential metals and heavy metals. This is consistent with the observation that mussel body burdens of zinc, chromium and lead at Woodhall were more than twice as high as in animals at Colintraive.

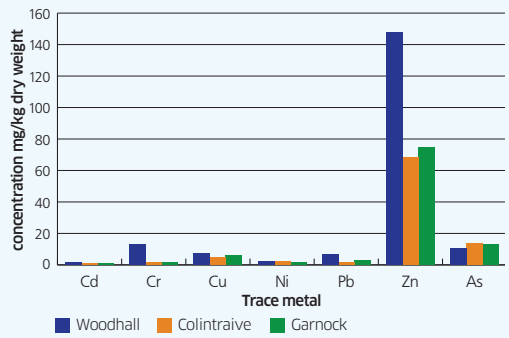
In contrast, the mussels collected from the Garnock Estuary showed no significant differences in MT10 or MT20 in any of the tissues compared to Colintraive, and body burdens of metals were also similar to those at Colintraive.

Elevated levels of catalase at Woodhall and HSP at Woodhall and Garnock may be indicative of oxidative stress resulting from exposure to heavy metals and/or to organic contaminants. Body burdens of several polycyclic aromatic hydrocarbons (chrysene and indeno (1, 2, 3-cd) pyrene) were more than 15 times higher at Woodhall compared to Colintraive. The gene transcript Trp was altered in the digestive gland at both Woodhall and Garnock. Elevated Trp may be associated with the presence of pathogens and mussels exposed to chemicals may be more susceptible to infections.

What do the findings of the study tell us?

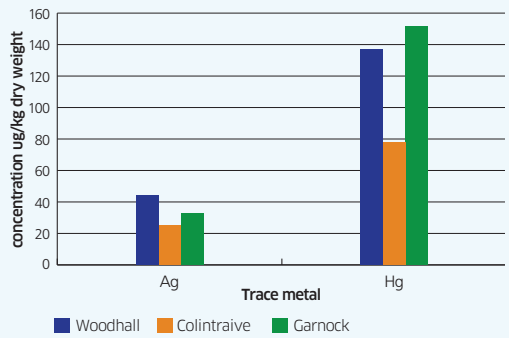
The study showed that the new analytical technique was able to measure changes in stress-response genes that reflected the exposure of mussel populations to contaminants. The chronic effects of contaminants may have implications for the health of mussel populations due to stress on the animals, since physiological energy is required to protect themselves from the environmental pollutants.

The concentration (mg/kg) of cadmium, chromium, copper, nickel, lead, zinc and arsenic in mussels at Woodhall, Colintraive and Garnock



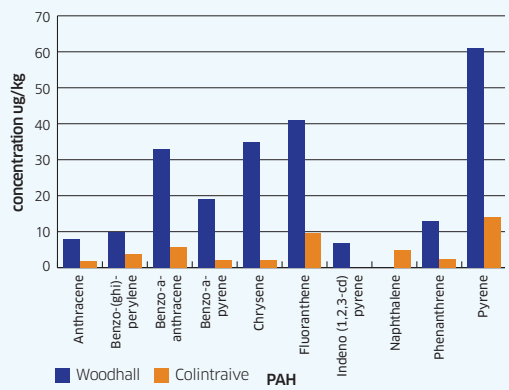
Source: SEPA

The concentration (µg/kg) of silver and mercury in mussels at Woodhall, Colintraive and Garnock



Source: SEPA

The concentration (µg/kg) of polycyclic aromatic hydrocarbon compounds at Woodhall and Colintraive

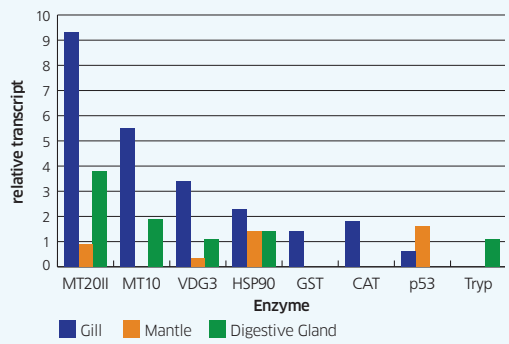


Source: SEPA

Mussels

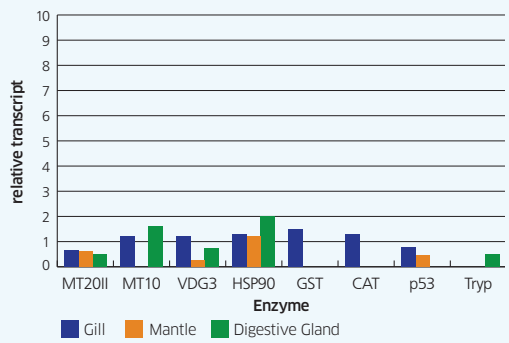
Source: SEPA

Relative levels of transcripts at Woodhall



Source: Glasgow Caledonia University

Relative levels of transcripts at Garnock



Source: Glasgow Caledonia University

OIL AND CHEMICAL SPILLS

Reporting spills

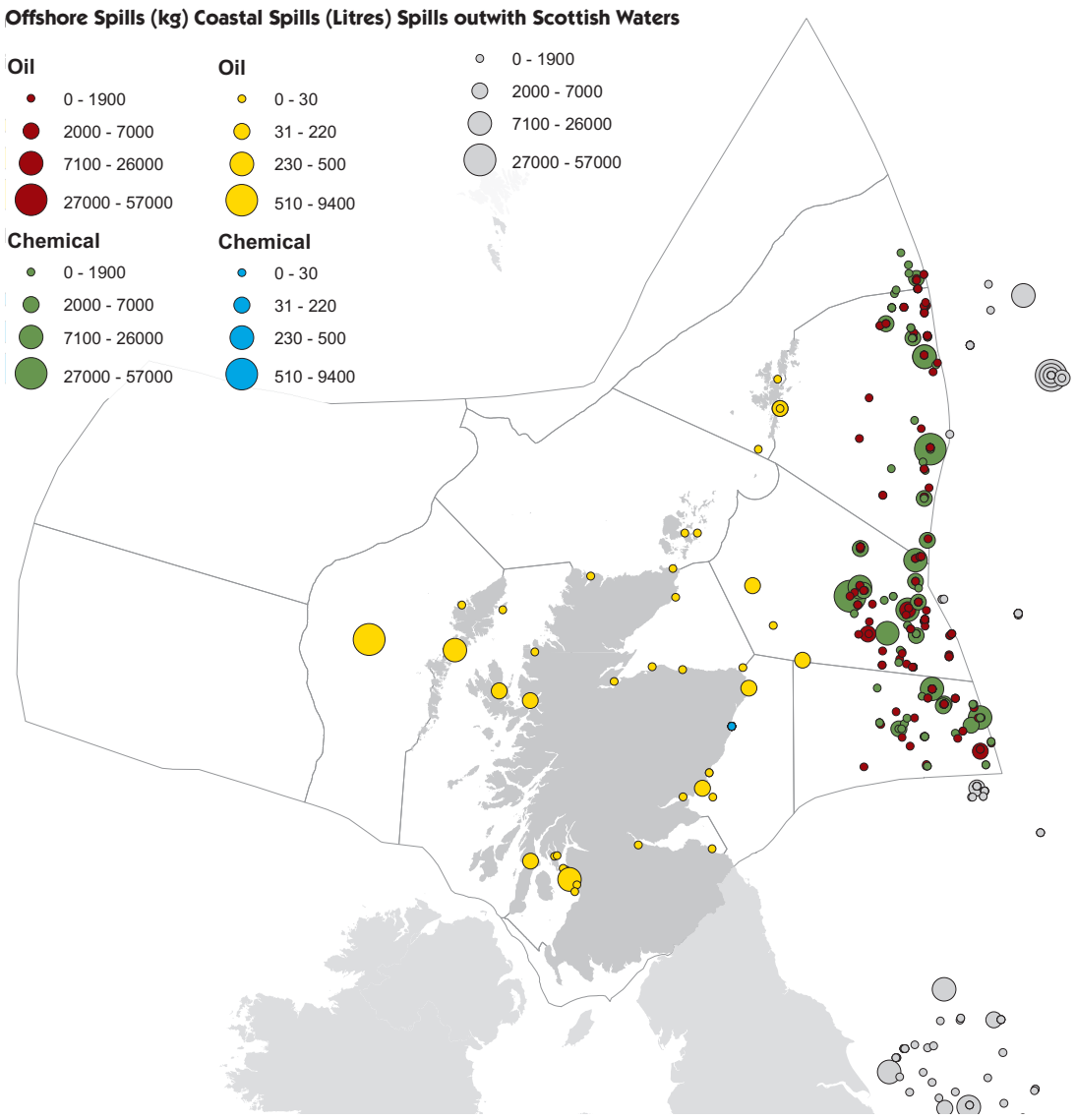
Oil and chemical spills are reported from vessels and offshore oil and gas installations operating in UK waters in the UK Pollution Control Zone (UKPCZ).

It is important to monitor oil and chemical spills as these may result in contamination of the seas and these spills may result in harm to birds or other marine animals.

The Maritime and Coastguard Agency (MCA) exercises the UK Government's statutory responsibilities for taking action when oil or any other hazardous or noxious substance emanating from any at-sea activity threatens the UK or its surrounding waters.

The MCA established the Advisory Committee on Protection of the Sea (ACOPS) in 1965, and each year the MCA publishes via ACOPS the results of an annual survey of reported spills. The survey results complement historical data and records, and enables the MCA's Counter Pollution and Response (CPR) Team to monitor the number of incidents, the amount of oil and chemicals spilt the geographical distribution of spills, the sources of pollution and the nature of the pollution. The ACOPS annual reports[2] include all of this information, and these can be accessed at www.acops.co.uk.[2]

Oil and chemical spills reported in 2008



2008 survey results

The survey results for 2008 are separated into coastal spills, offshore spills, and spills taking place further offshore that is, in UK territorial waters outside Scottish waters or in other international waters. Due to different methods of collecting the data, coastal spills are reported as litres by volume, whereas offshore spills are reported as kg by weight.

Most coastal spills involve oil and take place in ports or harbours around the Scottish coast, whereas most offshore spills involve chemicals and take place at oil and gas installations.

In general, since most oil spills in coastal waters are due to accidents in handling oil or due to vessels running aground, the frequency of the occurrence of these spills correlate to vessel activity and are spread around the coast.

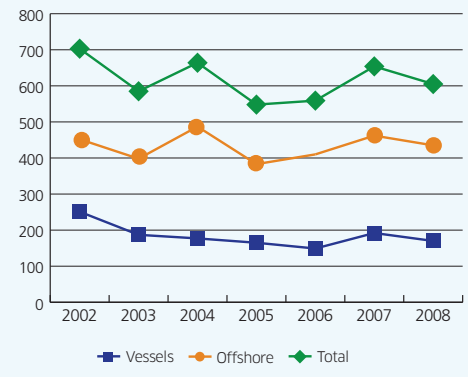
In contrast, most offshore spills occur at oil and gas installations, which are located mainly in the East Shetland, Fladen and Forties sea areas, hence most spillages in offshore waters are reported in these areas, with very few elsewhere.

Trend in spills

Reported spills for UK waters for 2008 included 1,530 incidents and 605 separate discharges from vessels and offshore oil and gas installations, an overall reduction of 8% compared to the total number of incidents reported in 2007.

Trends in numbers of reported spills between 2002 and 2008 are shown in the line graph, using data from ACOPS annual reports. Spills from vessels appear to be decreasing, while those from oil and gas installations show no clear trend. As a result, total spills show no clear pattern.

Numbers of Reported Oil and Chemical Spills/Year



Source: Scottish Transport Statistics[1]

What were the most serious coastal spills, and what action was taken?

There were 50 vessel-related oil pollution incidents in Scottish coastal waters in 2008, compared to 54 in 2007. None of these was serious, with only 3 spillages of more than 220 litres. One of these took place in Ardrossan harbour due to a 500-litre fuel oil spillage, which was boomed off and contained by the Clydeport Counter Pollution Team. At St Kilda a deep sea fishing vessel ran aground, and about 8 tonnes of diesel oil escaped to sea, where it was quickly broken up and dispersed by wave action. A fishing vessel went aground and later sank alongside Leverburgh pier, causing a 300-litre diesel spillage. The Western Isles Council Pollution Team carried out a clean-up operation using an absorbent boom to contain the pollution, but some oil reached the shore.

F.V. Spinningdale aground on St Kilda, 2008

© MAIB

Where were the most serious offshore spills and what action was taken?

The data for the offshore spills is provided by ACOPS on a UK basis, so it is difficult to assess the impacts for Scottish offshore waters. In 2008, there was a total of 272 accidental oil discharges attributed to offshore oil and gas installations, and 163 accidental discharges of chemical substances.

Of the oil discharges, 30% were identified as fuel oils, 29% as crude oils and 26% as lubrication or hydraulic oils, and of the total, 94% were less than 455 litres in volume.

Aberdeenshire and Moray Councils reported intermittent beach pollution following two spillages of crude oil from the Beatrice Alpha installation. A remote-sensing aircraft from the MCA detected crude oil residues on the foreshore but not in the open sea. All accessible shore areas were cleaned up successfully over 20 days with the assistance of staff from the company responsible.

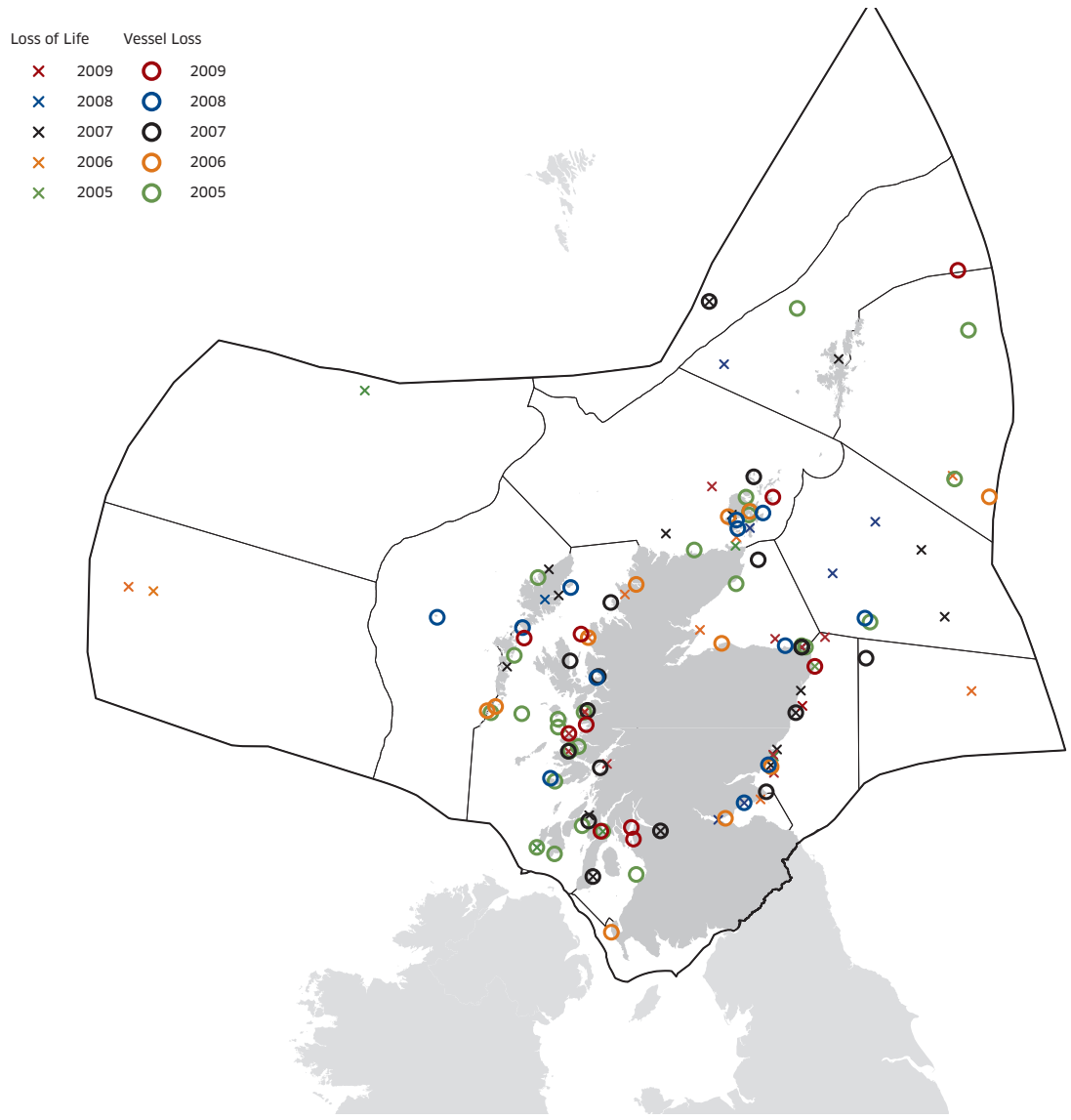
The estimated mass of accidental chemical discharges in Scottish waters ranged from about 1g up to 57,347kg, although few were 1 tonne or more, and many of the larger discharges occurred over extended periods of time.

The largest chemical spill involved the leakage of 57,347kg from August to October at the Petrojarl Banff installation in the Forties sea area, due to a fault in a subsea control system. Following diagnostic testing and subsea remotely-controlled vehicle inspections, repairs were carried out by a diving vessel support vessel, which stopped the leak.

What is the future outlook in this area?

Future trends in the numbers of oil and chemical spills reported are difficult to predict, as these are related to levels of industrial activity and arise mainly from accidents, either as oil spills in fuelling activities or as a result of vessels running aground, or as chemical discharges from oil and gas installations. However, if the level of shipping or oil and gas production or other offshore activities such as offshore wind power generation increases, the potential for the numbers of accidents to increase would also increase. Reductions in the numbers of oil and chemical spills rely on the application of best practice by companies, and by staff taking more care in operational activities.

Marine Accidents 2005-2009, Fatalities and Vessel Loss



Investigation of Accidents

Around Scotland, the Marine Accident Investigation Branch (MAIB), of the Department for Transport, examines and investigates all types of marine accidents to, or on board, UK ships and on other ships within territorial waters. It does so with powers under The Merchant Shipping (Accident Reporting and Investigation) Regulations 2005. The data collated by MAIB gives a full picture of the number of incidents (including vessel losses and fatalities) within territorial waters but limited to UK vessels beyond that.

The MAIB investigates all incidents reported to it, often making recommendations with a view to improving safety at sea. It publishes an Annual Report which may also make further recommendations and lists details of all incidents. There is no trend apparent in the data for the period 2005 to 2009. Some vessel losses can be correlated with data in the oil spills section. For example, the fishing vessel Spinningdale was wrecked on St Kilda in 2008 but was later removed completely.

Fatal injuries and vessel losses in Scottish waters (*) (2005-2009) reported to UK MAIB

Category	Fatalities per Year (**)						Vessel losses (†) per Year (**)					
	2005	2006	2007	2008	2009	Total	2005	2006	2007	2008	2009	Total
Fishing vessel	3	6	5	5	9	**28**	20	7	11	9	8	**55**
Merchant vessel (500grt or more)		3	9		1	**13**			1			**1**
Other		1	5	2	2	**10**	3	1	3	3	2	**12**
Pleasure craft (non-commercial)	5	2	8	3	2	**20**	4	3	2			**9**
Total	**8**	**12**	**27**	**10**	**14**	**71**	**27**	**11**	**17**	**12**	**10**	**77**

Source: MAIB

Note * excludes non-tidal waters, rivers and canals. ** Leisure vessels and Non UK registered vessels have only a limited requirement to report accidents to MAIB. For more information see Regulation 4 of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005. † Includes Constructive Total Losses

Regulation of radioactive substances

The Scottish Environment Protection Agency (SEPA) regulates the disposal of radioactive waste from nuclear licensed sites and permits the keeping and use of radioactive substances, and accumulation and disposal of radioactive waste from non-nuclear industrial sites.

SEPA is required to ensure that the amount of radiation that an individual is exposed to from the authorised disposal of radioactive waste does not exceed 1 millisievert per year (mSv – a measurement of dose). SEPA's environmental monitoring programme allows a retrospective assessment to be undertaken to ensure that the conditions and discharge limits in an operator's licence continue to provide the required protection of the public.

Monitoring the impact of authorised discharges

SEPA undertakes a comprehensive monitoring programme for environmental radioactivity across Scotland to assess the impacts of authorised discharges of radioactive waste. The programme is designed to provide the data required to undertake a retrospective assessment of the dose to the most exposed member(s) of the public. This individual(s) is termed the *representative person* and is defined as somebody who, because of their consumption and activity habits, is likely to be more exposed to radioactivity than other individuals or groups of people.

SEPA arranges for samples and measurements to be taken from around Scotland every year, to assess the radiation dose to the public. The programme focuses on areas where concentrations of man-made radioactivity might be higher, paying special attention to the areas around the following nuclear sites:

- Chapelcross, Dumfries
- Hunterston, Ayrshire
- Faslane & Coulport, Argyll & Bute
- Dounreay & Vulcan, Caithness
- Rosyth, Fife
- Torness, Lothian & Borders

The monitoring programme consists of the sampling and analysis of seawater, sediments, seaweed, fish and shellfish. Radioactivity in sediments and seawater is used as an indicator whereas other samples are used in the assessment of exposure via consumption.

Radiation exposures in the UK due to radioactive waste discharges, 2009

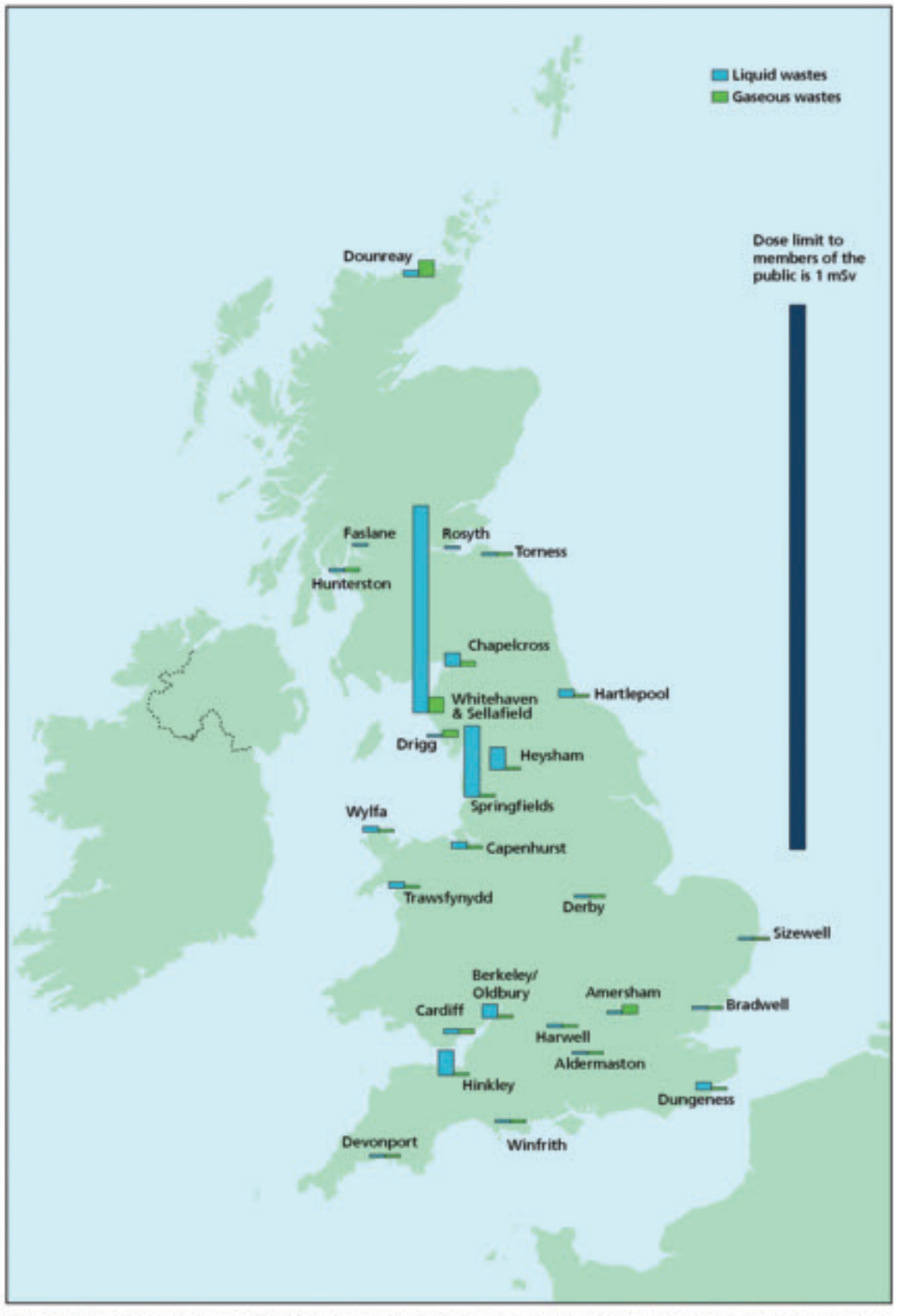


Figure S1. Radiation exposures in the UK due to radioactive waste discharges, 2009 (Exposures at Whitehaven and Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Monitoring is also carried out along the Dumfries and Galloway coastline and in the Solway Firth, to assess the effects of radioactive waste discharges from Sellafield into the Irish Sea.

In addition surveys are undertaken at each of these sites every five years to identify the food consumption habits, time spent in the area and lifestyles to assess people's exposure.

Measurement of radiation

© SEPA

Results of Monitoring

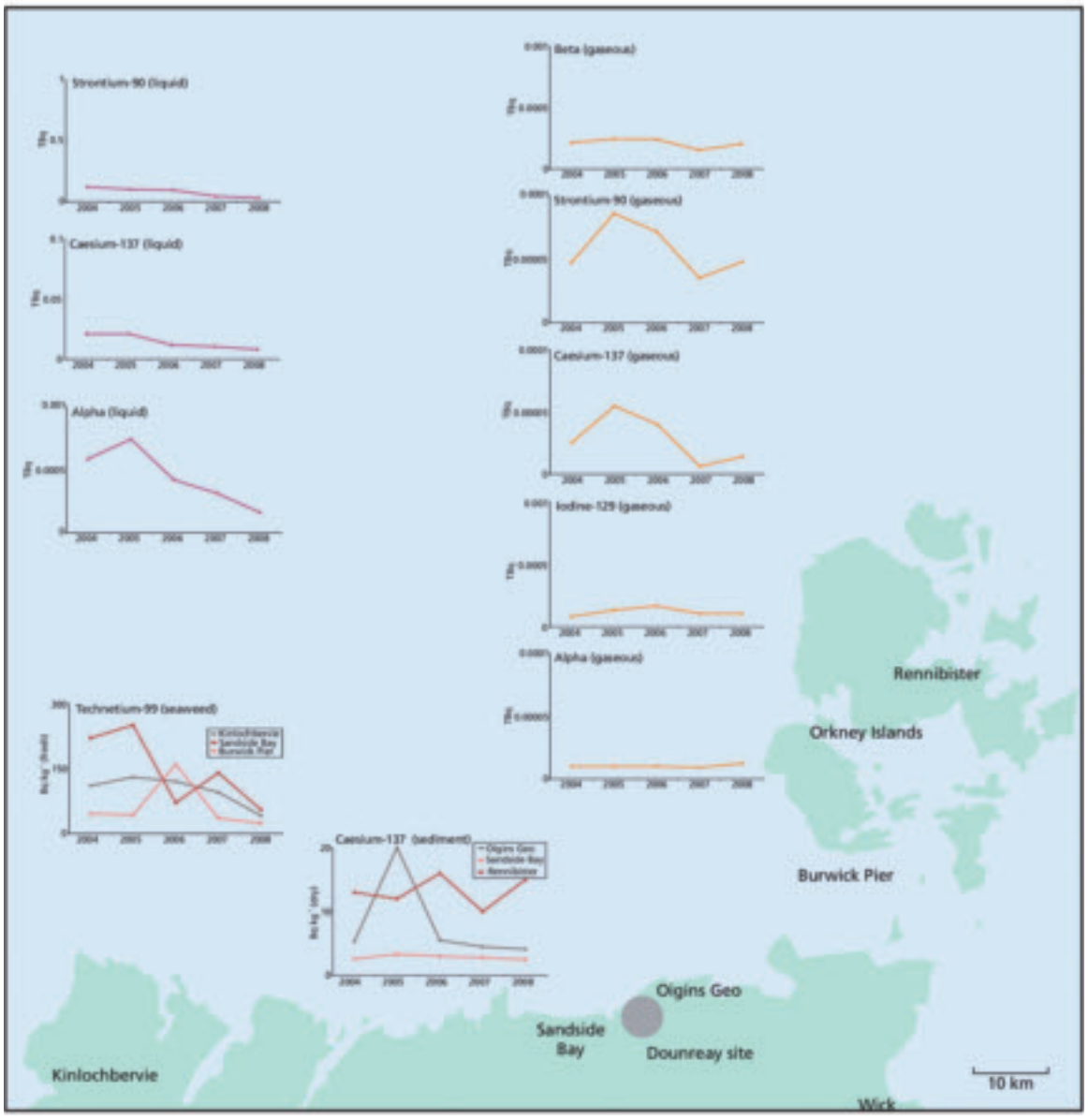
The results show that the dose to the most exposed members of the public in Scotland is well below the public dose limit. The people most affected in terms of exposure to radiation from waste discharges in Scotland were those on the Dumfries and Galloway coast who consumed large quantities of seafood. Data collected over the period from 2004 to 2008 shows no trends in dose.[3]

The results of the marine and terrestrial monitoring programmes are reported annually, together with an assessment of the impact of the discharges to the most exposed groups, in the Radioactivity in Food and the Environment (RIFE) reports.[4]

Monitoring at Dounreay

Discharges from Dounreay are routinely monitored and the results for the period 2004-2008 are shown on the map. In addition fragments of irradiated fuel have been found in the marine environment. The Dounreay Particles Advisory Group was established by SEPA and the UKAEA (now Dounreay Site Restoration Limited) in 2000. This group provided scientific and technical advice on monitoring and research programmes in relation to the fragments of irradiated nuclear fuel in the vicinity of the Dounreay nuclear licensed site. DPAG was reviewed in 2009 and was replaced by the Particles Retrieval Advisory Group (Dounreay). The Particle Retrieval Advisory Group's role is to provide advice on monitoring and retrieval of radioactive fragments on beaches and the offshore environment. Fragments are retrieved from the seabed offshore from Dounreay and local beaches. During 2009 115 fragments were retrieved from the seabed and 45 from local beaches. The presence of fragments on the seabed has resulted in a ban on fishing in the area. The risk to the public of exposure to particles on local beaches is reviewed each time a particle is identified. No particle has resulted in the closure of a local beach however access to the Dounreay foreshore is limited.

Monitoring sites and radioactivity at Dounreay



OSPAR & UK Strategy for Radioactive Discharges

The OSPAR Radioactive Substances Strategy was agreed by Ministers in 1998. Its strategic objective is to prevent pollution of the OSPAR maritime area (North-East Atlantic Ocean) from ionising radiation. The ultimate aim of the Strategy is to reduce discharges of radioactive substances to such a degree that environmental radioactivity concentrations in the marine environment above historic levels are near background concentrations for naturally-occurring radioactive substances and close to zero for man-made substances. The OSPAR Strategy is implemented through the UK Strategy for Radioactive Discharges 2009, which provides a strategic framework for reducing discharges from the nuclear industry.

Monitoring at Dalgety Bay

Dalgety Bay is a site of a former Ministry of Defence (MoD) airfield (HMS Donibristle & HMS Merlin). Donibristle was used as a military airfield between 1917 and 1959. Throughout this time it played a role as an aircraft repair, re-fitting and salvage yard. Since 1990 radium contaminated items, in the form of lumps and discrete fragments, have been detected at Dalgety Bay in Fife. It is suspected that the contamination is related to waste materials from the base. Historically these fragments have been monitored and removed periodically. The site is currently being assessed against the requirements of the Radioactive Contaminated Land (Scotland) Regulations 2007 and associated guidance.

Dounreay

© SEPA

Torness Power Station

© SEPA

MICROBIOLOGICAL CONTAMINATION

Monitoring requirements

Microbiological regulation and monitoring is driven by the risk to public health from contact with pathogens indicated by the presence of faecal indicator organisms of either human or animal origin. The EU Bathing Waters Directive (76/160/EEC) sets standards for faecal indicator organisms in waters at designated bathing beaches. Bathing beaches are designated on the basis of their recreational use and hence risk to the public of exposure to faecal indicator organisms. The Shellfish Waters Directive (2006/113/EC) sets standards for faecal coliforms in shellfish in designated waters. Shellfish Waters are areas where water quality must be protected or improved to protect shellfish growth and contribute to assuring the quality of shellfish for human consumption. The European food hygiene legislation (primarily regulation (EC) No. 854/2004 as amended for shellfish hygiene) sets standards in shellfish marketed for human consumption.

Standards in bathing waters

Bathing water quality is assessed by the presence of total and faecal coliforms and faecal streptococci. If swallowed in sufficient quantities by people in contact with water, faecal coliforms can cause stomach upsets and ear infections. These indicator organisms are analysed in 10 to 20 water samples collected at designated beaches over the course of each official bathing season (1 June to 15 September). The results are assessed against European standards to give an overall category of "guideline" pass, "mandatory" pass, or "fail" at the monitored beaches.

Standards in shellfish

The Shellfish Waters Directive sets a guideline standard of < 300/100ml faecal coliforms in shellfish flesh in designated Shellfish Waters. The Directive specifies that samples are collected quarterly and that this value must not be exceeded in 75% of samples, for compliance.

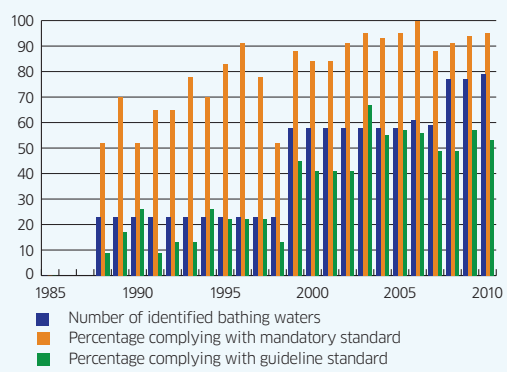
The shellfish hygiene regulations classify areas where shellfish are produced for human consumption. Shellfish hygiene sites are assigned into different classes based on the E. coli. content of the shellfish flesh.

In Scotland, results obtained from the analysis of samples for the shellfish hygiene regulations by the Food Standards Agency in Scotland (FSA(S)) are used to assess compliance with the guideline standard of the Shellfish Waters Directive, where the waters overlap. The shellfish hygiene Class A standard is similar to the Shellfish Waters guideline standard and the samples reflect the quality of shellfish for human consumption. In 2009 the majority of Shellfish Waters (62 from 78) in Scotland were assessed using shellfish hygiene data.

How good is bathing water quality in Scotland?

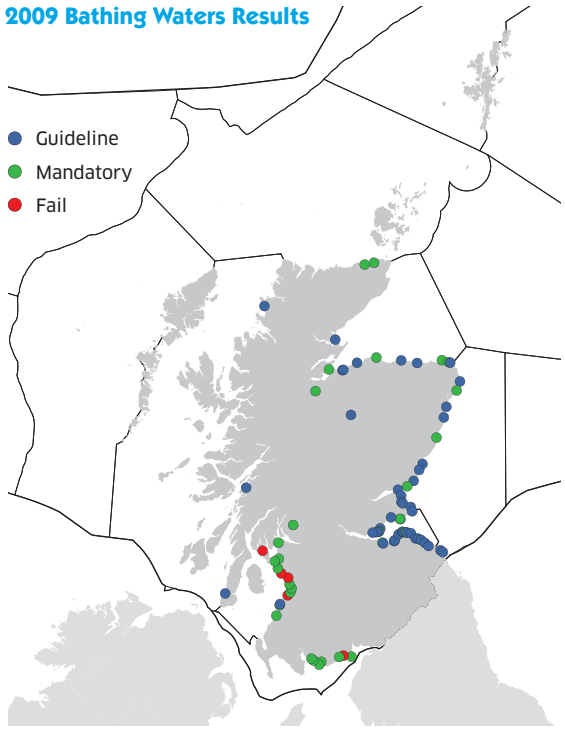
In 2009, 94% of bathing waters achieved the "mandatory" standard and more than half achieved the better "guideline" standard. It is not possible to determine trends in compliance between 1988 and 2009, as the number of designated bathing beaches has increased from 23 to 77. However, compliance with the "mandatory" standard at the original 23 sites rose from 52% in 1998 to 86% in 2009 indicating that water quality has improved at the original sites. Although bathing water quality appears to have improved, some beaches do not meet the minimum "mandatory" standard every year.

Trends in compliance with mandatory and guideline standards at designated bathing beaches in Scotland



Source: SEPA

2009 Bathing Waters Results



Bathing water sampling

© SEPA

Guideline and Mandatory standards for faecal indicator organisms in Bathing Waters

Level of pass	Total coliforms	Faecal coliforms	Faecal streptococci
"Guideline"	80% of samples should not exceed 500 total coliforms per 100 ml	80% of samples should not exceed 100 faecal coliforms per 100 ml	90% of samples should not exceed 100 faecal streptococci per 100 ml
"Mandatory"	95% of samples should not exceed 10,000 total coliforms per 100 ml	95% of samples should not exceed 2,000 faecal coliforms per 100 ml	The directive contains no mandatory standard for faecal streptococci

Classification under Shellfish Hygiene Regulation (EC) No. 854/2004

Classification	Permitted Levels	Outcome
A	≤ 230 *E.coli*/100g of flesh and intervalvular liquid.	May go direct for human consumption
B	≤ 4,600 *E.coli*/100g of flesh and intervalvular liquid in 90% of samples	Purification or relaying for 2 months (or heat treatment by approved process)
C	≤ 46,000 *E.coli*/100g of flesh and intervalvular liquid.	Must be re-laid for a period of at least 2 months, followed, where necessary, by treatment in a Purification centre to meet Category A requirements

Shellfish water quality

In 2009 56 percent of designated Shellfish Waters achieved the guideline standard for faecal coliforms in shellfish flesh. This is comparable with previous years however is not possible to determine trends in the quality of Shellfish Waters in Scotland as the number of designated sites changed from 20 in 1981 to 78 in 2009 and some of the original sites were de-designated as they no longer contained shellfisheries.

Shellfish harvesting sites are generally located within designated Shellfish Waters although some are not and there may be more than one harvesting area within a designated Shellfish Water. Many harvesting sites are given seasonal classification of A for part of the year (usually winter) and B for the rest of the year to reflect the seasonal changes in micro-organisms. In 2009 approximately 40% of harvesting sites were Class A all year round and the remaining sites were Class B for part or all of the year. The number of shellfish harvesting sites varies annually as sites move in to and out of production so it is difficult to determine trends in the data.

How do people know when it is safe to bathe or eat shellfish?

Signs posted at beaches provide daily forecasts of predicted water quality. Electronic signage was available at 11 beaches in Scotland during the 2009 bathing waters season. The guidance provided by the signs was shown to be accurate 98% of the time. Preparations are underway to expand this notification system.

Only shellfish which achieve Class A, either directly or following treatment are made available for human consumption to minimise the risk to public health.

Bathing water sign

© SEPA

Sources of faecal indicator organisms

Faecal indicator organisms exist in human sewage and in traces of animal faeces which may be washed from farmland during periods of wet weather. Animal faeces from a single source may not seem important, but across a whole catchment these diffuse sources can have serious implications for nearby waters. Water quality is particularly at risk following heavy rainfall, as this washes potentially polluting material from land into surrounding watercourses.

Sources of contamination

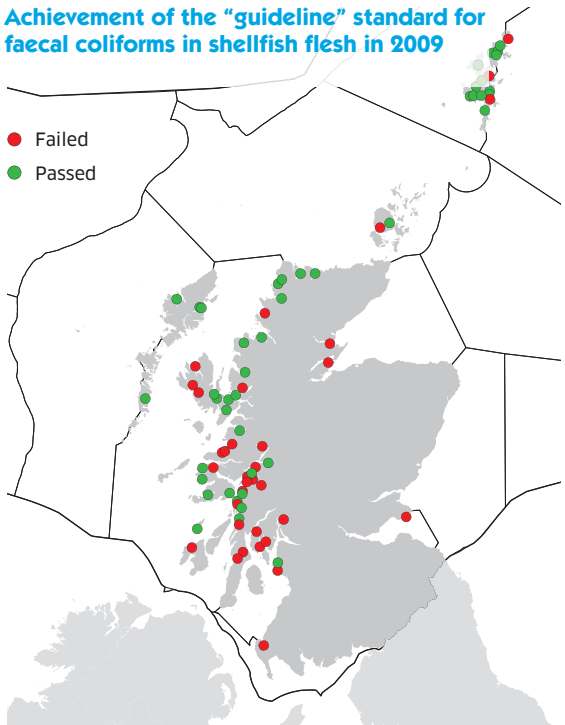
It is very difficult to distinguish between human and animal sources of contamination. Recently DNA matching techniques for microbial source tracking (MST) have been developed by specialist laboratories. MST can indicate whether the pollution in a particular sample has potentially arisen from human or animal sources. This information can then be used to manage the input at source either by improvements to sewage effluent treatment and storm overflows or by preventing animal faeces from entering water courses.

Improvements can be focussed on the main source of bacteria once it has been identified. Scottish Water is continuing to upgrade the sewerage network to improve compliance at beaches and Shellfish Waters affected by sewage discharges. River Basin Management Plans are being used to prevent contamination from animals entering water courses by fencing off water courses and spreading slurry in dry weather where diffuse inputs are a problem.

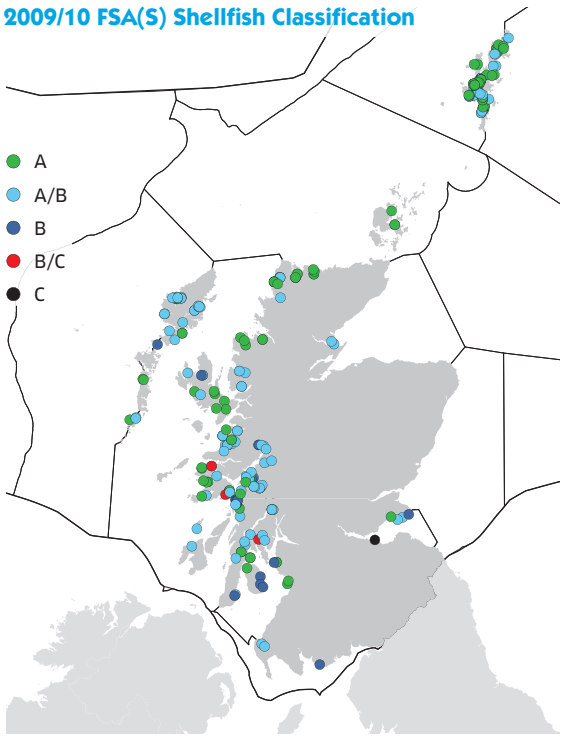
Inverboyndie Beach

© SEPA

Achievement of the "guideline" standard for faecal coliforms in shellfish flesh in 2009



2009/10 FSA(S) Shellfish Classification



Loch Eriboll Shellfish Water

© SEPA

BIOTOXIN MONITORING IN SCOTLAND

What are biotoxins?

Marine biotoxins are a group of natural substances produced by microscopic marine algae (phytoplankton, including diatoms and dinoflagellates). Biotoxins can accumulate in fish or shellfish as they feed on these algae. The biotoxins are a risk to human and animal health if these shellfish are consumed.

Biotoxin monitoring requirements

The cultivation, harvesting and sale of bivalve molluscs are important to the Scottish economy, with particular significance to the sustainable development of rural areas of the west coast and islands. Marine phytoplankton is the food source for these filter-feeding organisms.

The Food Standards Agency in Scotland (FSAS) is required, under Regulation (EC) No. 854/2004 to monitor shellfish harvesting areas around Scotland for the presence of toxins in shellfish and the occurrence of biotoxin producing phytoplankton. Fisheries are closed when necessary in order to prevent consumption of contaminated shellfish.

Three main groups of toxins are routinely monitored in Scottish waters. The potential for Paralytic Shellfish Poisoning is indicated by the presence of saxitoxin in shellfish and *Alexandrium* species in the phytoplankton. Toxins that cause Diarrhetic Shellfish Poisoning are generated by *Dinophysis* species in phytoplankton. The potential for Amnesic Shellfish Poisoning is indicated by the presence of domoic acid in shellfish flesh and the presence of *Pseudo-nitzschia* species in the phytoplankton. If the toxins are found above the maximum permitted level specified by the regulations the harvesting area is closed.

EU regulatory limits from Regulation (EC) No 853/2004 and the causative phytoplankton species

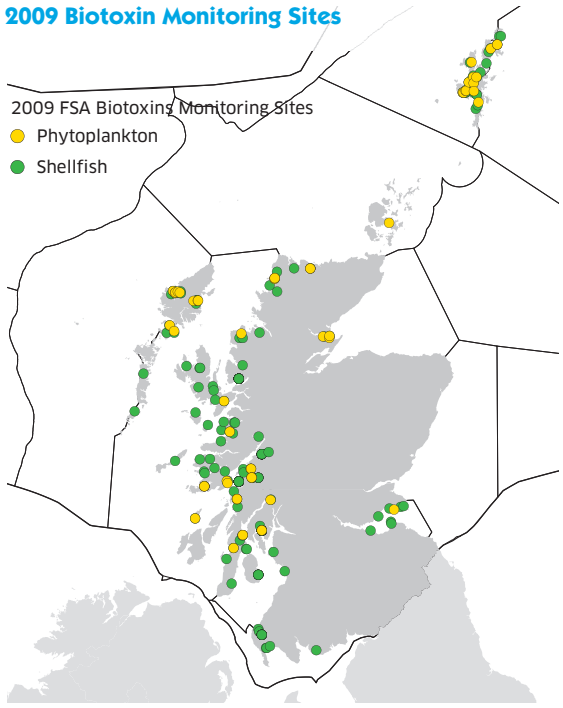
Type of Shellfish Poisoning	Maximum Permitted Level of biotoxins in shellfish flesh	Main causative phytoplankton species in Scottish waters
Paralytic Shellfish Poisoning	80 µg Saxitoxin di-HCl equivalent /100g	*Alexandrium* species
Diarrhetic Shellfish Poisoning	Positive bioassay result	*Dinophysis* species
Amnesic Shellfish Poisoning	20 µg Domoic Acid + Epi Domoic Acid /100g	*Pseudo-nitzschia* species

Biotoxin monitoring in Scotland

Biotoxins are monitored at sites classified for the production of shellfish. In 2009 there were 260 classified shellfish sites around Scotland, with shellfish routinely sampled from around 115 of these for the presence of the three groups of toxins. Samples are collected from Representative Monitoring Points within a group or 'pod' of classified shellfish sites. Shellfish sites within each 'pod' are considered to be similar hydrographically and environmentally. The Representative Monitoring Point is considered to be the point most likely to be representative or indicative of any toxicity in the area. Representative Monitoring Points are primarily selected on a geographical basis, and according to the history of toxic events in the area, although the shellfish species harvested at the site and ease of access are also taken into account. Sampling frequency for each of the three groups of toxins is based on a risk assessment, according to seasonal risk and harvesting activity.

The detection, at the Representative Monitoring Point, of any of the three biotoxin groups at levels which exceed EU regulatory limits, leads to the closure of all classified shellfish sites within the pod. Toxin-producing phytoplankton are also routinely monitored at 36 sites (mostly Representative Monitoring Points) around the coast, with the majority concentrated in the major shellfish producing regions of Argyll and Shetland. Enumeration of phytoplankton species can be used as an 'early warning' of the possible occurrence of shellfish biotoxin events. To facilitate this, threshold concentrations, or trigger levels, of the main genera of phytoplankton have been determined by comparing phytoplankton counts with the presence of biotoxins in shellfish. While Paralytic Shellfish Poisoning, Amnesic Shellfish Poisoning, and Diarrhetic Shellfish Poisoning are of greatest concern, other toxins produced by phytoplankton and the trigger levels for the key toxin producing genera are used to predict shellfish biotoxin event. In addition, the monitoring programme will report unusually large occurrences of any of the other harmful species detailed on the governmental Oceanographic Commission (IOC) taxonomic reference list of toxic phytoplankton http://www.bi.ku.dk/ioc/.

2009 Biotoxin Monitoring Sites



Shellfish sampling frequency for Representative Monitoring Points in Scottish waters during 2009

Type of Shellfish Poisoning	Weekly	Fortnightly	Monthly
Paralytic Shellfish Poisoning	April to October	November to March	
Diarrhetic Shellfish Poisoning	April to December		January to March
Amnesic Shellfish Poisoning	June to October	May	November to April

Phytoplankton species monitored in Scottish waters and the trigger levels for key toxin producing genera

Phytoplankton	Trigger level (cells/l)	Associated toxin
Pseudo-nitzschia (genus)	50,000	Amnesic Shellfish Poisoning
Alexandrium (genus)	Presence	Paralytic Shellfish Poisoning & spirolides
Dinophysis (genus)	100	Diarrhetic Shellfish Poisoning including: Okadaic acid (OA), Dinophysis toxins (DTXs) and Pectenotoxins (PTXs)
Prorocentrum lima	100	Diarrhetic Shellfish Poisoning
Prorocentrum minimum	None specified	Venerupin (hepatoxin)*
Lingulodinium polyedrum	None specified	Yessotoxin
Protoceratium reticulatum	None specified	Yessotoxin
Protoperidinium crassipes/curtipes	None specified	Azaspiracids#

* The toxicity of *P. minimum* and the production of hepatoxin are currently under scientific debate.

\# The causative organism of azaspiracid toxins has recently been identified as the small dinoflagellate *Azadinium spinosum*, with the heterotroph *P. crassipes/curtipes* being a vector for these toxins if it ingests *A. spinosum*, along with other heterotrophic phyto and micro zooplankton.

Detection of biotoxins in shellfish monitored in Scottish shellfish harvesting areas during 2009

Between March and October, Amnesic Shellfish Poisoning was detected in samples from 38 separate sites ranging from 1 µg/g to 13 µg/g. All of these were below the maximum permitted level of 20 µg/g. These samples originated from sites predominately on the West Coast, Western Isles and Shetlands. The results for these Representative Monitoring Points coincided with areas at which the largest bloom densities of *Pseudo-nitzschia* were detected.

During 2009, 100 samples from 30 Representative Monitoring Points recorded positive results for Diarrhetic Shellfish Poisoning toxins. January, March and October to December were the only months with no positive results. The samples originated predominately from the West Coast, Western Isles and Shetlands. Again, these results coincided with the areas at which the largest bloom densities of *Dinophysis* were detected.

During 2009, Paralytic Shellfish Poisoning toxin was detected in a total of 32 samples between March and June. Only 5 of these samples contained levels of Paralytic Shellfish Poisoning toxin above the maximum permitted level. These were sampled from 3 sites located in the west coast, between late April and early June 2009. Although significant *Alexandrium* blooms were detected in Shetland during 2009, these did not appear to lead to Paralytic Shellfish Poisoning toxins being detected in shellfish sampled from Representative Monitoring Points in this area. Paralytic Shellfish Poisoning toxicity in Scottish waters is thought to be generated by toxic (group I) ribotypes of *Alexandrium tamarense*. However, recent evidence indicates the co-occurrence of non toxic (group III) *A. tamarense* in Scottish waters. Blooms of these organisms would not generate shellfish toxicity. The biogeography of *Alexandrium*, and the factors driving this, are subjects of active current scientific investigation.

Detection of biotoxin producing phytoplankton in Scottish waters during 2009

During 2009, a total of 1,031 phytoplankton samples were screened for biotoxin producing phytoplankton. Of these, approximately 12%, 29% and 15% exceeded the regulatory threshold for the three major toxic genera *Pseudo-nitzschia*, *Alexandrium* and *Dinophysis*, respectively. The largest bloom density at each sampling location is depicted in the maps.

***Dinophysis* species**

© SEPA

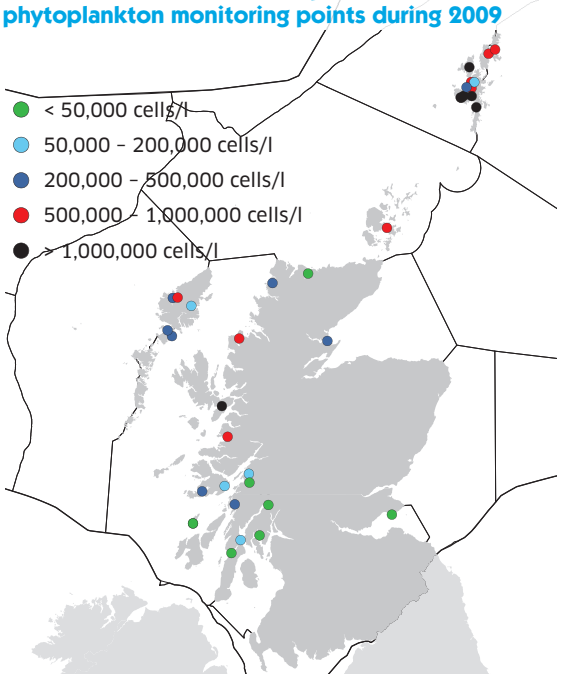
***Pseudo-nitzschia* species**

© SEPA

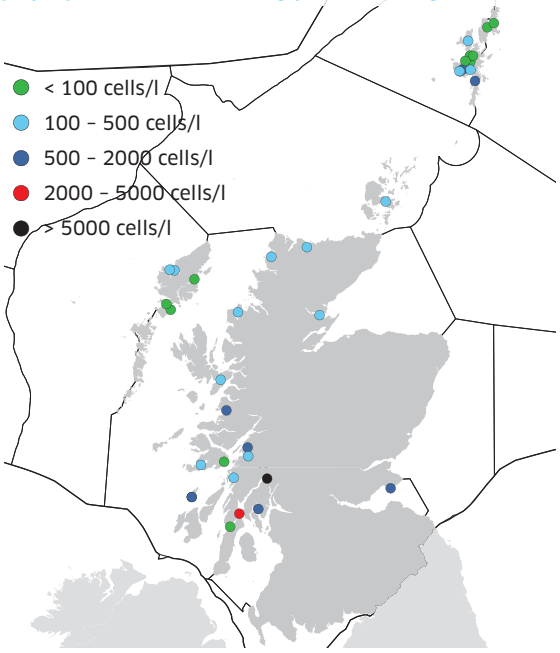
What do the results indicate?

During 2009, blooms of the phytoplankton species responsible for production of Amnesic Shellfish Poisoning, Diarrhetic Shellfish Poisoning and Paralytic Shellfish Poisoning were detected across Scotland, with blooms in Shetland and the West Coast resulting in the closure of commercial harvesting areas for Diarrhetic Shellfish Poisoning and Paralytic Shellfish Poisoning toxins in shellfish. These monitoring programmes confirm the importance, to both human health and the rural economy, of regular water sampling for the early detection of phytoplankton blooms and the prediction of biotoxin events in shellfish.

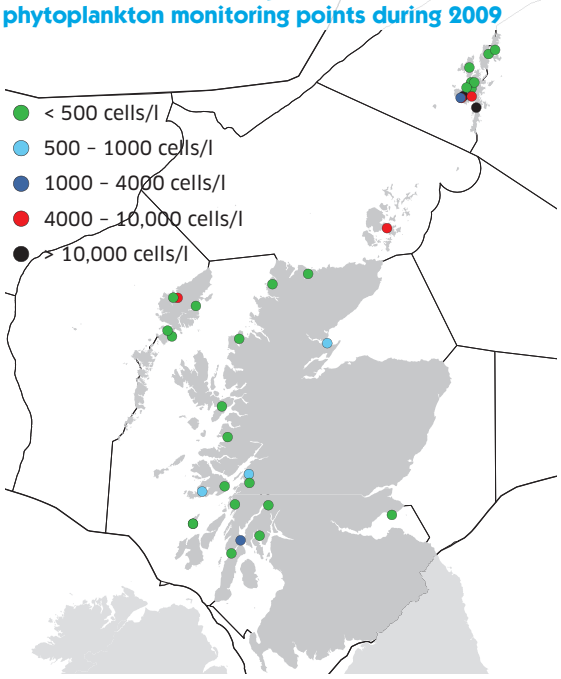
Levels of *Pseudo-nitzschia* species detected at phytoplankton monitoring points during 2009



Levels of *Dinophysis* species detected at phytoplankton monitoring points during 2009



Levels of *Alexandrium* species detected at phytoplankton monitoring points during 2009



What is eutrophication?

Eutrophication occurs when the enrichment of waters by nutrients (nitrogen and phosphorus) increases the growth of algae and plants in the water to the extent that they smother and suffocate wildlife.

Nutrient enrichment of watercourses results from agricultural run off and sewage. Algae and plants take up dissolved nutrients and require approximately sixteen times more nitrogen than phosphorus. Compared to seawater, rivers are rich in nutrients, particularly nitrogen, so algae and plant growth in rivers are usually limited by phosphorus. Algal growth in seawater is usually limited by available nitrogen. The limiting nutrient in estuaries changes as river water is diluted with seawater so that phosphorus may be limiting growth at the head of an estuary and nitrogen at the mouth.

Nutrient inputs to the sea from rivers, sewage and industrial discharges have been monitored since 1990 for the OSPAR riverine inputs and direct discharges programme. Inputs of total nitrogen (both dissolved and particulate) have remained at 70,000 tonnes per year whereas inputs of total phosphorus have reduced from 8,000 to 5,500 tonnes per year. Most of the nutrients are discharged to the East coast where the freshwater input is high compared to the rest of Scotland.

Are all nutrient inputs available for algae and plant growth?

Algae and plants use dissolved nutrients. Most of the nitrogen inputs (70%) are in the dissolved form, as nitrate, nitrite and ammonia. Less of the phosphorus inputs (60%) are dissolved.

Slurry spreading

© SEPA

Main source of nutrients

Rivers are the main source of nitrogen where it is mainly present as nitrate. Wastewater from sewage treatment plants is the main source of phosphate and contributes relatively small amounts of nitrogen in the form of ammonia and organic nitrogen associated with particulate matter. Within Scotland there are relatively high inputs of nitrate from arable land on the east coast and relatively high inputs of ammonia and phosphate from urban areas in the West and East.

Recent estimates of nutrients from the caged fish farm industry suggest they may be a significant source in the north and west of Scotland where freshwater inputs are low. The total nitrogen released from the caged fish farm industry in these areas is estimated to be similar to inputs from aqueous discharges at about 8,000 tonnes per year. Inputs of total phosphorus in these areas are about 1,000 tonnes per year. However, nutrient inputs from fish farms are mainly in the form of faecal and particulate organic matter, which is deposited on the seabed. Unlike dissolved nutrients in aqueous discharges, this organic matter is not immediately available as food for algae.

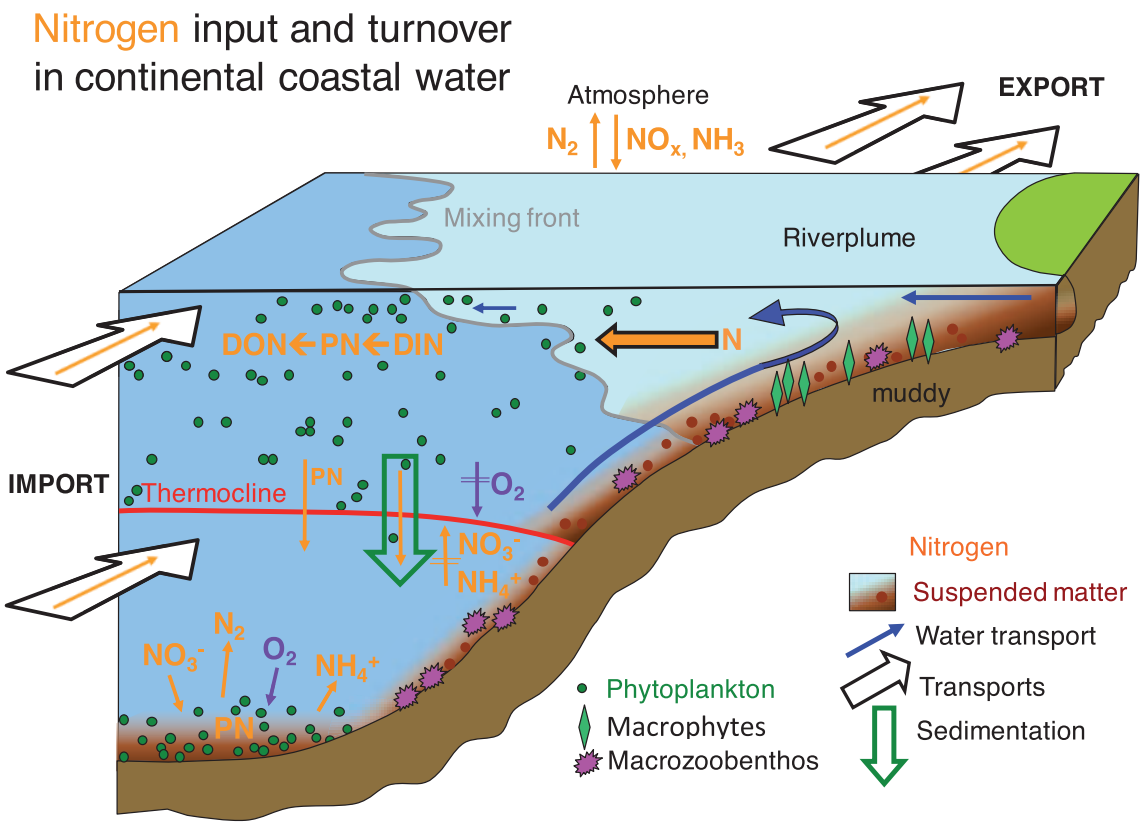
Is eutrophication a problem?

Eutrophication is a problem when nutrient enrichment causes accelerated growth of plants and algae to such an extent that they cause an 'undesirable disturbance' to the ecosystem. An undesirable disturbance is defined by changes from the natural state, which will vary depending on local conditions. Fish kills and the death of sediment dwelling organisms that result from the removal of oxygen by decaying algae are examples of an undesirable disturbance.

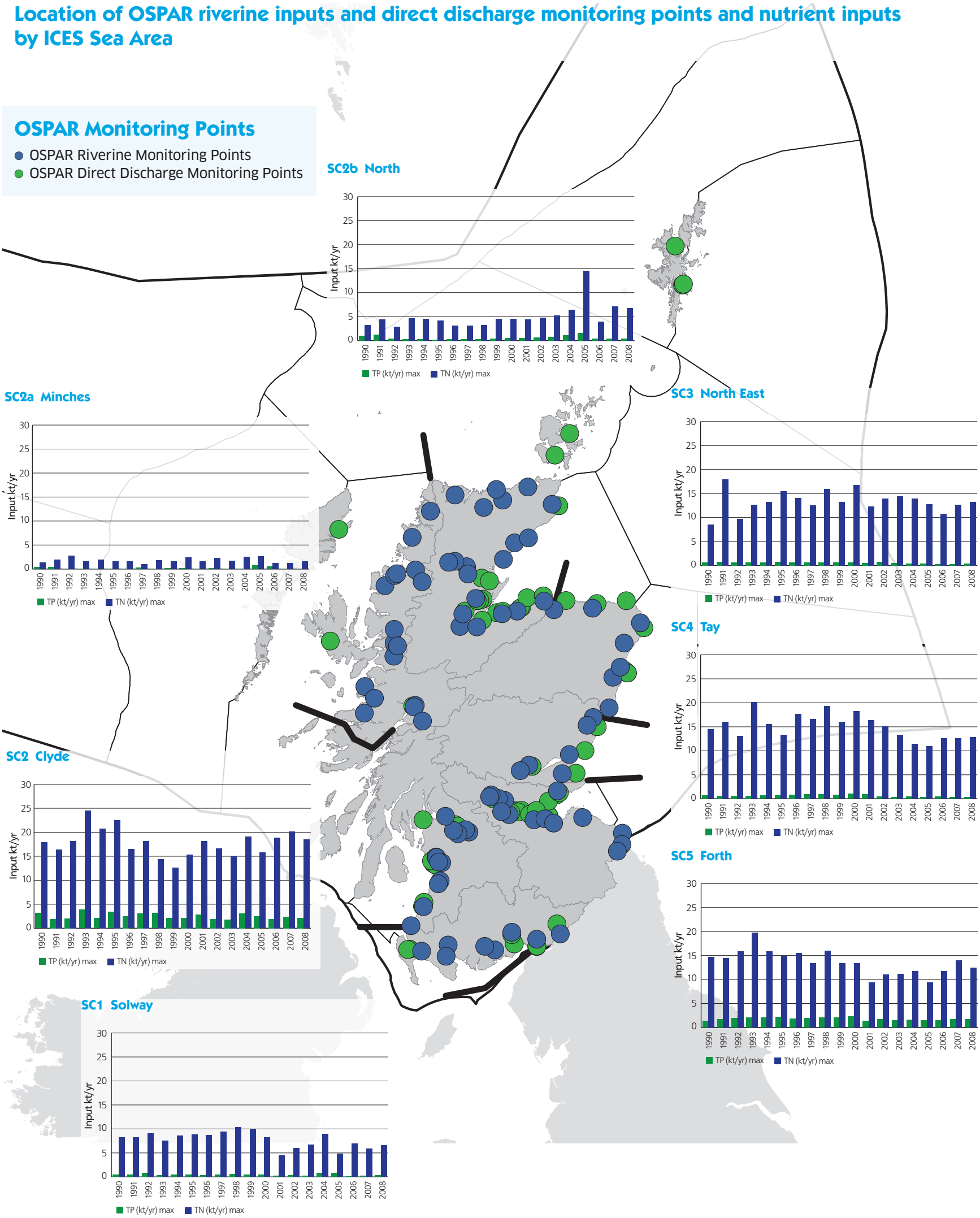
Nutrients from fish farms

© SEPA

Nitrogen Input and Turnover in coastal water



Location of OSPAR riverine inputs and direct discharge monitoring points and nutrient inputs by ICES Sea Area



Note: TP = total phosphorus, TN = total nitrogen

Evidence of nutrient enrichment

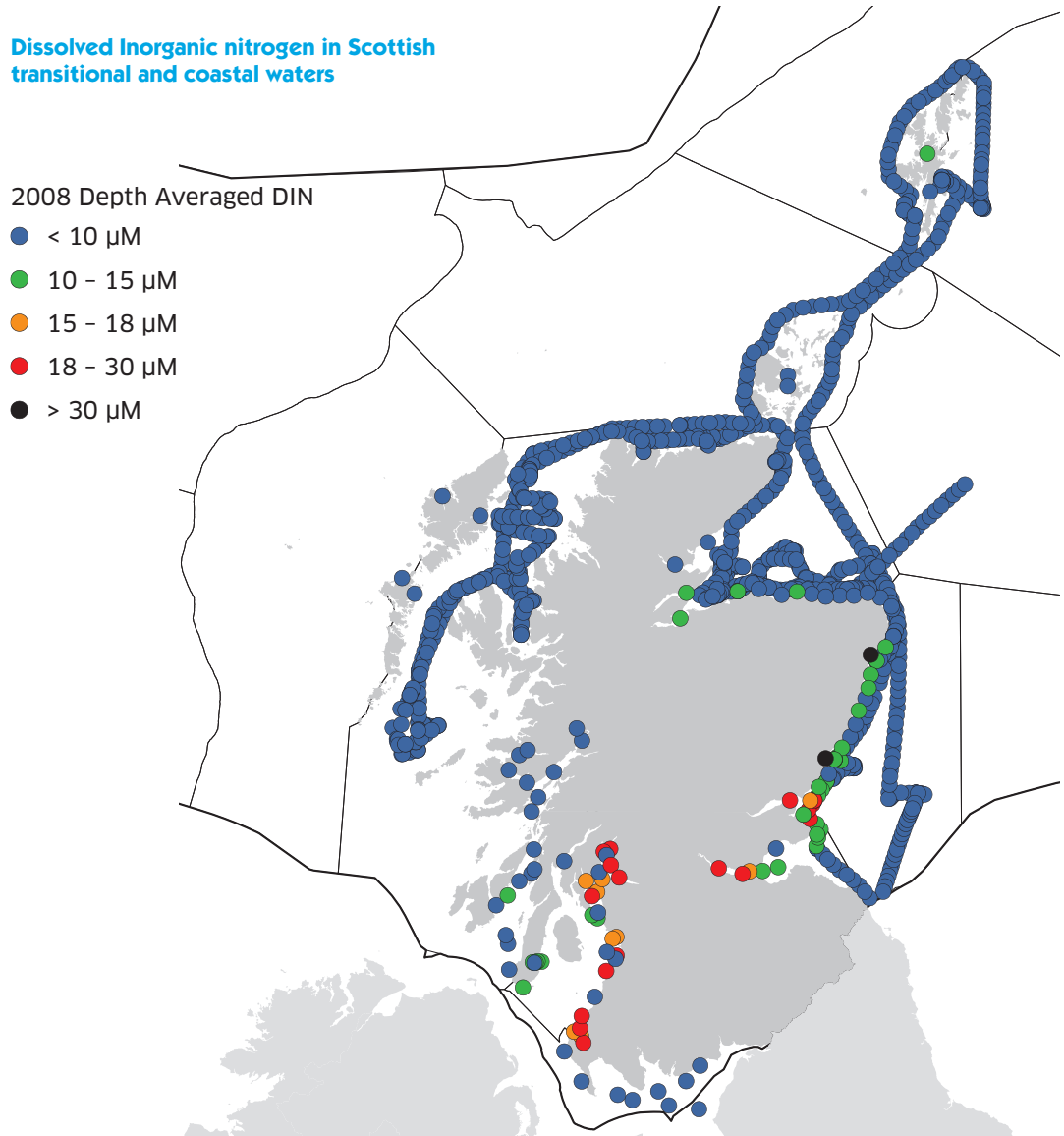
The concentration of dissolved inorganic nitrogen[1] (DIN) in winter is used as an index of nutrient enrichment in marine waters, as DIN usually limits algal growth in seawater. In winter, there is little removal of DIN by the growth of algae in the water column so the use of winter concentrations helps to reduce the variability in measurements. The concentration of DIN is considered high if it is more than 50% above a background concentration taken as 10 µM in seawater and 42 µM in river water.[2] Enrichment with nitrogen is therefore indicated by concentrations of DIN greater than 15 µM in offshore waters and 18 µM in regions of freshwater influence such as coastal waters. In estuaries, nitrogen enrichment is indicated by concentrations greater than 30 µM measured at a salinity of 25, which represents an approximate mix of 1:2.5 parts freshwater:seawater.

The concentration of winter DIN in Scottish coastal and estuarine waters is less than 50% above background in offshore and most coastal waters. Nitrogen levels are greater than 50% above background in the coastal waters of the Firth of Clyde and in Loch Ryan, and in two small estuaries on the East Coast, the Ythan estuary and Montrose Basin.

1 Dissolved inorganic nitrogen = ammonia +nitrate+nitrite.

2 The background concentration of DIN is based on the concentration in Atlantic seawater and the concentration in a river draining a relatively pristine catchment.

Dissolved Inorganic nitrogen in Scottish transitional and coastal waters



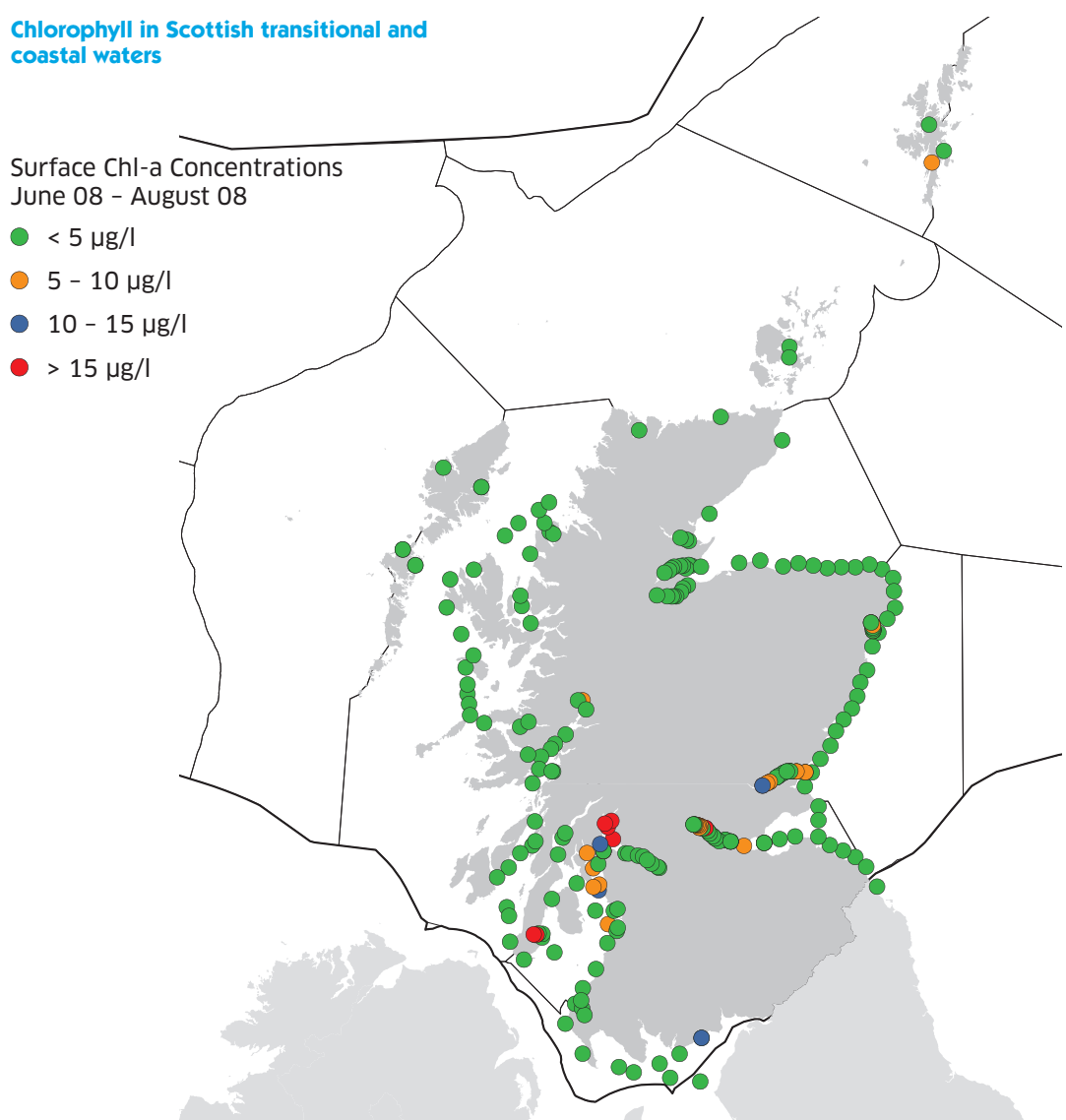
Evidence of excessive growth of phytoplankton

Excessive algal growth is assessed by the amount of phytoplankton in coastal and offshore waters and the amount of opportunistic green algae on intertidal mudflats in estuaries. Phytoplankton growth is not a suitable measure in estuaries because it is limited by the availability of light in turbid estuaries and by the residence time of water in smaller estuaries.

The amount of phytoplankton in the water is estimated by measurements of the plant pigment, chlorophyll. Phytoplankton growth typically varies throughout the growing season (April – September) as phytoplankton utilise available nutrients. Chlorophyll concentrations peak in the spring as phytoplankton growth is stimulated by increasing temperature and light, and nutrients are abundant. Growth stops when the available nutrients are depleted, and the population declines. Chlorophyll concentrations then fall as phytoplankton growth is limited by grazing animals and sustained by the recycling of nutrients. This natural variability in phytoplankton growth is taken into account by assessing the range of chlorophyll concentrations measured between April and September. Excessive growth is indicated when more than 10% of chlorophyll concentrations are greater than 15 µg/l in coastal waters and 10 µg/l in offshore waters.

Chlorophyll concentrations in Scottish coastal waters are generally less than 15 µg/l with the exception of a few sites in the inner Firth of Clyde.

Chlorophyll in Scottish transitional and coastal waters



Evidence of excessive growth of Opportunistic Green Algae

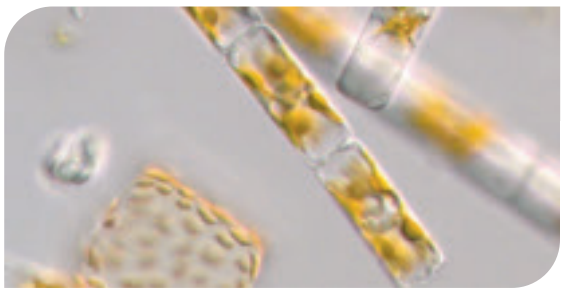
Excessive growth of opportunistic green algae in estuaries is assessed from the coverage and density of the mats formed by the algae on the intertidal area compared to a natural background or reference condition.

The extent of algal mat growth is monitored in two small estuaries on the East Coast where they are known to occur, the Ythan estuary and Montrose Basin in the South Esk estuary. Under the EC Water Framework Directive (WFD), the deviation from the background or reference condition is expressed as a number called the Ecological Quality Ratio (EQR) which is then classed from High to Bad. Algal mat growth in the Ythan estuary is close to the good/moderate boundary whereas algal growth in Montrose Basin is close to the moderate/poor boundary.

What the evidence indicates

There is no evidence of nutrient enrichment leading to accelerated growth of phytoplankton in Scottish coastal waters with the exception of a sea loch in the inner Firth of Clyde. There is evidence of nutrient enrichment leading to excessive growth of opportunistic green algae in the Ythan estuary and Montrose Basin. However, there is no evidence that the algal mats cause an undesirable disturbance as there are abundant benthic invertebrate populations in both these areas, and they support nationally important populations of wading birds.

Phytoplankton



© SEPA

Ecological Quality Ratio (EQR) for macroalgae in Montrose Basin 2007-2009

Source: SEPA

Ecological Quality Ratio (EQR) for macroalgae in the Ythan estuary 2007-2009

Source: SEPA

Opportunistic green algae

© SEPA

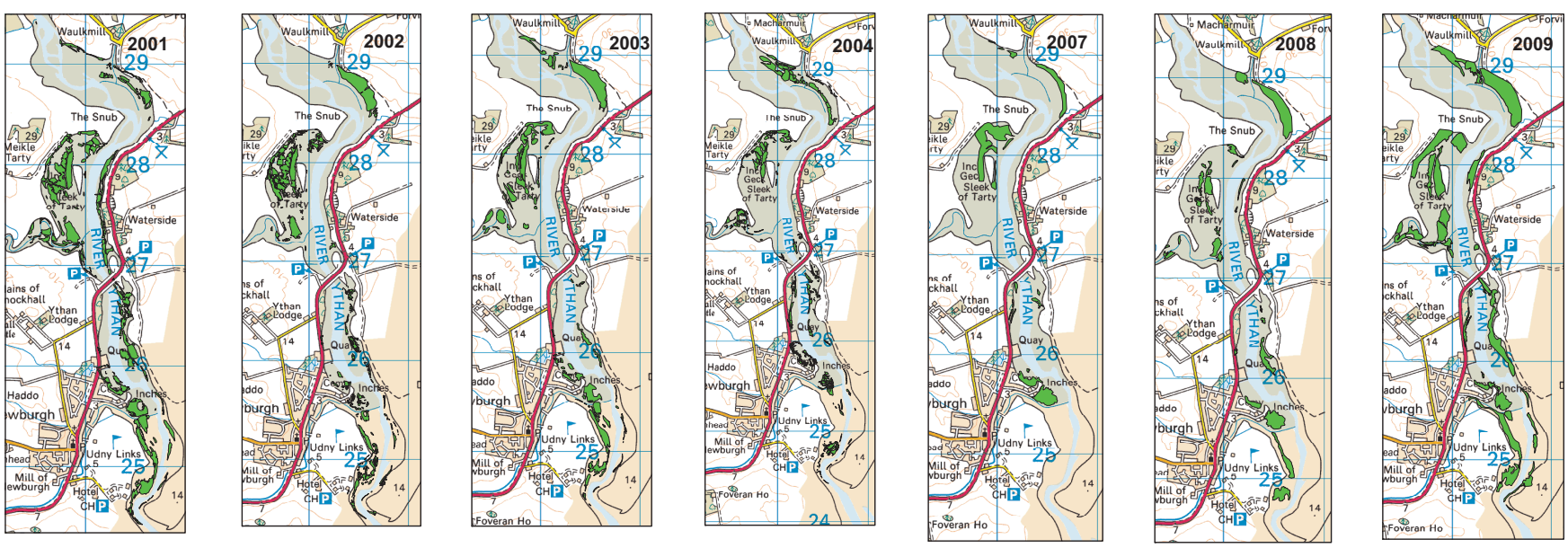
What can be done to prevent eutrophication?

There are several EU directives which aim to reduce nutrient inputs where they cause, or may cause, eutrophication. The Urban Waste Water Treatment Directive regulates nutrient inputs from waste waters and the Nitrates Directive regulates nitrate inputs from agriculture, whereas the Water Framework Directive and the OSPAR Strategy to combat eutrophication both consider the impact of nutrient inputs from all sources.

Areas with high nitrate concentrations in surface or groundwater have been designated as Nitrate Vulnerable Zones (NVZs), with measures set in place to regulate and reduce the application of fertiliser to agricultural land. The Ythan estuary was designated as an NVZ in 2000 and there is some indication that algal mats have decreased in recent years. The catchment for Montrose Basin is also designated as an NVZ, but there is insufficient data to assess any recent changes in the growth of algal mats. Recovery is expected to be slow as there will be a time lag between a reduction in fertiliser use and the reduction of nitrate concentrations in surface waters due to the large pool of nitrogen retained in the soil. Trends in inputs from land are also affected by changing weather patterns as an increase in rainfall causes an increase in nitrates washed off the land into rivers and discharged to sea.

Improvements to the treatment of waste water discharges have reduced inputs of nitrogen and phosphorus by removing the organic forms associated with suspended solids and converting ammonia to total oxidised nitrogen. Nitrogen inputs from waste water currently contribute 10% of the total dissolved inorganic nitrogen (ammonia plus total oxidised nitrogen) discharged to sea.

Spatial distribution of algal mats in the Ythan estuary



DISSOLVED OXYGEN IN THE CLYDE AND FORTH ESTUARIES

Why is dissolved oxygen measured?

Dissolved oxygen is an indicator of water quality because it is essential for the survival of most aquatic life, from animals living in the sediments to fish. Some species are more tolerant of low dissolved oxygen concentrations than others. Game fish such as salmon are indicators of good water quality because they require well oxygenated water.

Oxygen is removed from the water column by microbial activity involved in the breakdown of organic matter contained in natural detritus, sediments and discharges of organic waste from sewage treatment plants and industry.

Oxygen is considered to be depleted when removal exceeds supply from the atmosphere and from photosynthesis.

Water sampling

Source: SEPA

Clyde estuary

The Clyde estuary receives organic waste from the large conurbation of the Greater Glasgow region. Degradation of this organic matter deposited in the sediments and suspended in overlying water meant that the inner estuary was essentially devoid of dissolved oxygen in the 1970s, although there were slightly higher concentrations in the outer estuary. Dissolved oxygen concentrations increased as discharges of organic waste declined as a result of improvements to effluent treatment. This increase in dissolved oxygen resulted in the reappearance of salmon in 1983 following an absence of over a century. Salmon have reappeared each year since, along with increasing numbers of other fish species.

Further reductions in discharges of organic wastes may not result in an immediate increase in dissolved oxygen as organic matter trapped in the sediments continues to remove oxygen from the overlying water. Land reclamation and dredging have made the inner Clyde narrower and deeper than its natural state. These changes have reduced the strength of the tidal currents causing less mixing between freshwater and the incoming seawater, resulting in layering of the water column. This layering inhibits the transfer of oxygen from the surface allowing deeper water to become depleted in oxygen. A numerical model of the Clyde estuary is being used to predict the most cost effective option for increasing dissolved oxygen in the Clyde. These options include:

- Further reducing inputs of organic waste.
- Changing the operation of the tidal weir to increase mixing between fresh and salt water.
- Injecting pure oxygen into the estuary at critical times (e.g. during extended dry, hot spells) and locations.
- Changing the morphology of the estuary to improve flushing and reduce the residence time of organic waste.

Clyde estuary

Source: SEPA

Forth estuary

A zone of low dissolved oxygen occurs in the upper Forth estuary which is most pronounced during warm, dry weather in summer. This dissolved oxygen 'sag' is caused by the degradation of organic matter by bacteria attached to particulate matter in the muddy waters of the upper estuary. Bottom sediments are stirred into the overlying water of the upper Forth estuary by turbulence created when the incoming tide meets the outflowing river water. This creates a turbidity maximum zone downstream of the freshwater/saltwater interface which extends for several kilometres. This natural process is exacerbated by the degradation of organic waste discharged from sewage treatment plants and industry. The amount of oxygen consumed by effluent can be estimated using the biochemical oxygen demand (BOD) which measures the oxygen removed from a sample incubated at 20°C for five days. Dissolved oxygen concentrations in the upper Forth estuary have increased as discharges of organic waste have decreased.

Most of the oxygen is currently removed by the degradation of organic matter in the turbidity maximum zone. Numerical modelling is being used to establish the options for further improvement. These include:

- Further reduction in inputs of organic waste.
- Re-establishing salt marshes and reed beds in the upper estuary to reduce tidal currents.

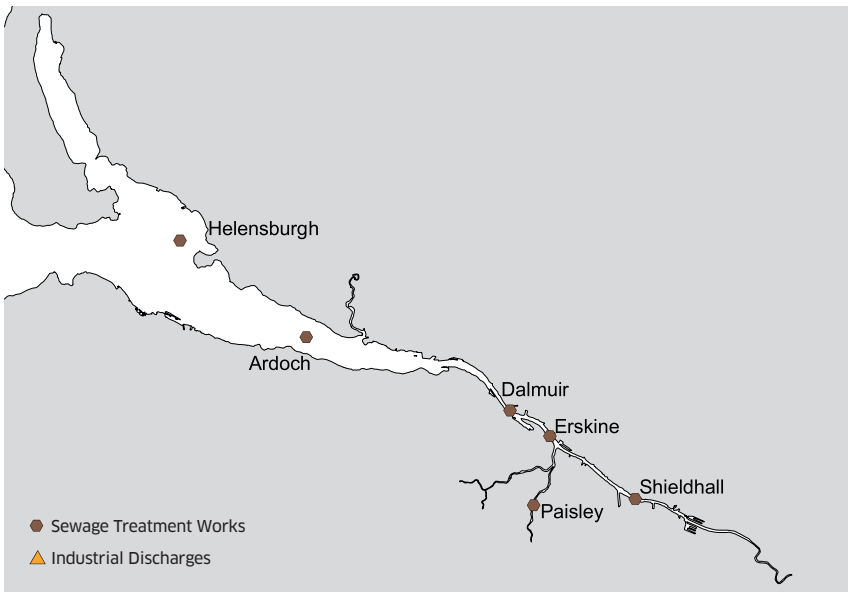
Much of the intertidal habitat of the Forth estuary has been lost due to land reclamation and flood defences. This reduces storage capacity which causes increased currents. Stronger currents increase the amount of sediment mixed into the water column so it is hoped that currents and hence the turbidity maximum will be reduced by restoring intertidal habitat. Restoration of the intertidal habitat is happening as the opportunity arises, for example at the RSPB reserve on Skinflats.

Forth estuary

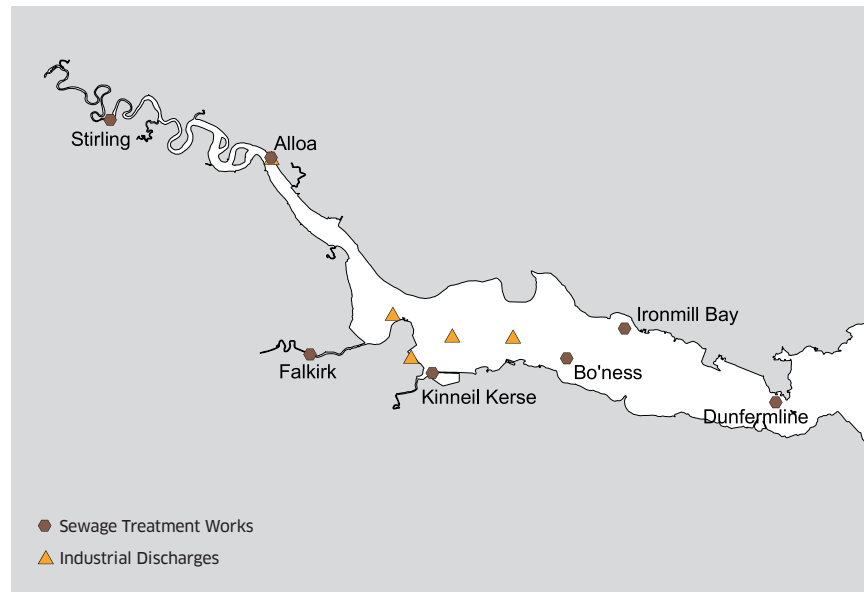
Source: SEPA

DISSOLVED OXYGEN IN THE CLYDE AND FORTH ESTUARIES

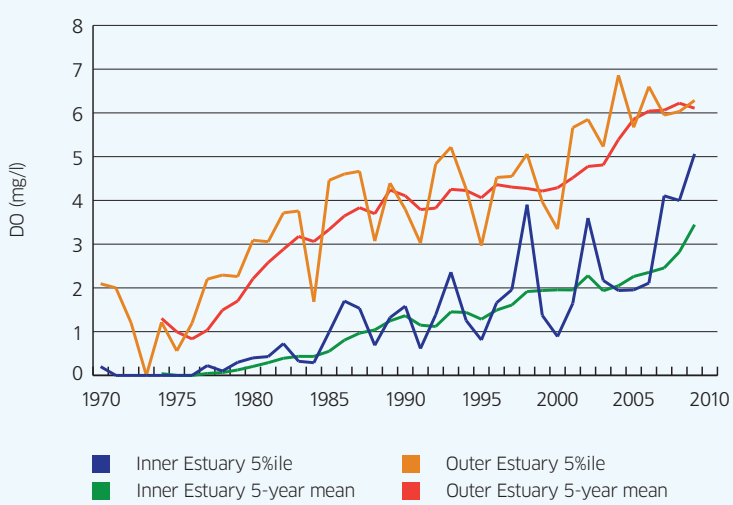
Location of waste water discharges to the Clyde estuary



Location of waste water discharges to the Forth estuary

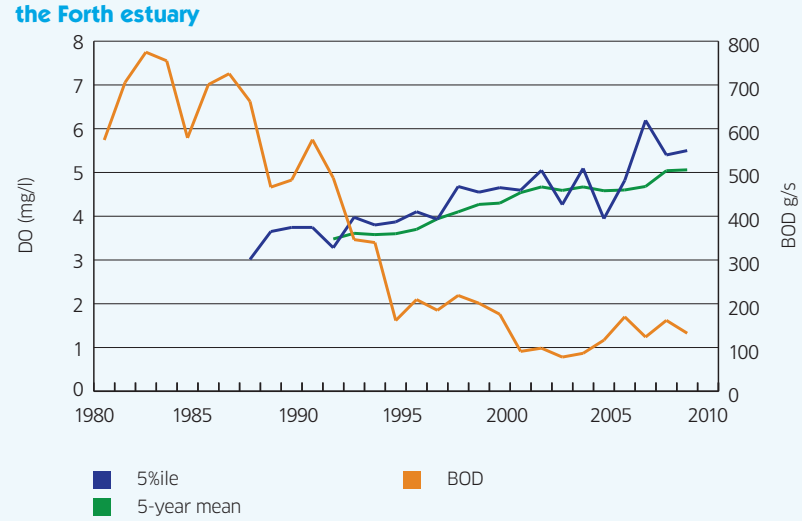


Long term trend in dissolved oxygen in the Clyde estuary



Graph showing how Dissolved Oxygen has been increasing over the years. The points correspond to the annual 5 percentile value, and the dotted line is the 5 year average.

Long term trend in dissolved oxygen and inputs of organic waste to the Forth estuary



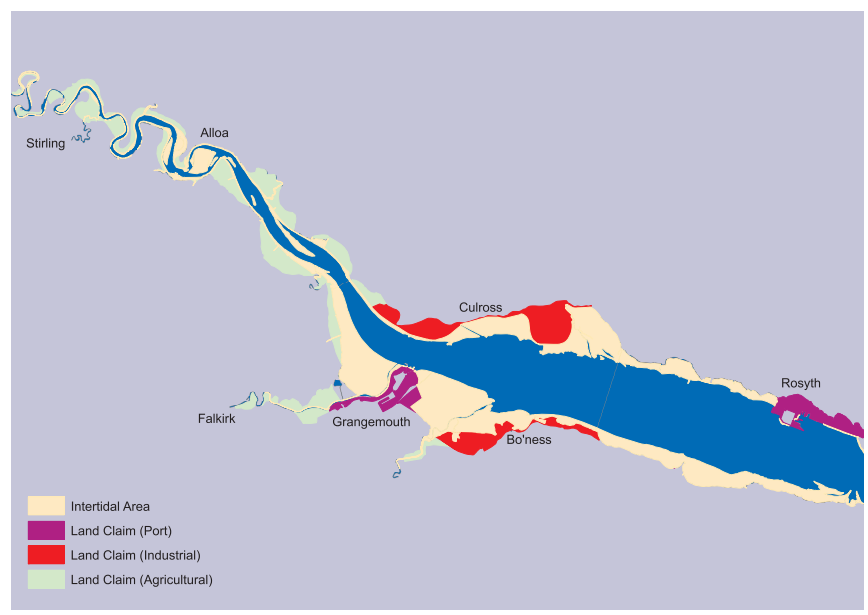
Graph showing the decrease in the discharge of organic waste (as BOD g/s) and increase in dissolved oxygen in the upper Forth estuary.

The increase in dissolved oxygen concentrations in the Forth estuary led to the reappearance of Sparling in 1989. The numbers of this oxygen sensitive species have continued to increase.

The Sparling

Source: Galloway Fisheries Trust

Land claim in the Forth estuary



Map of the Forth estuary and intertidal area claimed for agriculture (■), industry (■) and port and harbour development (■).

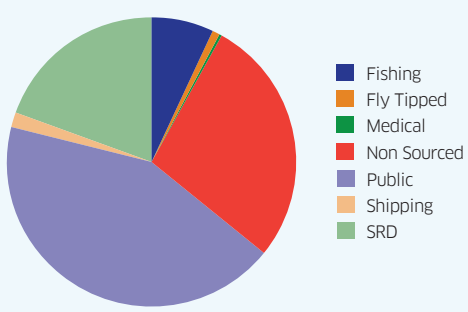
Why is marine litter a problem?

Significant quantities of marine litter appear in our seas and on our beaches. Litter is unsightly and can cause harm to marine wildlife through entanglement and ingestion, smothering of the seabed and as a platform for invasive species. The presence of sewage-related debris (SRD) also suggests that adjacent waters are contaminated by sewage, which constitutes a health risk to water users. Plastics are the main type of litter found both on beaches and offshore, including increasing quantities of microscopic pieces of plastic resulting from degradation of larger plastic products in the sea. Marine litter originates from the land, ships and carried on currents from other countries.

Litter on Scottish beaches

The density and type of litter found on beaches has been recorded on annual surveys organised by the Marine Conservation Society since 1993. The surveys take place on the third weekend of September, in line with the International Coastal Clean Up and rely on volunteers to select and survey a beach. A record 61 Scottish beaches were surveyed and cleaned during the Beachwatch Big Weekend 2009. Only a few beaches in remote areas were included.

Sources of litter on Scottish beaches



Source: MCS

Main sources of beach litter in Scotland

The main sources of beach litter in Scotland were public litter (dropped by visitors to the beach), sewage related debris (SRD), fishing litter and shipping litter. Plastic items made up the bulk of the material found, accounting for around 70% of the total litter. Every year a large percentage of litter cannot be confidently associated with a specific source. This 'non sourced litter' consists of small unidentifiable fragments or items that could have come from many different sources.

Rubbish on beach

© SEPA

How does this compare with the UK?

The proportion of sewage related debris found on Scottish beaches (19%) is higher than the UK average (5.5%) and exceptionally high numbers of cotton buds are found at beaches in the Clyde. Sewage related debris enters the water from combined sewer overflows which activate to release excess water from the sewerage network during storms. Some overflows are screened to trap this material but small items such as cotton buds can pass through these screens. Many of the overflows in the Clyde are not screened so cotton buds and other small non degradable items are carried by tidal currents to beaches where they accumulate and cause an aesthetic nuisance.

Number of cotton bud sticks found at beaches in the Clyde 2003 – 2007

Year	Erskine to Bowling	East Bay, Helensburgh
2003	10,000	353
2004	2,170	3,127
2005	5,900	5,180
2006	13,500	7,416
2007	no survey	8,525

Source: MCS

Litter on Helensburgh beach

© SEPA

'Bag It and Bin It'

Scottish Water's 'Bag It and Bin It' campaign aims to reduce sewage related debris on beaches by encouraging the public not to dispose of unsuitable items, such as cotton buds, via the sewerage network.

Main type of litter

Both beach and offshore litter surveys have shown that the majority of litter is made of plastic. Plastic litter can take hundreds, if not thousands, of years to break down, fragmenting into small pieces, and it may never truly biodegrade. The potential toxicity of degraded micro-particles of plastics is not fully understood, although it is thought that these can act as a mechanism by which toxic chemicals may enter the food chain.

Litter on shore at Arrochar

© SEPA

What do we know about seabed litter?

The Fishing for Litter scheme encourages fishermen to bring back to port litter brought up in fishing nets and gear. The litter is monitored on the quayside and then sent for proper disposal. During the project in Scotland from 2005 to 2008 15 harbours and 117 vessels took part in the scheme collecting just over 117 tonnes of litter. Plastic and polystyrene were the predominant types of litter found (KIMO 2008).

The International Convention for the Prevention of Marine Pollution from ships banned the dumping of plastic in 1989 and regulates the disposal of other waste.

Litter on shore

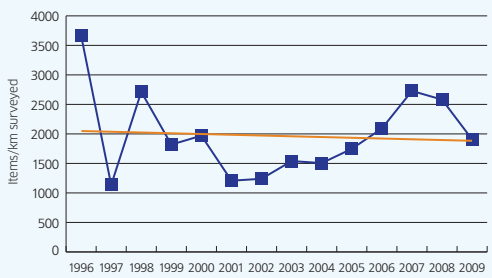
© SEPA

Reducing marine litter

The importance of tackling the problems caused by marine litter has been highlighted in the EU Marine Strategy Framework Directive (MSFD), which includes marine litter as one of eleven high level descriptors of good environmental status (GES).

All member states, including the UK, will have to put in place a programme of measures by 2016 to ensure that *'properties and quantities of marine litter do not cause harm to the coastal and marine environment'* by 2020. This will require a better understanding of the environmental impacts of marine litter, and if necessary, action will be taken to reduce the amount of litter in the marine environment.

Trends in average beach litter density in Scotland



Source: MCS

What can be done to reduce marine litter?

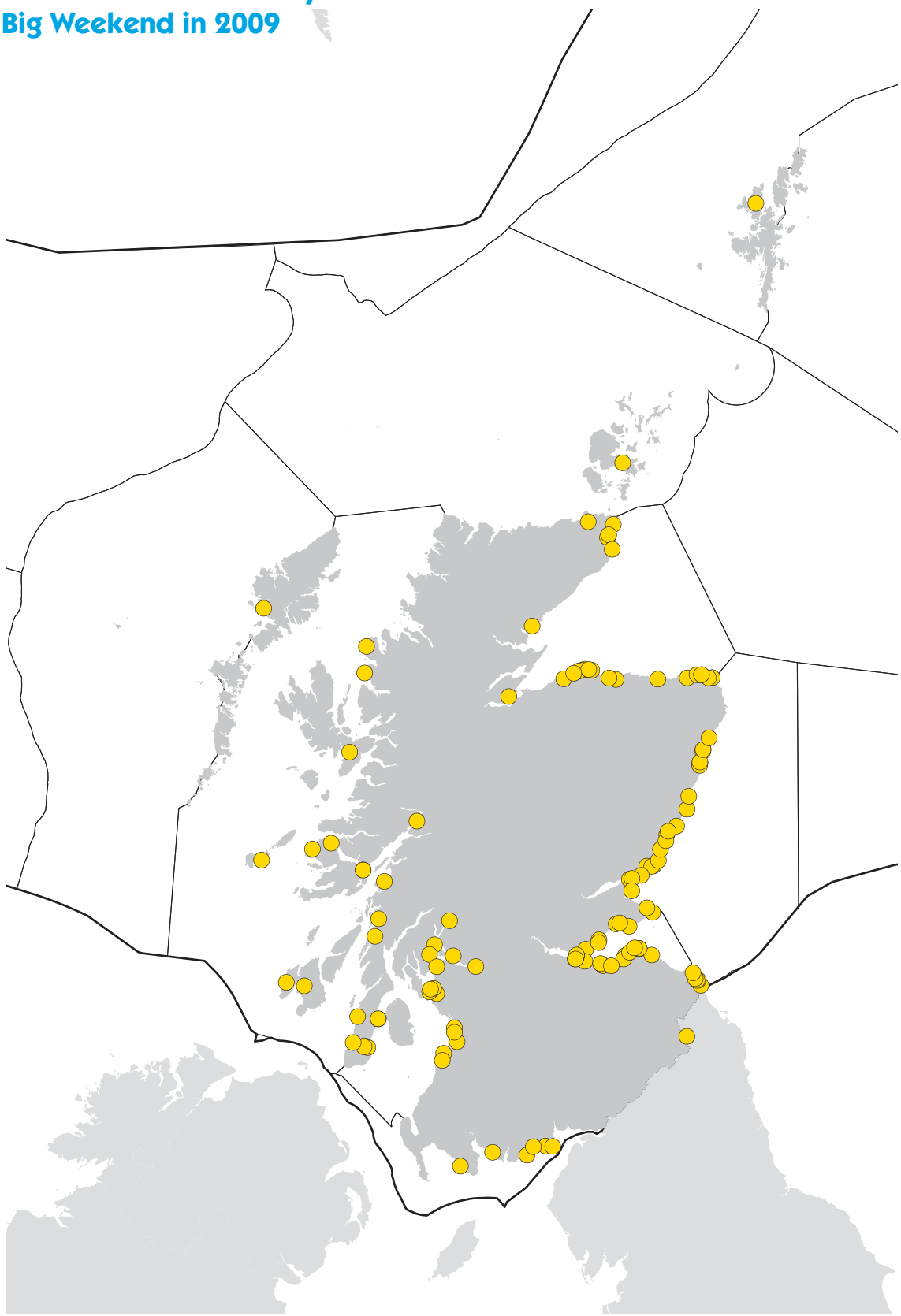
Whilst marine litter would appear to be a largely preventable issue, the wide range of sources of litter, the number of pathways by which it enters the marine environment, and the fact that litter can be easily transported by winds and currents, makes it difficult to tackle. Overall there appears to have been a slight decrease in average beach litter density recorded since 1996 but it is very variable.

At present responsibility for regulating marine litter is spread across several UK bodies e.g. Local Authorities, Scottish Government and the Maritime and Coastguard Agency. Further efforts need to be made to help all bodies or agencies responsible for litter to coordinate efforts and to enable them to fully enforce existing legislation.

- Future action needs to be focussed on achieving zero input of litter to the marine environment, i.e. stopping litter at source.
- There needs to be better education regarding the problems and effects of marine litter in schools, for the general public and for all seafarers.
- We need more data on the extent and spread of offshore litter – both floating and on the seabed.
- Action needs to be taken to reduce the problems caused by derelict and abandoned fishing gear.

The Scottish Government is developing a Marine Litter Strategy to reduce impacts of litter on our Coasts and Seas.

Scottish Beaches surveyed in the Beachwatch Big Weekend in 2009



The average litter density recorded in the 2009 Beachwatch survey in Scotland was 1,908 items/kilometre, this is higher than the UK average of 1,849 items/kilometre but a decrease of 26% from 2008 results. Average beach litter density has declined since 1996 although there is large inter annual variation.

Average litter density in Scotland compared to the UK average

Region	Public		Fishing		SRD		Shipping		Fly-tipped		Medical		Non-sourced	
Country	%	Items/km	%	Items/km	%	Items/km	%	Items/km	%	Items/km	%	Items/km	%	Items/km
Scotland	42.9	817.8	7.0	133.4	19.3	368.4	1.8	34.0	1.0	18.3	0.2	3.6	27.9	532.0
UK average	**41.5**	**767.6**	**15.1**	**279.3**	**5.5**	**100.9**	**2.0**	**37.5**	**0.9**	**16.2**	**0.2**	**3.1**	**34.9**	**644.8**

Source: MCS

CASE STUDY – SILVER IN INTERTIDAL MUSSELS

What is the source of silver in the aquatic environment?

Historically, silver entered the aquatic environment in the effluents from sewage treatment works. The main source was photographic chemicals. However, the use of photographic chemicals has decreased significantly, as a result of the increasing use of digital cameras. In recent years, recognition of the antimicrobial properties of nano-silver (extremely small particles of silver) has led to an increase in the use of silver in nano-particles added to clothes during their manufacture to prevent bacterial activity on the surface.

Why is silver of concern in the environment?

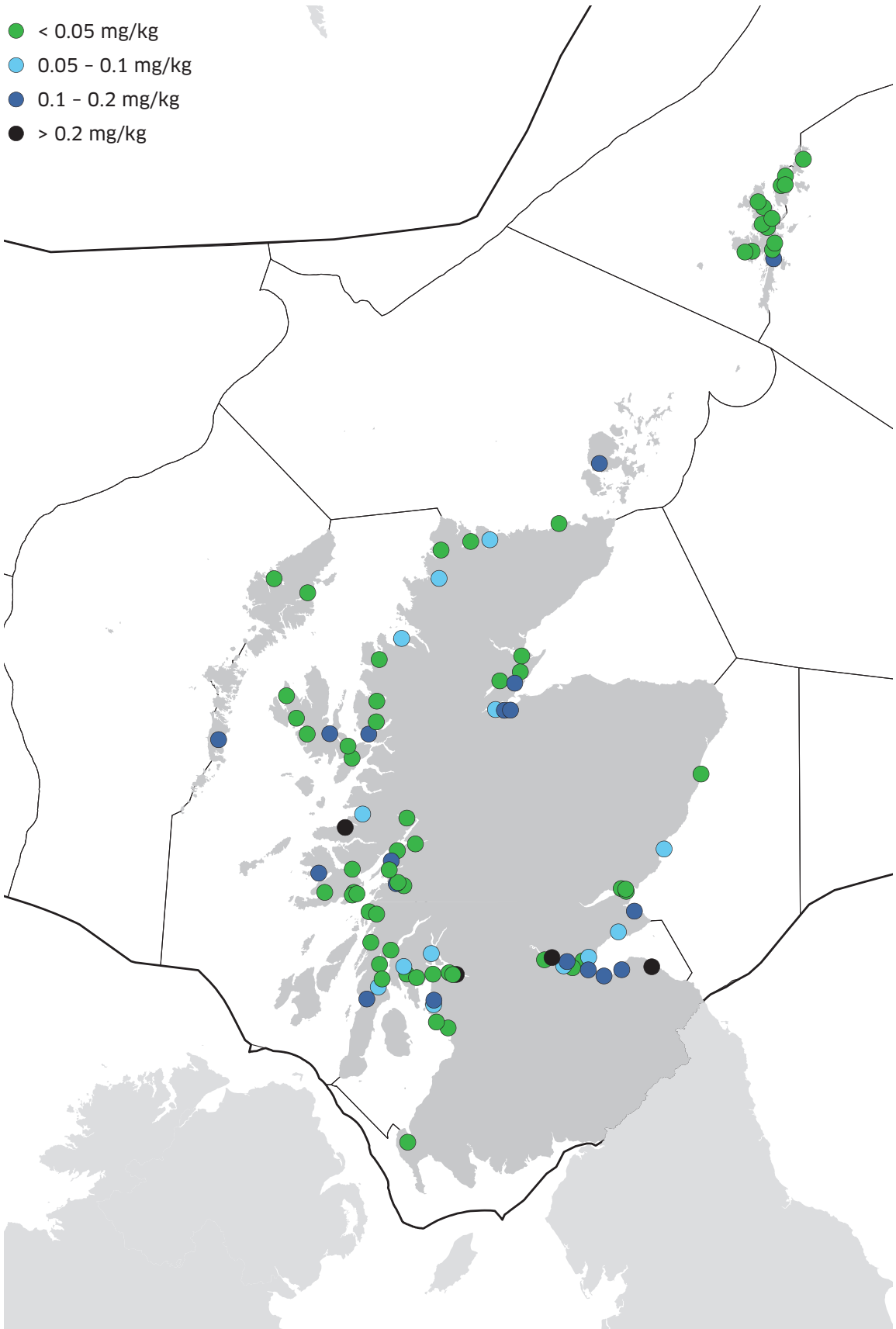
Silver is classed as an environmental hazard because it is toxic, persistent and it accumulates within animals. The release of silver from photographic processing led to evidence of adverse ecological effects. Recent studies suggest that nano-silver may be more toxic than inorganic silver (i.e. silver that is not incorporated within biologically-generated material, Gaiser *et al* 2009[5]), and studies have confirmed that these particles can be taken up by mussels (Luoma, 2008[6]). Silver nanoparticles have been found to cause DNA damage and chromosome aberrations in human cell cultures (Ashern Remi *et al*, 2009[7]).

Concentration of silver in the marine environment

Silver was measured in intertidal mussels from a range of sites around Scotland. There is currently insufficient data to assess the ecological significance of measured concentrations in mussels so the data have been split into quartiles to allow spatial comparison. Overall the concentration of silver in mussels is lowest in less densely populated areas and highest in industrialised estuaries. However, relatively high concentrations are measured in mussels collected close to sewage treatment works in less populated areas, suggesting that the presence of the metal in mussels is associated with these point source discharges.

Clothes containing silver

2009 Silver in Intertidal mussels



What the evidence indicates

Given the decline in the use of silver in photography, the detection of elevated silver concentrations in mussels collected close to sewage discharges is probably caused by the increasing use of nano-silver as an antibacterial agent in clothes. Nano-silver is leached from clothes during washing and hence released to the marine environment via waste water discharges. Once in the marine environment the particles are taken up and retained by filter-feeding organisms such as mussels.

What further evidence is needed?

Further information is needed on sources and the effects of silver on organisms in the marine environment in order to consider whether controls need to be established.

Why is underwater noise a problem for marine life?

For most marine mammals, many marine fish, and perhaps some shellfish sound is important for communication, locating mates, searching for prey, avoiding predators and hazards, and for short- and long-range navigation. Noise at inappropriate volume and frequency can mask biologically relevant signals; it can lead to a variety of behavioural reactions; and, at very high levels, hearing organs can be adversely affected and, in extreme circumstance, sound can injure or even kill marine life. The total amount of man-made sound has been increasing globally and is likely to go on increasing in Scottish waters in association with increasing offshore industrial activity. Sound produced at low frequencies could have effects well beyond Scottish waters.

Sources of underwater noise

Sound sources of primary concern are explosions, shipping, seismic surveys, offshore construction and offshore industrial activities and sonars of various types, including military sonar, which has previously been implicated in deaths of beaked whales. The cumulative effects of many different sound sources are difficult to predict but are likely to be a challenge to some marine wildlife.

Impacts of underwater noise

There is currently not enough evidence to provide a quantitative assessment of underwater noise in UK waters, but increasing activity in constructing, for example, offshore wind farms, is likely to have raised local noise levels while the developments were underway. Other types of renewable energy systems can also add significantly to the level of man-made sound. The management of subsurface noise emitted from shipping is currently the subject of international debate within the International Maritime Organization and further guidance on this issue is expected in the future.

There is a need to develop effective systems for monitoring noise, and this needs to be accompanied by studies that quantify the related risks to the marine environment.

Variations in underwater noise

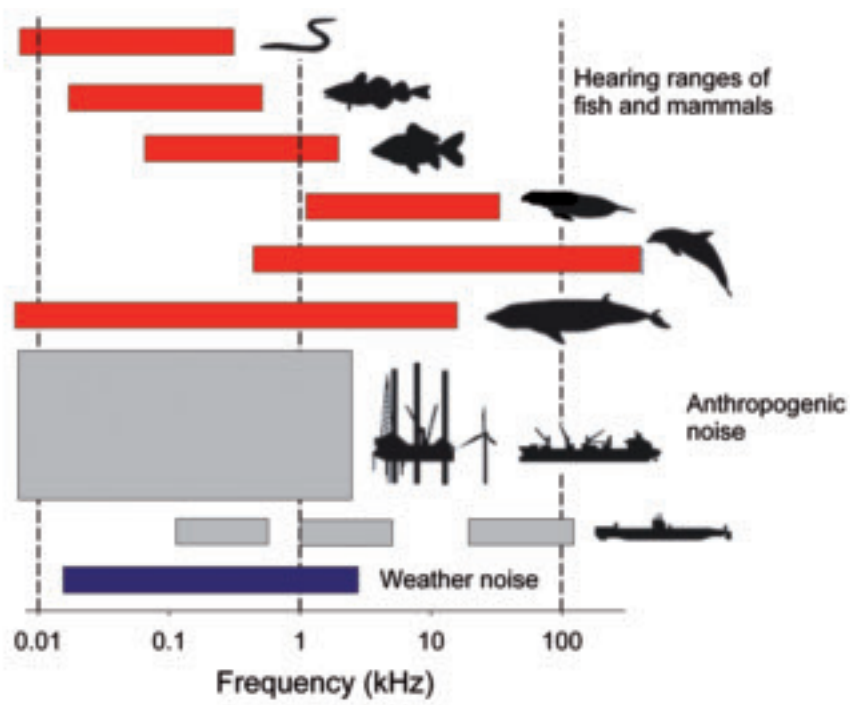
The range of frequencies of underwater noise that can be heard by fish and marine mammals and the overlap with the frequency of underwater sound produced by different types of man-made sound sources and weather, including wave and wind noise, are shown in the diagram.

Sources and impacts of underwater noise

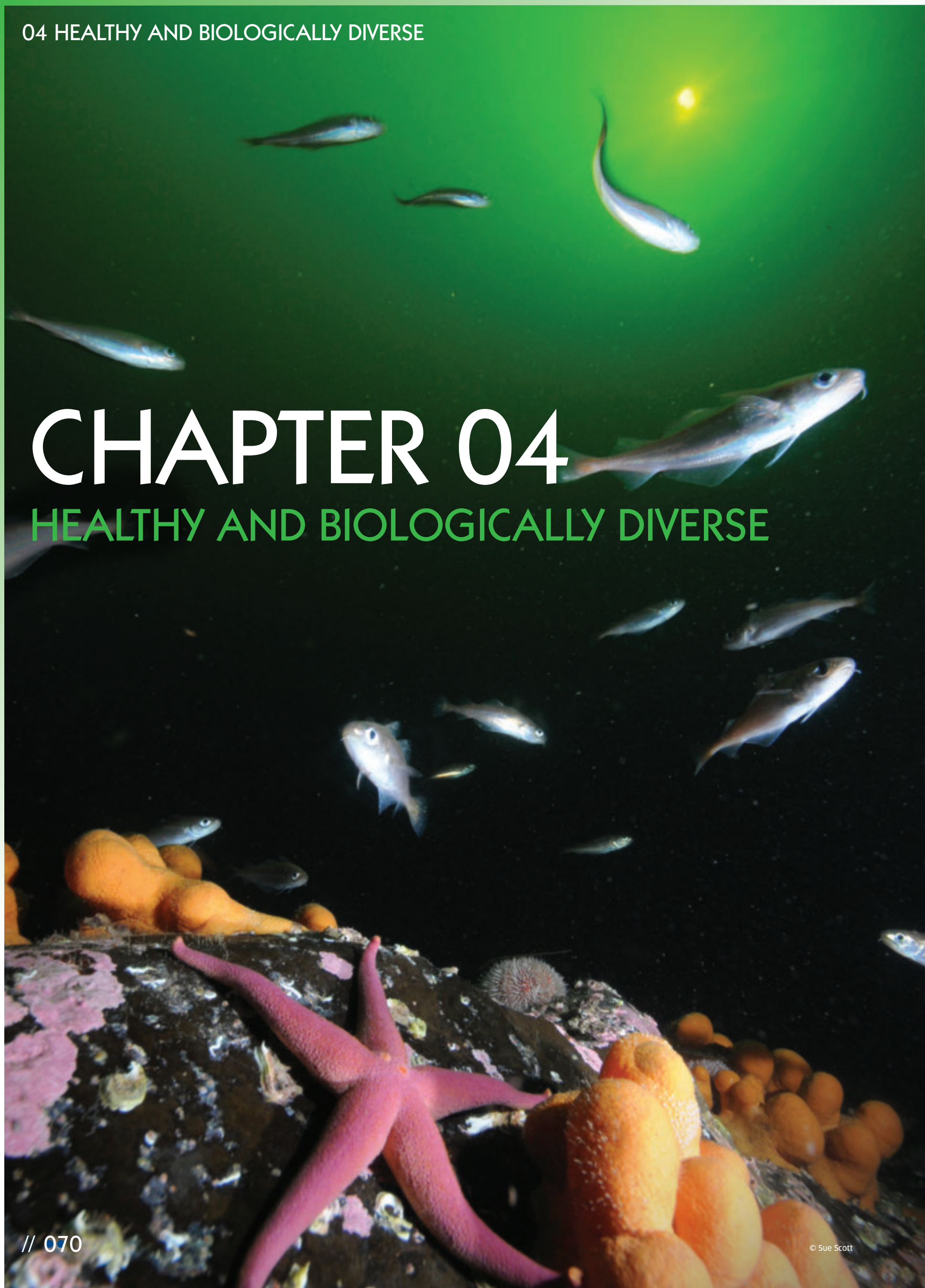
Source	Effects of greatest concern
Vessels	Masking Habitat displacement
Air guns	Masking Physical trauma Hearing loss Behavioural change Habitat displacement Behaviourally-mediated effects
Intense low-or mid-frequency sonar	Physical trauma Hearing loss Behavioural change Behaviourally-mediated effects
Pile driving	Physical trauma Hearing loss Behavioural change Behaviourally-mediated effects
Other sonars (depth sounders, fish finders)	Masking Hearing loss Behavioural change Behaviourally-mediated effects
Dredges	Behavioural change Behaviourally-mediated effects Habitat displacement
Drills	Hearing loss Behavioural change Behaviourally-mediated effects
Bottom towed fishing gear	Behavioural change Behaviourally-mediated effects Habitat displacement
Explosions	Physical trauma Hearing loss Behavioural change Behaviourally-mediated effects
Recreational vessels	Masking Behavioural change Behaviourally-mediated effects
Acoustic deterrents	Behaviourally-mediated effects
Over flying aircraft (including sonic booms)	Behaviourally-mediated effects

Source: SMRU

Range of frequencies of underwater noise



Source: Modified from Slabbekoorn *et al* (2010)[8]



CHAPTER 04

HEALTHY AND BIOLOGICALLY DIVERSE

© Sue Scott

Introduction

The Healthy and Biologically Diverse Seas chapter describes the range of habitat types and key species groups, their distribution and characteristics in Scotland's seas. It is intended to inform the national marine plan and is the basis upon which more detailed descriptions can be made at different scales. It will also serve to highlight key knowledge gaps and help focus and prioritise the deployment of future resources.

Scotland's seas are positioned between subpolar and subtropical influences and support a spectacular and diverse assemblage of habitats and species. There remains much to be discovered about the marine wildlife of Scotland but current best estimates suggest there are around 6,500 species of animals and plants (excluding the microbial flora) in Scotland's seas.[1]

An introductory section reviews the current status of nature conservation protection around the coast and in the sea. There are also sections that outline the scale of non-native invasions and those species that are considered only occasional visitors to Scotland's seas but which might be good indicators of changing conditions.

The majority of sections describe the key habitat types and species and highlight a range of Priority Marine Features. These are species and habitats that have been identified through a scientific evaluation of Scotland's marine biodiversity[2] and the list is being finalised by SNH and JNCC. The Priority Marine Features represent species and habitats of marine conservation importance for which it would be appropriate to use both area based and non-area based mechanisms to achieve better protection, and for which action will be prioritised via a three-pillar approach, i.e. species measures, site-based measures, and wider seas policies and measures as set out in Marine Scotland's Marine Nature Conservation Strategy.

Furthermore a second list of Marine Protected Area (MPA) search features has been compiled. These mostly comprise the Priority Marine Features for which it is considered MPAs are an appropriate conservation measure. The full methodology to be adopted for the selection of MPAs and the development of the MPA network are set out in *Marine Protected Areas in Scotland's Seas – Guidelines on the selection of MPAs and development of the MPA network* (Marine Scotland, 2011)[3].

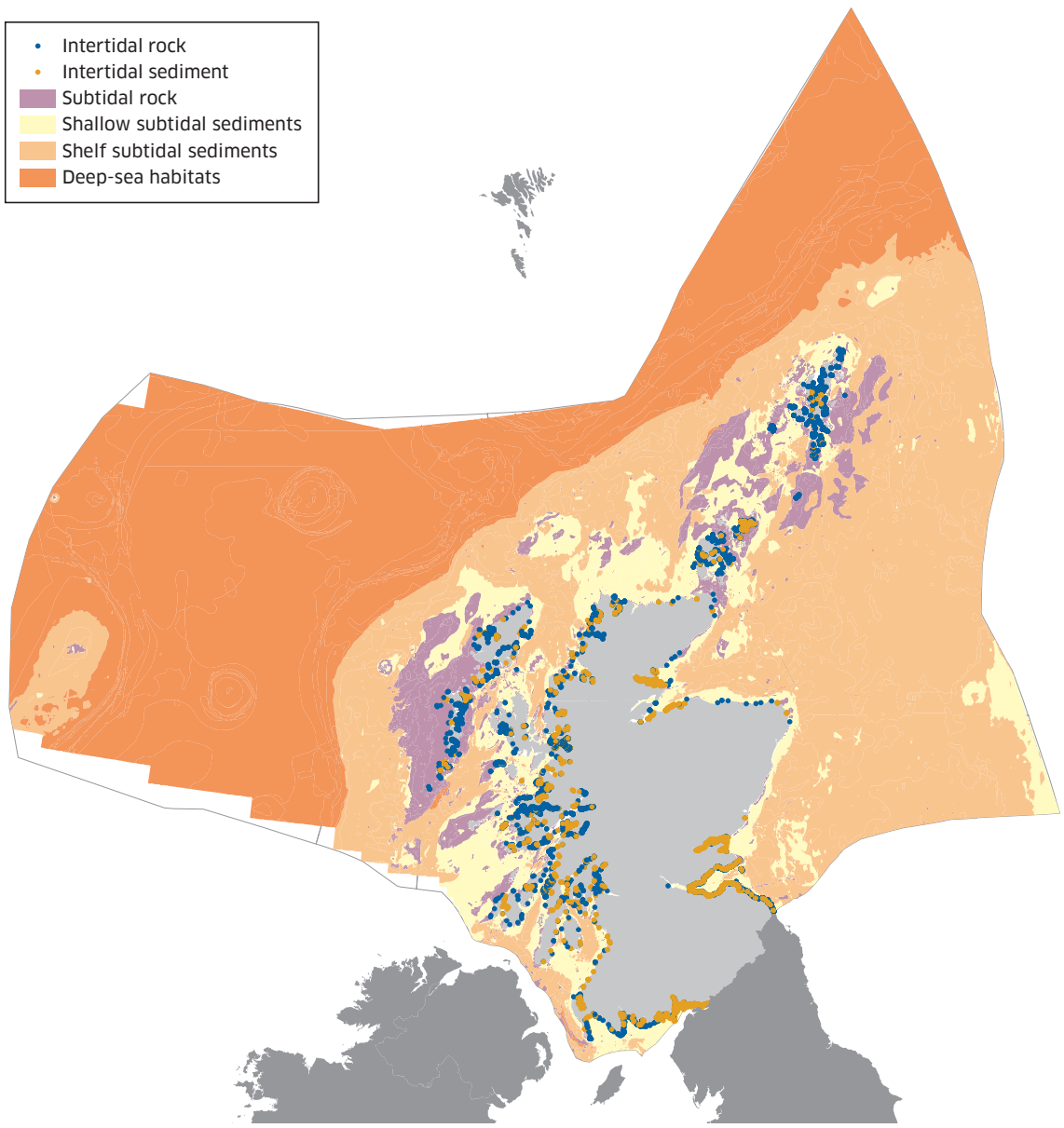
Information sources

The descriptions of the Priority Marine Features and the pressures they are facing are derived from a report prepared for SNH, *Descriptions of Priority Marine Features in the seas around Scotland*[4], based on MarLIN (Marine Life Information Network), FishBase, AlgaeBase and other specialist sources. The information on species distributions was derived from a range of sources including MarLIN, JNCC and Agency databases, NBN, OSPAR, the Shark Trust, etc.. Additional information on the distribution of fish species was obtained from Marine Scotland-Science, ICES, Defra, SEPA and NASCO. Seal numbers and distribution data were provided by the Sea Mammal Research Unit at St Andrews University. The seabird data are derived from the Seabird Monitoring programme which is led and coordinated by the JNCC in partnership with others whilst the waterbird data are from the Wetland Birds Survey. The maps of the distribution of the broad habitat types were produced by JNCC and are based on a combination of survey data and modelling. The maps showing the distribution of the individual Priority Marine Features are based on a number of datasets:

- SNH Marine Nature Conservation Review dataset
- SNH Marine Recorded database of additional surveys
- JNCC/NBN Marine Recorded database
- MESH data layers
- Defra MPA layers project (MB0102)
- DASSH (Archive of Marine Species and Habitats Data) data holdings.

Additional data on certain species such as sharks and rays were provided by the Shark Trust.

Modelled distribution of broad habitats



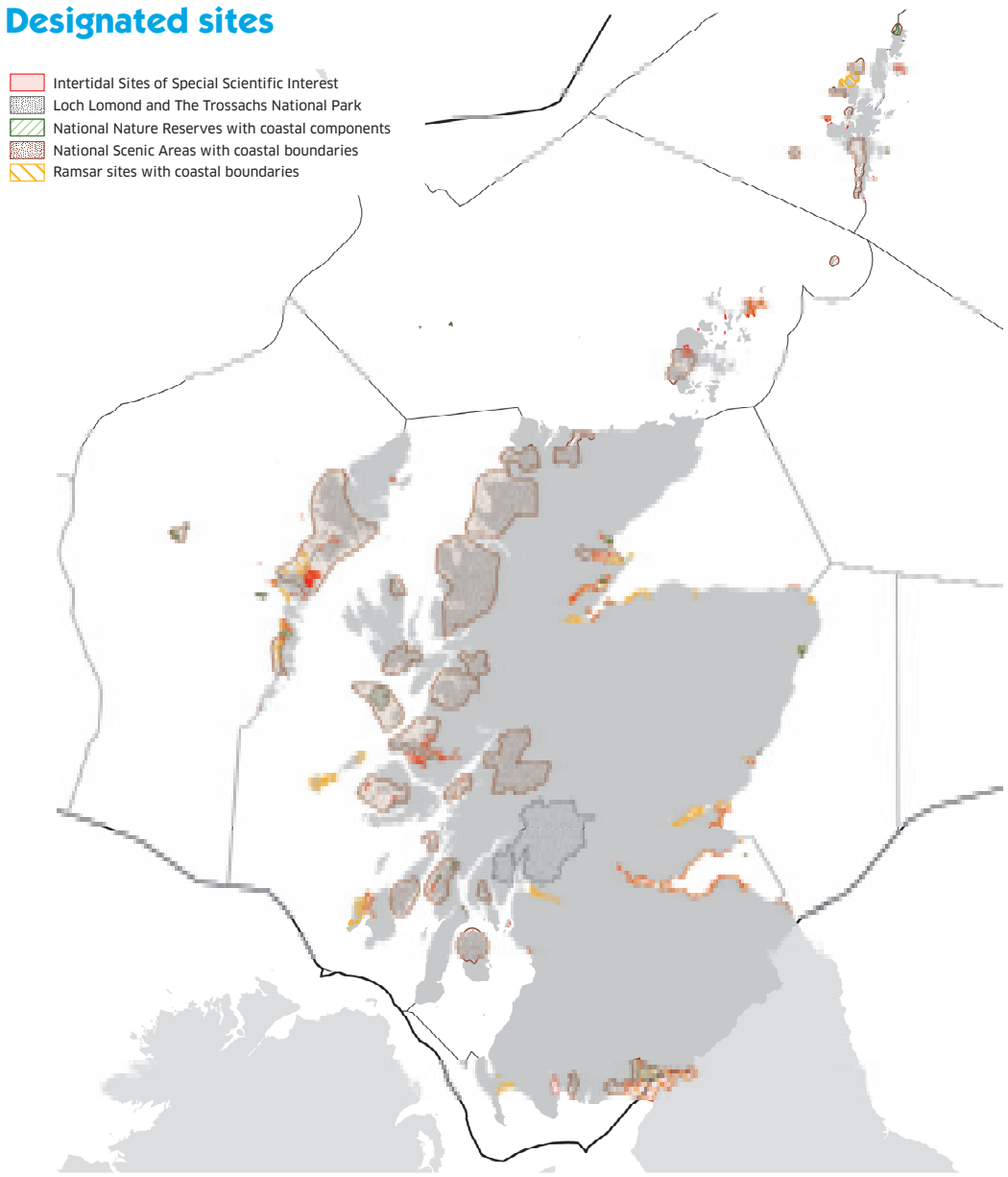
PROTECTED AREAS

Protected Areas

Protection of the marine environment is considered of the highest priority, as reflected by the general duty under the Marine (Scotland) Act 2010, *'to act in the way best calculated to further the achievement of sustainable development including the protection and, where appropriate, enhancement of the health of that area, so far as is consistent with the proper execution of that function'.*

The Wildlife and Countryside Act 1981 as amended by the Nature Conservation (Scotland) Act 2004 provided the mechanism for the designation of Sites of Special Scientific Interest (SSSI), but these powers only extend down to the limit of mean low water spring tide. At present there are 56 SSSI in Scotland which contain some intertidal and seal features of interest. In addition there are a number of other designations that apply to coastal areas, such as National Parks, National Nature Reserves and National Scenic Areas.

Designated sites



Site of Special Scientific Interest	Intertidal and Seal Features
Ballochmartin Bay	Sand flat
Balranald Bog and Loch nam Feithean	Mudflat
Berwickshire Coast (Intertidal)	Reefs Sea caves
Bogside Flats	Mudflat
Bridgend Flats	Sand flat
Cree Estuary	Mudflat
Cromarty Firth	Mudflat Sand flat Saline lagoon
Dornoch Firth	Eelgrass bed
East Sanday Coast	Reef Mudflat Sand flat Harbour seal
Eden Estuary	Mudflat
Eynhallow	Harbour seal
Faray and Holm of Faray	Grey seal
Firth of Forth	Saline lagoon
Gribun Shore and Crags	Mudflat Saline lagoon
Gruinart Flats	Mudflat
Howmore Estuary, Lochs Roag and Fada	Saline lagoon
Isle of May	Grey seal
Kames Bay	Sand flat

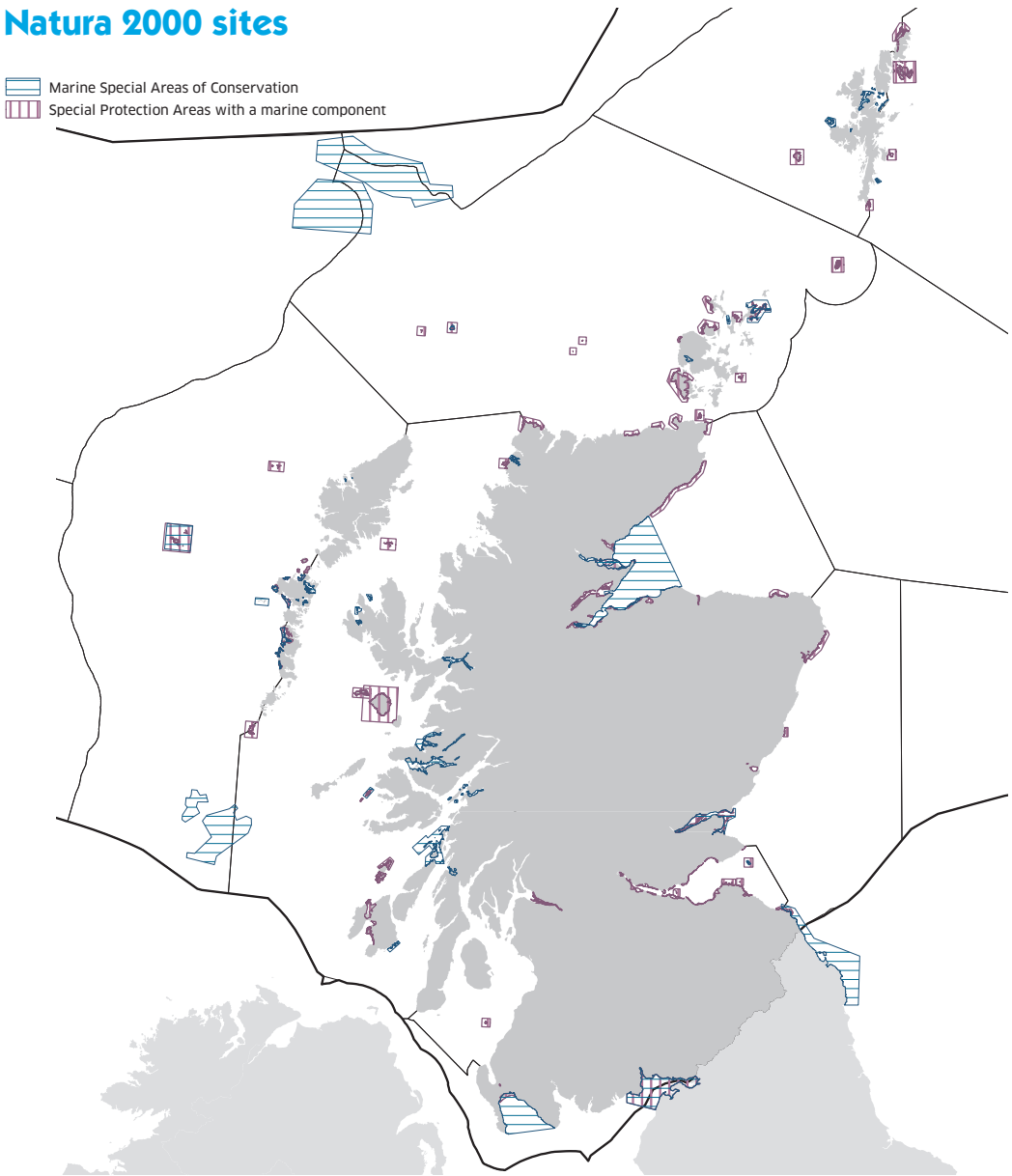
Site of Special Scientific Interest	Intertidal and Seal Features
Kentra Bay and Moss	Mudflat
Loch an Duin	Tidal rapids Saline lagoon
Loch Bee	Saline lagoon
Loch Fleet	Eelgrass bed Sand flat
Loch Moidart	Mudflat
Loch nam Madadh	Reefs Mudflat Tidal rapids Saline lagoon
Loch Obisary	Saline lagoon
Loch Siadar	Tidal rapids Saline lagoon
Lochs at Clachan	Saline lagoon
Lochs of Harray and Stenness	Saline lagoon
Longman and Castle Stuart Bays	Eelgrass bed Mudflat
Luskentyre Banks and Saltings	Sand flat
Lynn of Lorn Small Islands	Common seal
Montrose Basin	Mudflat
Mound Alderwoods	Saline lagoon
Mousa	Common seal
Muckle and Little Green Holm	Grey seal
Munlochy Bay	Mudflat
North Fetlar	Grey seal Harbour seal

Site of Special Scientific Interest	Intertidal and Seal Features
North Rona and Sula Sgeir	Grey seal
Northton Bay	Saline lagoon Sand flat
Obain Loch Euphoirt	Saline lagoon
Oronsay and South Colonsay	Grey seal
Papa Stour	Reefs
Pool of Virkie	Mudflat
Rosehearty to Fraserburgh Coast	Mudflat
Sandness Coast	Reefs
Small Seal Islands	Grey seal
Sunart	Reefs Eelgrass bed
Taynish Woods	Reefs Tidal rapids
Tayport – Tentsmuir Coast	Mudflat Harbour seal
The Vadills	Tidal rapids Saline lagoon
Tob Valasay	Tidal rapids Saline lagoon
Tong Saltings	Mudflat
Treshnish Isles	Grey seal
Ulva, Danna and the McCormaig Isles	Mudflat Tidal rapids Saline lagoon
Upper Solway Flats and Marshes	Mudflat
Whiteness Head	Mudflat

Natura 2000 sites, Special Protection Areas (SPA) and Special Areas of Conservation (SAC) designated respectively under two European directives, Directive 79/409/EEC (otherwise known as the Birds Directive) and Council Directive 92/43/EEC (otherwise known as the Habitats Directive) represent some of the very best of Scotland's marine natural heritage.

The Birds Directive provides member states with the responsibility to classify Special Protection Areas to protect birds which are rare, or vulnerable, in Europe as well as all migratory birds which are regular visitors. There are currently 58 SPA in Scotland with marine/coastal components, and of these, 31 of the seabird breeding colony SPA have recently had their boundaries extended by either 1.2 or 4.0km into the adjacent marine environment (marked with an * in the table below). At present there are no entirely marine SPA in Scotland although work is underway to identify areas important for inshore aggregations of non-breeding waterbirds and for offshore aggregations of seabirds. (see jncc website jncc/gov.uk/pdf/SPA_AOS_Maps%2020100304.pdf)

Natura 2000 sites



Special Protection Areas which are within or have links to the marine environment

The SPAs listed in the table comprise:

1. Sites which support true seabirds i.e. truly marine birds – auks, gulls, terns, petrels, gannets, etc. 2. Sites which support species which, at times, use maritime habitats. 3. Sites which include maritime habitats which are sometimes used by terrestrial species. 'Waterfowl' is used to include seaduck, waders and divers. 'Seabirds' is used to refer to the 24 species of seabirds listed in the Seabirds Section and Mitchell *et al.* (2004).[1]

Special Protection Areas	Summary interests
Ailsa Craig *	seabirds
Auskerry	seabirds
Buchan Ness to Collieston *	seabirds
Caithness and Sutherland Peatlands	waterfowl
Calf of Eday *	seabirds
Canna & Sanday *	seabirds
Cape Wrath *	seabirds
Copinsay *	seabirds
Cromarty Firth	waterfowl, seabirds
Dornoch Firth & Loch Fleet	waterfowl, seabirds
East Caithness Cliffs *	seabirds
East Sanday Coast	waterfowl
Fair Isle *	seabirds
Fetlar *	seabirds
Firth of Forth	waterfowl
Firth of Tay & Eden Estuary	seabirds, waterfowl
Flannan Isles *	seabirds
Forth Islands *	seabirds
Foula *	seabirds, waterfowl
Fowlsheugh *	seabirds
Glas Eileanan	seabirds
Gruinard Flats	waterfowl
Handa *	seabirds

Special Protection Areas	Summary interests
Hermaness, Saxa Vord & Vallafield *	seabirds, waterfowl
Hoy *	seabirds, waterfowl
Imperial Dock Lock	seabirds
Inner Clyde	waders
Inner Moray Firth	waterfowl, seabirds
Lewis Peatlands	waterfowl
Loch of Strathbeg	waterfowl, seabirds
Marwick Head *	seabirds
Mingulay & Berneray *	seabirds
Mointeach Scadabhaigh	waterfowl
Monach Islands	seabirds
Montrose Basin	waterfowl
Moray & Nairn Coast	waterfowl
Mousa	seabirds
North Caithness Cliffs *	seabirds
North Colonsay & Western Cliffs *	seabirds
North Rona and Sula Sgeir *	seabirds
North Uist Machair & Islands	waterfowl
Noss *	seabirds
Orkney Mainland Moors	waterfowl
Otterswick and Graveland	waterfowl
Papa Stour	seabirds

Special Protection Areas	Summary interests
Papa Westray	seabirds
Pentland Firth Islands	seabirds
Priest Island	seabirds
Ramna Stacks & Gruney	seabirds
Ronas Hill – North Roe & Tingon	waterfowl, seabirds
Rousay *	seabirds
Rum *	waterfowl, seabirds
Shiant Isles *	seabirds
Sleibhtean agus Cladach Thiriodh (Tiree Wetlands and Coast)	waterfowl
South Uist Machair & Lochs	waterfowl, seabirds
St Abb's Head to Fast Castle *	seabirds
St Kilda *	seabirds
Sule Skerry & Sule Stack *	seabirds
Sumburgh Head *	seabirds
Treshnish Isles	seabirds
Troup, Pennan & Lion's Heads *	seabirds
Upper Solway Flats & Marshes	waterfowl
West Westray *	seabirds
Ythan Estuary, Sands of Forvie & Meikle Lochs	waterfowl, seabirds

[1] Seabird Populations of Britain and Ireland: Results of the 'Seabird 2000' Census 1999-2002.

04 HEALTHY AND BIOLOGICALLY DIVERSE PROTECTED AREAS

The Scottish Government is committed to establishing a well managed, ecologically coherent network of Marine Protected Areas through OSPAR for a number of marine habitats and species considered to be under threat or in decline, as well as others that are representative of Scotland's marine environment.

Scotland has international commitments to establish an ecologically coherent network of Marine Protected Areas (MPAs) by the end of 2012. Existing protected areas (SACs, SPAs, SSSIs and Ramsar sites) will make a significant contribution to the network but are limited in their ability to recognise features of national importance in the marine environment. There is considerable overlap between the OSPAR list of threatened and/or declining species and the list of Marine Protected Area search features which have been identified to help underpin the development of the MPA network in Scotland's seas.

The Marine (Scotland) Act 2010 and the UK Marine and Coastal Access Act 2009 both include powers to designate Marine Protected Areas (MPAs) in the seas around Scotland to enable the network to be completed.

Under the Marine (Scotland) Act 2010 there are three different types of MPAs that can be designated in territorial waters:

- Nature Conservation MPAs
- Demonstration and Research MPAs
- Historic MPAs.

Species	OSPAR Feature	MPA search feature
Arachnanthus sarsi		✓
Leptometra celtica		✓
Atrina pectinata		✓
Glossus humanus		✓
Arctica islandica	✓	✓
Nucella lapillus	✓	
Ostrea edulis	✓	
Palinurus elephas		✓
Rissa tridactyla	✓	
Sterna dougalii	✓	
Cepphus grylle		✓
Alosa alosa	✓	
Anguilla anguilla	✓	
Centroscymus coelolepis	✓	
Centrophorus squamosus	✓	
Cetorhinus maximus	✓	✓
Dipturus batis	✓	✓
Raja montagui	✓	
Gadus morhua	✓	
Hoplostethus atlanticus	✓	✓
Lamna nasus	✓	
Raja clavata	✓	
Molva dypterygia		✓
Ammodytes spp.		✓
Salmo salar	✓	
Squalus acanthias	✓	
Squatina squatina	✓	
Caretta caretta	✓	
Dermochelys coriacea	✓	
Balaenoptera musculus	✓	
Eubalaena glacialis	✓	
Phocoena phocoena	✓	
Balaenoptera acutorostrata	✓	
Grampus griseus	✓	
Lagenorhynchus albirostris	✓	

Habitats	OSPAR Feature	MPA search feature
Coral gardens	✓	✓
Deep sea sponge aggregations	✓	✓
Blue mussel beds	✓	✓
Intertidal mudflats	✓	
Cold water coral reefs	✓	
Maerl beds	✓	✓
Maerl or coarse shell gravel with burrowing sea cucumbers		✓
Horse mussel beds	✓	✓
Native oysters	✓	✓
Sabellaria spinulosa reefs	✓	
Seamount communities	✓	✓
Sea pen and burrowing megafauna communities	✓	✓
Seagrass beds	✓	✓
Carbonate mound communities		✓
Flame shell beds		✓
Inshore deep mud with burrowing heart urchins		✓
Kelp and seaweed communities on sublittoral sediment		✓
Low or variable salinity habitats		✓
Northern sea fan and sponge communities		✓
Offshore deep sea muds		✓
Offshore subtidal sands and gravel		✓
Sea loch egg wrack beds		✓
Serpulid aggregations		
Shallow tide-swept coarse sands and burrowing bivalves		✓
Shelf banks and mounds		✓
Shelf deeps		✓
Shelf fronts		✓
Tide-swept algal communities		✓

Following the Ministerial Statement on MPAs in March 2010, the Scottish MPA Project was established with the aim of providing advice to Scottish Ministers on the selection of MPAs and development of the MPA network. Identification of MPAs will be carried out by the end of 2012. The Scottish MPA Selection Guidelines set out the selection process and highlight the opportunities for stakeholders to become involved. There will be one network in the seas around Scotland which will contribute towards UK, North-East Atlantic and global networks.

See the Selection Guidelines at www.scotland.gov.uk/marinescotland/mpaguidelines

Summary of condition of marine habitats and species on designated sites in Scotland (as at January 2011)

Feature	Number of features	Number of features assessed	Favourable	Unfavourable recovering	Unfavourable
Habitats	129	96	94	1	1
Mammals	50	49	42	2	5
Species	4	3	3	0	0
Seabirds	470	464	261	12	191
Waterfowl	250	248	208	0	40

Hoy coast

© John M Baxter

Eden Estuary

© John M Baxter

The Habitats Directive is a major contribution by the European Community to implementing the Biodiversity Convention agreed in Rio in 1992. Special Areas of Conservation (SACs) are designated for particular habitats and species which are listed in annexes to the directive. There are eight habitat types and four species listed on Annexes I and II respectively for which there are marine SACs designated in Scotland. Some sites contain more than one feature. There are currently 34 marine SACs covering ~4% of the total area of territorial waters within 12nm. There are also six offshore SACs that have either been designated or proposed.

Isle of May

© P&A Macdonald/SNH

Loch of Stenness

© John M Baxter

Special Areas of Conservation	Interest Features
Ascrib, Isay and Dunvegan	Harbour seals
Berwickshire and North Northumberland coast	Mudflats and sandflats not covered by seawater at low tide Large shallow inlets and bays Reefs Submerged or partially submerged sea caves Grey seals
Braemar Pockmarks	**Submarine structures made by leaking gases**
Darwin Mounds	**Reefs**
Dornoch Firth and Morrich More	Estuary Mudflats and sandflats not covered by seawater at low tide Sandbanks which are slightly covered by seawater all the time Reefs Harbour seals Otters*
Eileanan agus Sgeiran Lios mor	Harbour seals
Faray and Holm of Faray	Grey seals
Firth of Lorn	Reefs
Firth of Tay and Eden estuary	Estuary Reefs Mudflats and sandflats not covered by seawater at low tide Harbour seals
Isle of May	Reefs Grey seals
Loch Creran	Reefs
Lochs Duich, Long and Alsh	Reefs
Loch Laxford	Large shallow inlets and bays Reefs
Loch Moidart and Loch Shiel Woods	Mudflats and sandflats not covered by seawater at low tide
Loch nam Madadh	Large shallow inlets and bays Lagoons Reefs Mudflats and sandflats not covered by seawater at low tide Sandbanks which are slightly covered by seawater all the time Otters*
Loch of Stenness	Lagoons
Loch Roag Lagoons	Lagoons
Luce Bay and Sands	Large shallow inlets and bays Mudflats and sandflats not covered by seawater at low tide
Moine Mhor	Mudflats and sandflats not covered by seawater at low tide
Monach Isles	Grey seals

Special Areas of Conservation	Interest Features
Moray Firth	Sandbanks which are slightly covered by seawater all the time Bottlenose dolphins
Mousa	Reefs Submerged or partially submerged sea caves Harbour seals
North Rona	Reefs Submerged or partially submerged sea caves Grey seals
North West Rockall Bank	**Reefs**
Obain Loch Euphoirt	Lagoons
Papa Stour	Reefs Submerged or partially submerged sea caves
St Kilda	Reefs Submerged or partially submerged sea caves
Sanday	Reefs Submerged or partially submerged sea caves Sandbanks which are slightly covered by seawater all the time Mudflats and sandflats not covered by seawater at low tide Harbour seals
Scanner Pockmark	**Submarine structures made by leaking gases**
Solway Firth	Sandbanks which are slightly covered by seawater all the time Estuary Mudflats and sandflats not covered by seawater at low tide Reefs
Sound of Arisaig	Sandbanks which are slightly covered by seawater all the time
South-east Islay Skerries	Harbour seals
South Uist Machair	Lagoons
Stanton Banks	**Reefs**
Sullom Voe	Reefs Lagoons Large shallow inlets and bays
Sunart	Reefs Otters
The Vadills	Lagoons
Treshnish Islands	Reefs Grey seals
Wyville Thomson Ridge	**Reefs**
Yell Sound Coast	Harbour seals Otters*

* There are further SACs identified for otters but these are entirely terrestrial and freshwater sites and have no marine component.

Offshore SACs

INTERTIDAL ROCK

Intertidal rock

Rocky intertidal represents around 48% of the total Scottish coast. This includes habitats of bedrock, boulders and cobbles and is affected by numerous physical variables including wave exposure, salinity, temperature and tides. Wave exposure is most commonly used to characterise intertidal rocky communities. This ranges from extremely exposed as found on some of the remote islands such as Rockall and St Kilda and the Atlantic facing coasts of the Western and Northern Isles as well as parts of the mainland, to extremely sheltered, typical of the upper reaches of many of the west coast sea lochs and Shetland voes. Large stretches of the west coast and Northern Isles are predominantly rocky whereas on the east coast it is much more patchy and interspersed by large stretches of sandy and muddy coastline.

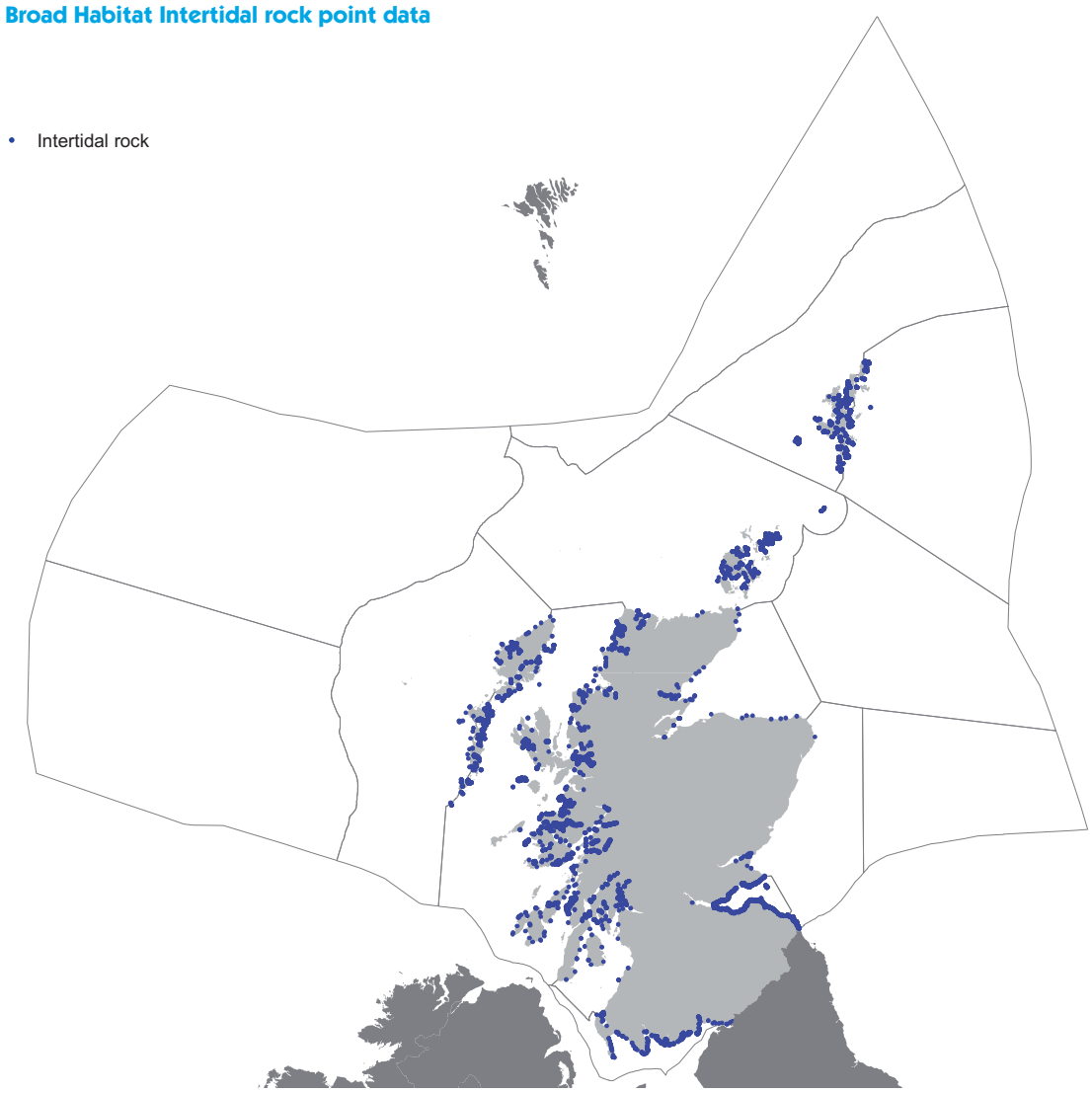
On many rocky shores there is a distinct vertical zonation pattern caused by a small number of dominant species of algae and encrusting animals that cover broad bands determined by their tolerance to the length of time they are exposed at low tide. This distinct zonation pattern is most striking on the steeply sloping rocky coasts whereas on the more gently sloping bedrock and boulder areas the picture is much more complex.

The upper regions of many rocky shores are relatively species poor, especially on the more exposed coasts, but towards the bottom of the shore, which is only occasionally exposed on the largest spring tides, the species richness can be very high. Where there are tidal rockpools, however, these can result in increased species richness even at high shore levels.

Some rocky shores are popular places for winkle collecting and the harvesting of some edible seaweeds as well as bait collecting. They are also important resting and foraging places for many animals such as harbour and grey seals, otters and various wading birds including oystercatchers, curlews and turnstones.

The various animals and plants that are found on rocky shores are especially adapted to survive the considerable stresses imposed by the regular immersion and emersion in sea water and the associated dramatic fluctuations in temperature and salinity caused by exposure to the sun and rain at low tide. There are a number of species that are at the geographical limits of their distribution both in terms of northern species at their southern extreme (e.g. tortoiseshell limpet *Tectura testudinalis*) and southern species at their northern extreme (e.g. topshell *Gibbula umbilicalis*). With climate change and increasing sea temperatures, changes in rainfall patterns etc., these species are likely to face increased pressures and their distributions could change. This may be further exacerbated by the introduction of invasive non-native species (that may or may not be a consequence of climate change) such as wireweed (*Sargassum muticum*) which could overgrow native species (see Non-natives section).

Broad Habitat Intertidal rock point data



Ascophyllum dominated sheltered shore

© ENTEC/SNH

Semi-exposed rocky shore

© SNH

Extreme wave exposed shore – Rockall

© Keith Hiscock/MNCR

Rockpools

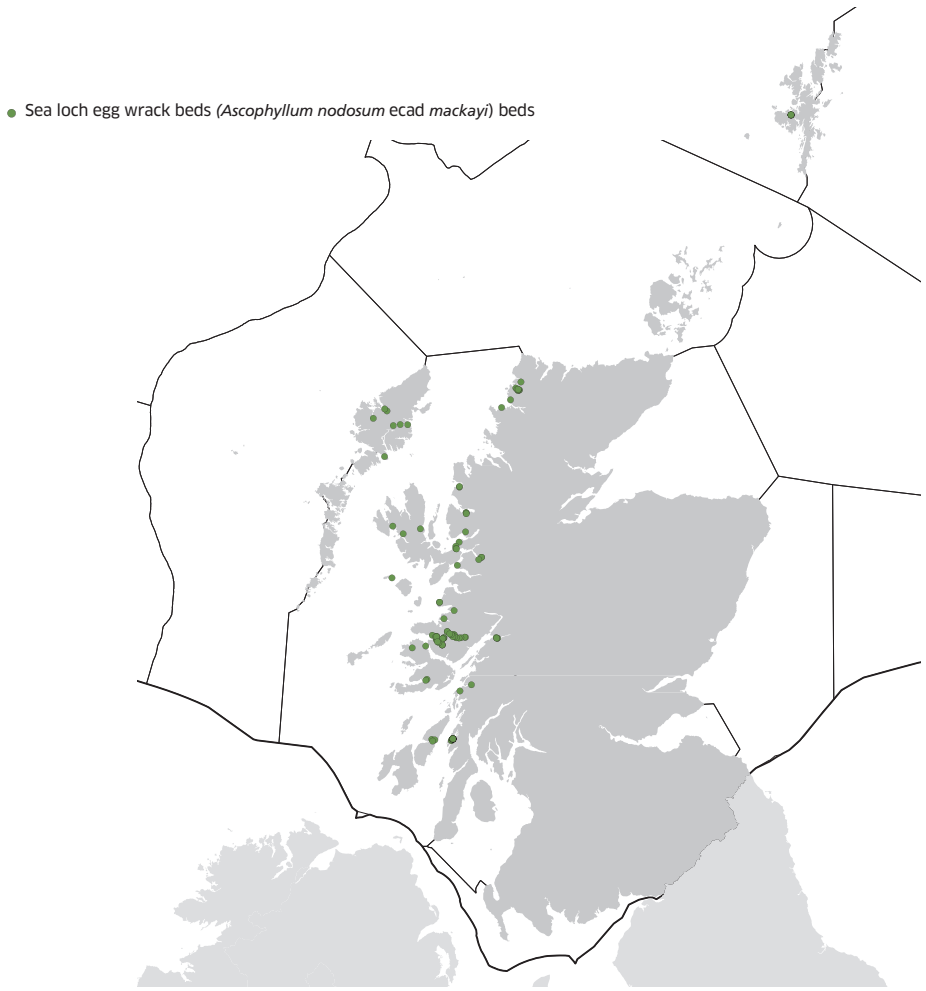
© Keith Hiscock/JNCC

Sea loch egg wrack beds

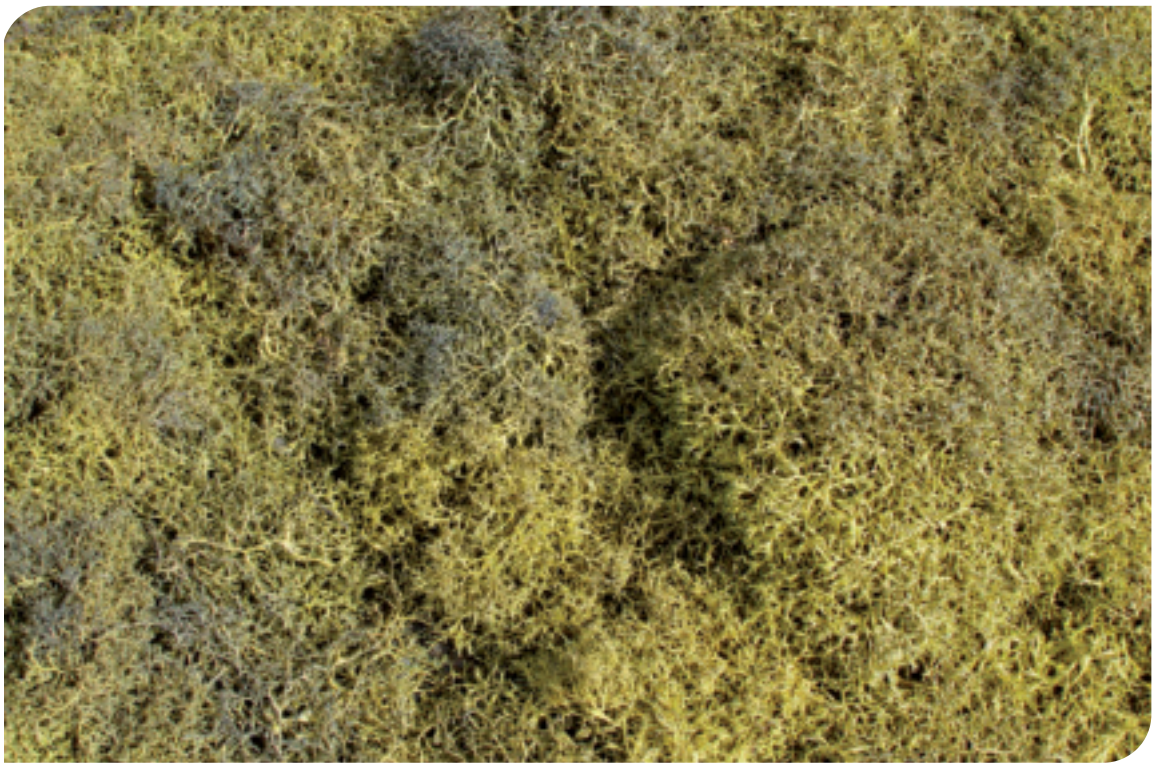
Ascophyllum nodosum (eggwrack) is a large brown seaweed that is widespread, occurring in great abundance in the mid shore of semi-exposed and sheltered beaches, typically attached to bedrock and boulders. *Ascophyllum nodosum* ecad *mackayi* (crofter's wig) is a detached form and only found in very sheltered conditions such as the upper reaches of many sea lochs and near land-locked bays. Individual plants rarely exceed 60cm in diameter and are either found as small clumps on the upper shore ('turf' form) or as dense beds ('beach' form) in the mid shore. In these circumstances the entire bed is lifted off the rock as the tide advances and then settles again as it recedes. The complex three-dimensional structure provides a humid habitat for shrimps, crabs, snails, mussels, barnacles and worms. This can only happen in places where there is minimal wave and current action, otherwise the plants would be washed away. Scottish sea lochs on the west coast and Western Isles and Brindister Voe in Shetland support most the the UK's and the world's population of *Ascophyllum nodosum* ecad *mackayi* making Scotland of global importance for this species.

Pressures

It is sensitive to coastal development and is still collected on a small scale for packing shellfish.



Ascophyllum nodosum* ecad *mackayi



© SNH

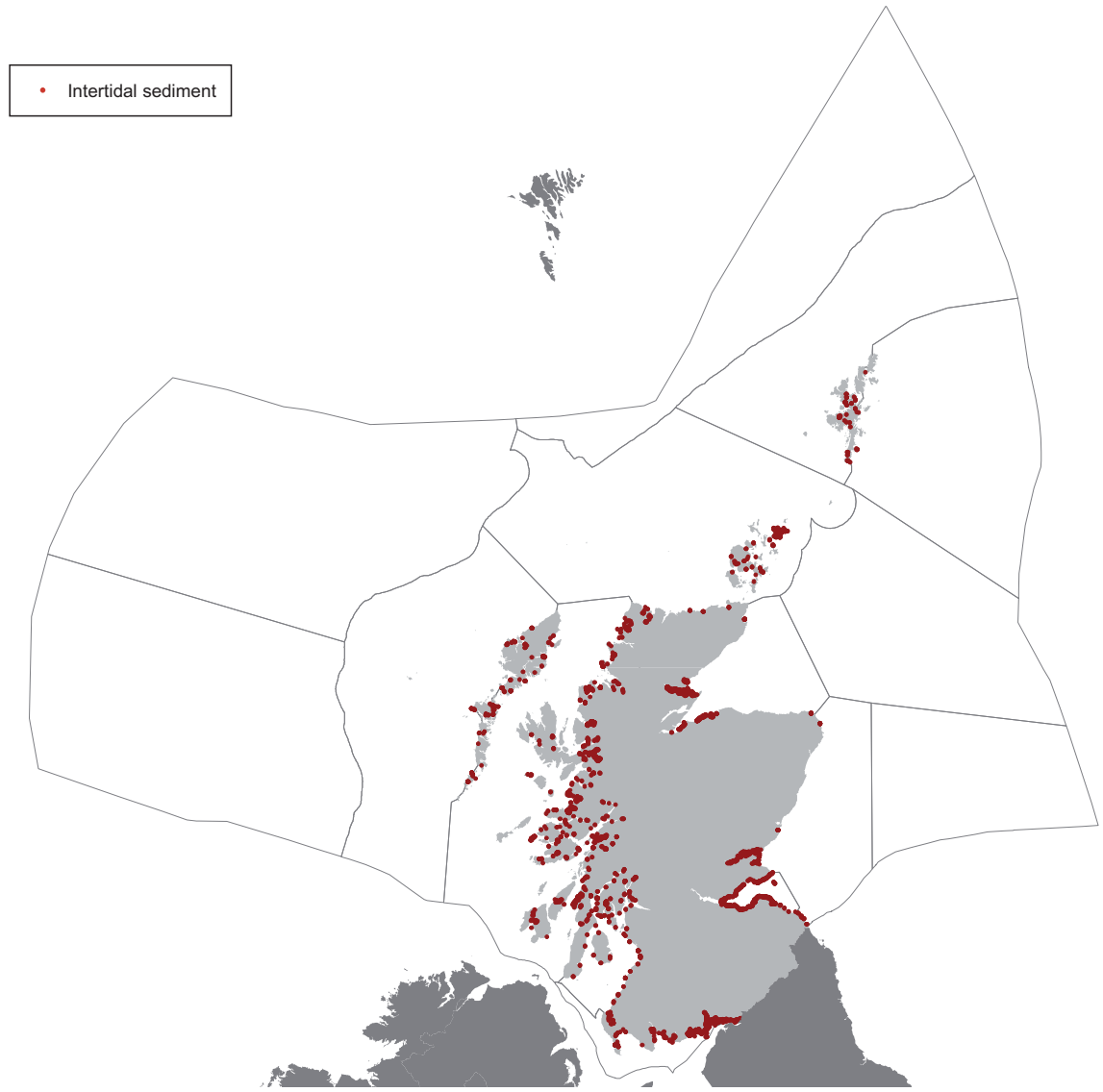
INTERTIDAL SEDIMENTS

Intertidal sediments

The intertidal sedimentary coastline represents around 50% of the total Scottish coastline. This includes habitats of mobile shingle and gravel, sand and mud or combinations of these, as well as vascular plant communities in the upper shore that form saltmarshes. In some places the sediments are overgrown by biogenic reefs of blue mussels.

Intertidal sediments support communities that are tolerant of exposure to air and variable temperatures and salinities, particularly the expansive mudflats and sandflats found in estuaries. These habitats support communities of animals that are typically species poor, but highly productive. They comprise burrowing worms, crustaceans, bivalve molluscs and echinoderms.

Broad habitat intertidal sediment point data



Sandflats

On the more exposed stretches of coast, especially up the east coast, around Orkney and the more open coastal areas of the west coast, the shores comprise clean, relatively coarse grained sand. In slightly more sheltered areas the shores comprise muddy, finer-grained sands. The more mobile the sand the more impoverished the fauna. Muddy sands in contrast are more species rich, supporting communities of amphipods, polychaetes and bivalve molluscs such as tellins and cockles. In some places where there are large spring tides it is also possible to find razor shell beds at extreme low water. Cockles are also sometimes harvested commercially although with recent increased mechanisation this is not always biologically sustainable. Both cockles and razor shells (known as 'spoots' in Orkney) are also harvested at much smaller scales by local people for personal consumption. The expansive sandy beaches of the east coast in particular, e.g. the Dornoch Firth and Tentsmuir, are favoured places for harbour and grey seals to haul out. The wide expanses of sand provide them with a degree of security and an easy escape route to the sea if disturbed. Many are areas of outstanding beauty and can be of considerable importance for recreation.

Pressures

Sandflats are sensitive to physical disturbance, changes in wave regimes, sea-level rise and pollution as well as fisheries and various damaging recreational activities.

Sandflats – Solway Firth

© Lorne Gill/SNH

Mudflats – Skinflats – Firth of Forth

© P&A Macdonald/SNH

Mudflats

Mudflats are found in the most sheltered areas, within the upper reaches of estuaries, sea lochs and voes. The sediments are finer (silt and clay) and have a high organic content. The resultant high microbial activity can result in an anoxic layer forming close to the surface. Fully marine mudflats are dominated by burrowing polychaete worms, such as lugworms, bivalve molluscs (e.g. Baltic tellin) and mud shrimps. The upper estuaries, where there is reduced salinity, are dominated by oligochaete worms. Found all round the Scottish coast, some of the most notable examples are at Montrose Bay, the Firth of Tay, the Firth of Forth, the Inner Moray Firth and the Cromarty Firth. Mudflats are much undervalued because they tend not to be seen to be useful for recreation or other activities, yet they are vital habitat. They provide a natural sea defence by absorbing wave energy and are an important sink for organic material. They also are an important habitat for many juvenile fish including commercial species such as plaice and a vital habitat for thousands of wintering waders and wildfowl.

Pressures

Mudflats are sensitive to physical disturbance, changes in wave regimes, sea-level rise and pollution.

Priority Marine Features

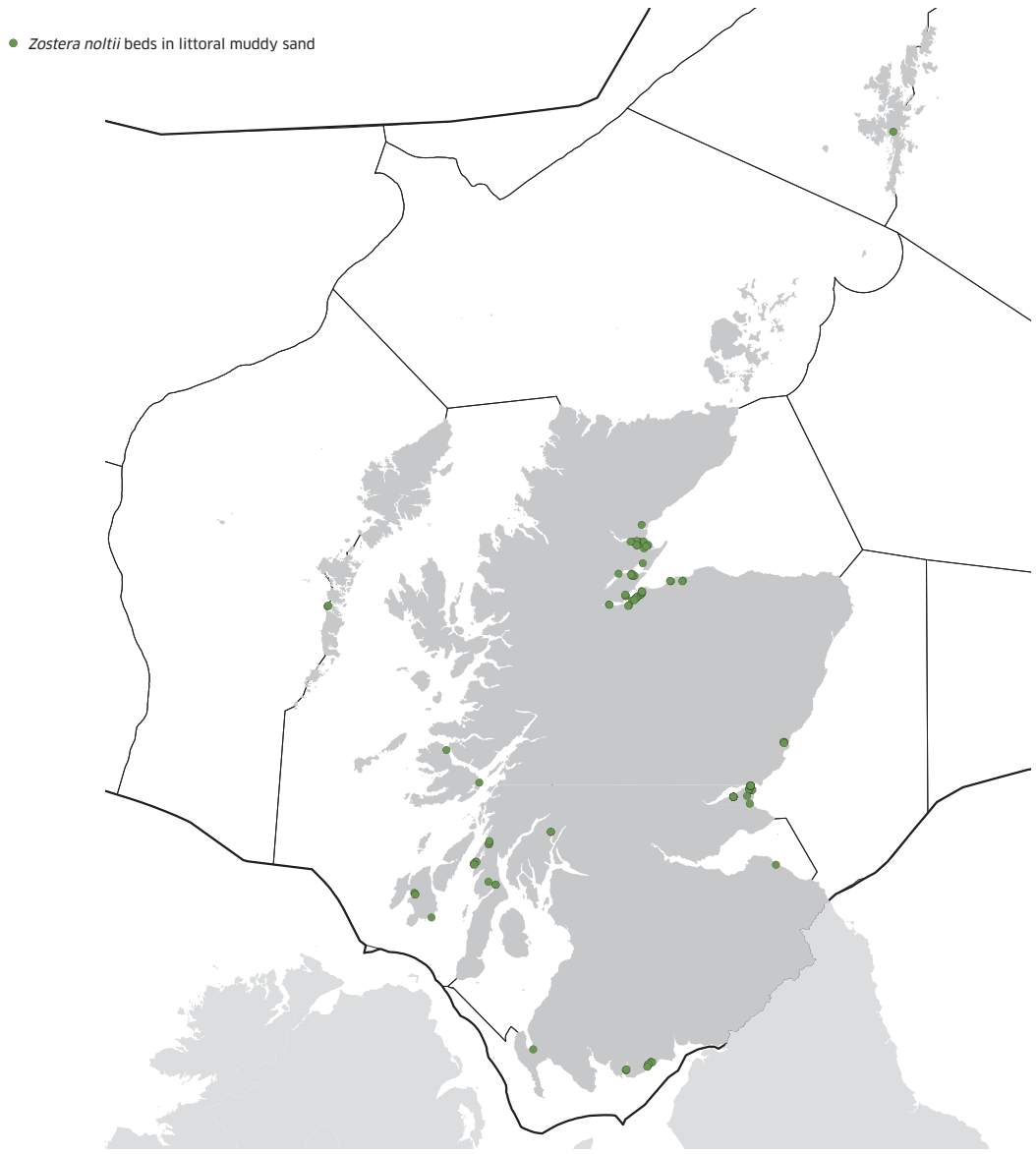
Seagrass beds (*Zostera noltii*)
Blue mussel beds (*Mytilus edulis*)
Native oysters (*Ostrea edulis*)

Seagrass beds *Zostera noltii*

Beds of the dwarf eelgrass *Zostera noltii* are found on the mid and upper shore in muddy sand or sandy mud on wave-sheltered coasts. This habitat is sparsely distributed around Scotland but is present at various sites in the Moray Firth, Firth of Tay, Shetland and the west coast and Western Isles. Scotland has about 20% of the north-west European beds and the Cromarty Firth supports the largest bed known in the UK. The eelgrass roots serve to stabilise and bind the underlying sediment and support a community of polychaete worms, mud shrimps, mud snails, shore crabs and bivalves including the edible cockle (*Cerastoderma edule*).

Pressures

Seagrass beds are sensitive to suction dredging for cockles and to bait digging as well as a range of coastal developments. There have been significant declines in recent years and UK seagrass populations are currently considered as degraded.



Intertidal seagrass bed in Dornoch Firth

© SNH

Blue mussel beds
Mytilus edulis

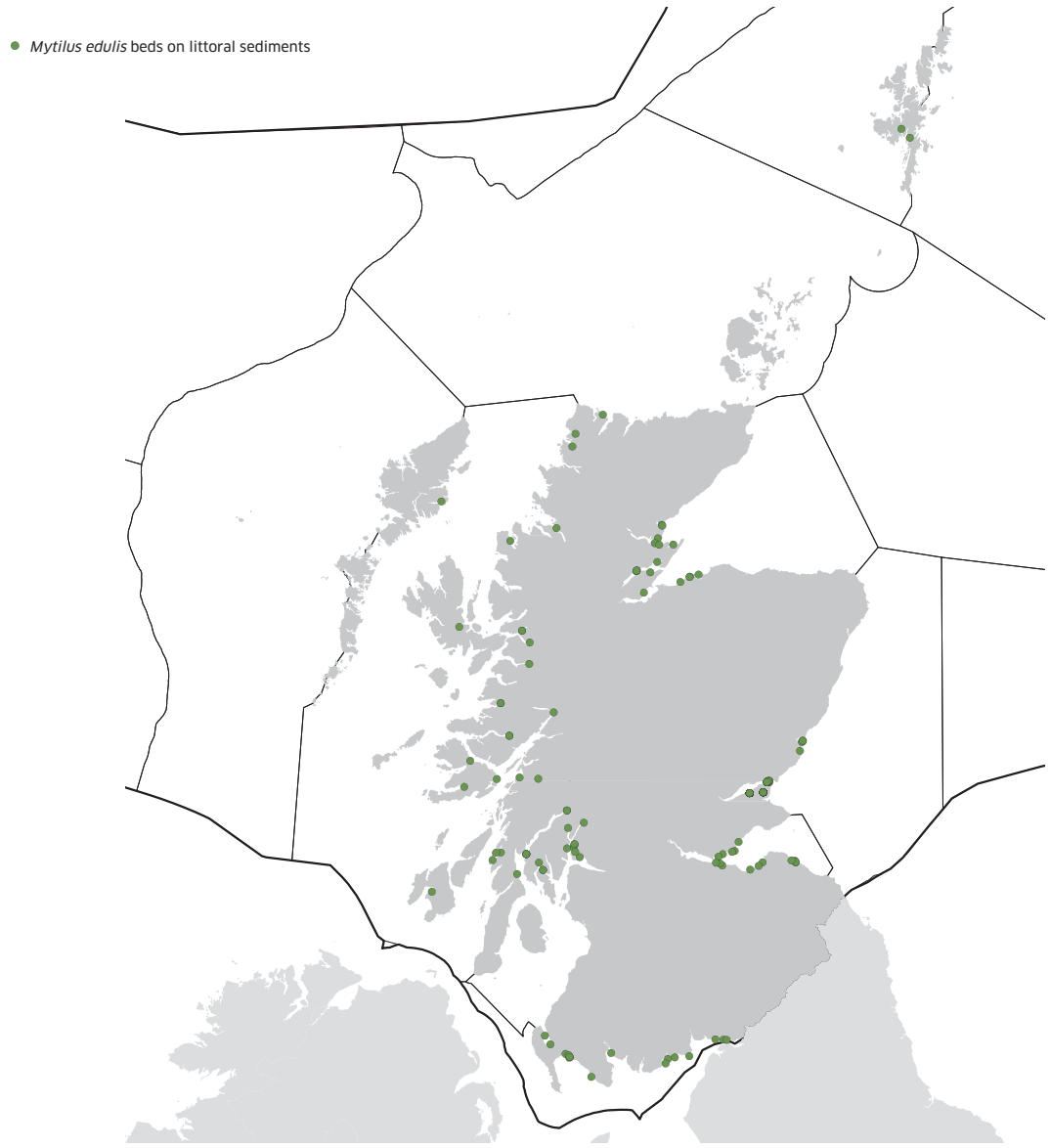
Blue mussels forming dense beds or reefs can be found typically in the more sheltered firths and bays. The dense aggregations of mussels form a complex three-dimensional matrix held together by byssus threads that stabilise the sediments beneath. It is often so dense that the anoxic layer reaches the surface of the sediments. The mussels provide a hard substrate on which other animals and plants can attach. Many, such as barnacles, dog whelks, sea squirts and scavengers such as starfish and crabs, would not otherwise be able to survive on the bare muddy surface. Seaweeds also use the mussel shells as attachment points. These beds occur around Scotland with the majority on the west coast and in the Firth of Forth and the Moray Firth.

A particular form of mussel bed comprising high densities of juvenile blue mussels on pebbles, gravel and sand forming a thin bed with the fan worm (*Fabricia sabella*), along with other bivalve molluscs and worms, is found exclusively in the Dornoch and Moray Firths.

Some beds are very well and long established, others are more ephemeral, but all are important foraging areas for waders and eider ducks.

Pressures

Blue mussel beds are particularly sensitive to any operations that cause physical damage and in particular demersal fishing operations, bait-digging, anchoring, coastal developments, chemical pollution and harvesting.



Intertidal blue mussel bed in the Dornoch Firth

© SNH

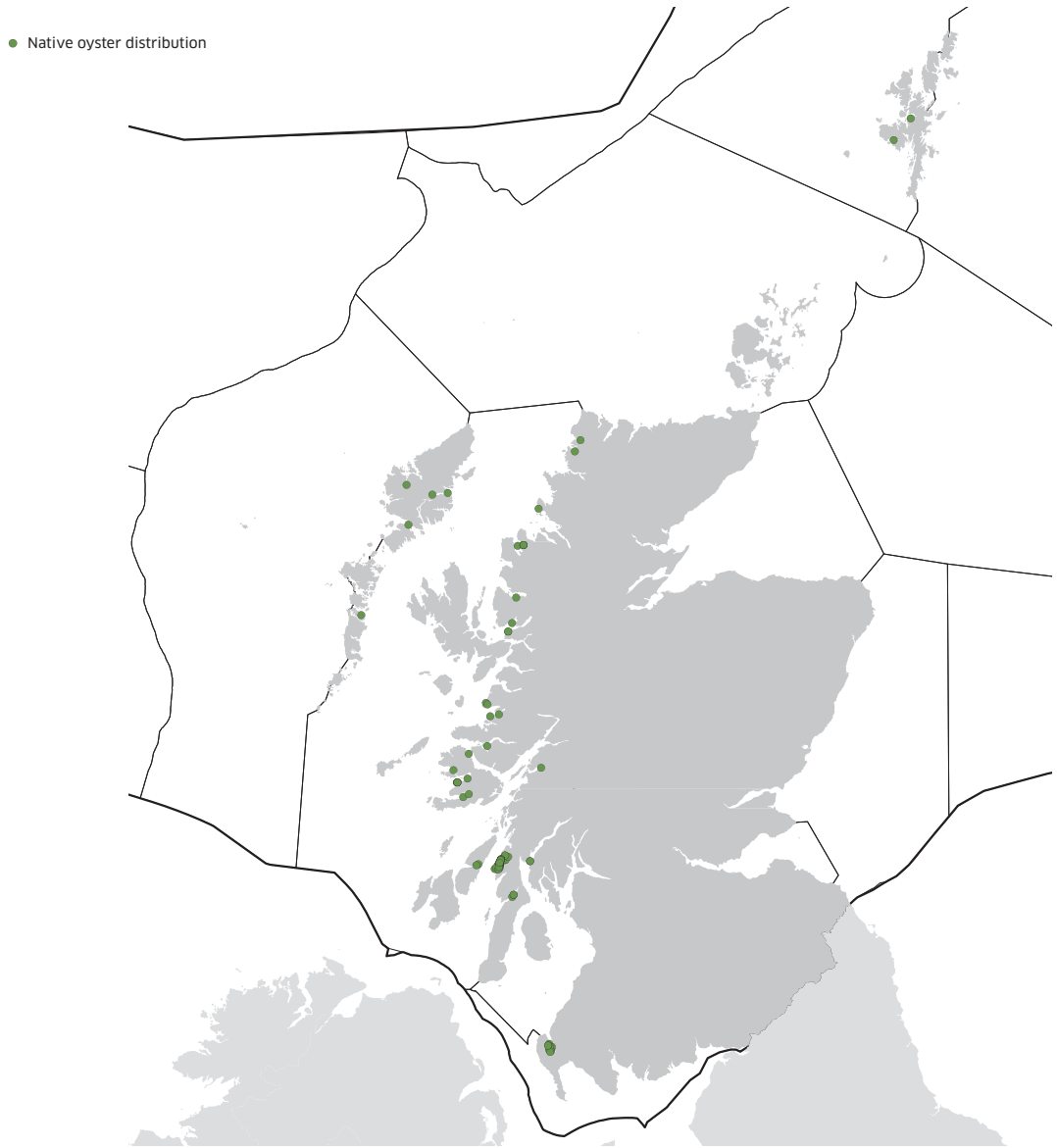
Native oyster
Ostrea edulis

The native oyster is typically found attached to rocks or other shells on muddy substratum in estuaries and other coastal habitats. These are found along the west coast, in the Hebrides and Shetland. Specimens have been recently discovered in the Firth of Forth where there was once a highly productive fishery before disappearing in the 1950s. Given the recent nature of this discovery it is not shown on this map.

Native oyster beds were once widespread. Dense beds of oysters once formed reefs that stabilised the underlying sediments and provided a hard substrate for a range of other animals such as sea squirts, sponges, sea slugs and small seaweeds. They are now considered to be nationally rare with only scattered occurrences on the west coast, most notably lochs Ryan, Sween and Scridain.

Pressures

Native oysters are sensitive to over-fishing, pollution, disease and non-native species.



Native oyster

© Graham Saunders/SNH

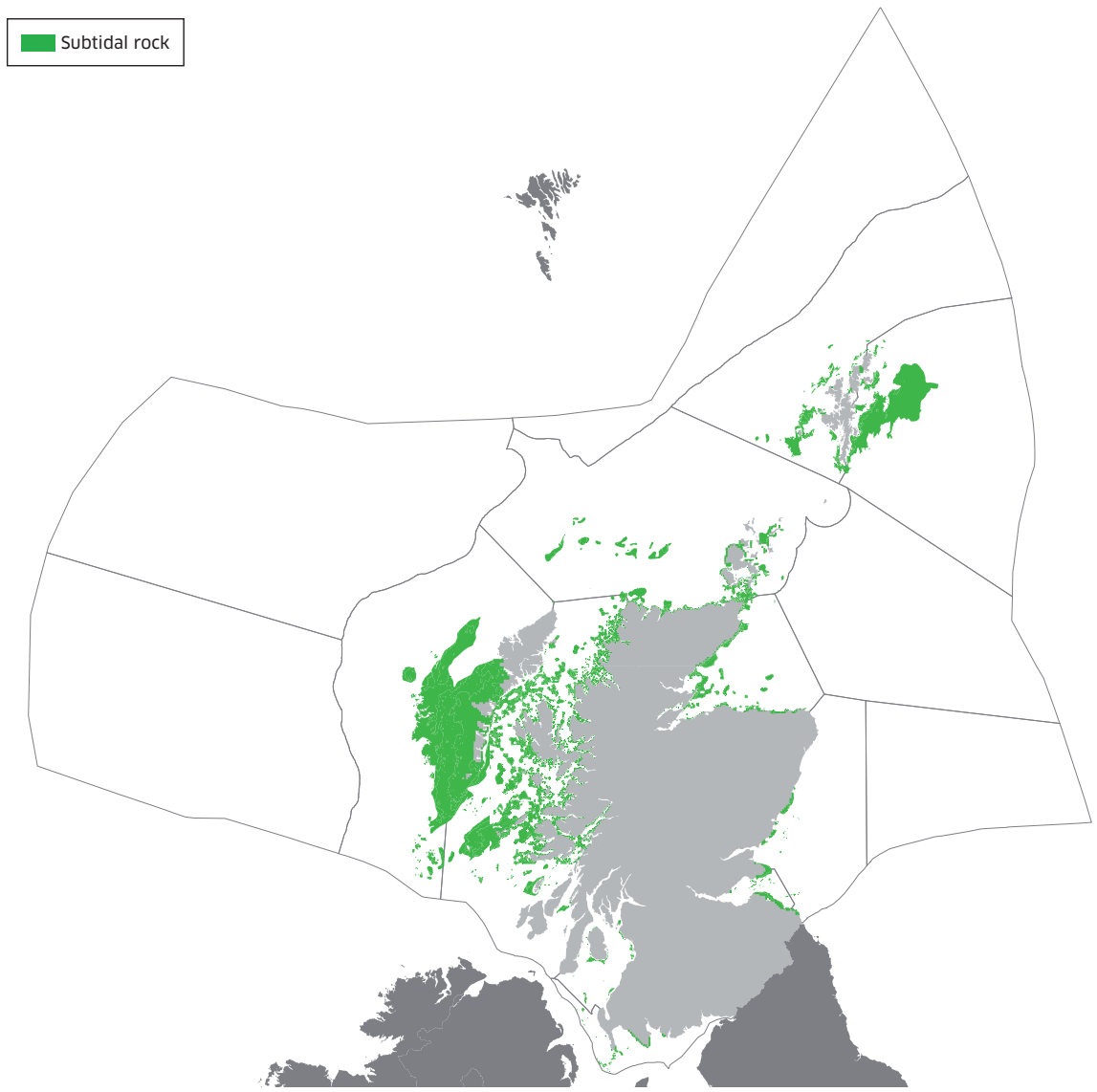
Subtidal Rock

Subtidal rock habitats comprise bedrock, boulders and cobbles occurring below low water mark. The communities found here are strongly affected by the availability of light; shallow areas are typically dominated by seaweeds and in deeper areas below the photic zone (about 50m) communities comprise exclusively animals. Other factors influence the composition of communities including wave action, tidal stream strength and salinity.

Seaweed communities are dominated by several species of large kelp, *Laminaria digitata*, *Laminaria hyperborea* and *Laminaria saccharina*. On the east coast of Scotland in the more turbid waters of the North Sea these may extend down only a few metres before a more sparse community of small foliose and encrusting red seaweeds take over. On the outer west coast, and especially on some of the more remote islands such as St Kilda, the kelp can extend down to depths in excess of 40m.

On the east coast of Scotland subtidal rock is rare and occurs only in isolated pockets. There is much more on the west coast with many of the sea lochs having extensive areas of bedrock extending to considerable depths. There are also extensive areas of bedrock to the west of the Hebrides and around Shetland. The extensive, relatively shallow bedrock to the west of the Hebrides support a dense kelp forest that is important in dissipating a lot of wave energy, thus protecting the vulnerable west facing coasts of the Outer Hebrides from erosion.

Broad habitat subtidal rock



Soft coral with dead man's fingers

© Paul Kay

Orange jewel anemones

© Sue Scott

Kelp forest understorey of encrusting red algae, sponges, soft corals, etc.

© Paul Kay

Priority Marine Features

Northern sea fan and sponge communities
White cluster anemone *(Parazoanthus anguicomus)*
Pink sea fingers *(Alcyonium hibernicum)*
European spiny lobster *(Palinurus elephas)*
Tide-swept algal communities
Blue mussel beds *(Mytilus edulis)*
Horse mussel beds *(Modiolus modiolus)*
Flame shell beds *(Limaria hians)*
Serpulid aggregations *(Serpula vermicularis)*

Northern sea fan and sponge communities

Northern sea fan communities comprise dense aggregations of the northern sea fan (*Swiftia pallida*) and the cup coral (*Caryophyllia smithii*) together with a wide range of other species occurring on upward-facing and vertical rock surfaces. *S. pallida* plays host to the nationally rare sea fan anemone *Amphianthus dohmii*. These communities are characteristic of the moderately exposed rocky habitats of the west coast and Outer Hebrides and occur below ~20m. Ninety-seven percent of current UK records of *Swiftia pallida* are from the west coast of Scotland and the Outer Hebrides and St Kilda where it is at the southern limit of its range and rising sea temperatures may lead to its reduction or loss.

There are a number of important Northern sea fan and sponge communities:

Caryophyllia smithii and *Swiftia pallida* on circalittoral rock

Recorded from a number of locations on the west coast and Outer Hebrides. It is a very species rich community supporting a range of soft corals, sea firs, sea mats, sea squirts etc.

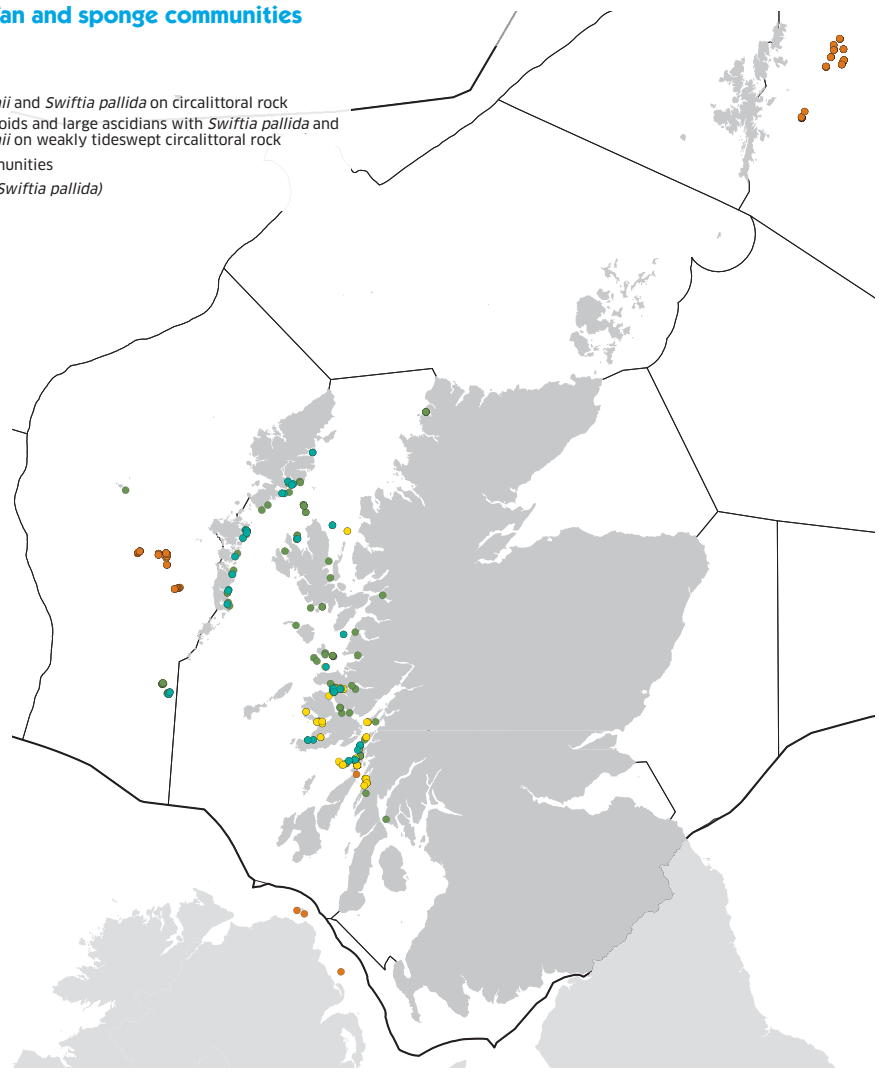
Mixed turf of hydroids and large ascidians with *Swiftia pallida* and *Caryophyllia smithii* on weakly tideswept circalittoral rock

Sparsely recorded with a restricted distribution in a few sea lochs and inlets on the west coast, especially around the Isle of Mull. It represents a particularly diverse community of dense cup corals, sea firs, sea squirts, sea fans, sponges, soft corals, sea mats and feather stars, as well as sea cucumbers, squat lobsters and fish.

Deep sponge communities

Deep sponge communities are found off the west of the Hebrides and the north-east coast of Shetland as well as a few other locations along the west coast. They are very diverse communities with the majority of UK records from Scotland.

Northern sea fan and sponge communities



Northern sea fan *Swiftia pallida*

The northern sea fan occurs in many sea lochs and inlets along the west coast of Scotland and the Outer Hebrides, from Loch Laxford in the north to Sound of Jura in the south, and out to St Kilda. It usually occurs at depths of 15-60 m but may occur up to 200m. Virtually all (97%) of UK records are from Scotland and as such is of national importance. It is also host to the nationally rare sea fan anemone *Amphianthus dohrnii*.

Pressures

These communities are vulnerable to physical damage from bottom fishing gear and siltation from fish farms. It is also possible that with increasing temperature as a result of climate change sea fans could decline or disappear as they are currently on the southern limit of their distribution.

Caryophyllia smithii and *Swiftia pallida* on circalittoral rock

© Paul Kay

Mixed turf with northern sea fan

© Paul Kay

Deep sponge communities

© Marine Scotland Science

Northern sea fan *Swiftia pallida*

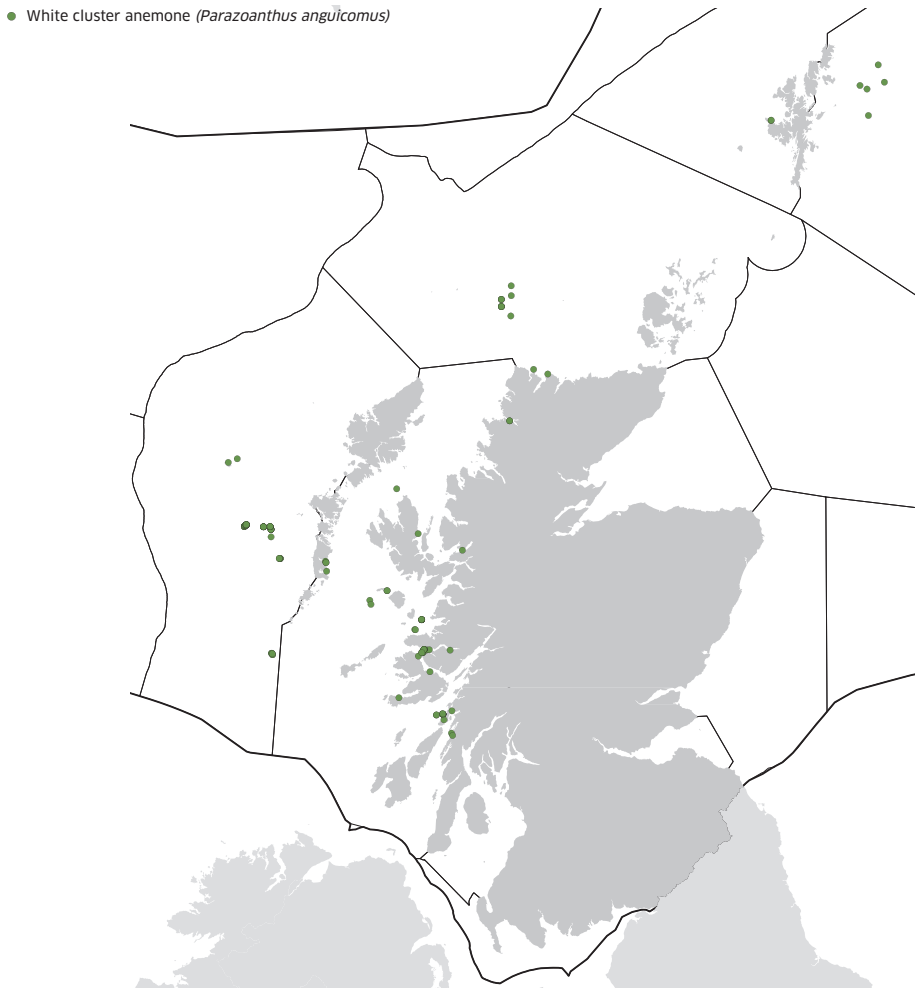
© Paul Kay

White cluster anemone *Parazoanthus anguicomus*

Usually found at depths down to at least 400m but can occur as shallow as 20m. This is a scarce sea anemone found at a number of scattered locations around northern and western Scotland that represent a large proportion of all known records. It may be more widespread and is almost certainly under recorded in deep water. It is considered nationally scarce in the UK.

Pressures
Populations growing on stones and cold water corals may be threatened by demersal fishing activities.

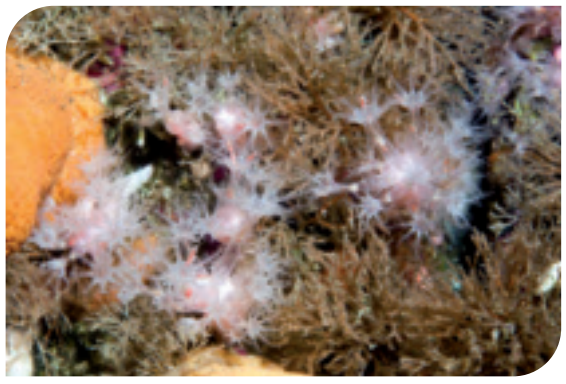
© Paul Kay



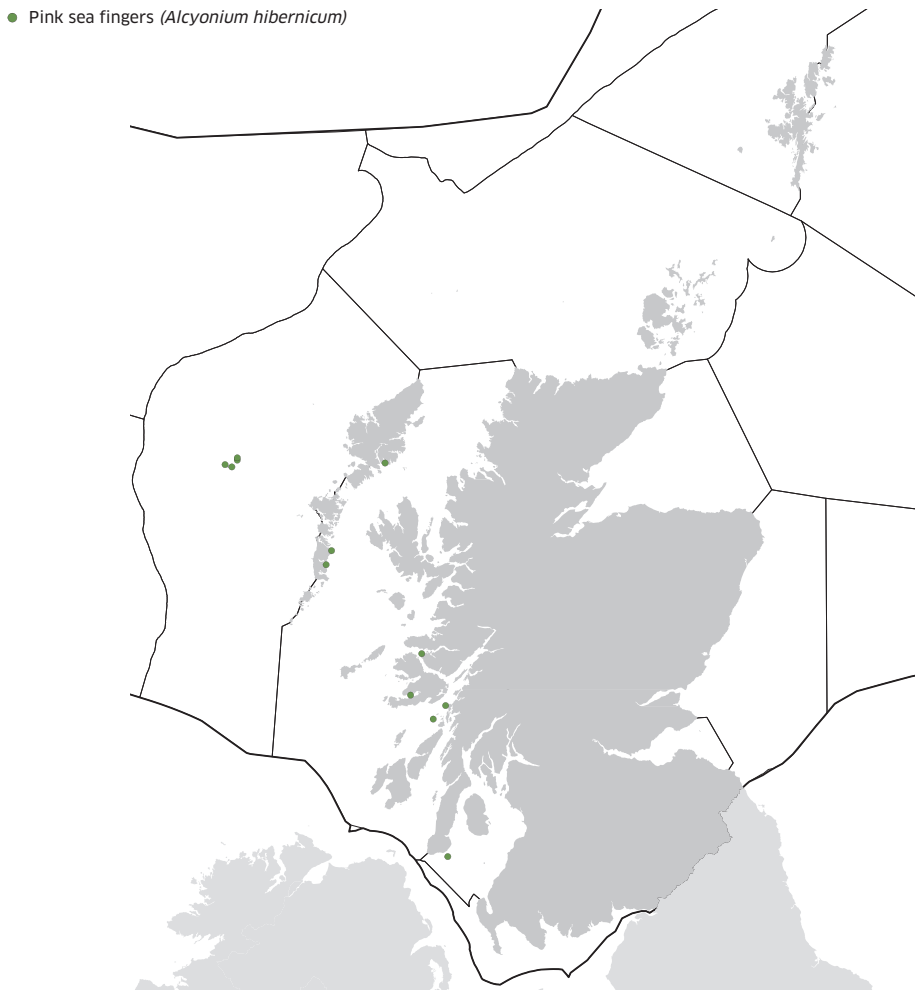
Pink sea fingers *Alcyonium hibernicum*

Found on shaded vertical rock surfaces between 1-30m depth. This species has a very restricted distribution and is confined to British waters but it can be common in those locations where it occurs. Almost 50% of global records are from Scotland around western coasts, north to Mull and particularly in the Firth of Lorn, the Outer Hebrides and St Kilda. Pink sea fingers soft coral is considered nationally scarce in the UK and Scottish populations are probably of global importance.

Pressures
Pink sea fingers may be vulnerable to the impacts of climate change and pollution.



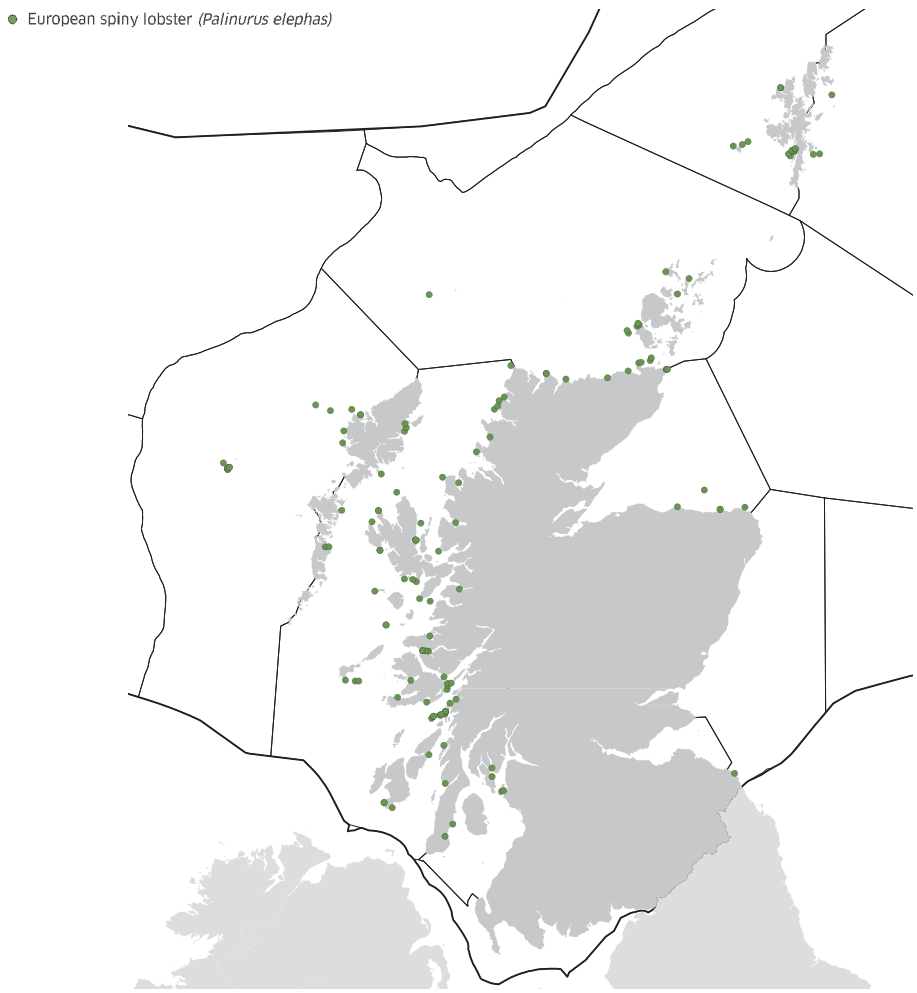
© Paul Kay



European spiny lobster *Palinurus elephas*

Usually occurs at depths of 5-70m but can occur down to around 160m. It was once considered common in Scotland. It is now found along the north and west coasts of Scotland with occasional records from the east coast, but numbers have been declining, especially towards the northern extremes of its range. It is now considered scarce.

Pressures
European spiny lobster is vulnerable to overfishing.



European spiny lobster

© Paul Kay

Tide-swept algal communities

This includes the tidal rapids of sea lochs, areas of water between islands and also the strong tidal regions found between mainland Scotland and islands (e.g. the Pentland Firth). Large volumes of sea water are forced through narrow channels by tidal processes culminating in fast currents that, in certain locations, can exceed 10 knots. Although the turbulent conditions are largely associated with the top 5m of the water column, some tidal streams can be felt at depths in excess of 30m.

Many of these habitats are found on the west coast around the sills and narrows of sea lochs. These areas are inhabited by a wide range of animals such as sea mats, sea firs, sea squirts, sea anemones and sponges. Where the substrate is particularly stable, kelp parks may develop which in turn provide suitable habitat for a diverse epiphytic fauna and flora of sponges, sea squirts and foliose seaweeds. In deeper water, where light is limited, the sea bed is dominated by animals and it is not uncommon to see dense beds of brittlestars. Tide swept channels are particularly well represented in Scotland and are extremely important for a great diversity of marine organisms including a range of biogenic reef habitats such as horse mussel beds, flame shell beds and maerl.

There are a number of important tide-swept algal dominated communities:

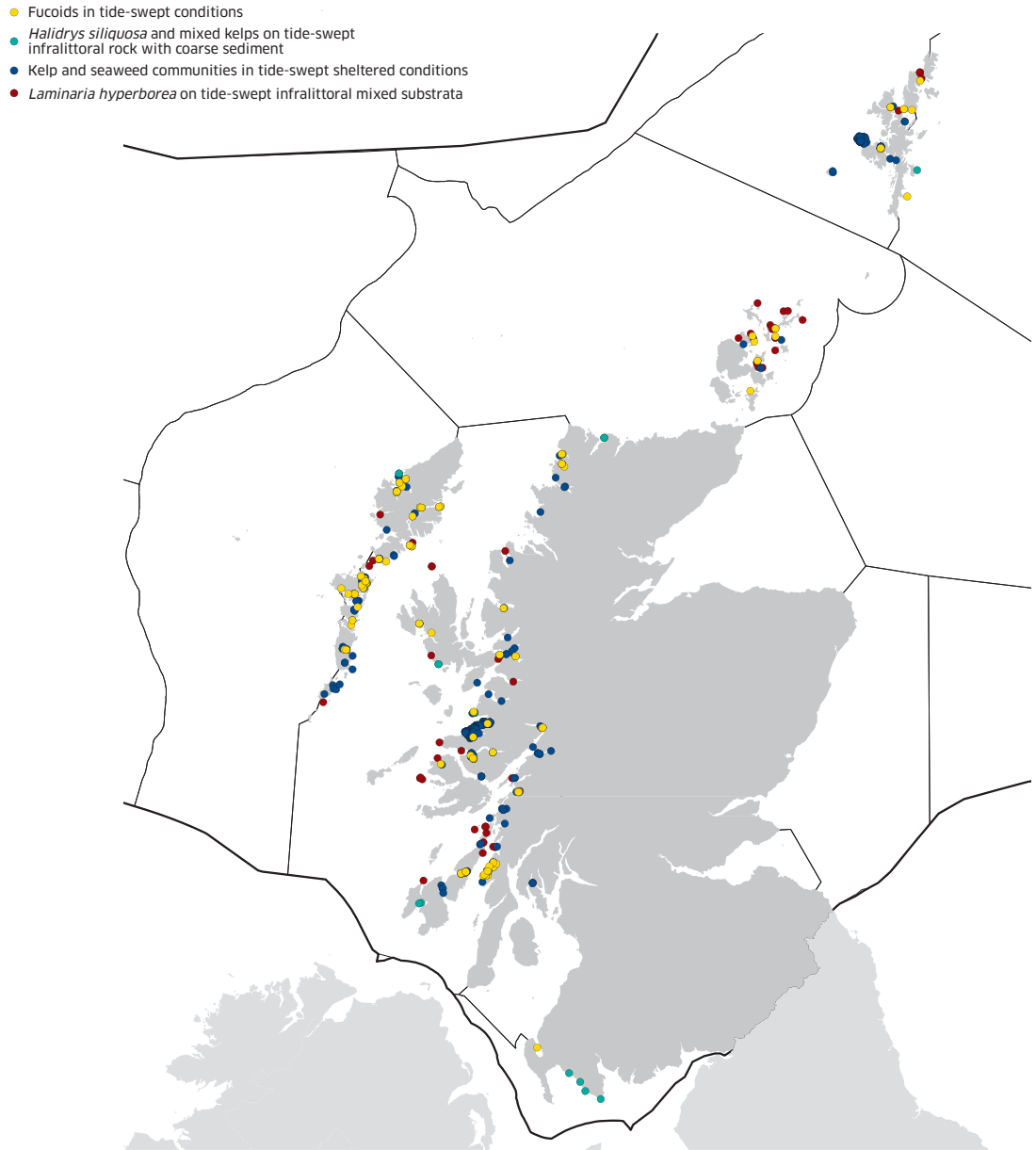
Fucoids in tide-swept conditions
A species rich complex habitat occurring in sea lochs, embayments and between islands in the Inner and Outer Hebrides, Orkney, Shetland and the west and north-west of Scotland.

***Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock and coarse sediment**
Very few records in Scotland but considered to be under-recorded. It is structurally complex and species rich supporting a diverse community of red seaweeds, sea firs, sea mats, sea squirts, starfish, topshells and sea anemones.

Kelp and seaweed communities in tide-swept sheltered conditions
A large proportion of records in UK are from Scottish sea lochs, the Outer Hebrides, Orkney and Shetland. It is dominated by kelp (*Laminaria digitata, L. hyperborea* and *L. saccharina*) with an understorey of red seaweeds, sponges, sea squirts and sea mats.

***Laminaria hyperborea* in tide-swept infralittoral mixed substrata**
A large proportion of UK records are from sea lochs of west coast mainland and Orkney, Outer Hebrides and Shetland. The kelp canopy supports a diverse range of red seaweeds along with sponges, sea squirts, sea mats and sea anemones, echinoderms and molluscs.

Pressures
Until recently tide-swept channels have remained largely unaffected by human developments and activities. However, seaweed harvesting, scallop dredging and any activity that reduces water flow will adversely affect these habitats.



Fucoids in tide-swept conditions

© SNH

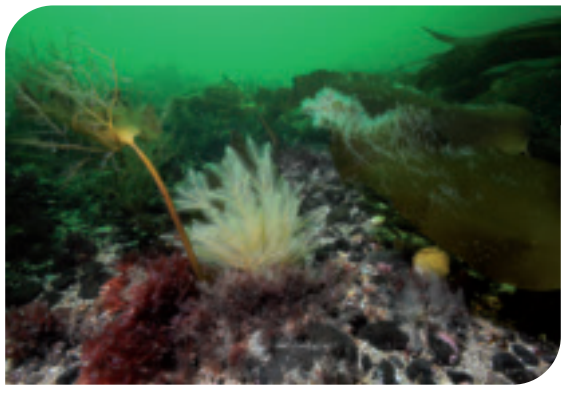
***Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock and coarse sediment**

© SNH

Kelp and seaweed communities in tide-swept sheltered conditions

© Paul Kay

***Laminaria hyperborea* in tide-swept infralittoral mixed substrata**



© Sue Scott

Biogenic reefs

There are a number of habitats created by the accumulation of shelled organisms that transform sedimentary sea bed into 'rocky' habitat. Biogenic reefs are formed by blue mussels (*Mytilus edulis*), horse mussels (*Modiolus modiolus*), flame shells (*Limaria hians*) and serpulid worms (*Serpula vermicularis*) all of which are considered priority marine features.

Blue mussel beds *Mytilus edulis*

These are typically found on shallow mixed sediments. The mussel beds stabilise the underlying sediment creating a highly complex habitat for a diverse community of plants and animals living on, within or under the bed. The hard substrate they provide in otherwise sedimentary areas increases the overall biodiversity of the area. They have an important role in nutrient cycling and for filtering sea water and removing potentially toxic algae and are an important source of food for a range of other species including wildfowl, seabirds and humans.

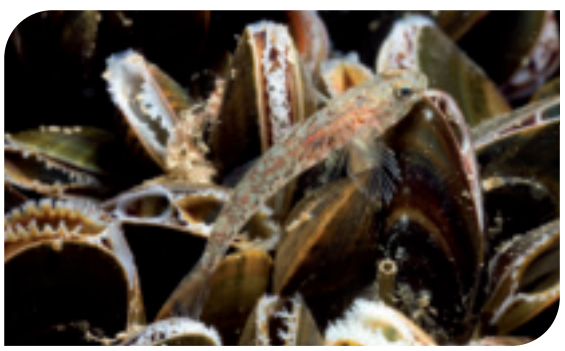
There are two subtidal blue mussel bed communities:

***Mytilus edulis* beds on sublittoral sediments**
Found in areas of moderately strong to strong water movement in relatively shallow areas in both full and variable salinities. The mussel beds act to stabilise the sea bed sediments creating a habitat that support a dense community of animals. It is recorded from only a few locations around the coast.

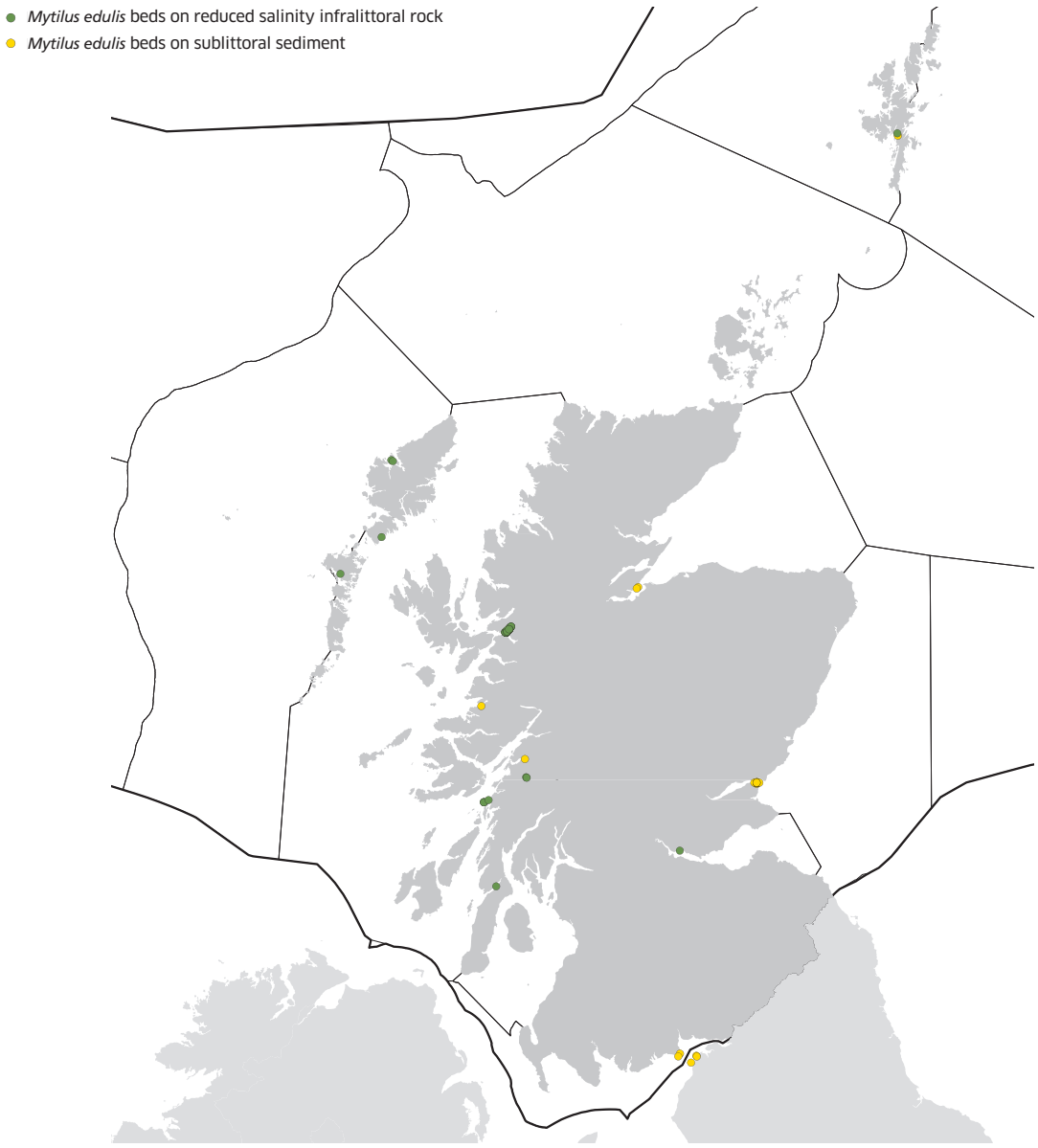
***Mytilus edulis* beds on reduced salinity infralittoral rock**
Typically found in the tide swept entrances to sheltered or very sheltered basins in sea lochs and voes. The majority of UK records are from Scotland.

Pressures
Blue mussel beds are vulnerable to various activities including anchoring, demersal fishing operations and coastal developments and pollution.

***Mytilus edulis* beds on sublittoral sediments**



© Paul Kay



***Mytilus edulis* beds on reduced salinity infralittoral rock**

© Paul Kay

Horse mussel beds *Modiolus modiolus*

Horse mussels can form dense raised beds and occur down to around 100m depth. They significantly modify the underlying habitat and provide substratum and refuge for a wide variety of species, including brittlestars, featherstars, crabs, whelks, sponges, sea firs, sea mats and sea squirts and are important settling grounds for commercially important bivalve molluscs such as scallops. Scotland holds around 85% of the known horse mussel beds in the UK and are found in sea loch and embayments from Shetland and Orkney and down the west coast and Outer Hebrides.

There are a number of important horse mussel bed communities:

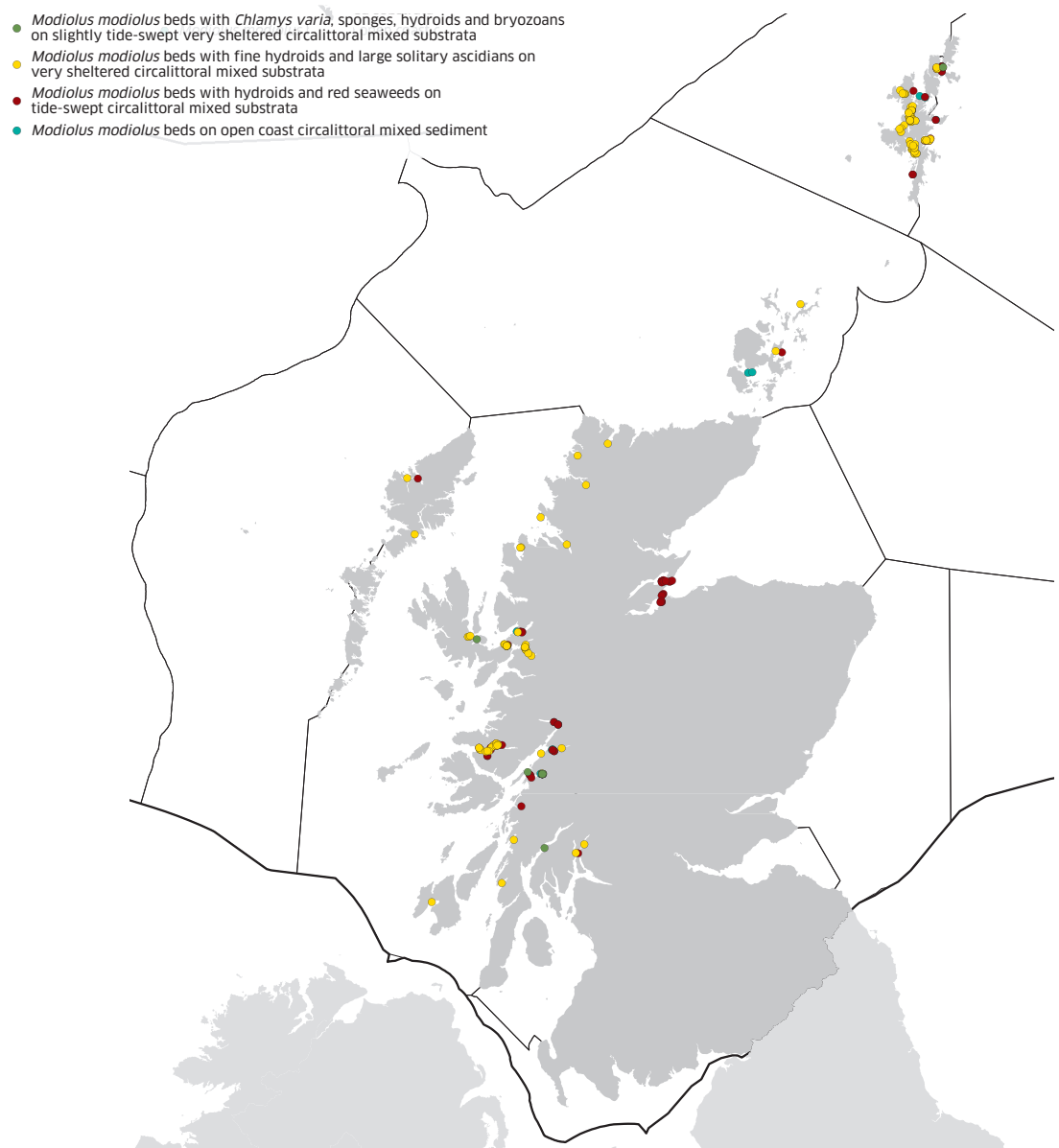
***Modiolus modiolus* beds with hydroids and red seaweeds on tide swept circalittoral mixed substrata**
Found on the open coast and in tide-swept channels between 5-50m depth. The mussel beds support a diverse range of red seaweeds, sea firs, tube worms, molluscs and sea anemones. Recorded from Shetland, Orkney, the Hebrides and west coast sea lochs, the majority of records are from Scotland.

***Modiolus modiolus* beds on open coast circalittoral mixed sediments**
Typically found in current swept areas at depths of 50-100m, the horse mussels support a rich diversity or organisms, especially polychate worms, bivalves and brittlestars. The only known records from Scotland are from Sullom Voe, Shetland and Hoy Sound, Orkney.

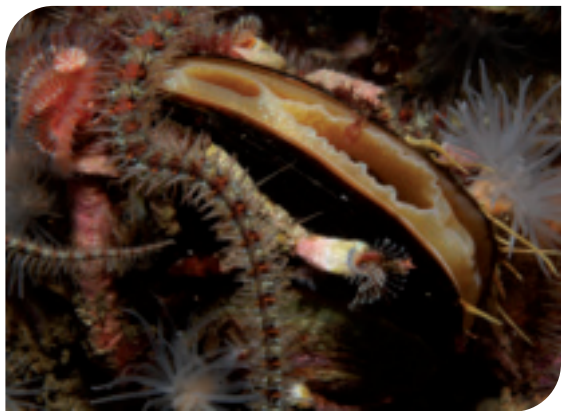
***Modiolus modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata**
Typically at depths of between 5-30m in very sheltered conditions, the mussel beds support a variety of brittlestars, scallops, crabs and gastropods. Found in Shetland, Orkney, the Hebrides and west coast sea lochs, it is not found anywhere else outside Scotland.

***Modiolus modiolus* beds with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata**
Found in very sheltered conditions at depths of between 5-30m, the mussel beds support a variety of organisms including the variable scallop, brittlestars, feather stars, crabs, sponges, sea firs, sea mats, and sea squirts. Only a few records occur from the west coast sea lochs, Skye and Bluemull Sound, Shetland.

Pressures
Horse mussel beds are particularly sensitive to physical damage from mobile fishing gear which may severely damage or even destroy beds.

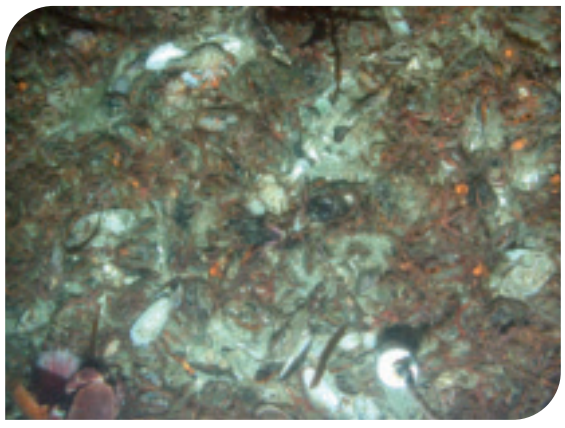


***Modiolus modiolus* beds with hydroids and red seaweeds on tide swept circalittoral mixed substrata**



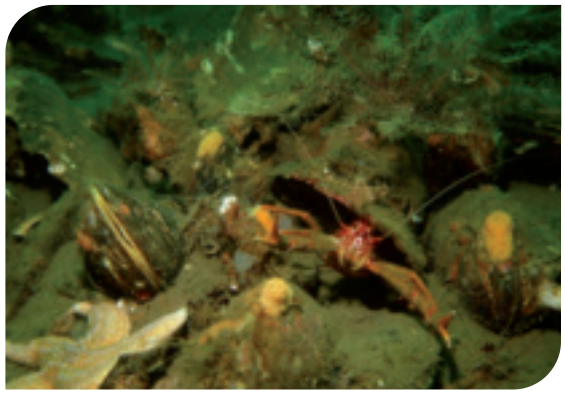
© Sue Scott

***Modiolus modiolus* beds on open coast crircalittoral mixed sediments**



© Crown Copyright Marine Scotland Science.

***Modiolus modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata**



© SNH

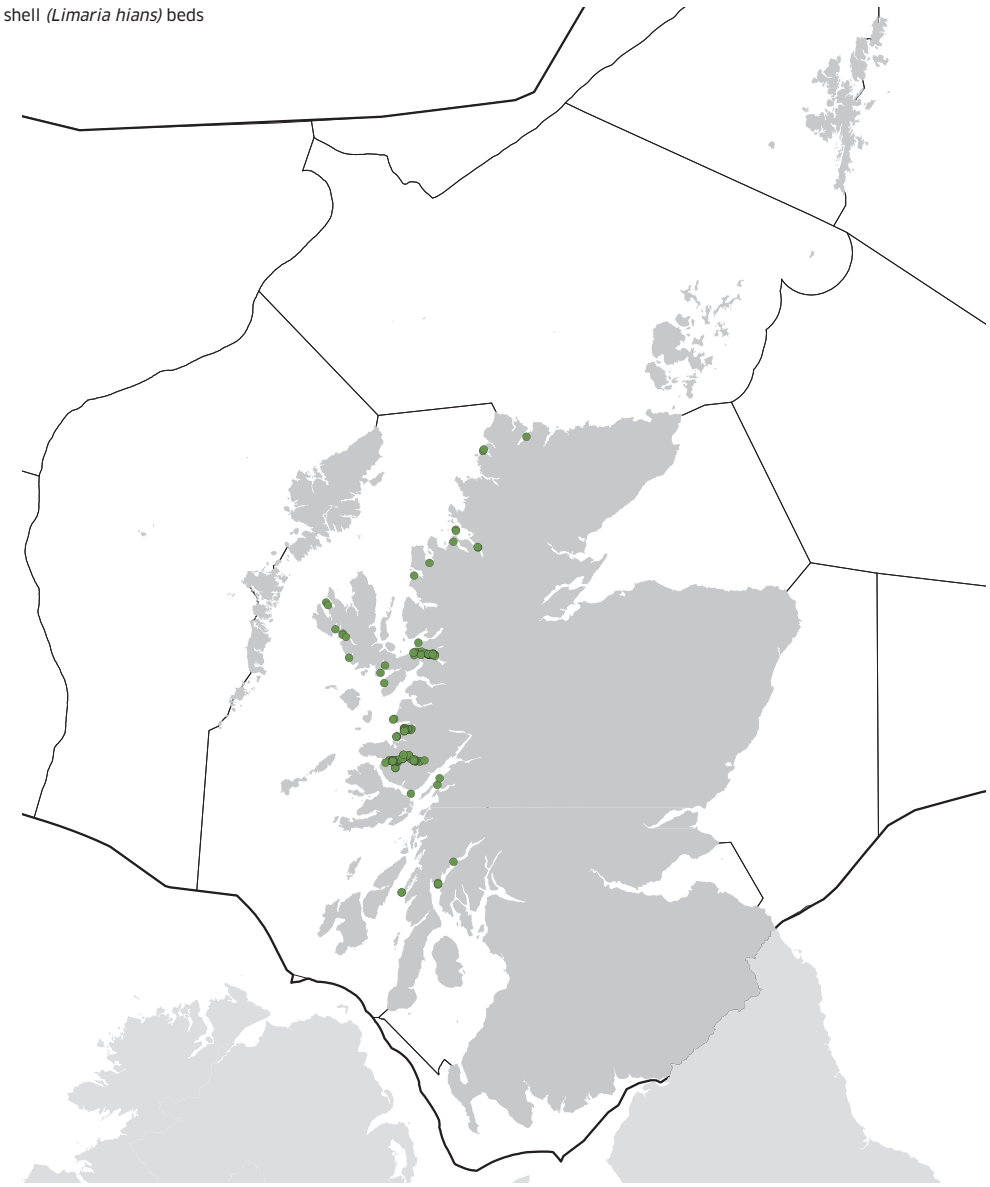
***Modiolus modiolus* beds with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata**

© SNH

Flame shell beds *Limaria hians*

These are most commonly found on mixed muddy gravel and sand in tide-swept narrows in sea lochs. They are formed by the intertwining of the byssus threads of *Limaria* with seaweed, maerl, shells and stones creating a unique habitat that consolidates the underlying sediments providing a surface to which other animals and plants can attach. They are scarce in the UK, the majority of records are from west Scotland and are considered of national importance. The most extensive beds are in Loch Sunart and Loch Fyne. Large beds once found in the Firth of Clyde have declined considerably.

Pressures
Flame shell beds are sensitive to damage from mobile fishing gear, dredging and boat anchoring as well as coastal developments resulting in changes in water flow patterns.

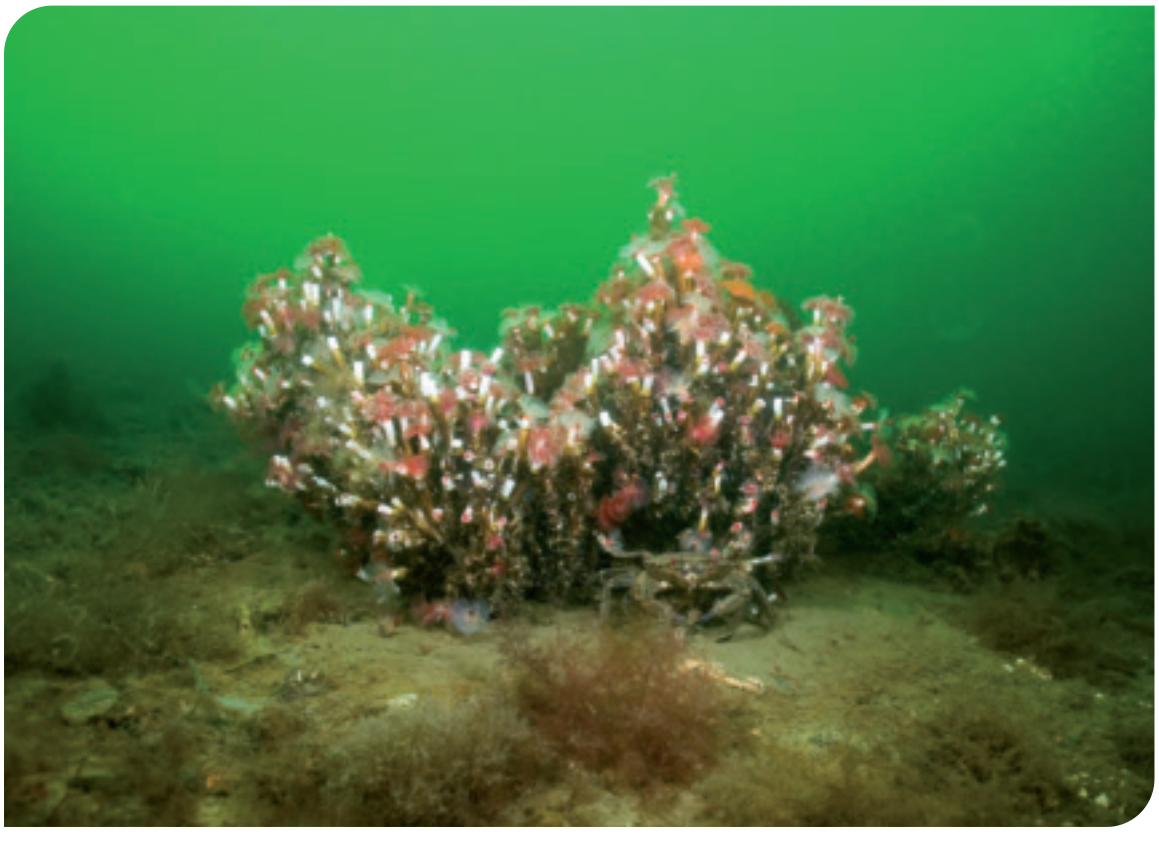


© Sue Scott

Serpulid aggregations *Serpula vermicularis*

Large clumps of the calcareous tubes of the worm *Serpula vermicularis* rise from the sea bed to in excess of 1m high and 2m diameter in some of the oldest aggregations. They provide a hard substrate on an otherwise sedimentary sea bed and support a highly diverse epifauna of sponges, sea squirts, brittlestars and sea urchins etc.. Serpulid aggregations are nationally rare, only known from two places in Scotland, Loch Creran and Loch Teacuis, and from only two other places in the world. The reefs in Loch Creran are considered the best example of this habitat in the world.

Pressures
They are extremely sensitive to physical disturbance and abrasion, loss of suitable substratum and changes in water flow and salinity. They are vulnerable to demersal fishing activities and anchoring of boats and fish farm cages.



© Paul Kay

INSHORE AND SHELF SUBTIDAL SEDIMENTS

Inshore and shelf subtidal sediments

Inshore subtidal sediments include shingle, gravel, sand and mud extending to the depth at which there is no effect from waves, typically around 50-70m. The shelf sediments extend to around 200m depth. Inshore subtidal sediments also include lagoons and maerl, a red seaweed with a hard chalky skeleton that forms small twig-like nodules which accumulate to form loosely interlocking beds, creating the ideal habitat for a diverse community of organisms.

Inshore subtidal and shelf sediments cover an extensive area of the sea bed. The east coast of Scotland in general has a relatively narrow fringe of largely sandy sediments with mud in the inner firths but there are more extensive areas of sand and mixed sediments in the Moray Firth and around the Orkney Islands. There is an extensive area of shallow sand in the south-west of Scotland off the coast of Dumfries and Galloway, whilst much of the sea bed in the Minches and many of the west coast sea lochs is of mud. These differences are the result of differences in depth, wave exposure and tidal currents with the mud habitats occurring in the deeper more sheltered areas. Much of the sea bed out to the continental shelf break comprises subtidal sediment.

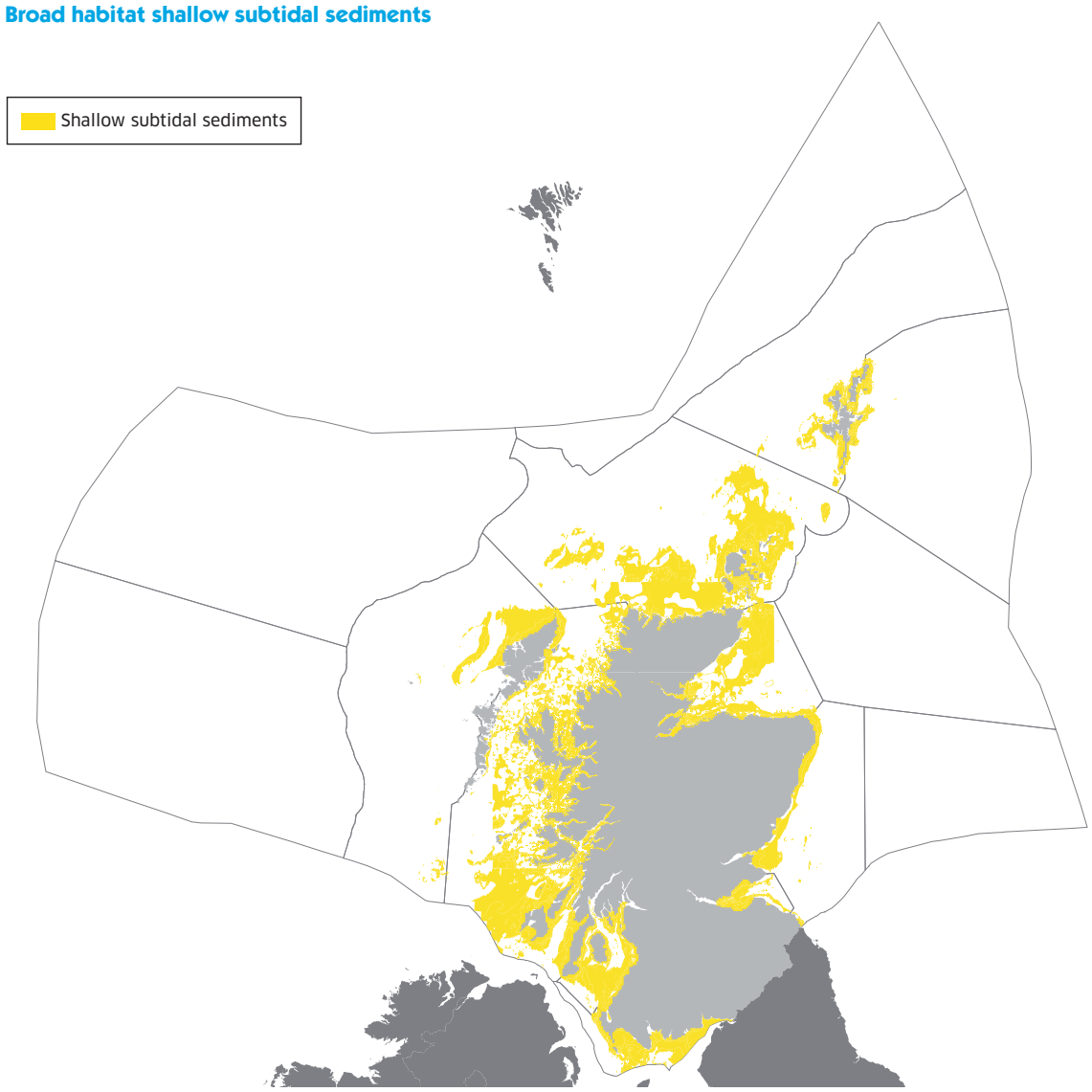
Pressures

These habitats and the species that live within then are particularly vulnerable to damage from dredging and bottom trawling. Other potentially damaging activities would include disturbance from seabed development, anchoring and pollution.

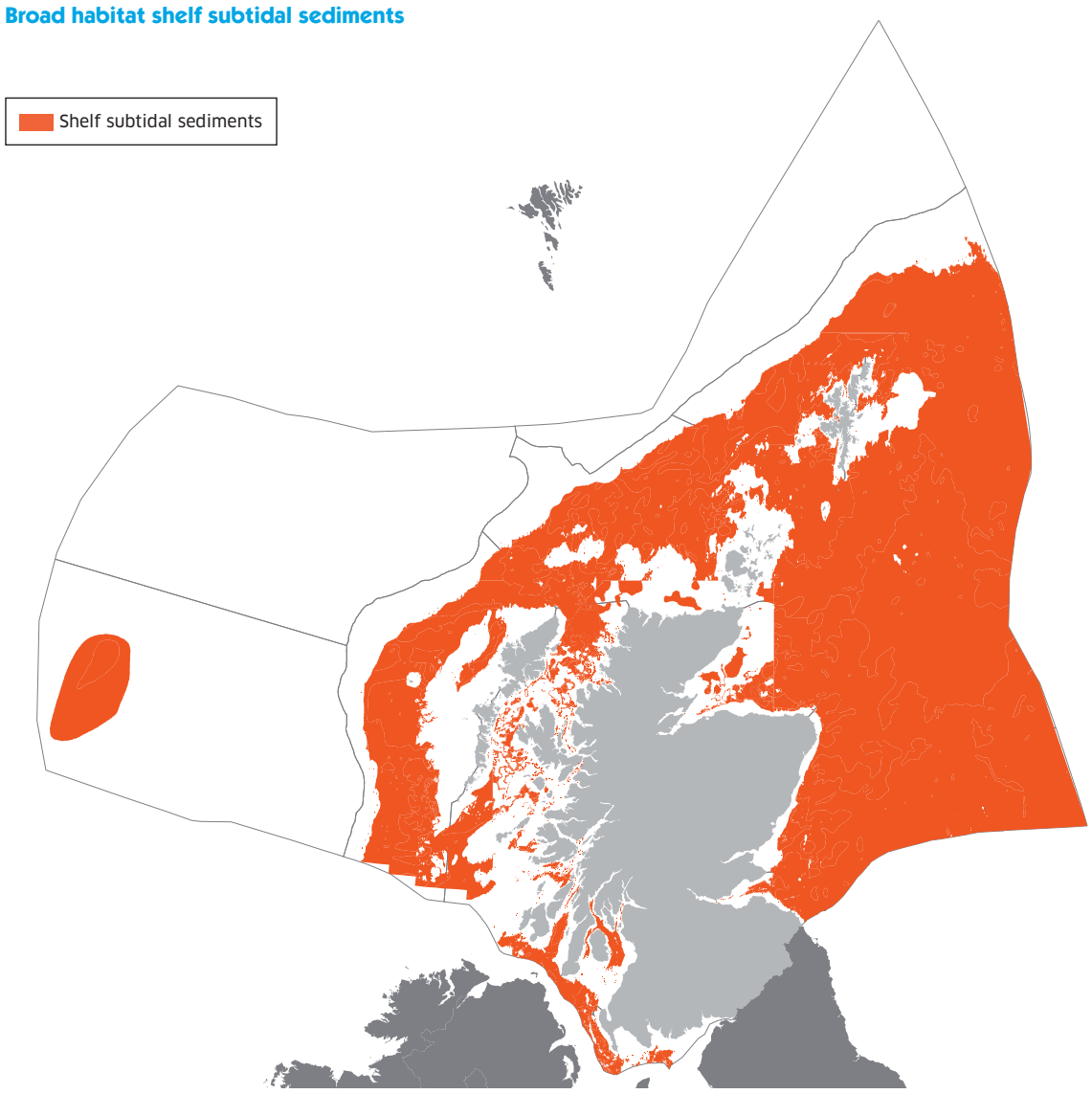
Priority marine features

Burrowing sea anemone – *Arachnanthus sarsi*
Northern feather star – *Leptometra celtica*
Fan mussel – *Atrina pectinata*
Heart cockle – *Glossus humanus*
Ocean quahog – *Arctica islandica*
Burrowed mud
Maerl beds
Maerl or coarse shell gravel with burrowing sea cucumbers
Inshore deep mud with burrowing heart urchins
Shallow tide-swept coarse sands with burrowing bivalves
Seagrass beds
Low or variable salinity habitats

Broad habitat shallow subtidal sediments



Broad habitat shelf subtidal sediments



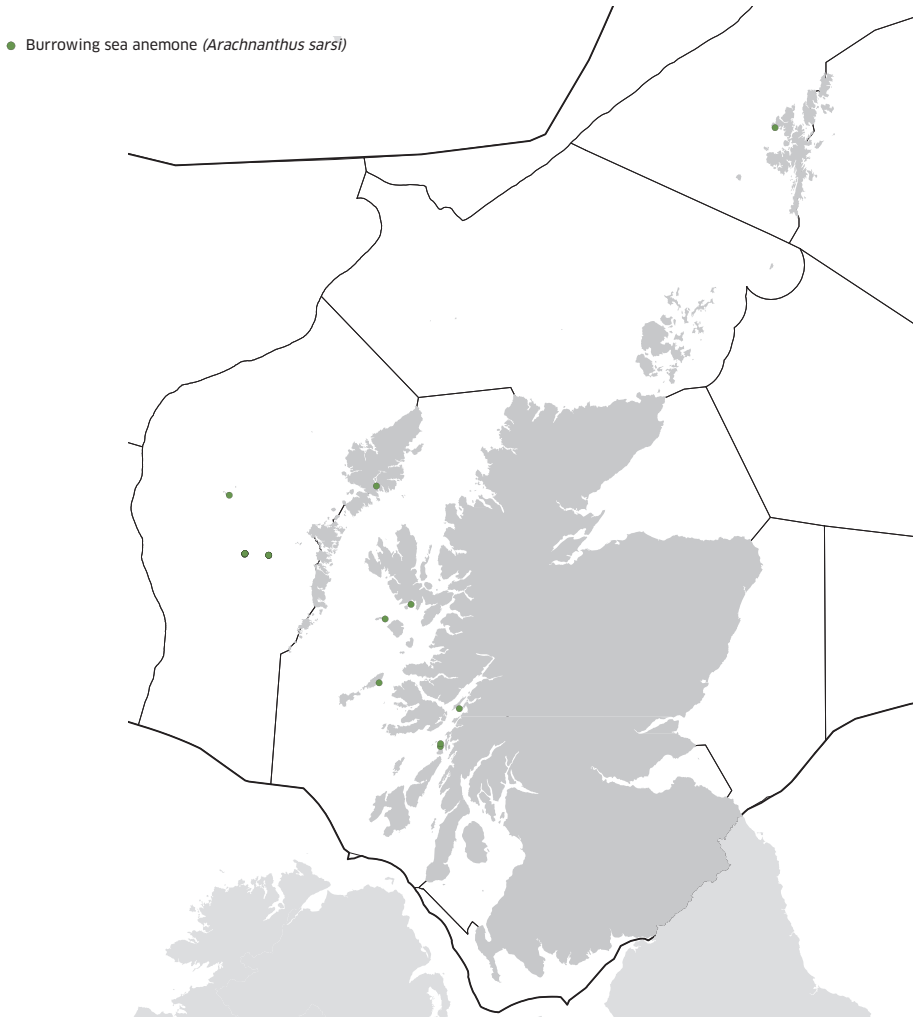
Burrowing sea anemone *Arachnanthus sarsi*

This large tube-dwelling sea anemone lives buried in mud, sand or shelly mud between 10 and 36m depth. There are scattered records from St Kilda, the Inner and Outer Hebrides and the Firth of Lorn with one further record from Shetland. It is considered nationally rare at the UK scale and Scottish populations may be of international importance as the majority of the records are from Scotland. Populations appear to be isolated and fragmented and recruitment is likely to be sporadic.

Pressures

The main pressures are from dredging and demersal fishing.

© Bernard Picton



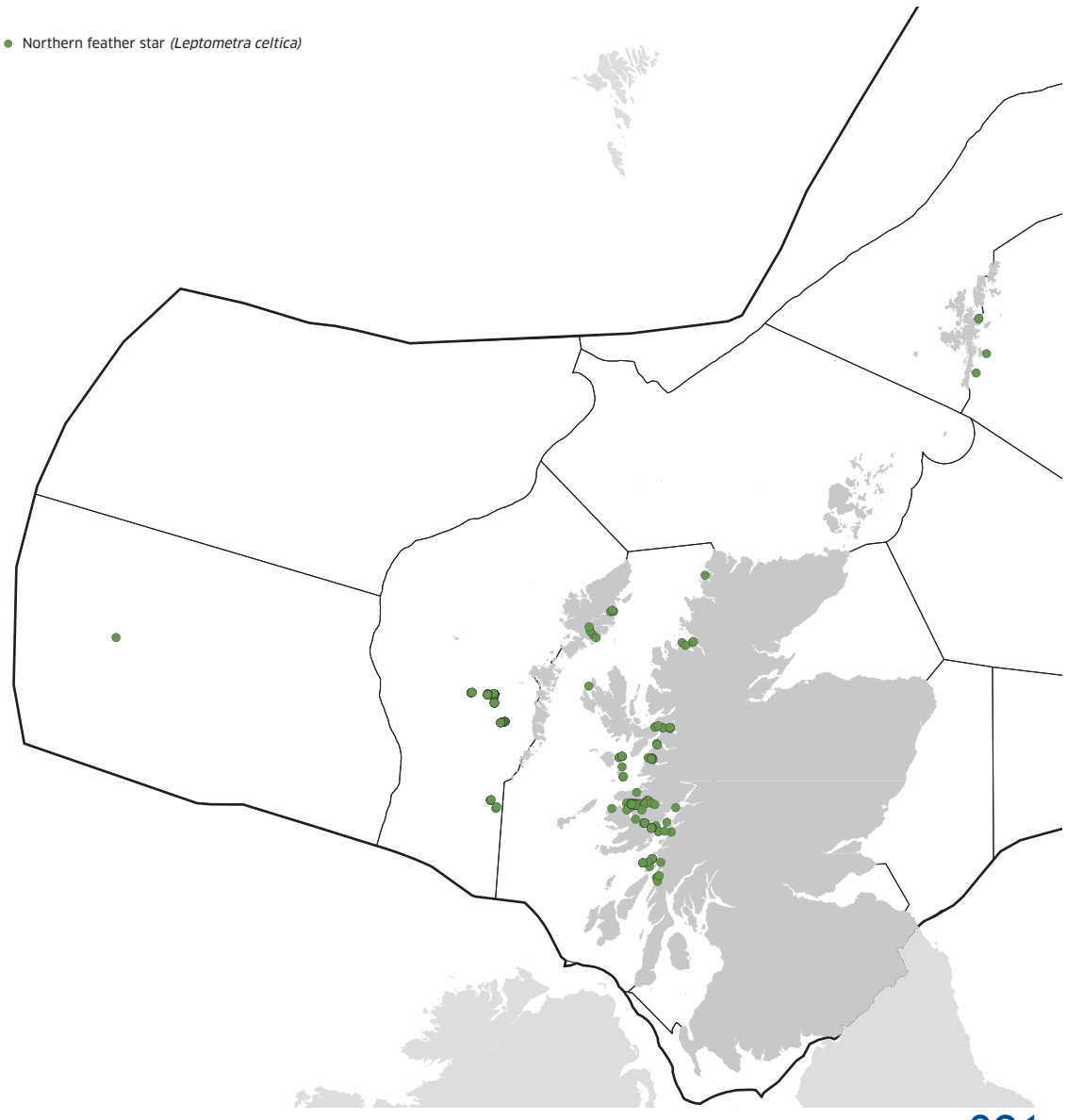
Northern feather star *Leptometra celtica*

Commonly found on sediment, shell, gravel or bedrock from 40 to 200m depth, it can on occasions form very dense aggregations on the sea bed. The majority of records from the UK are from the west and north coasts of Scotland and Shetland.

Pressures

The main pressures are from dredging and demersal fishing.

© SNH



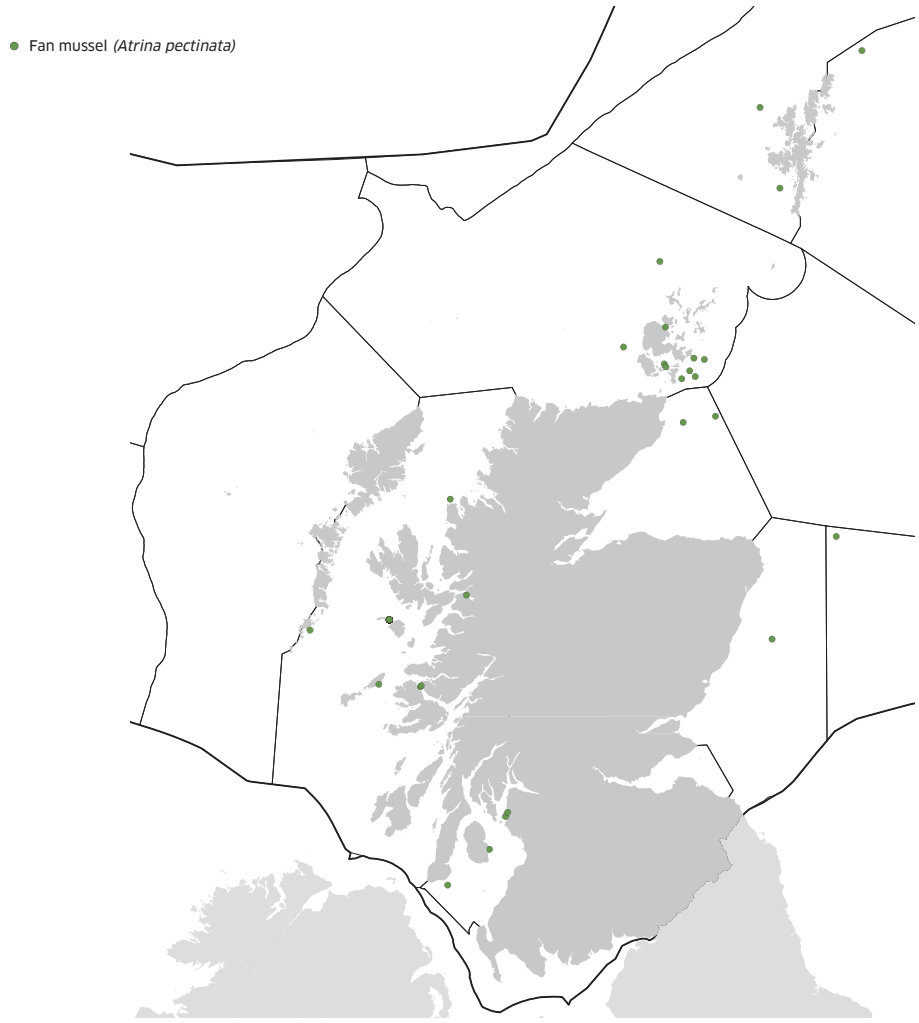
Fan mussel
Atrina pectinata

The fan mussel is one of Britain's largest molluscs growing up to 48cm in length it is found embedded in the sediment with one end protruding into the water column. It is one of the most endangered molluscs in the UK and considered nationally scarce, with over 50% of recent records from Scottish waters on the western and northern coasts. The densest known bed of fan mussels has been discovered recently in a dredge spoil disposal site off Canna.

Pressures

Fan mussels are particularly sensitive to damage from scallop dredging and other mobile fishing gear.

© Sue Scott/SNH

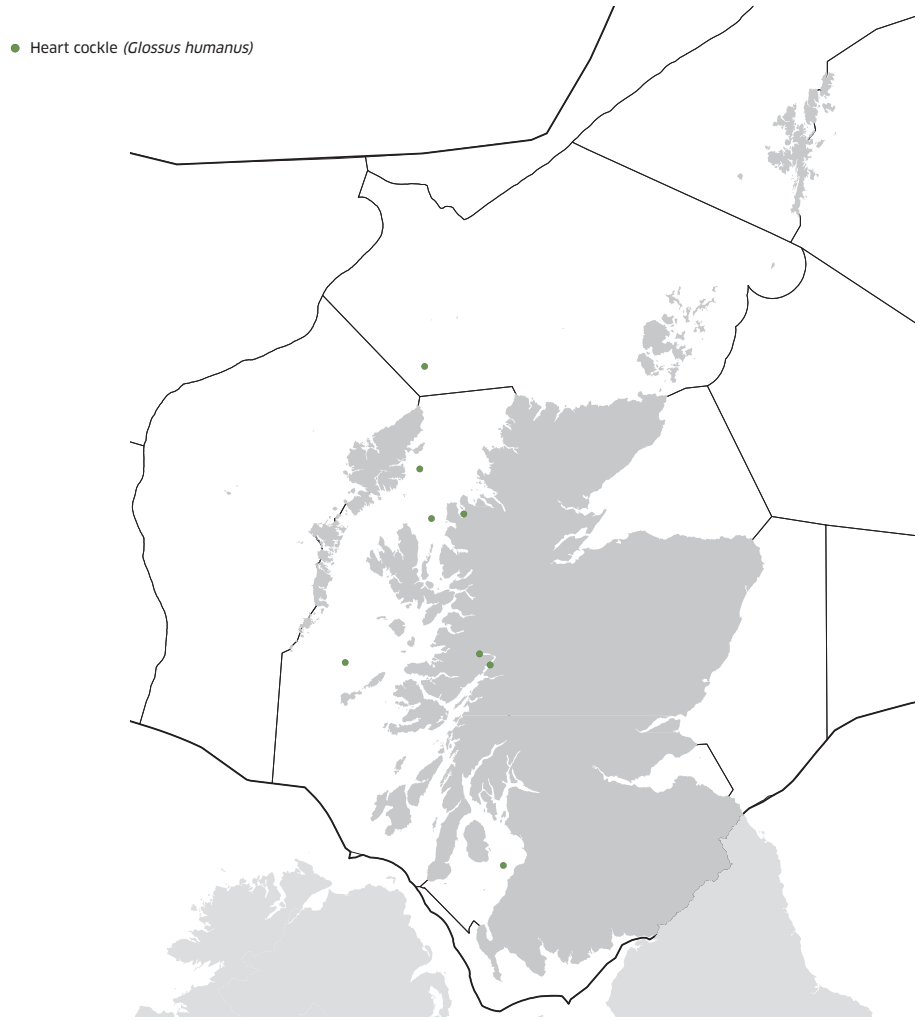


Heart cockle
Glossus humanus

This large heart shaped cockle is found in undisturbed soft muds typically below 50m depth. It is likely to be under-recorded at present and may be more abundant, especially offshore, than the scattered records suggest. The Scottish records are all from the west coast and off the Hebrides and represent 80% of UK records.

Pressures

The heart cockle is threatened by dredging and demersal fishing activities.



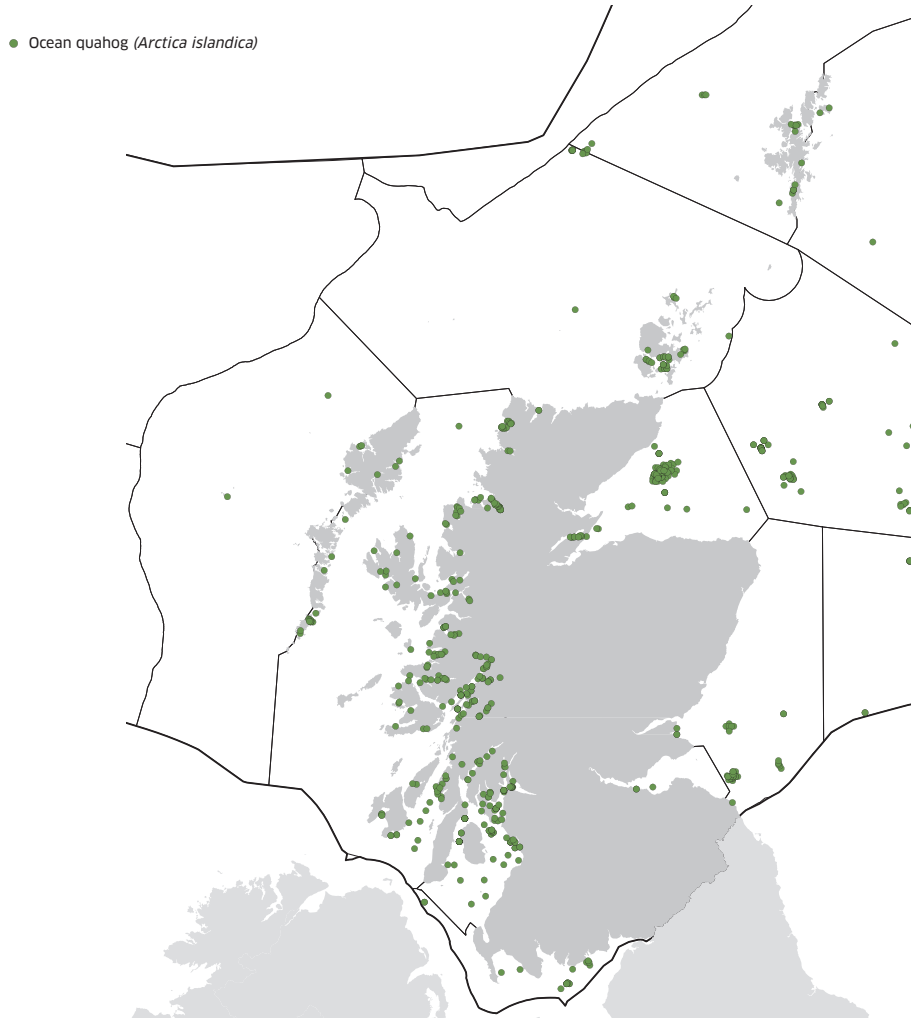
Ocean quahog
Arctica islandica

The ocean quahog is the longest living mollusc known, and may live for over 400 years. It is most commonly found in sandy and muddy sediments between 10 and 280m depth from all around Scotland, mainly offshore in the east of Scotland and northern North Sea. Seventy percent of the British records occur in Scotland but it is now in decline.

Pressures

It is at risk from mechanical damage particularly caused by bottom fishing gear.

© Paul Kay



Burrowed mud

In areas where this habitat is undisturbed it is extensively burrowed by several species including the commercially important Norway lobster (*Nephrops norvegicus*). It also supports a number of characteristic and important species such as the fireworks anemone (*Pachycerianthus multiplicatus*) and the tall sea pen (*Funiculina quadrangularis*). This habitat type is concentrated within Scottish waters. Ninety-five percent of UK records of inshore and deep burrowed mud are from the northern North Sea and the sea lochs of western Scotland and the Hebrides and are of international importance.

There are a number of important burrowed mud communities and species:

Seapens and burrowing megafauna in circalittoral fine mud

Burrowing megafauna and *Maxmuelleria lankesteri* in circalittoral mud

Tall seapen – *Funiculina quadrangularis*

Fireworks anemone – *Pachycerianthus multiplicatus*

Mud burrowing amphipod – *Maera loveni*

Nephrops emerging from burrow

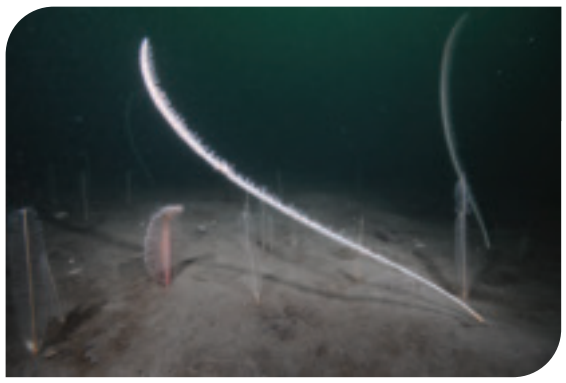
© Paul Kay

Seapens and burrowing megafauna in circalittoral fine mud

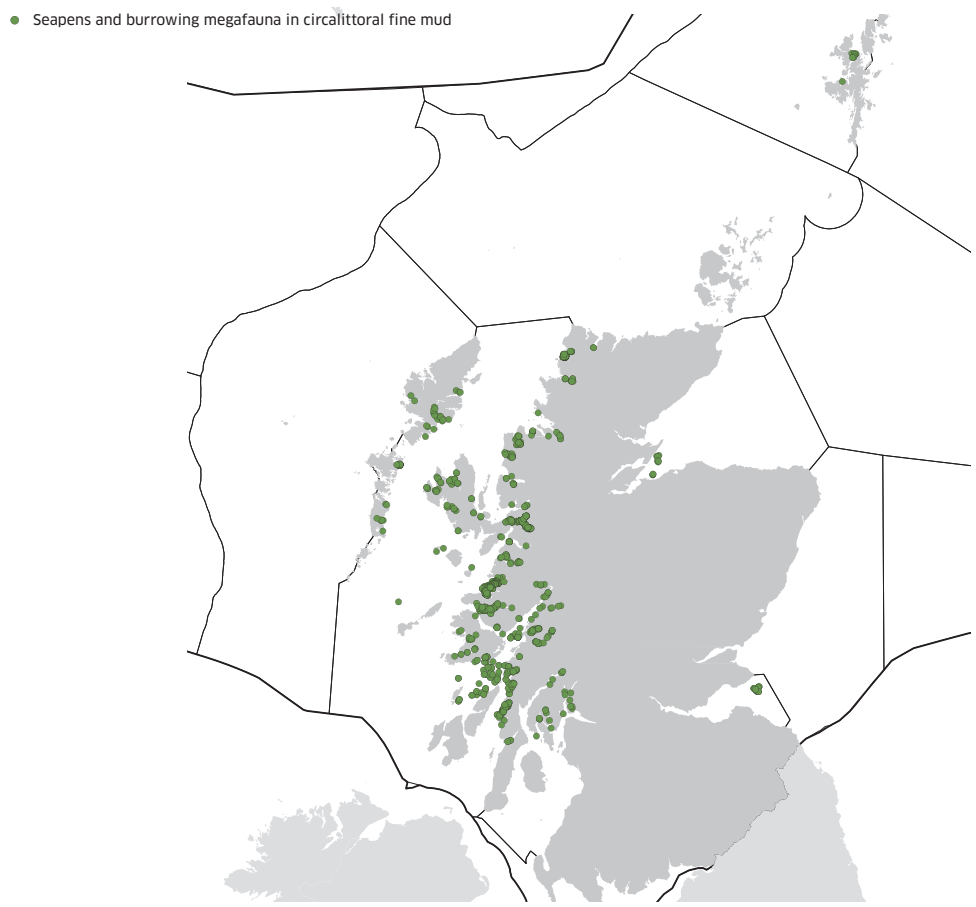
Extensively distributed throughout the sea lochs of the west coast, Hebrides and voes of Shetland it occurs at depths of between 10-100m. It supports a diverse burrowing fauna and in particular various seapens in the deeper, sheltered areas. The majority of the UK records are from Scotland.

Pressures

The habitat is vulnerable to the direct effects from fish farms (smothering, nutrient enrichment and chemical pollution) as well as from trawling for *Nephrops* which can cause severe physical disturbance and damage.



© Sue Scott

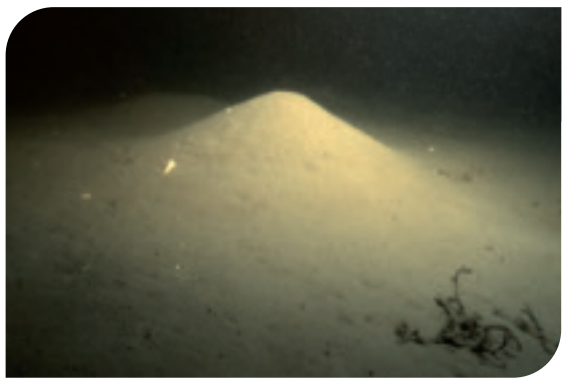


Burrowing megafauna and *Maxmuelleria lankesteri* in circalittoral mud

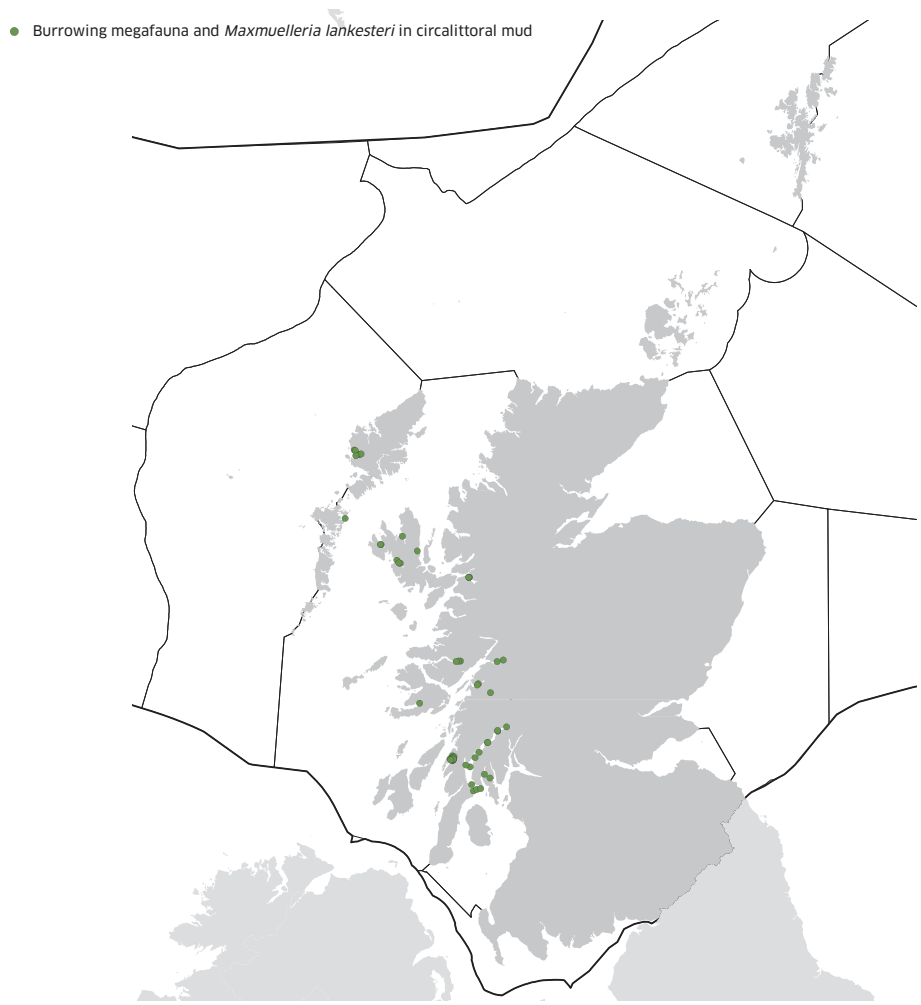
Found at depths of 10-100m in sheltered and extremely sheltered conditions in sea lochs on the west coast of Scotland and the Outer Hebrides. The great majority of UK records are from Scotland.

Pressures

Bottom trawling and creeling are likely to cause severe physical disturbance, and chemical pollution from fish farms is also potentially damaging.



© David Hughes

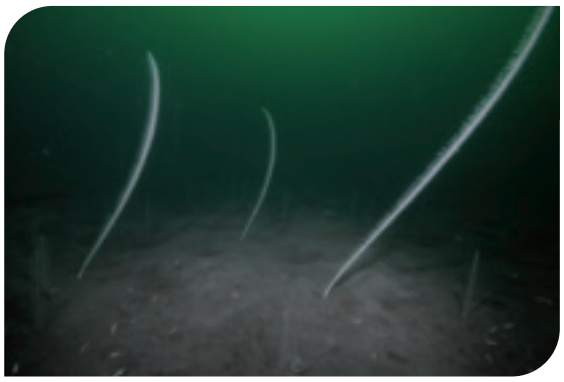


Tall sea pen
Funiculina quadrangularis

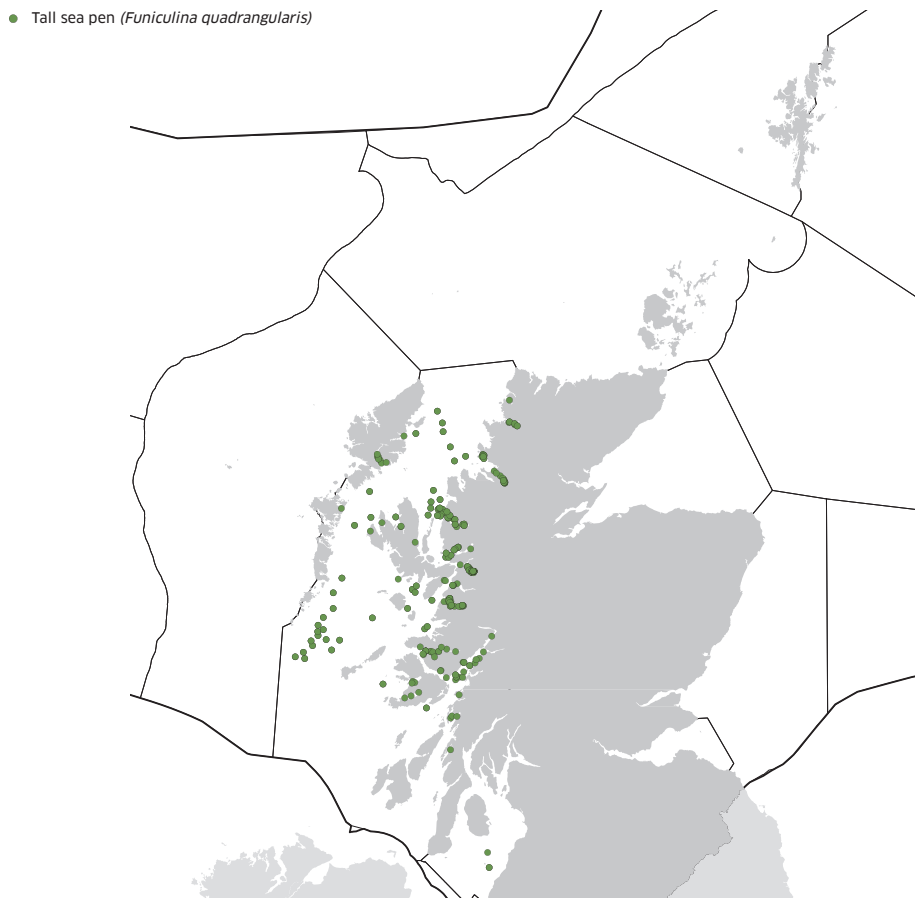
Found in deep sheltered waters up to 200m depth it has also been recorded from as shallow as 20m in some sea lochs. In the UK it is almost entirely restricted to western Scotland and the Hebrides; Scottish populations are considered of global importance.

Pressures

Tall sea pens are extremely sensitive to physical disturbance especially from mobile fishing gear and to a lesser degree from creels.



© Sue Scott



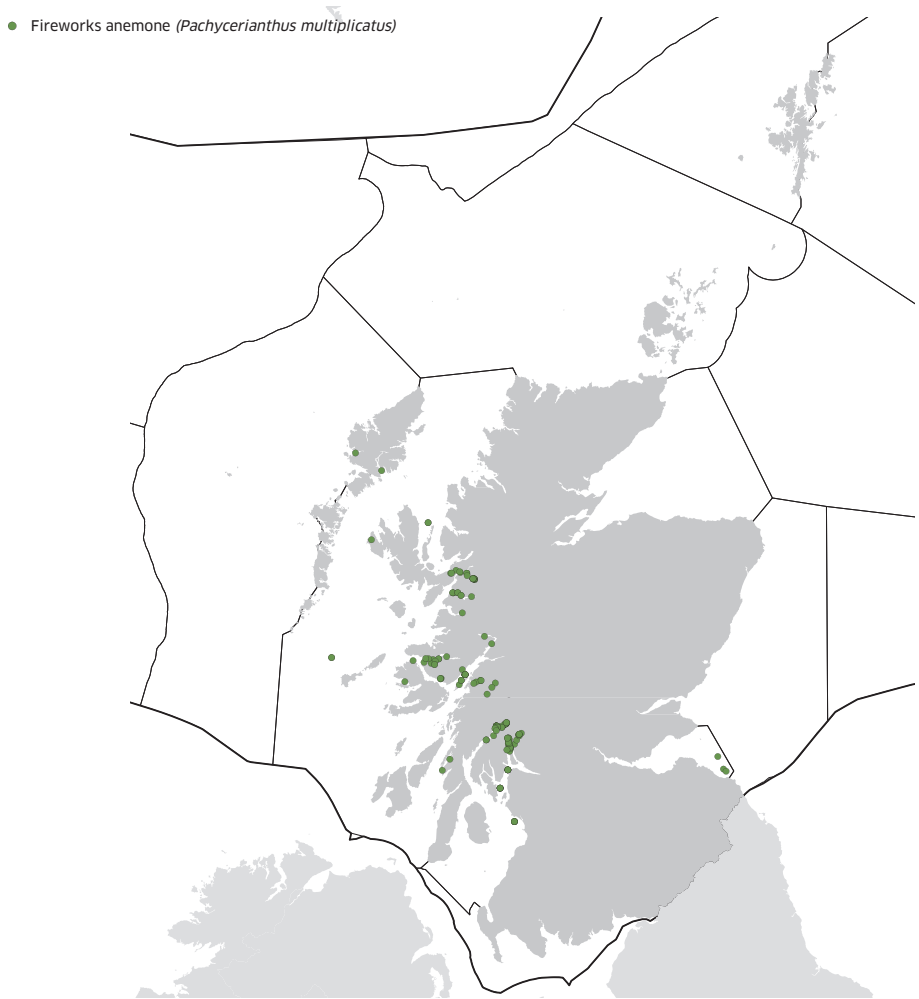
Fireworks anemone
Pachycerianthus multiplicatus

This large burrowing sea anemone lives in a long thick tube buried in mud or muddy sand at depths of 10-130m in very sheltered areas. It is restricted to a number of sea lochs on the west coast of Scotland. It is nationally scarce in the UK, Scottish populations represent 95% of all records and are of international and possibly global importance.

Pressures

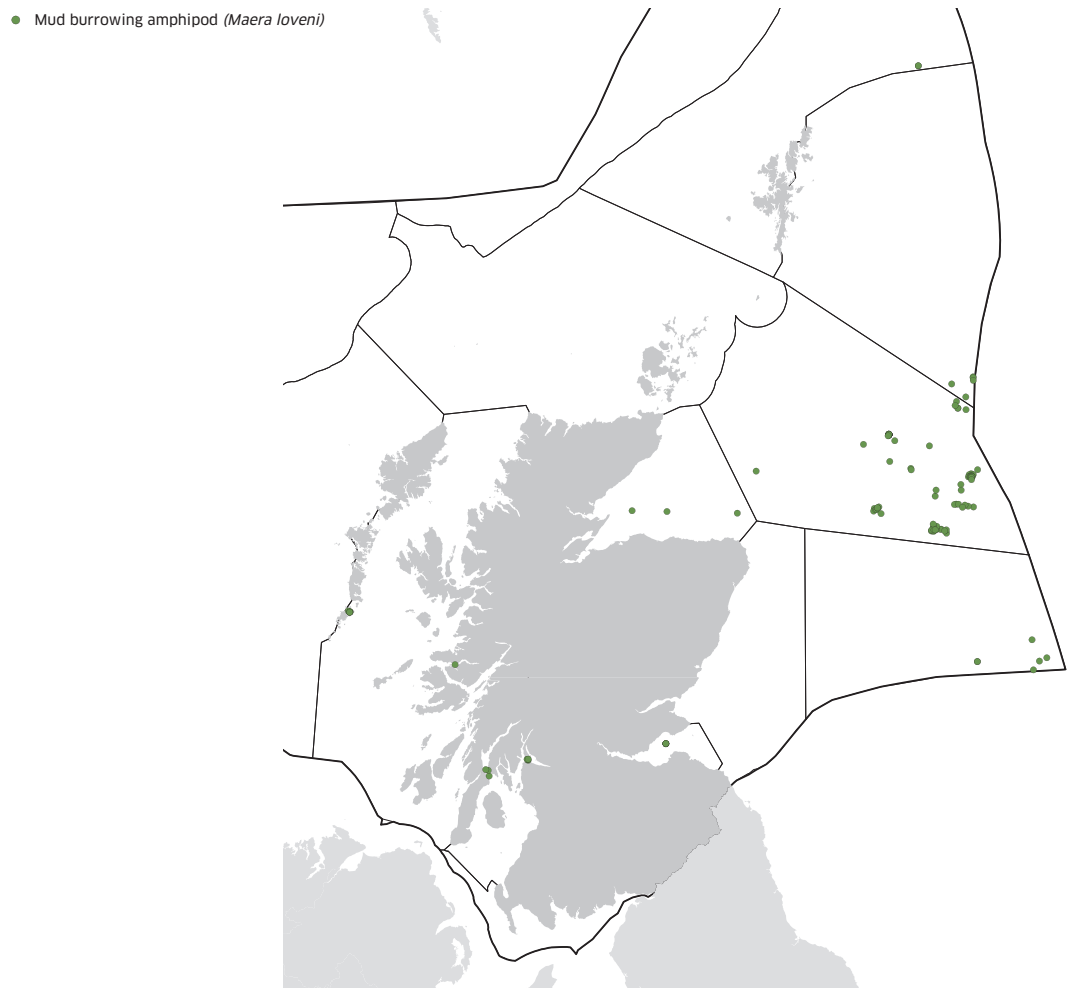
The fireworks anemone is highly sensitive to mechanical damage from mobile fishing gear particularly trawling for *Nephrops* and to a lesser degree from creels.

© Sue Scott



Maera loveni

This amphipod lives in burrows in muds in depths of 20-400m. It is a northern cold water species that has reached its southern limit in Scotland where it is sparsely distributed around the coast. Ninety-five percent of British records are from sea lochs and the northern North Sea.

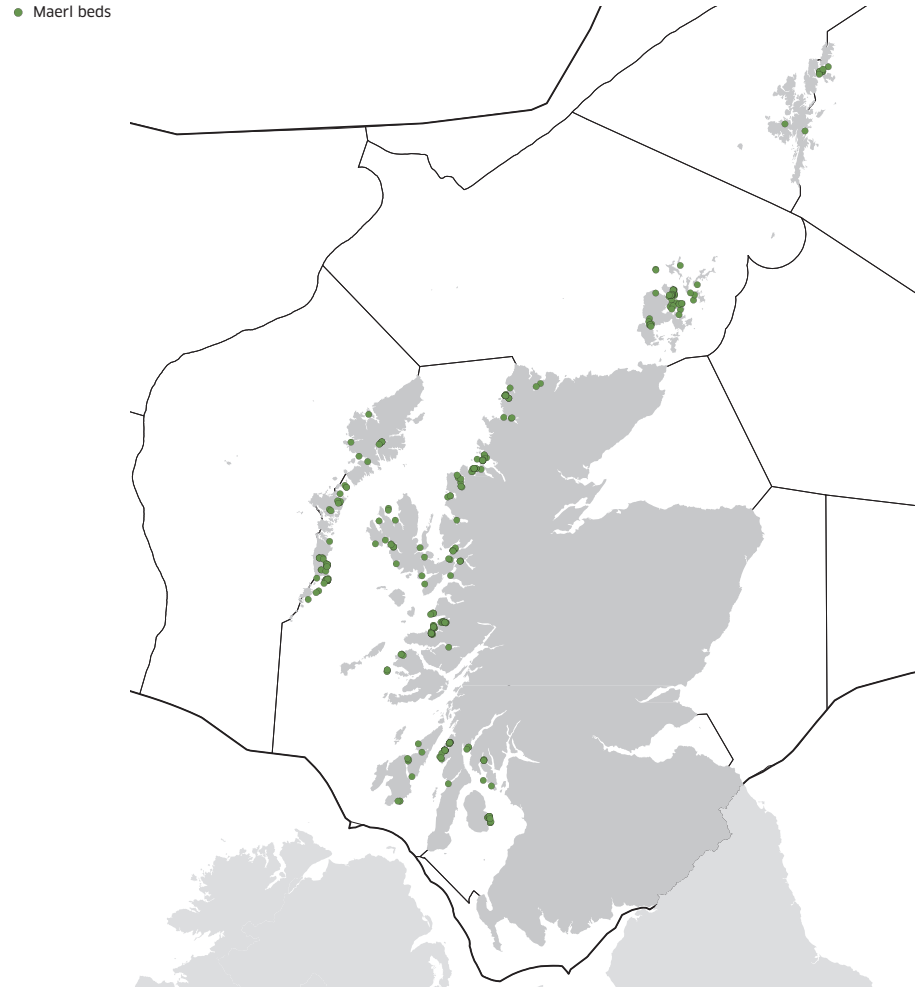


Maerl beds

Maerl beds are found along the entire west coast of Britain but the vast majority are in Scotland where they are widespread along the west coast, the Hebrides and the Northern Isles and together represent about 30% of all maerl beds in north-west Europe. Maerl is extremely slow growing and some of the extensive beds may be over 1000 years old. Maerl beds create a complex, open structure that supports diverse associated communities of red seaweeds and animals such as sea firs, scallops, brittlestars, sea cucumbers and tube dwelling sea anemones and including the juvenile stages of a range of commercially important species.

Pressures

Maerl beds are extremely sensitive to physical disturbance and smothering, as a result of scallop dredging, bottom trawling, aquaculture and extraction as a fertiliser.



© Sue Scott

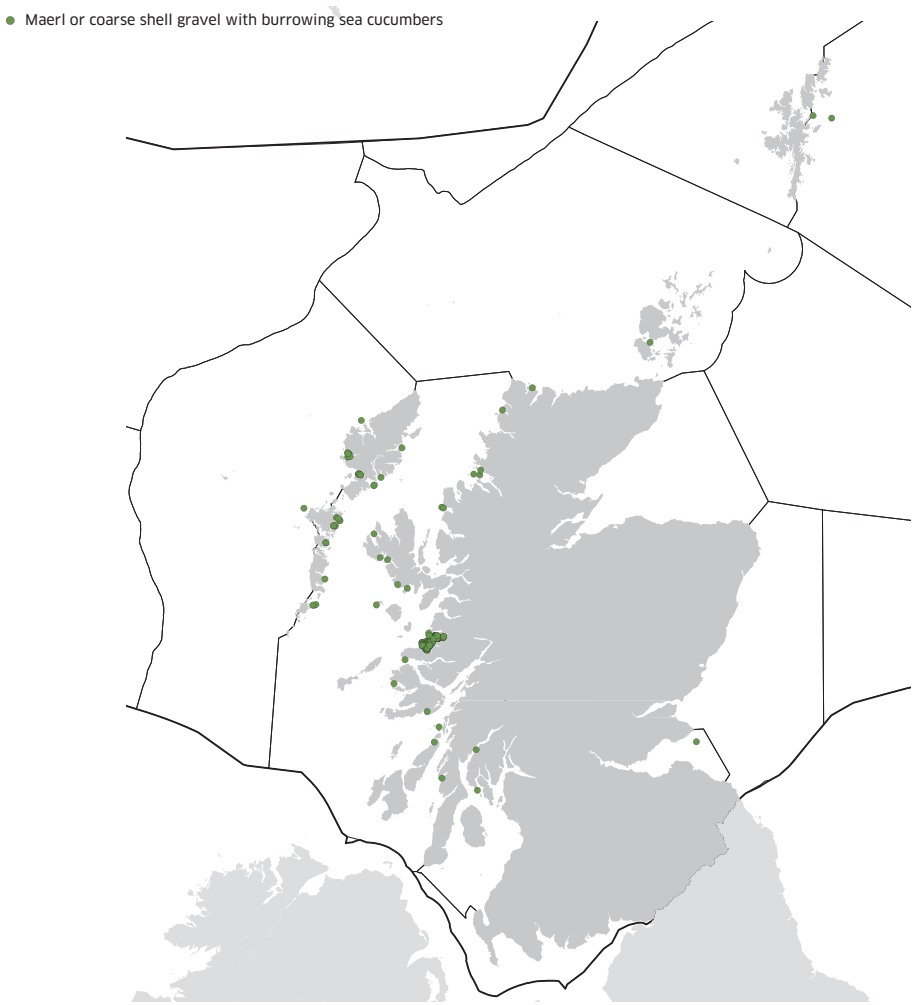
Maerl or coarse shell gravel with burrowing sea cucumbers

This habitat is found along the west coast of Scotland and the Outer Hebrides with occasional records for the Northern Isles and the Isle of May on the east coast. The gravel sea cucumber (*Neopentadactyla mixta*) can be found in high densities within the gravel, maerl, coarse sand mixture along with scallops, brittlestars, crabs and dragonets.

Pressures

It is especially sensitive to physical disturbance from scallop dredging or maerl extraction.

© Ben James/SNH



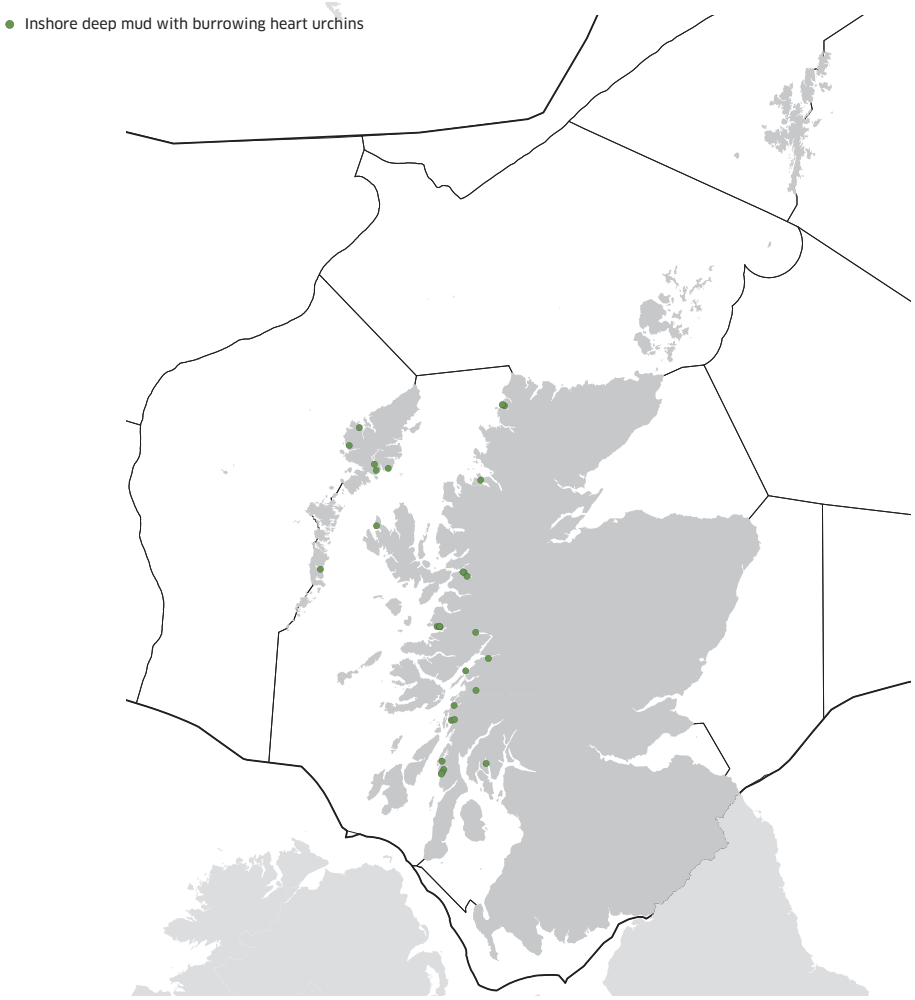
Inshore deep mud with burrowing heart urchins

The deep silty-muddy basins of some sea lochs support a community dominated by the heart urchin (*Brissopsis lyrifera*) and the brittlestar *Amphiura chiajei* as well as supporting various burrowing polychaete worms and bivalves and prawns. The majority of records are from Scotland from various sea lochs on the west coast and Outer Hebrides.

Pressures

The community is particularly vulnerable to damage from benthic trawling for *Nephrops* which may result in the removal of heart urchins and other sensitive species such as seapens.

© Paul Kay



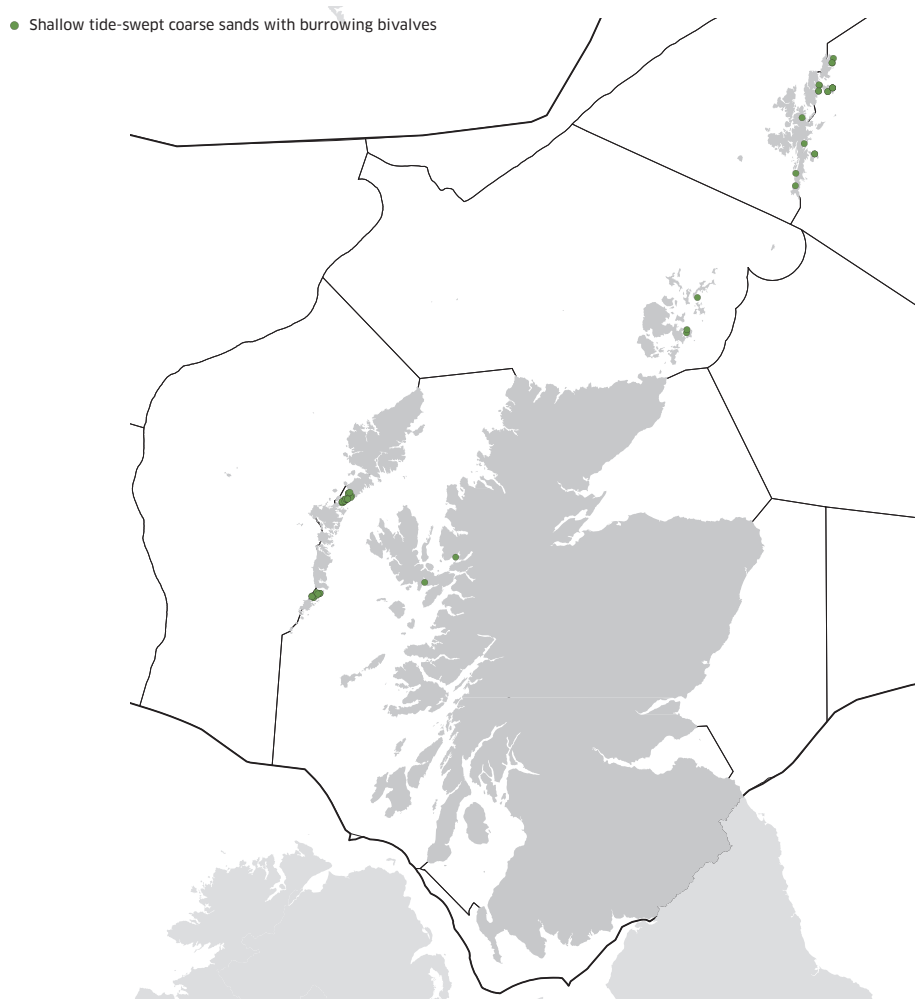
Shallow tide-swept coarse sands with burrowing bivalves

Coarse gravelly sand on exposed coasts extending down to around 20m supports an abundance of burrowing bivalve molluscs, particularly *Tellina* spp. and surf clams, and polychaete worms, tanaids and sand hoppers. It has a very limited distribution with most records from Shetland and a few from Orkney, the west coast of Scotland and Outer Hebrides. Scottish records are probably of national importance at the UK scale.

Pressures

It is likely to be targeted for scallop dredging and surf clam fisheries and whilst the overall habitat is relatively robust these slow growing molluscs are sensitive to overfishing and physical disturbance.

© Paul Kay

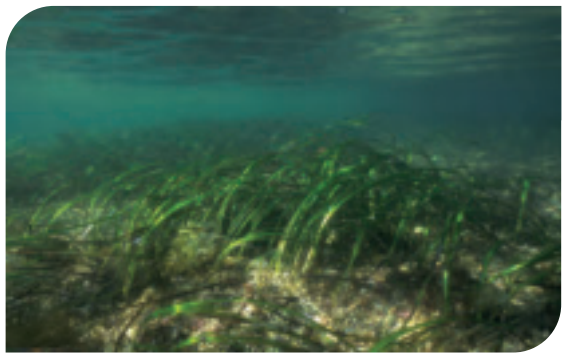


Seagrass beds

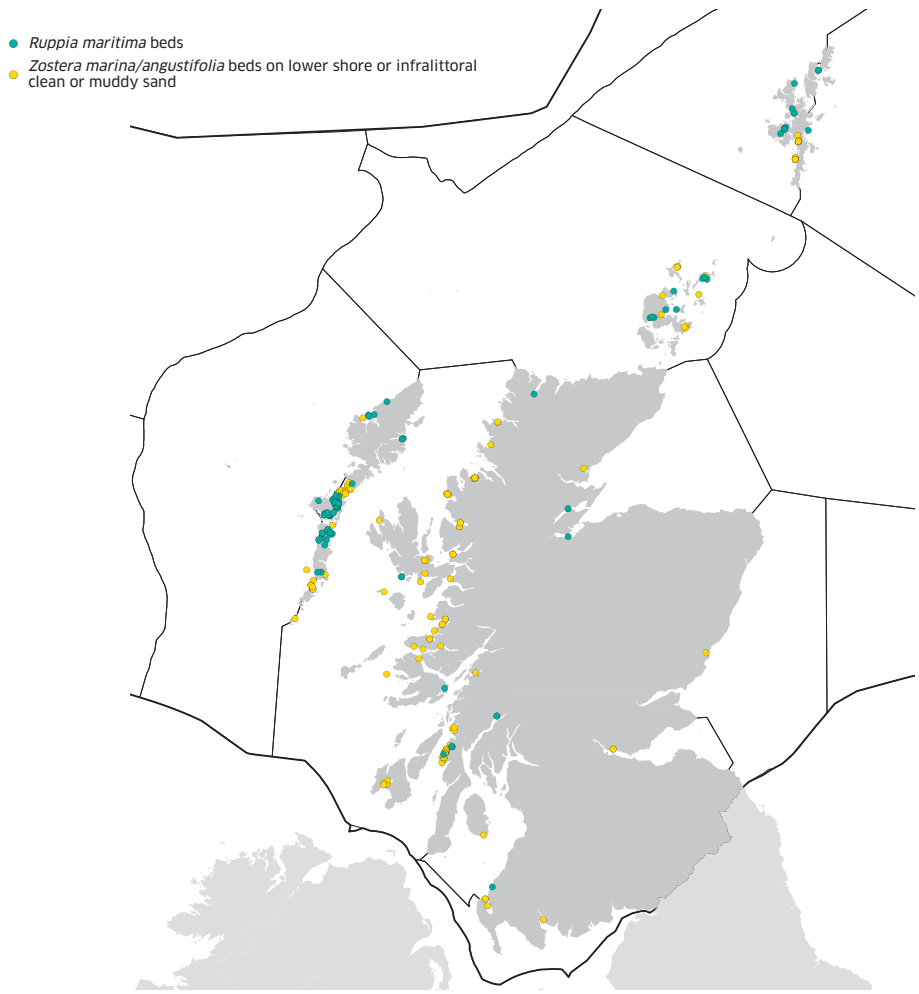
Subtidal seagrass beds of the eelgrass *Zostera marina* are considered nationally scarce and found on the west coast of Scotland extending up to the Northern Isles with a few records from the east coast in more sheltered bays and firths. The eelgrass stabilises the underlying sediment and absorbs a proportion of the wave energy as well as being a nursery area for many commercially important species of fish. Scotland holds about 20% of the seagrass beds in north-west Europe with many being considered degraded following significant declines.

Pressures

Seagrass beds are particularly vulnerable to physical damage from anchors, nutrient enrichment and increasing turbidity that reduces the available light.



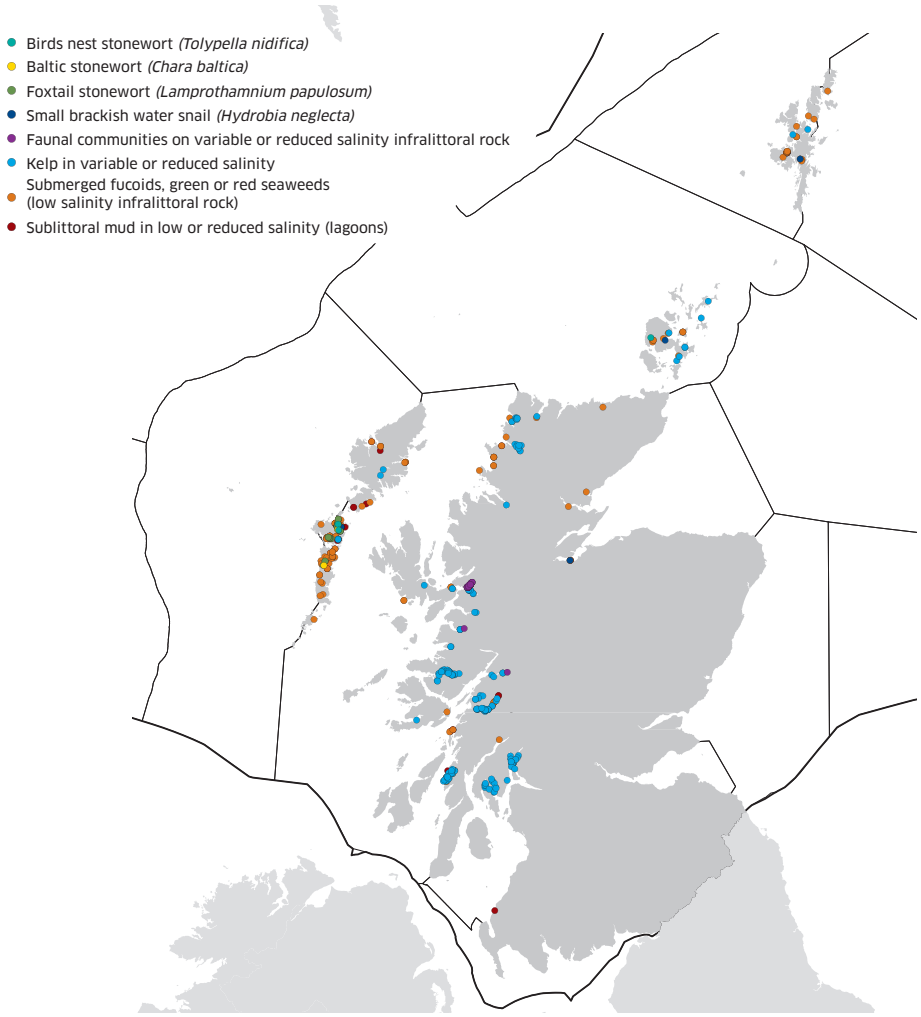
© Sue Scott



Low or variable salinity habitats

Saline lagoons are shallow, coastal water bodies with varying salinity and support a diverse assemblage of specialised species that are able to tolerate the wide range of environmental conditions that exist within these habitats. Scotland contains the largest proportion of saline lagoons in the UK with 150 recorded covering around 3,900 hectares.

© Sue Scott



There are a number of priority marine habitats and very rare and endemic species:

Faunal communities on variable or reduced salinity infralittoral rock
Very few records of this habitat exists. Examples include Firth of Forth, Shetland and Outer Hebrides and some west coast sea lochs. Typically it comprises dense beds of blue mussels which support barnacles, sea firs and sea mats.

Kelp in variable or reduced salinity
Very few records occur outside Scotland where it is found in saline lagoons in Orkney, Shetland, the Hebrides and west coast of Scotland. The habitat is dominated by sugar kelp and various red and green seaweeds and is only found on very wave sheltered bedrock and boulders.

Submerged fucoids, green or red seaweeds (low salinity infralittoral rock)
This is a characteristic lagoon community dominated by dense seaweeds with a very restricted fauna due to the low salinity. It is unique to Scotland where there are numerous records from the Outer Hebrides, Orkney and Shetland. Scotland is of national importance for this habitat.

Sublittoral mud in low or reduced salinity (lagoons)
This is a very characteristic lagoon community comprising various short-lived species such as blow lugworms and mud shrimps. The beaked tasselweed (*Ruppia*) may also be present. Only a few records of this habitat exist outside Scotland where it is found in the Outer Hebrides, Shetland and within the Beauly Firth.

Baltic stonewort *(Chara balthica)*
Status: Found in three locations in the Outer Hebrides the Scottish populations are likely to be of national importance but threatened by habitat loss. Listed as Vulnerable on the Red Data Book of Britain and Ireland.

Bird's-nest stonewort *(Tolypella nidifica)*
Status: Scottish records from Loch of Stenness, Orkney and Loch an Duin and Loch an Strumore in the Outer Hebrides are the only British records. This species is declining throughout Europe. These sites are of national and probably international importance. Listed as Endangered on the Red Data Book of Britain and Ireland.

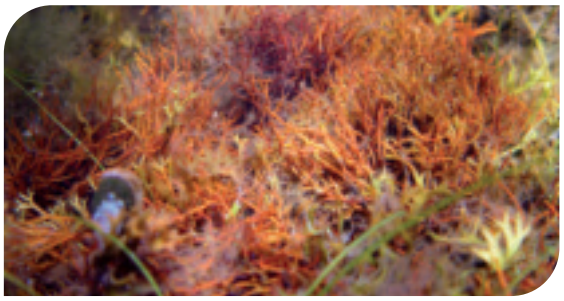
Foxtail stonewort *(Lamprothamnium papulosum)*
Recorded from North and South Uist in the Outer Hebrides. Of national importance with the Hebridean sites thought to represent the most secure global stronghold for this species. Listed as Near Threatened on the Red Data Book of Britain and Ireland.

Small brackish water snail *(Hydrobia acuta neglecta)*
Scattered records of this small snail occur on the west coast, the Outer Hebrides, Orkney and Shetland and in Montrose Basin on the east coast.

Pressures

Saline lagoons are threatened by a range of activities such as coastal development, land claim, water abstraction etc. that can either completely destroy the habitat or change it through altering the water flow and salinity regime. They are fragile habitats susceptible to sea-level rise and pollution as well as extreme weather events such as storms.

Submerged fucoids, green or red seaweeds

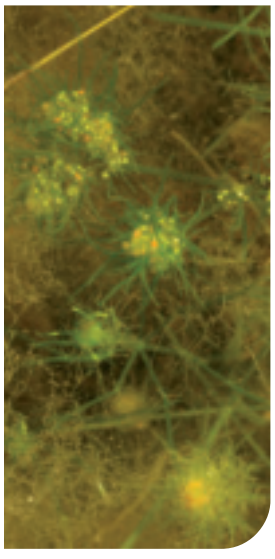


© JNCC

Baltic stonewort

© Sue Scott

Bird's-nest stonewort



© Sue Scott/SNH

DEEP SEA HABITATS

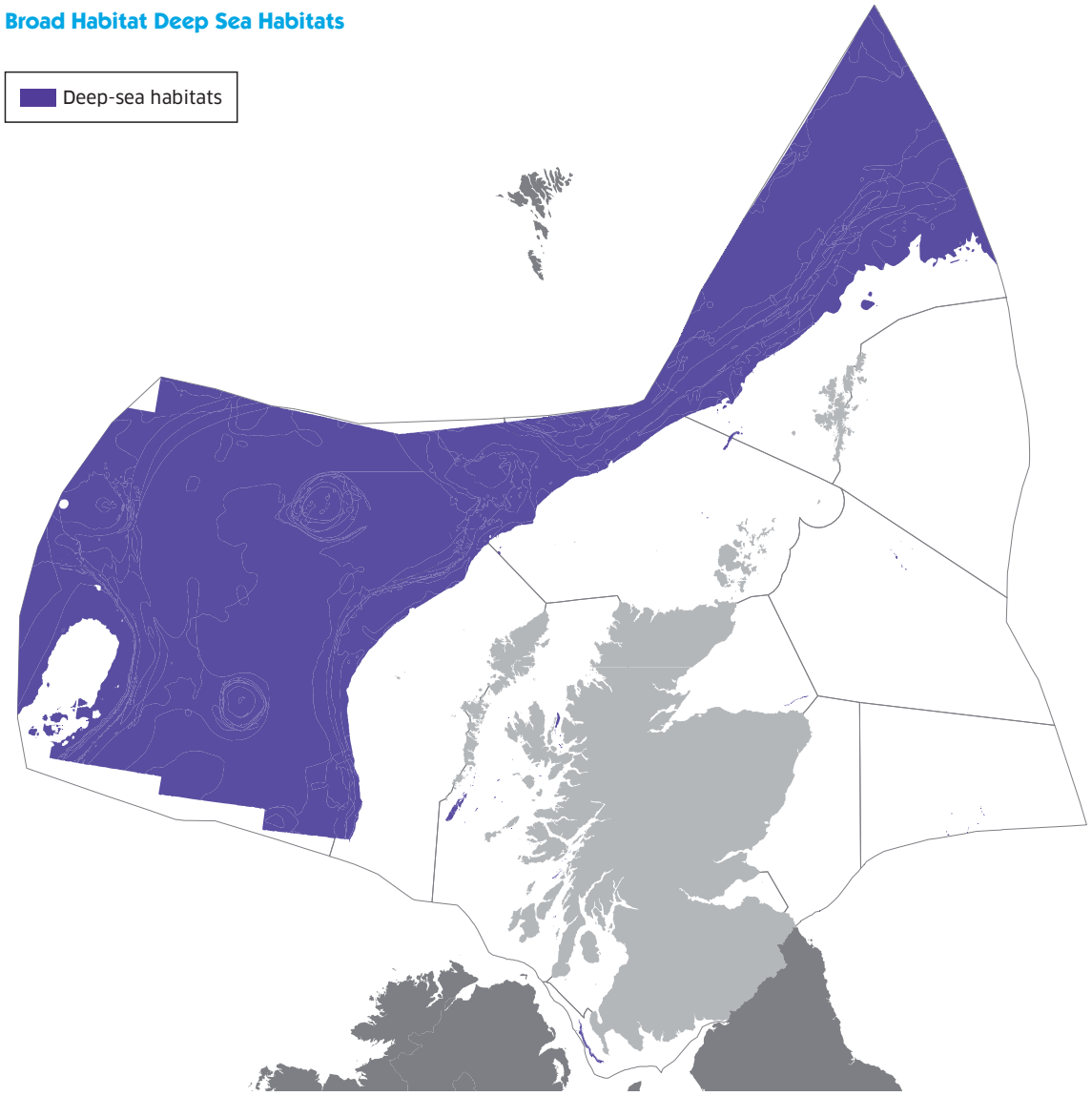
Deep Sea Habitats

These are habitats occurring beyond the continental shelf break at depths typically greater than around 200m. Knowledge of these habitats is very patchy and limited but is growing all the time, revealing more and more about the rich diversity of life found in the deep waters off Scotland. These habitats are found almost entirely to the north and west of Scotland and comprise cold water coral reefs, coral carbonate mounds, submarine canyons, sea mounts and deep sea sediments. There is relatively little abyssal plain habitat within the boundaries of Scottish waters.

Priority marine features

Seamount communities
Carbonate mound communities
Coral gardens
Deep sea sponge aggregations
Offshore deep sea muds
Cold-water coral reefs

Broad Habitat Deep Sea Habitats

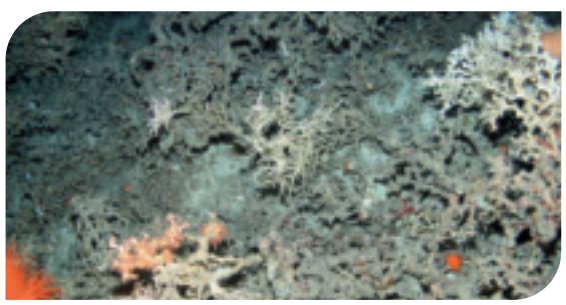


Seamount communities

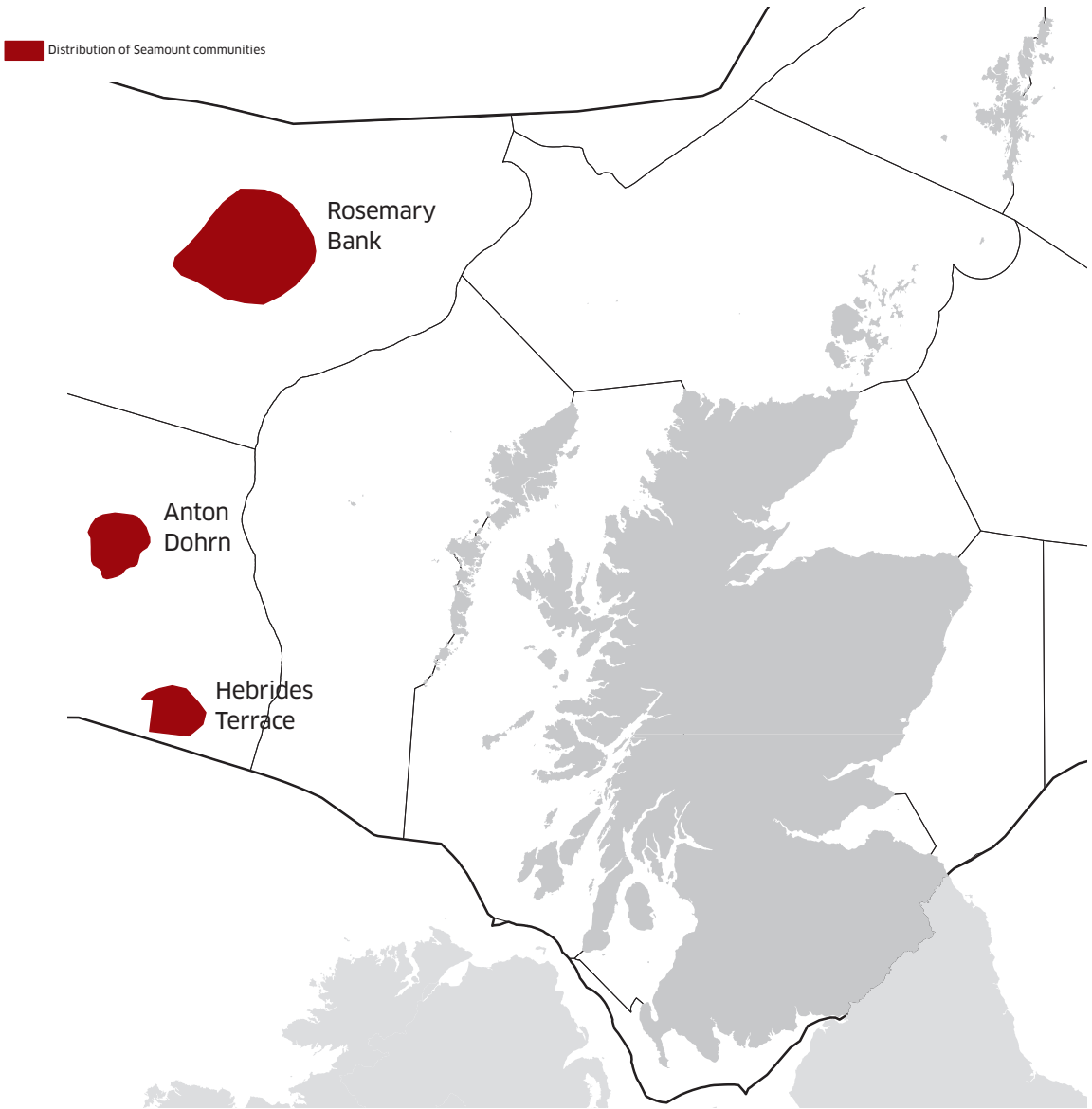
Seamounts are undersea volcanic mountains that can rise up to 1000m from the sea bed. They have relatively diverse biota in comparison to the surrounding sea bed supporting corals, sponges, hydroids and sea squirts as well as various commercial fish species such as orange roughy. They also act as a focal point for many top predators such as sharks, rays, tuna and swordfish as well as various cetaceans including bottlenose, common and spotted dolphins. There are a large number of seamounts across the Mid-Atlantic ridge but the main ones in Scottish waters are Anton Dohrn, Rosemary Bank and the Hebrides Terrace.

Pressures

Demersal and pelagic trawling, long-lining and deep sea mining all pose threats to seamounts.



© JNCC

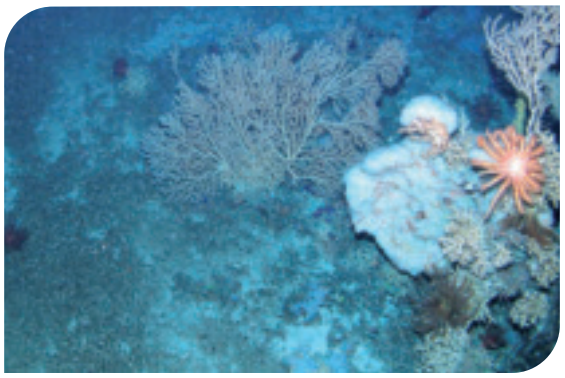


Carbonate mound communities

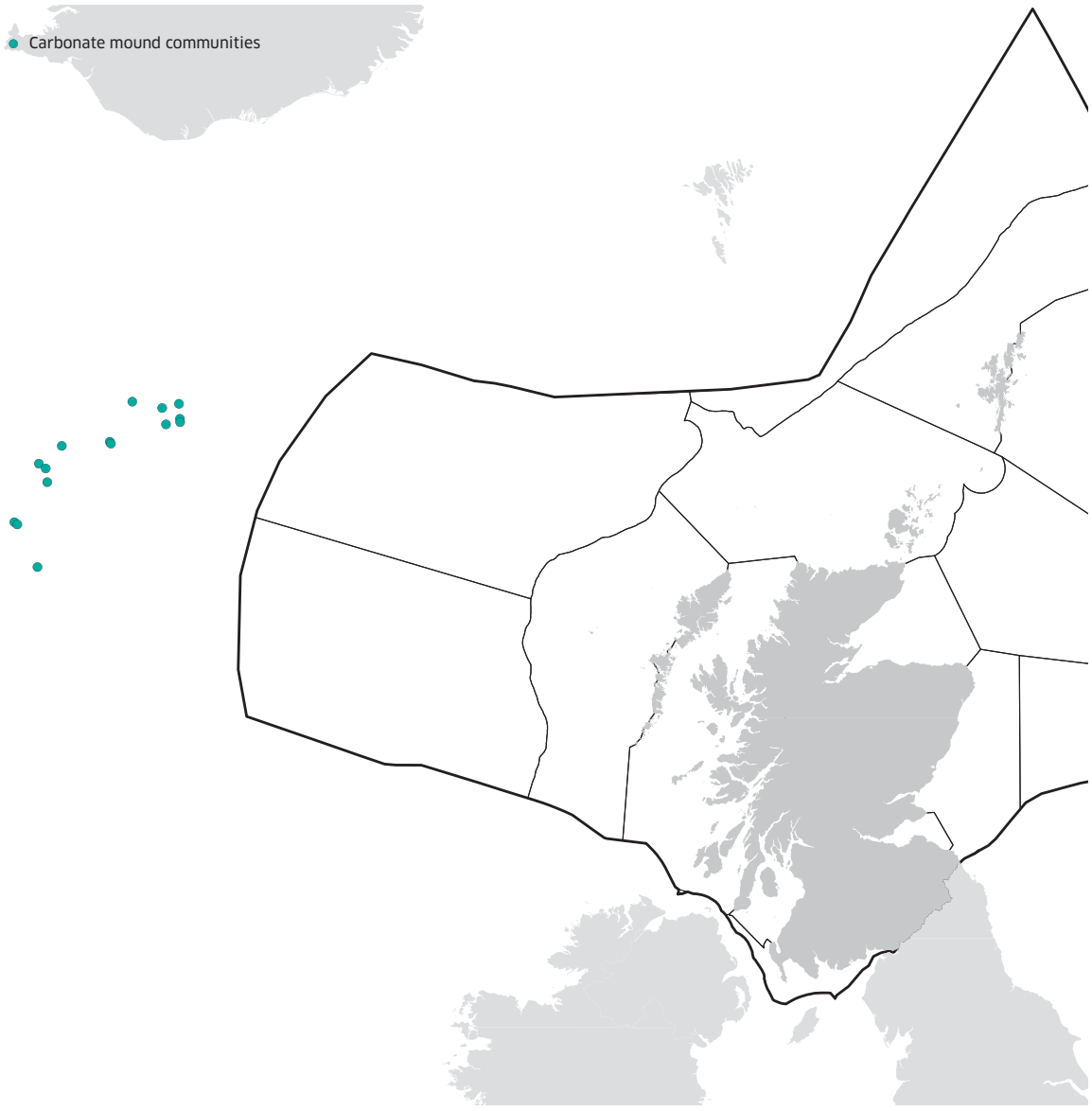
These are typically steep-sided mounds that may be up to 350m high, formed from the debris of cold water coral reefs occurring at depths of between 500 and 1100m. They support a diverse community comprising echiuran worms, sponges, bryozoans, soft corals, ascidians, tube worms, crinoids and bivalve molluscs. They are known to occur on the Hatton Bank in the far west of Scottish waters but have a wider distribution in the north-east Atlantic such as the Porcupine Bank and the Rockall Trough.

Pressures

These carbonate mound communities are particularly vulnerable to demersal trawling activities.



© JNCC

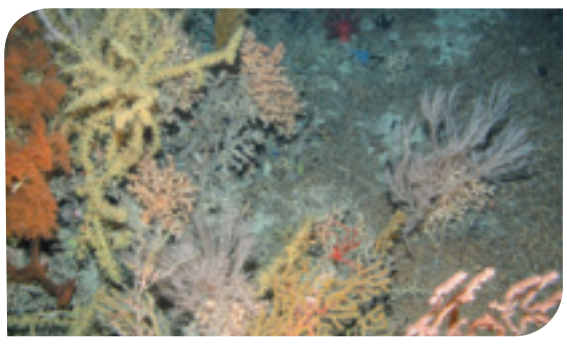


Coral gardens

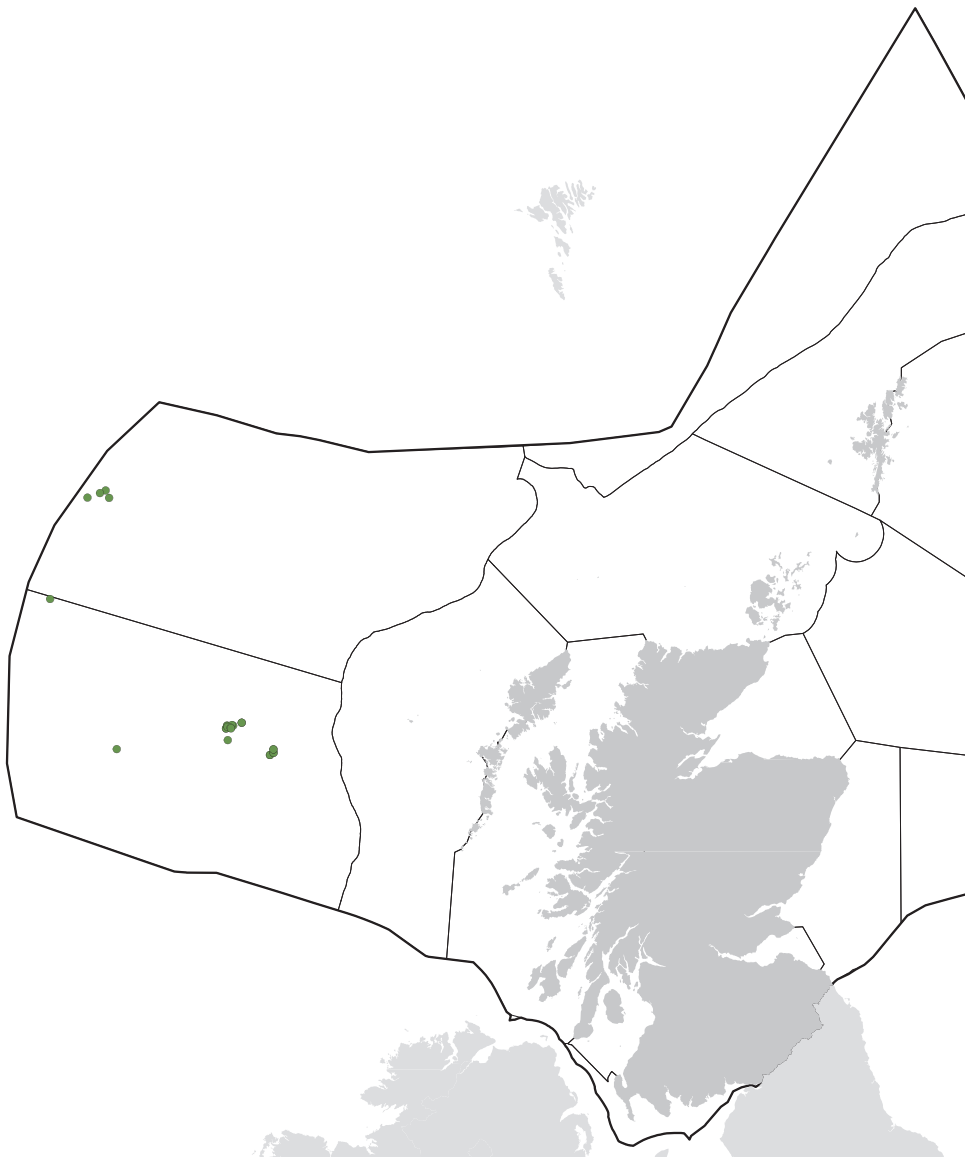
These are highly diverse habitats comprising dense aggregations of corals which may reach densities of between 100 and 700 colonies per 100m^2. Coral gardens can occur on both soft and hard substrate. They favour areas where there is a moderate to strong current and include solitary hard corals, sea pens, bamboo coral, gorgonians, hydro-corals and black coral. The associated fauna is also biodiverse comprising basket stars, brittlestars, featherstars, molluscs, crustaceans and various fish species. At present in Scottish waters they are known principally from the Anton Dohrn sea mount but further surveys are likely to discover new locations.

Pressures

Like most coral communities these are likely to be sensitive to demersal trawling activities and the effects of smothering.



© JNCC



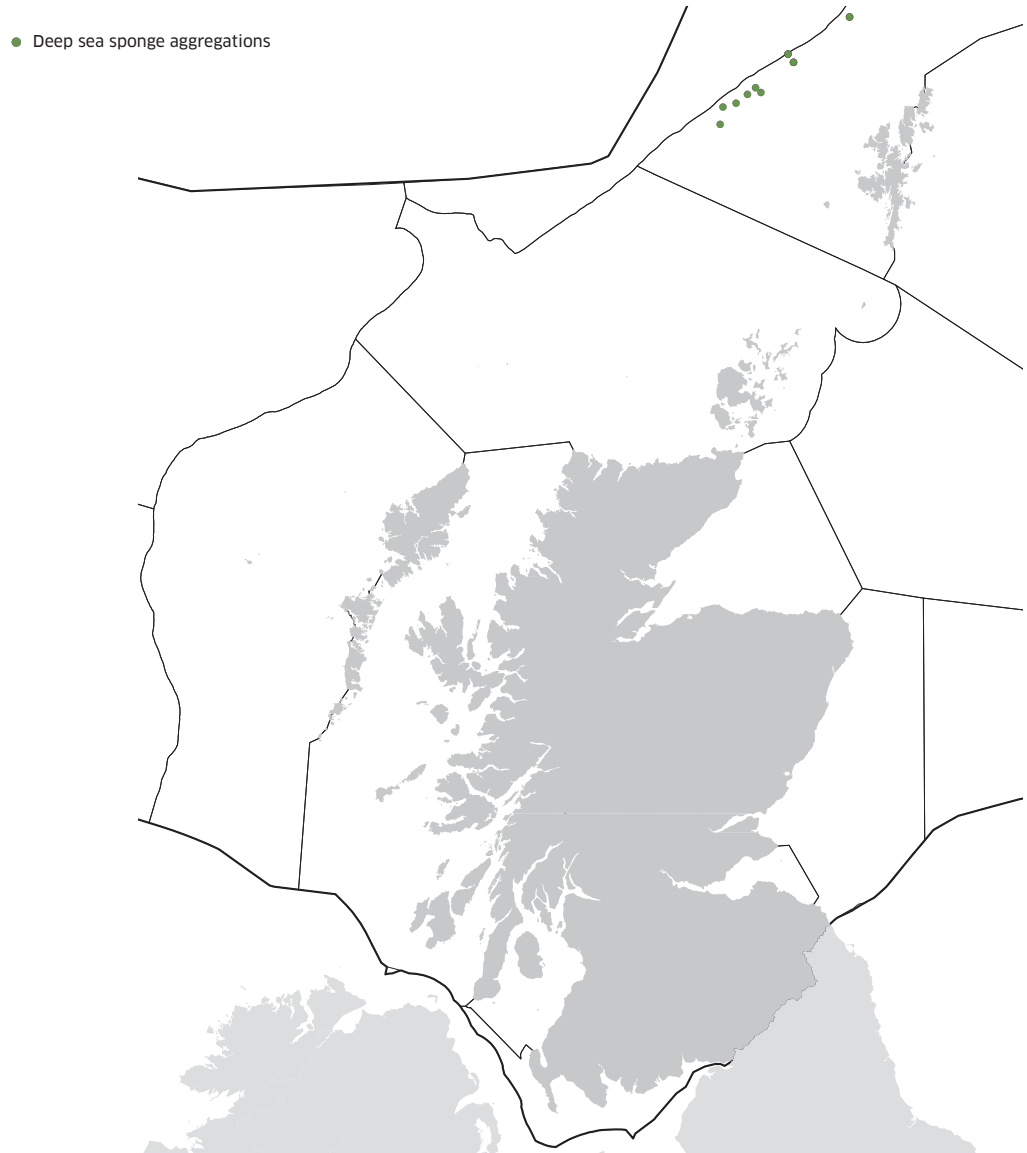
DEEP SEA HABITATS

Deep sea sponge aggregations

Deep sea sponge aggregations are found on both hard and soft substrates at depths of between 250 and 1300m; ancient iceberg plough marks are an ideal habitat as the stable boulders and cobbles provide numerous attachment points for the sponges. They are composed principally of glass sponges and the giant sponges (*Desmospongia*). The spicules from dead sponges that cover the seabed inhibit the colonisation of the sediments by burrowing animals but the sponges provide an ideal attachment point for brittlestars lifting them above the sea bed where they can catch passing food particles. At present these aggregations are known from the Faroe-Shetland channel at around 500m deep and also occur in the Porcupine Seabight in the north-west Atlantic.

Pressures

Physical disturbance to the seabed from demersal trawling may cause direct damage to these communities along with the associated increase in turbidity and subsequent sedimentation. They are also potentially vulnerable to pollution from oil and gas operations and from bio-prospecting.



Offshore deep sea muds

This is one of the most widespread and common habitats in the Scottish offshore environment occurring at depths of between 200 and 500m. It supports a community of burrowing animals such as Dublin Bay prawns (*Nephrops norvegicus*), polychaete worms, bivalve molluscs, brittlestars and foraminifera (the latter are an important potential early indicator of the impacts of ocean acidification).

Pressures

Deep sea muds are threatened by demersal fishing operations for *Nephrops* and other deepsea species that can lead to disturbance of the sea bed. Anchoring in oil and gas developments, cables and pipelines and deep sea mining also pose threats.

© Paul Kay

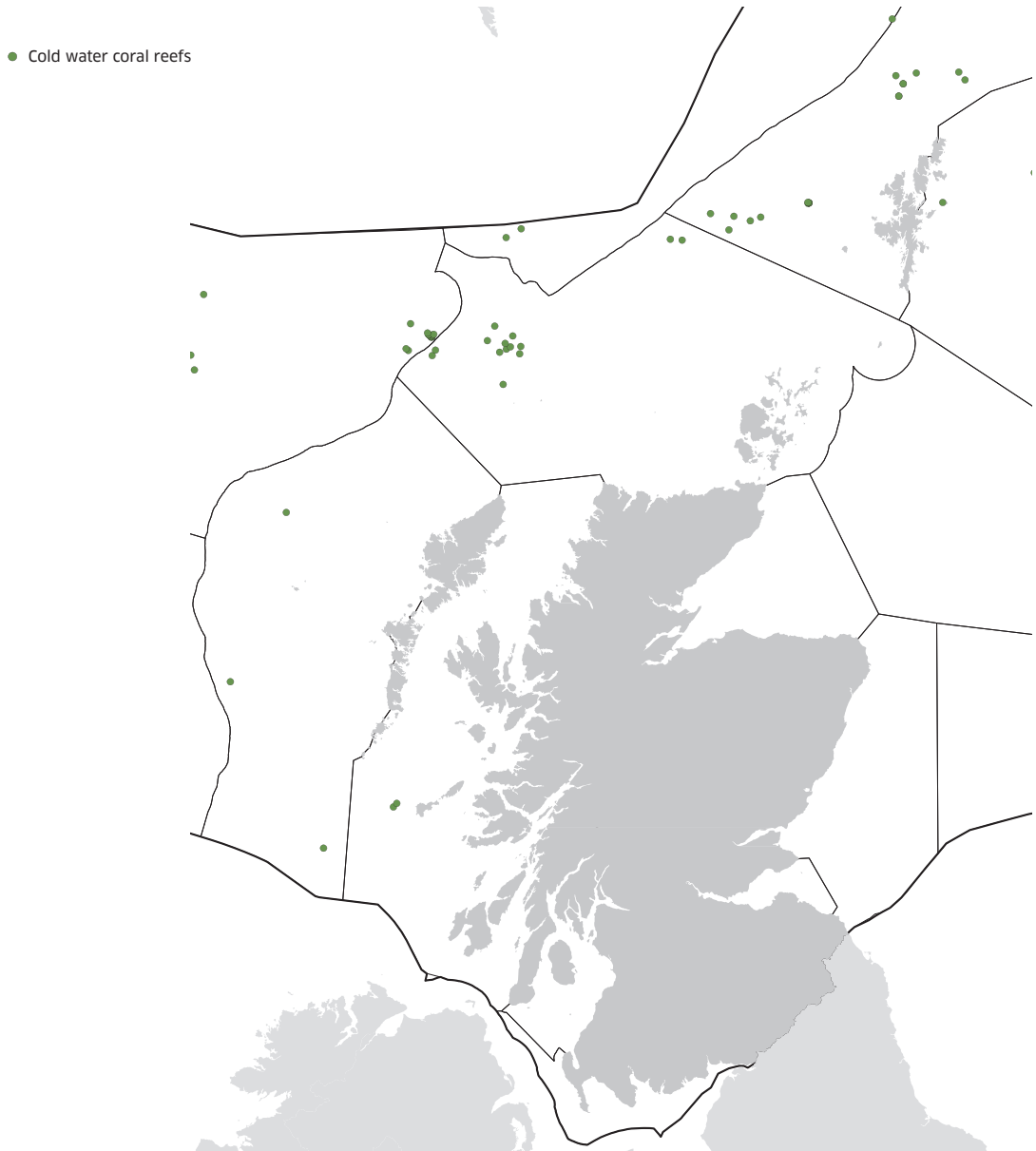
Cold-water coral reefs

Reefs of the hard, cold water coral *Lophelia pertusa* in association with other hard corals (e.g. *Madrepora oculata* and *Solenosmilia variabilis*) are found in water between 130 and 2000m depths, and can cover extensive areas of the sea bed up to several kilometres long and standing more than 20m high. The oldest of these reefs are estimated to be around 8000 years old. The reef structure provides shelter and an attachment surface for a wide range of species; over 1300 different species have been found living associated with *Lophelia* reefs in the North Atlantic including extremely rich assemblages of starfish, sea urchins, anemones and sponges. They also attract a wide range of mobile species such as red fish (*Sebastes* spp.), ling (*Molva molva*) and tusk (*Brosme brosme*), some of which are important commercial species. This has resulted in some reefs being seriously damaged by fishing gear as the industry has increasingly targeted these deep water species.

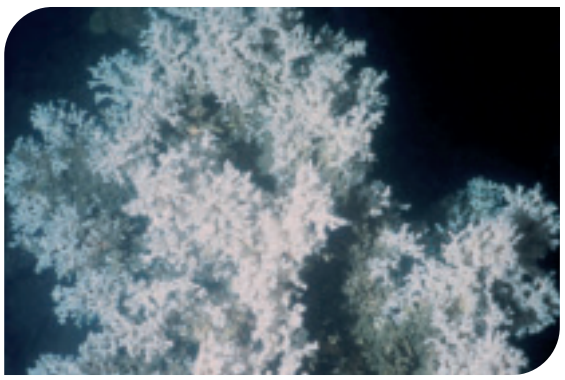
A large proportion of the global records of *Lophelia pertusa* are from Scottish waters on the continental slope beyond the shelf break, principally in the North Atlantic on the Rockall, Hatton and George Bligh Banks, on Anton Dohrn and Rosemary Bank seamounts and the Wyville-Thomson Ridge as well as the Darwin Mounds. A significant reef has recently been discovered in the Minches off Mingulay in relatively shallow water at around 110m depth.

Pressures

Lophelia reefs are threatened by demersal trawling operations, smothering and pollution.



Lophelia pertusa



© JM Roberts

Cold water coral reefs

© JNCC

Plankton

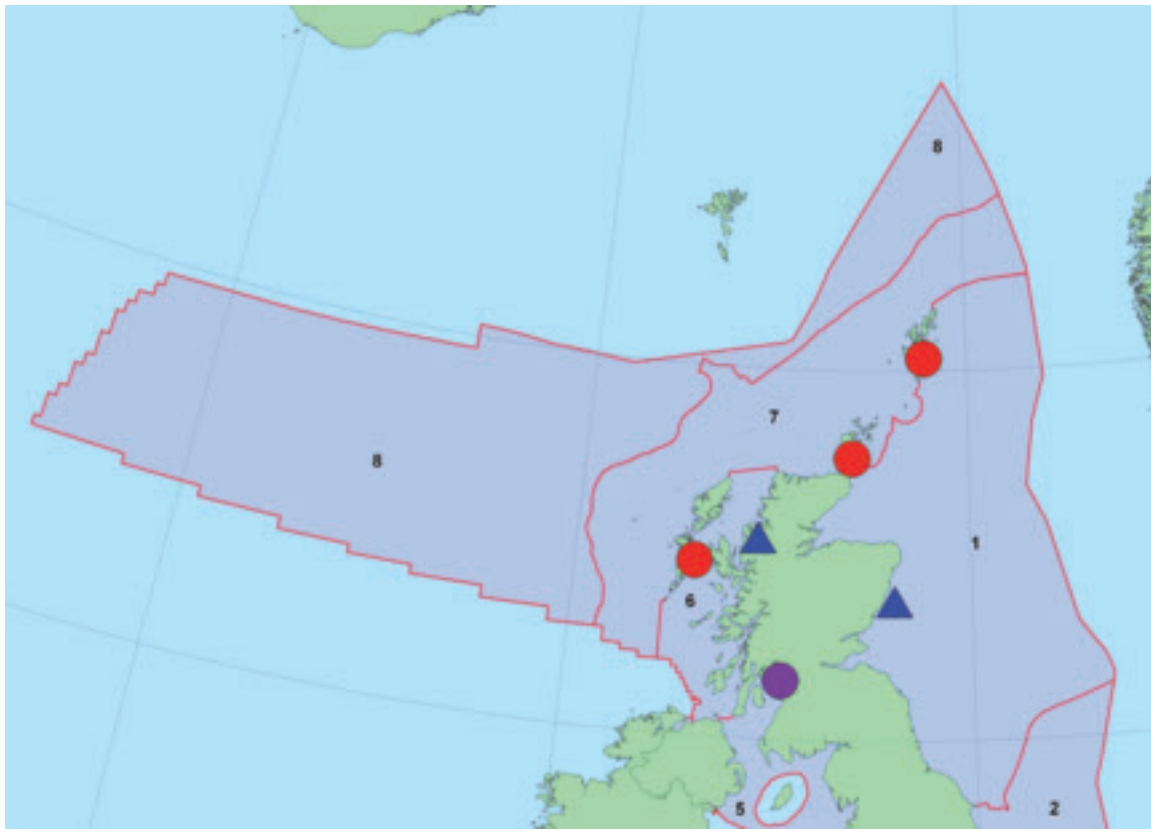
Plankton is the term for organisms that drift in the sea, from bacteria through microscopic plants (phytoplankton) and animals (zooplankton), to large jellyfish and the larvae of most fish and shellfish. Phytoplankton and zooplankton form the base of the food chain and sustain all other life in marine ecosystems. Plankton are sensitive to the environment in which they grow and a number of climate driven changes have already been identified in the North-east Atlantic area from the data collected by the Continuous Plankton Recorder (CPR). Ocean acidification is also likely to have an impact on the plankton components of the food web through the speciation of nutrients in the water column as well as its influence on calcifying organisms.

Plankton have a very rapid turnover rate (on a scale of days/weeks) and so in order to obtain an accurate estimate of their abundance and diversity a high frequency time series of data is required. There are few historic records of plankton abundance from Scottish waters. The longest data sets from the CPR are from the east coast region and the Northern Isles. This time series has revealed a number of changes in the plankton community on a decadal scale. An apparent regime shift occurred in the late 1980s which resulted in directional shifts in the composition of both the phyto- and zooplankton communities in the North Sea. This shift in the plankton community was also reflected in changes in larval fish populations.

Regional differences in phytoplankton species distribution

A number of differences in the diversity of the phytoplankton community around the Scottish coast have been observed between 2000 and 2009. For example, the diatom *Mediopyxis helysia* has only recently been described from samples in the southern North Sea. To date this species has only been identified in samples from CP2 region 1 (east coast) in Scottish waters. The distribution of this species is being observed to examine if its range expands into other regions. The dinoflagellate genus *Ceratium* has been observed along the east and west coasts and around the Orkney Islands. Its abundance at the Shetland monitoring site, has been consistently lower than in these other areas. In contrast, the dinoflagellate genus *Gonyaulax* has been dominant at this Shetland site during the summer months. These data suggest that the diversity of the phytoplankton community in Scottish water exhibits regional differences.

Regional map showing CP2 regions with sampling sites

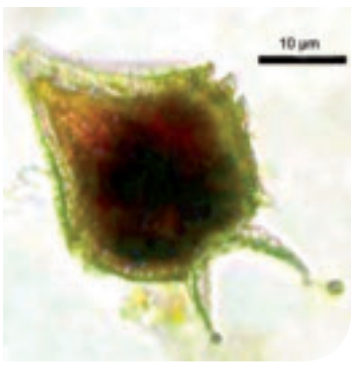


Marine Scotland ecosystem monitoring sites in Scottish coastal waters. Combination of parameters measured: ● temperature and phytoplankton, ● temperature, salinity, nutrients, phytoplankton and ▲ temperature, salinity, nutrients, phytoplankton and zooplankton.

Phytoplankton species showing a regional distribution around the Scottish coast

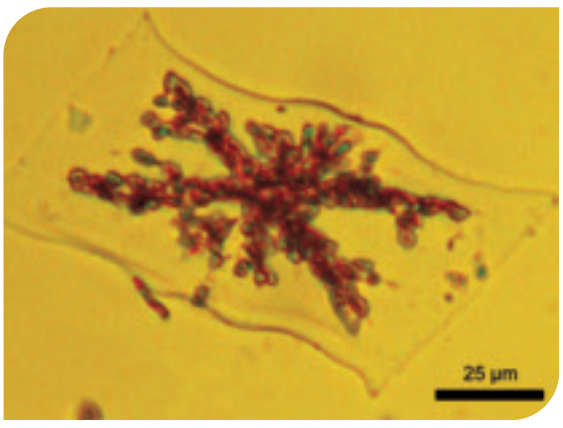
Ceratium furca

Gonyaulax verior



© Crown copyright/Marine Scotland

Mediopyxis helysia

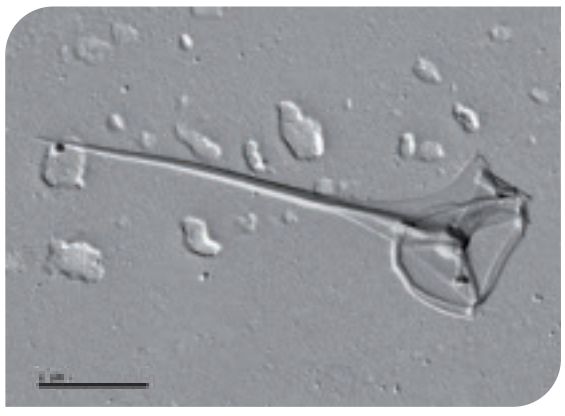


© Crown copyright/Marine Scotland

Small flagellates, nanoplankton and picoplankton

Small flagellates (< 10 µm in diameter), nanoplankton (< 2 µm in diameter) and picoplankton (< 0.2 µm in diameter) have been identified as important primary producers in the marine food web. Little is known about these organisms in Scottish waters. These phytoplankton require additional microscopic techniques (such as transmission electron microscopy) or laser based fluorescence (flow cytometry) to allow identification and counting. A preliminary study was performed on the diversity of the haptophyte genus *Chrysochromulina* in 2008. These are very small flagellated cells, approximately 5 µm in diameter. *Chrysochromulina polylepis* has been associated with fish mortalities in Scandinavia and its interplay with the spring diatom bloom and resulting influence on the marine food web has yet to be fully investigated. Examination of *Chrysochromulina* cells from the phytoplankton monitoring sites has highlighted the difference in the diversity of species found between east and west coasts.

Scale from a *Chrysochromulina elegans* cell

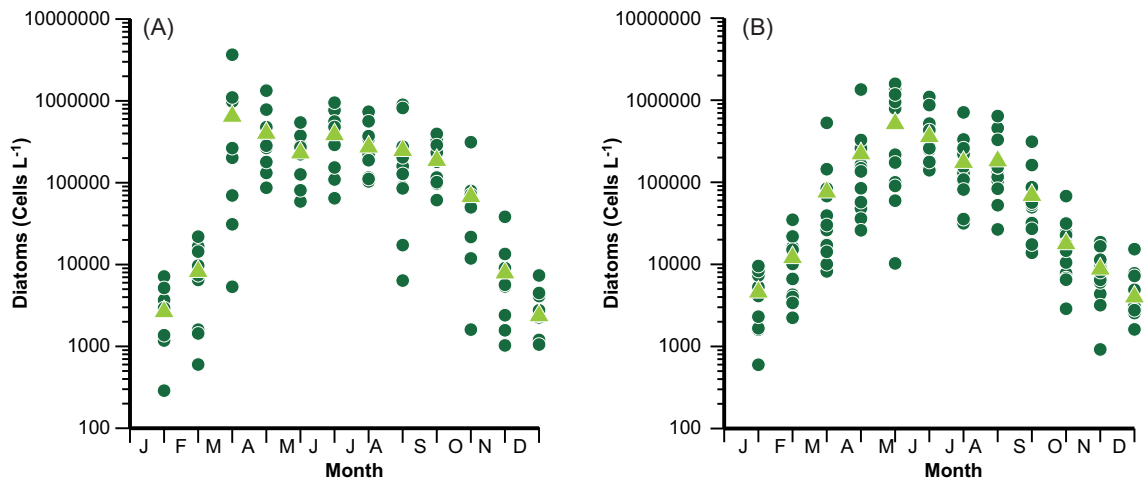


© Crown copyright/Marine Scotland

Phytoplankton

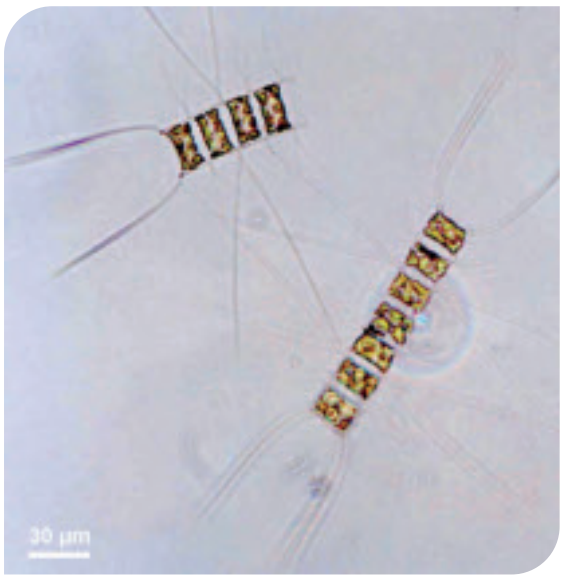
Phytoplankton occupy the very base of the food chain, they utilise energy from the sun which is passed up the marine food web when grazed by zooplankton. Phytoplankton growth declines in the winter because it is limited by the short winter days and lower water temperatures. During spring, as the days lengthen and the waters begin to warm, there is a rapid burst of phytoplankton growth, dominated by small rapidly growing diatoms. This is known as the spring diatom bloom. During the summer months the phytoplankton community is dominated by dinoflagellates. In some years, but not all, there is a second bloom of diatoms in the autumn. The diatom species dominating this autumn bloom are larger than those found in the spring. The phytoplankton community in Scottish waters is typical of those found in northern latitudes.

Many phytoplankton species experience periods of rapid growth where they multiply in number to form a bloom. Phytoplankton blooms are natural events but some can have a negative impact on the marine ecosystem and associated activities. These are known as 'Harmful Algal Blooms' or HABs. HABs in Scotland have been responsible for the death of benthic organisms because of toxins produced by the algae or because of anoxia caused by the algae removing oxygen from the water. HABs can result in enforced closures of shellfish harvesting areas to prevent algal toxins entering the human food chain. See Microbiological Contamination section in Chapter 3.



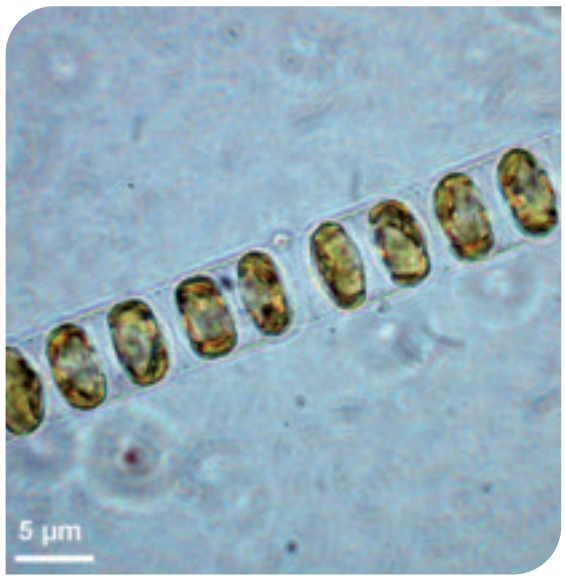
Seasonality of diatoms on (A) west coast (CP2 region 6) and (B) east coast (CP2 region 1). The green dots represent the monthly average of diatoms observed and the green triangles represent the overall monthly average since 2000.

Chaetoceros



© Crown copyright/Marine Scotland

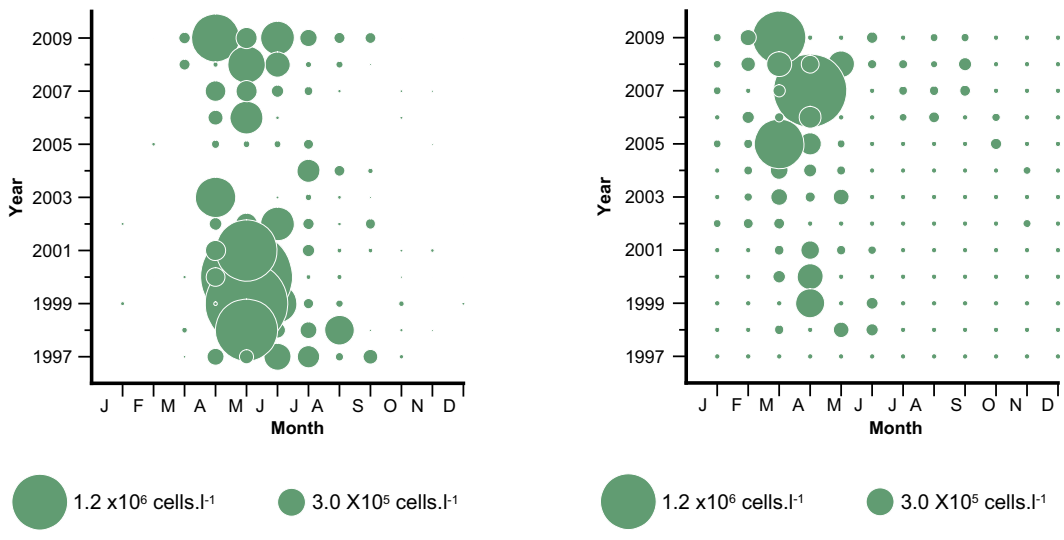
Skeletonema



© Crown copyright/Marine Scotland

Spring diatom bloom

The water temperature around the Scottish coast shows regional and seasonal variability (see Temperature, Salinity and Ocean Acidification section in Chapter 2). The water temperature on the west coast tends to be 1-2°C warmer than the east during the spring period. This may explain the difference in the timing of the spring diatom bloom between the phytoplankton monitoring sites in these two regions. During the spring bloom the highest number of diatoms is observed in March at the monitoring site on the west coast whereas on the east coast the highest number of diatoms is observed in May. Since monitoring began in 1997 there has been a change in the dominant species of the spring diatom bloom. The diatom genus *Chaetoceros* was observed to be more abundant in the late 1990s but more recently the diatom *Skeletonema* has been observed to be dominant.



An example of the change in the monthly averages of (A) *Chaetoceros* and (B) *Skeletonema* cells since 1997 from the monitoring site on the east coast (CP2 region 1). The size of bubble is related to number of cells observed.

Using phytoplankton to assess the ecological state of Scottish coastal waters

With the implementation of the Water Framework Directive (WFD) in 2000, European member states have evolved systems to assess the biological status of marine waters, using five status levels from bad to high. The phytoplankton community is a key component of the assessment of marine ecosystem 'health' due to its ability to rapidly respond to changing environmental conditions (e.g. sea temperature, salinity, nutrients). The most recent classification of the status of Scottish marine waters used two different tools to assess the health of the phytoplankton community compared to defined reference conditions. The Scottish Environment Protection Agency (SEPA) sampled phytoplankton, chlorophyll a and associated physical and chemical data at 47 sites across 44 water bodies. The classification was based on species abundance of the major phytoplankton groups (i.e. diatoms or dinoflagellates), and the size and frequency of bloom events. All investigated water bodies in 2008 showed "high" status, displaying a healthy phytoplankton community under the assessment criteria of the WFD.

Scottish marine water bodies that were classified using phytoplankton as a biological parameter under the WFD in 2008 highlighted in blue ("high" status)

Ecological Status Classes according to the WFD CIC Guidance (2003). All investigated sites in 2008 were classified with "high" status.

Status	Code	
High		"Reference condition"
Good		Acceptable ecological condition
Moderate		Action needed for achieving acceptable ecological status
Poor		
Bad		

Zooplankton

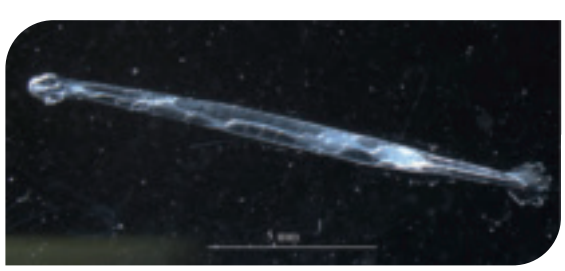
Zooplankton populations form complex communities that react to and cause change in the dynamics and productivity of marine ecosystems. They respond to changes in the availability of food, or in the pressures of predation; and are sensitive to salinity, pressure, temperature, acidity and chemicals, including pollutants. The global rise in atmospheric CO_2, and corresponding increases in ocean acidity, may affect planktonic organisms, particularly those with carbonate shells and skeletons, such as the common planktonic pteropod mollusc *Spiratella retroversa* which is an important food item for pelagic fish and their larvae. An increase in sea temperature may also cause changes in the timing of life cycle events. Most planktonic organisms are dependent on temperature to stimulate physiological developments, and the seasonal cycles of some have advanced, possibly in response to warming seas. Studies on multi-decadal time-series have shown that the seasonal peak of *Evadne* species (water fleas) has moved substantially. Such temporal shifts could have implications for other species in the food web.

Data from the monitoring sites on the east coast (CP2 region 1) and the west coast (CP2 region 6) reveal regional differences in diversity of the species community composition between these two sites.

Chaetognaths: indicators of habitat

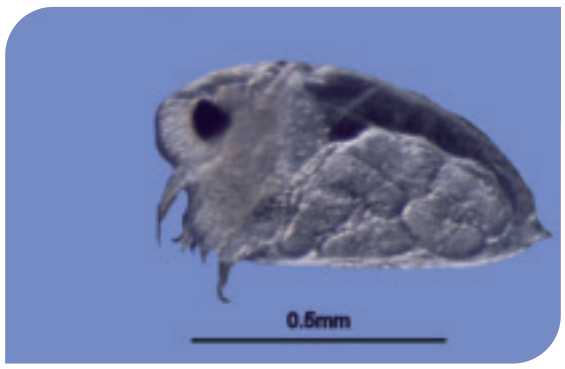
The predatory arrow worms (chaetognatha) are a major component of the zooplankton community and can sometimes represent 10-30% of the zooplankton biomass in some areas of the world's ocean. The two chaetognath species *Parasagitta setosa* and *Parasagitta elegans* that are common in UK seas can be used as indicators of different water masses. There is a difference in the species diversity of these two arrow worms between the Scottish east and west coasts monitoring stations which highlights the habitat differences of these two coasts. On the east coast, *P. elegans*, which is indicative of mixed coastal and oceanic waters, is most abundant, and on the west coast, *P. setosa*, which is indicative of more inshore and southern coastal waters, is most abundant.

Zooplankton *Parasagitta elegans*



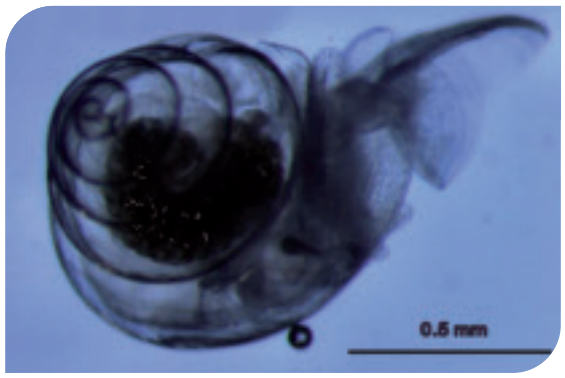
© Crown copyright/Marine Scotland

Evadne nordmanni

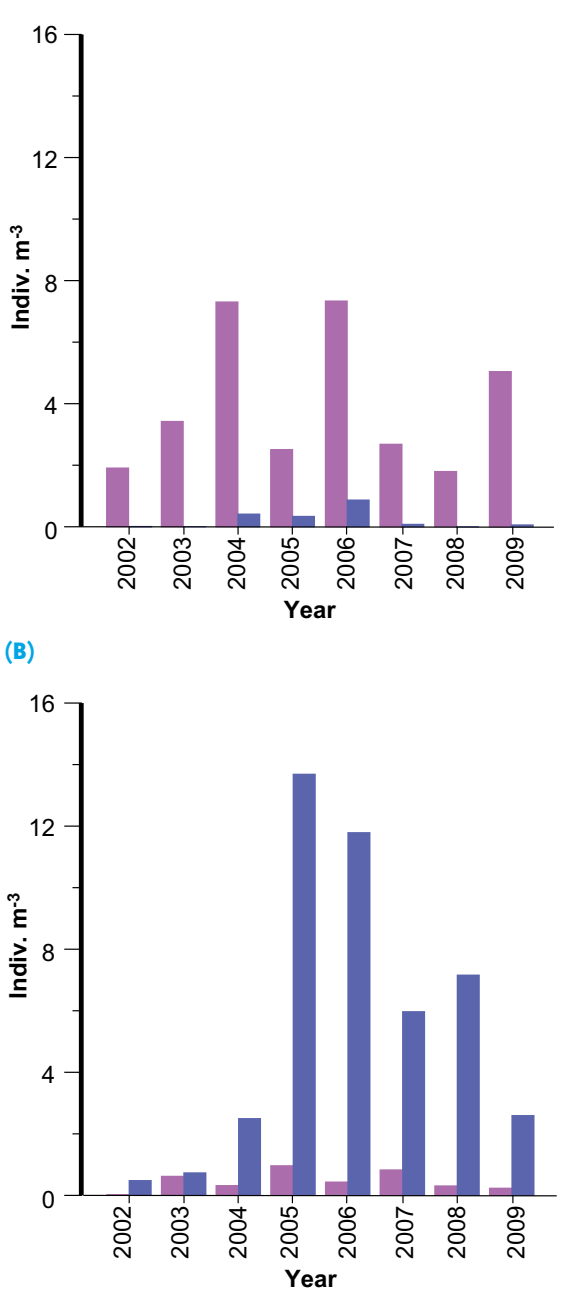


© Crown copyright/Marine Scotland

Spiratella retroversa



© Crown copyright/Marine Scotland



Annual abundance of *P. elegans* and *P. setosa* at (A) east coast (CP2 region 1) and (B) west coast (CP2 region 6).

Seasonality

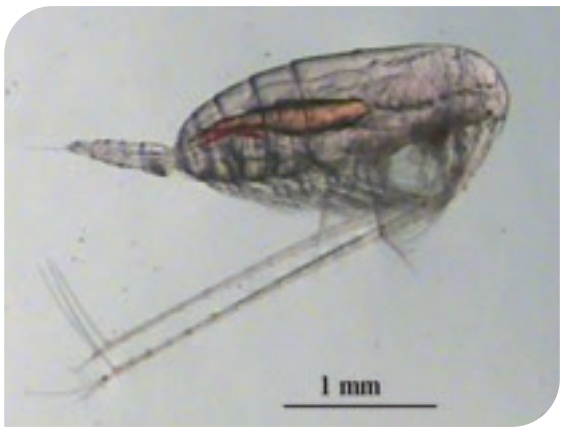
The abundance of *C. finmarchicus* typically peaks around April/May and *C. helgolandicus* around September/October in Scottish waters. *C. helgolandicus* exhibits a bimodal abundance on the west coast site (Minches and Malin Sea) more typical of southern waters. In recent years there is a suggestion of an increase in the abundance of *C. helgolandicus* around April/May on the east coast.

Changes in relative abundances of *Calanus finmarchicus* and *Calanus helgolandicus*

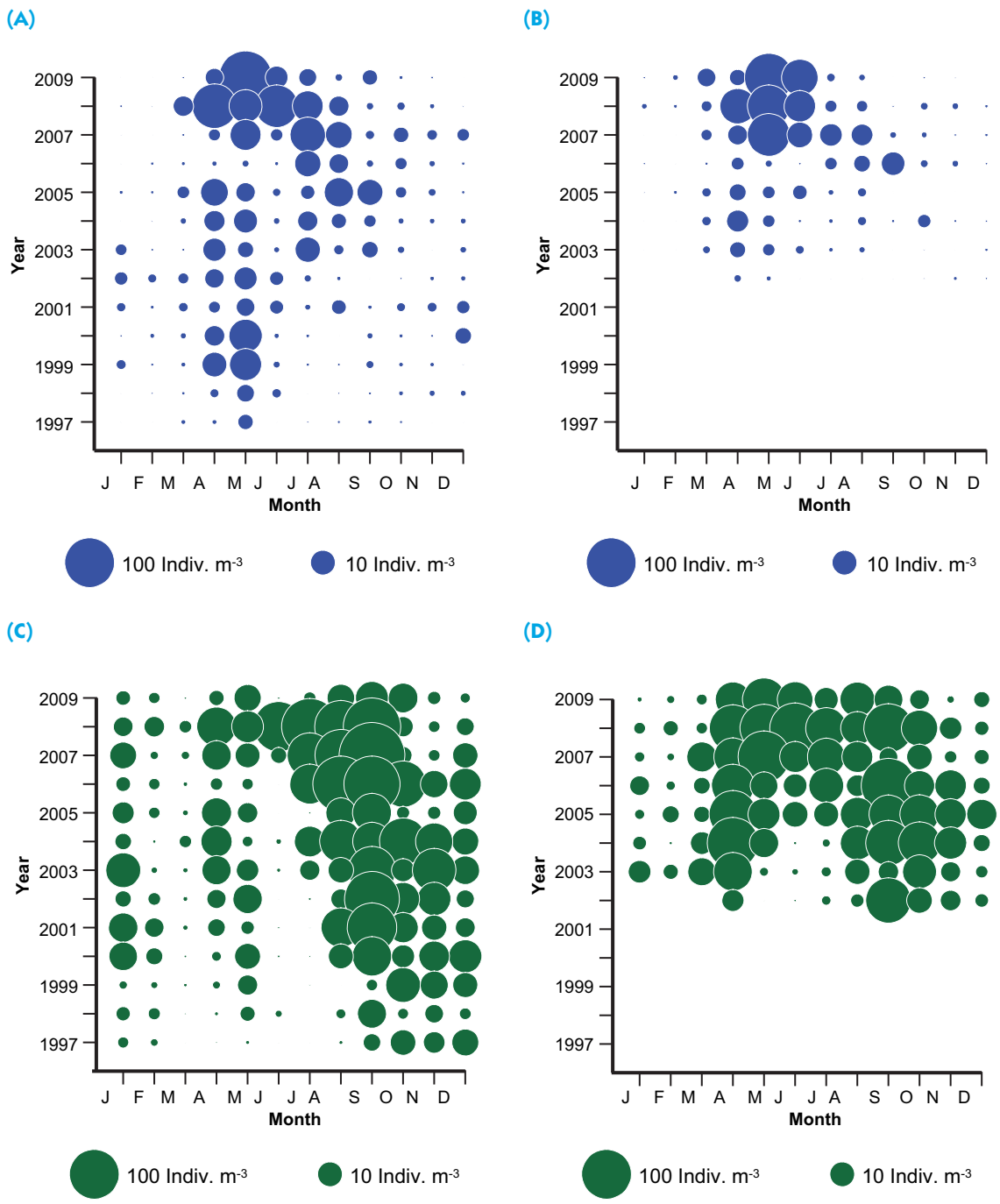
The warming climate is considered to have had a significant impact on the geographic distribution of two key calanoid copepods, *Calanus finmarchicus* and *Calanus helgolandicus*. Data generated by the CPR survey have shown that the abundance of the cold water species *C. finmarchicus* has decreased in the North Sea since the 1960s, whereas at the same time the warmer water species *C. helgolandicus* has increased. These shifts in plankton have wider consequences for other levels in the marine food web as *Calanus* species are productive herbivores and an important food source for commercial fish larvae.

More detailed observations than those from the CPR have shown an increasing trend in the abundance of *C. finmarchicus* on the east and west coasts of Scotland in recent years. This could result in improved feeding conditions for larval fish, as *C. finmarchicus* is a more lipid-rich source of food than *C. helgolandicus*.

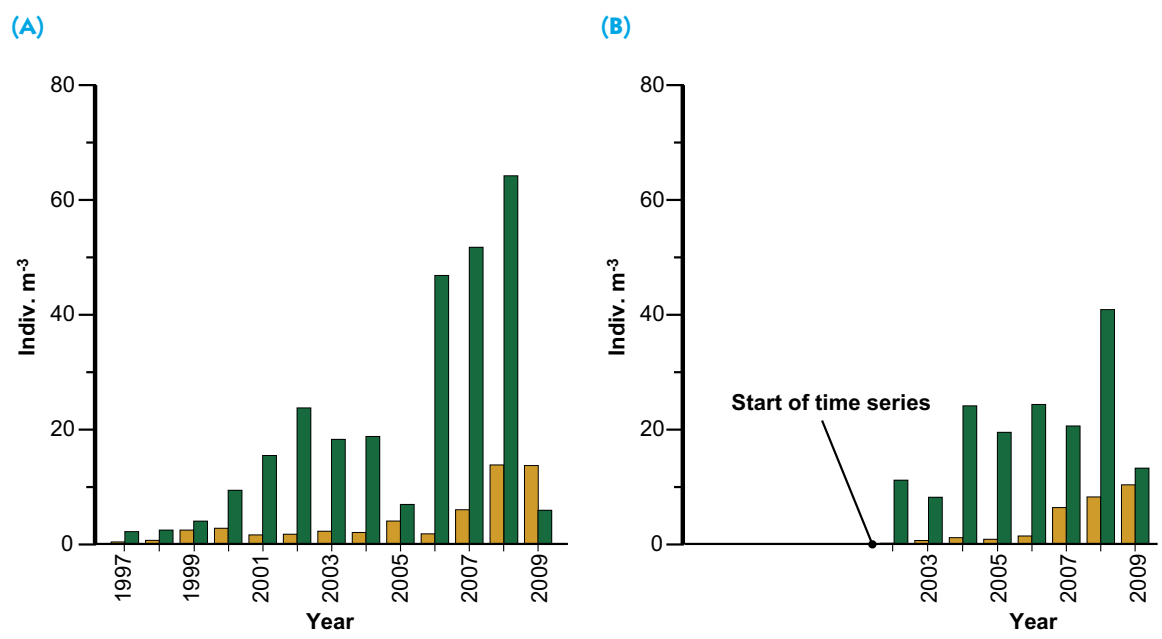
Zooplankton – *Calanus finmarchicus*



© Crown copyright/Marine Scotland



Monthly averaged abundance (transformed (log+1) individuals m^{-3}) of *C. finmarchicus* (in blue) on the east coast (CP2 region 1) and west coast (CP2 region 6) (A and B) respectively, and *C. helgolandicus* (in green) on the east coast (CP2 region 1) and west coast (CP2 region 6) (C and D) respectively. Note difference in the start of the time series at the two sites.



Plots showing the average annual abundance of *C. finmarchicus* and *C. helgolandicus* at (A) east coast (CP2 region 1) (B) west coast (CP2 region 6) monitoring sites.

COMMERCIAL FISH AND SHELLFISH STOCKS

Commercial fish and shellfish stocks

The seas around Scotland support significant populations of commercially important species of fish and shellfish. Overall landings in Scottish ports and catches in Scottish waters are detailed in Chapter 5 – Fishing. The fish cover a diverse range of species falling into two broad categories. Pelagic species such as mackerel and herring move about throughout the water column while demersal species such as cod and haddock spend most of their life in close proximity to the sea bed. The distribution of most of these stocks extends over quite wide areas, frequently into waters where they are also fished by other countries. Assessments of the state of stocks are performed internationally by the International Council for the Exploration of the Sea (ICES), thus reporting at the scale of the Scottish sea areas used in this Atlas is not possible. Assessments of fin fish stocks are instead provided here according to three area descriptions: i) widely distributed stocks located right around Scotland and often close to the shelf edge (200m depth) ii) North Sea stocks and iii) West of Scotland stocks.

Data on commercial catches and from scientific surveys are collected by Scotland and other nations and combined in the assessment process to provide estimates of the size of the stock (measured as the spawning stock biomass, SSB), the numbers of young fish entering the fishery (recruitment) and the rate of removal by fishing (fishing mortality rate, F). ICES scientific advice is provided in a framework which judges the state of each stock against precautionary reference points for biomass (Bpa) and fishing mortality rate (Fpa). Where possible, stocks included here are noted as above Bpa and below Fpa. Recently, ICES has provided advice in relation to long term maximum sustainable yield (MSY). A four panel plot is included to show where each stock is placed with respect to this. A third measure, in the form of a percentile bar chart, is provided to give a broad indication of trends in SSB and F. These plots show the percentage of stocks which are in a worse state, same state or better state in the most recent 10 year period compared with the previous 10 years.

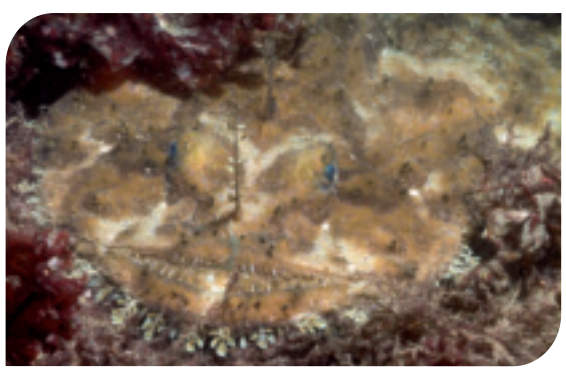
The scientific advice is used to inform the management processes under the EU Common Fisheries Policy and for a number of the finfish species of interest to Scotland, stocks are also shared with countries outside the EU (for example Norway). Amongst the measures presently used in management the principal ones are total allowable catches (TAC – shared out into quotas for each country), effort control and technical measures (for example fishing net mesh sizes). Scientific advice on these measures is provided by ICES, consistent with the frameworks described above.

In recent years a positive development has been that of long term management plans (LTMP) which are designed to help recovery and subsequently maintain stocks in a healthy condition and may incorporate mechanisms which assist industry such as limits on catch variability. Scottish stocks subject to such plans have generally performed quite well in recent years. For some stocks, however, high exploitation rates in the 1980s and 1990s led to marked declines in stock biomass and the emphasis of recent management has been to help their recovery. Most notable are a number of the cod stocks in the North-east Atlantic, including the North Sea and West of Scotland. Cod recovery plans have been in place for a number of years and have been the main driver for effort regulation. So far stock improvements have been limited, although in the North Sea mortality has fallen since 2000 and there has been a modest increase in biomass. In Scotland a new and innovative approach, 'Conservation Credits', has been in place since 2008 which rewards fishermen for avoiding cod. Various tools are employed such as real time closures and gear measures and the process is co-managed with industry. So far this has helped to reduce the amounts of cod discarded by Scottish vessels.

Widely distributed stocks

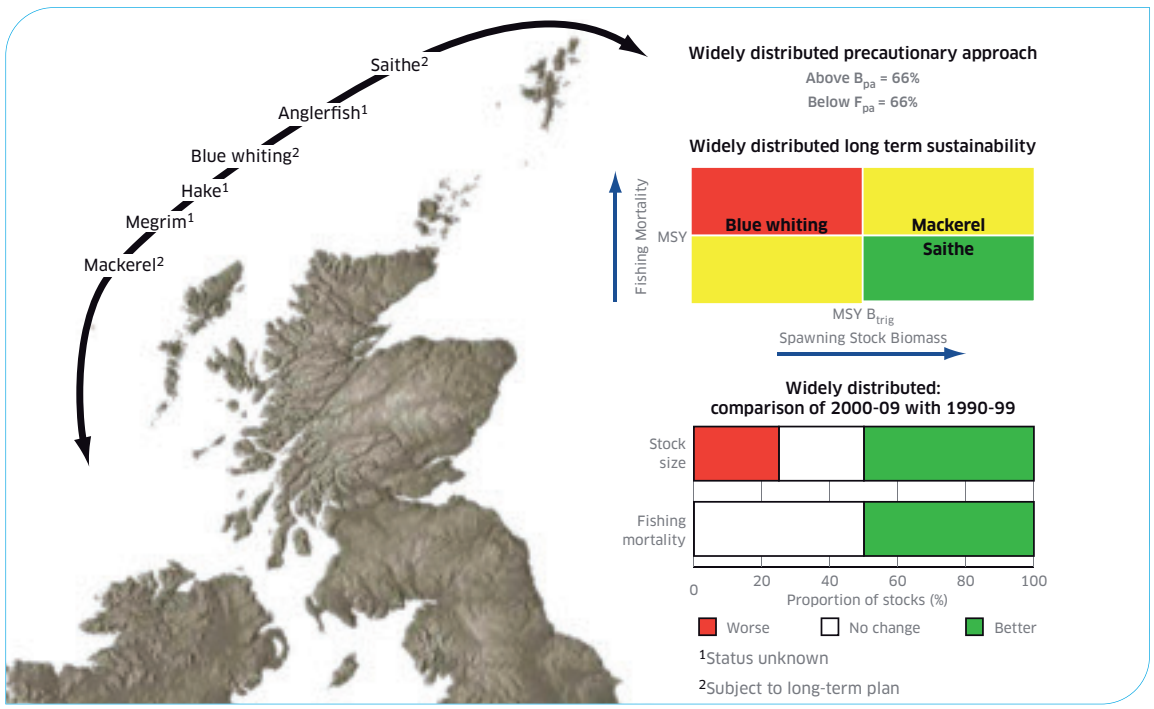
A number of commercially important stocks are distributed widely around the north and west of Scotland. The most important of these include two species (mackerel and blue whiting) which are taken in extensive international pelagic fisheries and four demersal species: anglerfish and megrim are taken in more recently developed specialist fisheries of growing importance to Scotland; saithe has been fished for many years and now provides an increasingly important contribution to Scottish vessels' earnings; and hake, which has become more abundant in Scottish waters recently. The state of several of these stocks for which there are accepted ICES assessments shows a generally positive picture for two thirds of them with fishing mortalities in line with MSY and precautionary approach principles and healthy biomasses. An additional widely distributed stock, Atlanto-Scandian herring which is fished by Scotland but well to the north of Scotland is also being fished sustainably. The current state of blue whiting, however, gives cause for concern and a series of poor recruitments following irresponsible management by certain coastal states has reduced the stock size to below precautionary limits. In common with the other widely distributed stocks, blue whiting is now subject to a LTMP and providing the recommendations of this are followed by all Contracting Parties, stock improvement is expected to follow. ICES assessments for anglerfish and megrim are in a developmental stage and reference points against which to measure the states of these stocks are not presently available. Nevertheless, results from joint industry/science surveys indicate recent increases in the megrim stock and a generally stable anglerfish abundance.

Anglerfish



© Paul Kay

State of widely distributed stocks



Source: Marine Scotland – Science

Note: black arrow indicates distribution of named stocks

Mackerel

Amongst the widely distributed stocks, the western mackerel is commercially the most important. Catch information is in Chapter 5 – Fishing. This stock exhibits migratory behaviour that extends its distribution from the Iberian peninsula to waters north of Scotland and a number of countries participate in the internationally managed fishery. The migrations give rise to seasonality in the fishery with catches occurring mainly from the west of Britain in quarter 1 (January – March) shifting to the north of Scotland and west of Norway in quarter 4 (October – December). Assessment of this stock is complex and relies heavily on an internationally coordinated survey of egg numbers from which a back calculation estimates the stock size. The core of egg production occurs in the waters to the west of Britain.

The mackerel stock is currently in good condition and the recent results from the 2010 egg survey indicate a marked increase in stock biomass. A number of good recruitments, together with implementation of a sustainable long term management plan, has led to a biomass well above precautionary limits and the stock is fished just above Fmsy. The continued health of the stock depends on adherence to the plan and observance of the agreed catch limits.

Mackerel

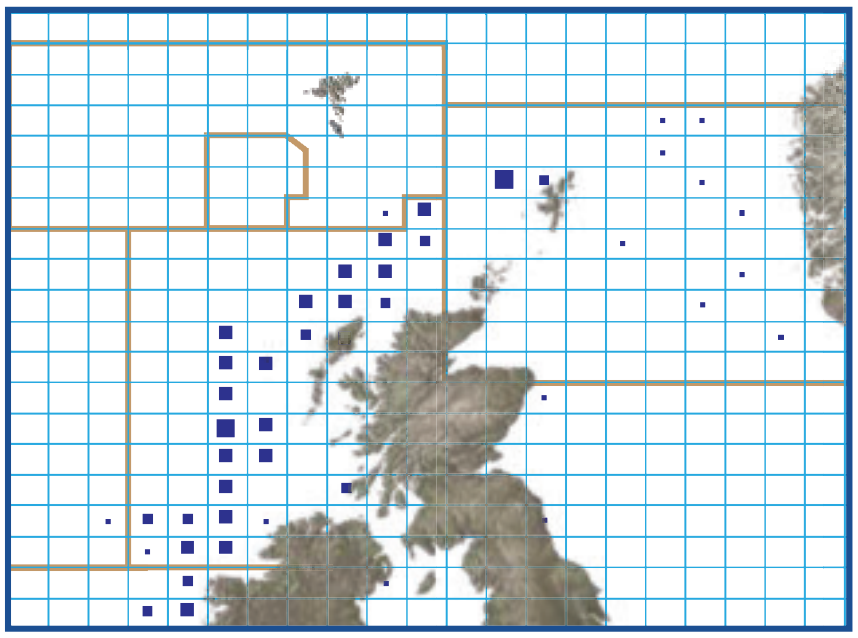
© Marine Scotland

Saithe

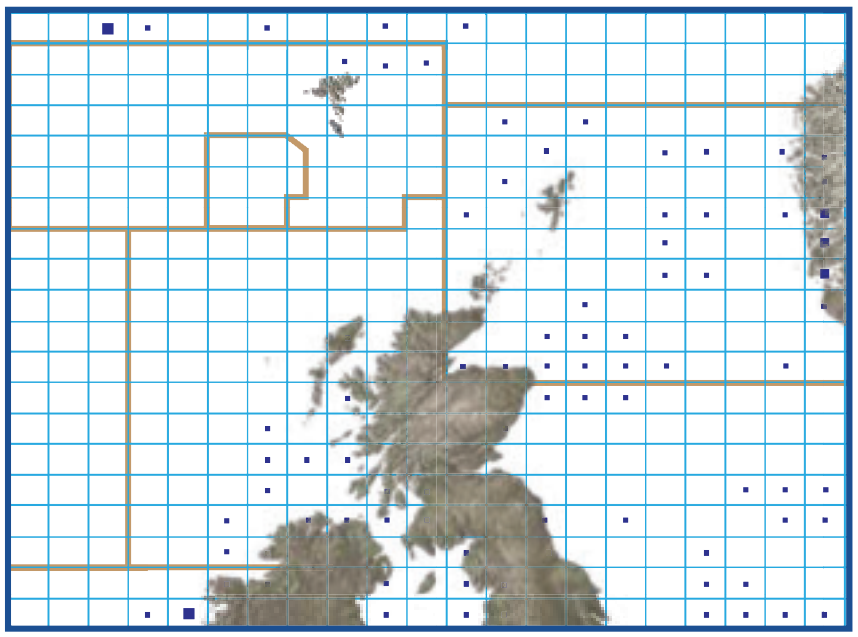
© Paul Kay

Mackerel stock – distribution of catches and egg production

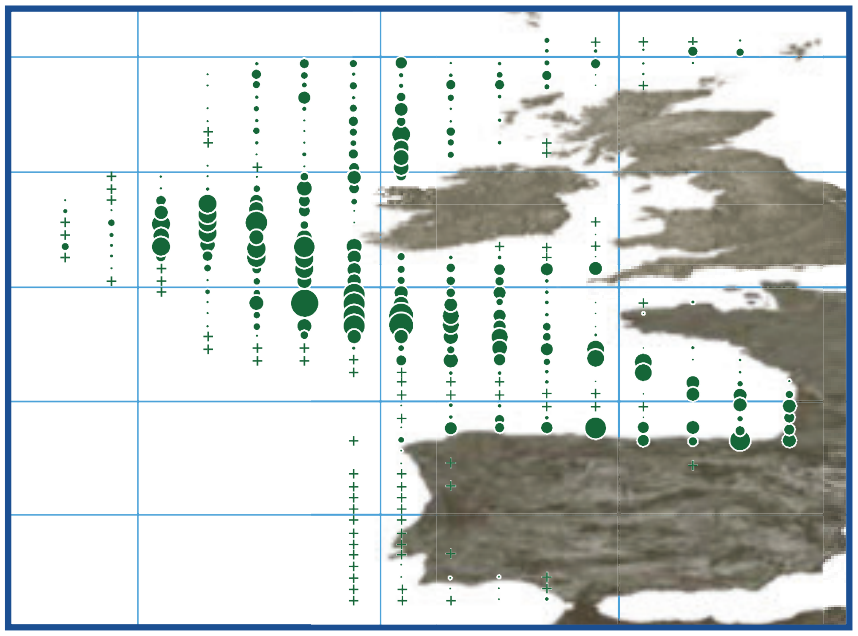
Quarter 1: Distribution of mackerel catches 2008



Quarter 4: Distribution of mackerel catches 2008



Distribution of mackerel eggs from surveys 1992-2007 average by ICES stat rectangle



Size of green dot and blue squares is proportional to abundance.

North Sea stocks

Some of the most important and long standing Scottish fisheries are located in the North Sea prosecuting stocks which are distributed principally in this area. Most of the important fish stocks are shared with other EU member states and Norway and a number are subject to long term management plans. Scottish whitefish fishing effort (mostly by trawl and seine net gears) is distributed mainly in the northern parts of the North Sea particularly towards the shelf edge; a significant proportion of this effort occurs in the Norwegian sector, as shown by the blue shading in figure below. Accepted ICES assessments are available for five of the six main stocks and the states of the stocks present a mixed picture when compared with MSY targets and precautionary reference points. Herring, haddock and plaice are fairly close to Fmsy targets while cod and sole are being fished above sustainable rates. In terms of precautionary reference points the position is more positive and 80% are fished appropriately. In the case of stock biomass only 40% are above the precautionary approach level.

When compared to the previous 10 year period, the most recent 10 years have shown reductions in the rate of fishing of all assessed stocks in the North Sea but a less positive picture on stock biomass which has only improved in a third of cases.

The whiting stock continues to present assessment challenges and its condition is not known. Regional differences in abundance have led to the suggestion that more than one stock may be present, this would confound the process of estimating stock trends.

Successes in bringing fishing mortality down and maintaining it at appropriate levels in a number of stocks may be attributed to LTMPs and the continued development of these is seen as key to ensuring sustainability. In the case of the cod stock the challenge is bigger, requiring a significant rebuilding of the stock; from 2005 onwards a slightly larger year class has led to some increase in the stock biomass. The agreement for a cod recovery plan led to the implementation of stringent Europe wide measures to reduce fishing mortality, with member states subjected to reductions in fishing effort. The plan provides scope for measures other than effort to be used to reduce mortality and Scotland has developed a unique scheme which encourages cod avoidance including the use of real time closures and selective gears. In return for complying with the scheme, some effort is granted back to the fishermen. So far this has led to marked reductions in cod discard rates by Scottish vessels.

Cod

© Paul Kay

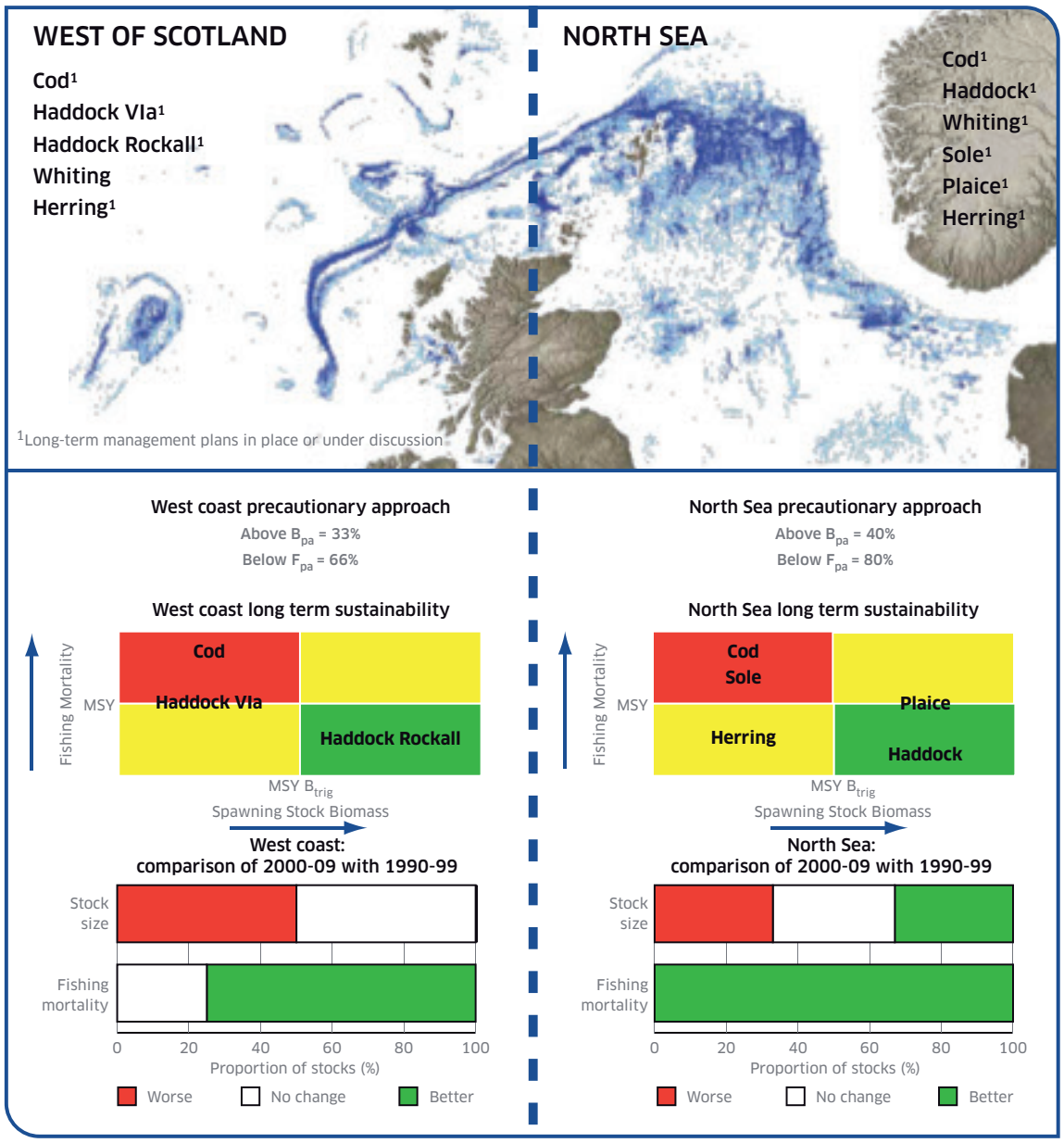
Atlantic herring

© Marine Scotland

West of Scotland stocks

On the west coast of Scotland the fish stocks are also in various states and the overall picture is less positive than in the North Sea. The distribution of Scottish whitefish effort close to the shelf edge on the west coast is even more pronounced than in the North Sea. Information with which to judge the state of these stocks is only fully available for three of the stocks. The two haddock stocks, VIa and Rockall are fished close to Fmsy, but the stock size of the former continues to give cause for concern. The cod stock remains in a very poor condition and like the North Sea stock is subject to the cod recovery plan. Here, however, there has been little response and stock biomass remains too low. West coast herring, subject to a LTMP, is being fished at a broadly sustainable rate but the lack of biomass reference points prevent a judgement on stock size. Information on the west coast whiting stock is very sparse but all indications are of a stock in very poor condition. The stock trends plot suggests that while there has been some progress in reducing F over recent years, it is not so striking as in the North Sea and also the position on stock biomasses has deteriorated, with 50% in a worse condition.

State of stocks – west of Scotland and North Sea



Shellfish

Shellfish species also support valuable fisheries in Scotland. Nephrops, scallops and edible crabs represent almost one third of the value of all landings by Scottish vessels in 2009. Many of these species contribute to important export markets in Europe and worldwide. See Chapter 5 – Fishing, for more detail.

With the exception of squid species which are highly mobile, shellfish species are sedentary and live on the sea bed. Different species have different benthic habitat requirements and species distribution is heavily dependent on the availability of suitable substrates. The geographical distribution of different habitats around Scotland is highly complex, especially on the west coast, and as a consequence shellfish species populations are distributed patchily but in discrete aggregations. For many species numerous stocks can be identified and where possible these are assessed separately. Although the centres of distribution of many of the shellfish stocks do not align perfectly with the boundaries used in this Atlas, it is nevertheless possible to say more about the state of local stocks in different parts of Scotland than it is for the fish stocks.

Crabs and lobsters

Several species of shellfish are fished using baited creels, these include edible crabs, velvet swimming crabs and lobsters. Unlike fish, these crustacean species cannot be aged and so assessments make use of length composition data. The assessments provide an indication of the state of exploitation of the stock and whether or not increased yields could be expected by fishing at a reduced rate and leaving the animals in the sea for longer in order to allow them to grow. Potentially, management measures can be applied on the basis of these results to reduce mortality and allow the animals to grow before capture. At present, the main management measure for crab and lobster is use of the minimum landing size. Edible or brown crabs are distributed on cobble and gravely substrates which occur around the Scottish coasts. Traditional inshore fisheries in the south east of Scotland and the various island groups have in recent years been overtaken by new developments in slightly more offshore areas to the north and west of Scotland. Most edible crab stocks are fully exploited or overexploited. Stocks to the north and west of the Hebrides are presently underexploited. Velvet crabs and lobsters are widely distributed in more rocky areas. Lobster stocks are either fully or over exploited and a recent maximum landing size has been introduced in an effort to protect large mature females to try to enhance egg production. The fishery for velvet crabs is a more recent development beginning on the west coast and now extending to most areas, the state of exploitation is quite variable and a number of stocks remain underexploited.

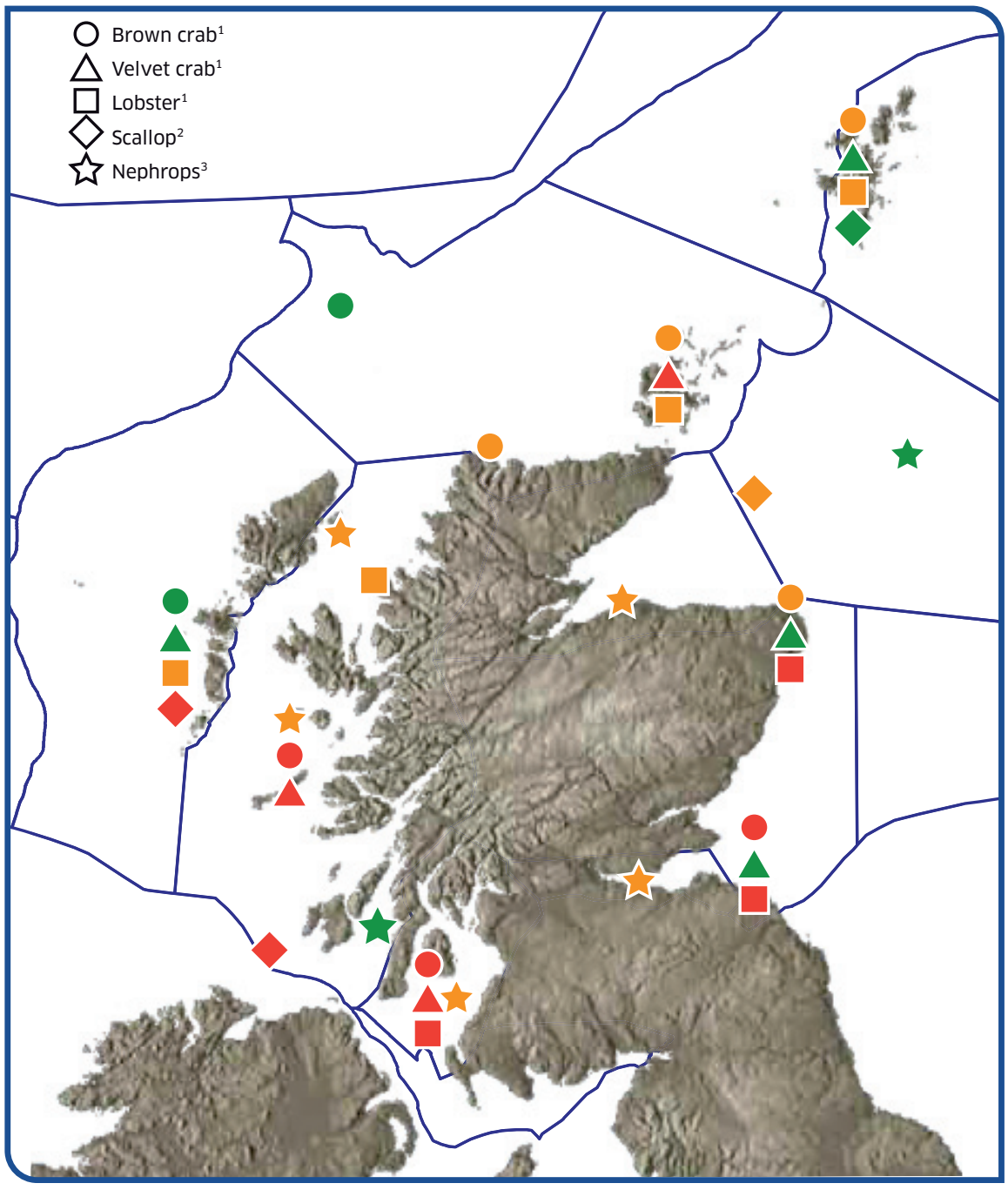
Scallops

The second most valuable shellfish species, scallops is distributed widely over sandy and gravely substrates and assessments are available for four of the stocks. This species can be aged and conventional age based assessments supplemented by scientific surveys provide indications of stock trends. Stocks to the west of Scotland currently exhibit declining biomass and reduced recruitment while those to the east are fluctuating without an obvious trend. The healthiest stock appears to be in Shetland waters.

Nephrops

© Paul Kay

State of shellfish stocks



[1] Length based yield per recruit assessment
[2] Age based assessment of stock size
[3] MSY based on TV survey assessment

overexploited
fully underexploited

04 HEALTHY AND BIOLOGICALLY DIVERSE COMMERCIAL FISH AND SHELLFISH STOCKS

The most valuable shellfish species (and sometimes the most valuable commercial species overall to Scotland) is the Norway lobster, *Nephrops*. This species is distributed in all areas where soft mud and sandy mud occurs. These areas dominate most of the firths of Scotland and extensive areas of the west coast. In more recent years a major fishery has developed at the offshore Fladen Ground in the North Sea and this is now the biggest Nephrops fishery in the world. Nephrops fisheries are prosecuted by a large fleet of generally smaller vessels using otter trawls and on the west coast there is an extensive creel fishery. Trawl activity is shown by the blue shading in the figure to the right. The patchy distribution of Nephrops gives rise to a number of separate stocks or functional units which are assessed using underwater television camera techniques. Estimates are made of the population size by counting the numbers of burrows in which the animals live. On the west coast the three stocks (North Minch, South Minch and Clyde) are reasonably stable but are fished slightly above Fmsy. In the North Sea, the Moray Firth and particularly Firth of Forth, are also fished above Fmsy while the Fladen Ground is being fished at a rate below Fmsy. In all cases the biomasses appear to be healthy. A smaller stock, the Noup, exists to the North of Scotland although its state is not known.

The overall assessment of shellfish stocks broadly suggests that those in the south and west are heavily exploited, compared to stocks in the more northerly and easterly parts of Scottish waters which show signs of a general improvement with more examples of under-exploited stocks.

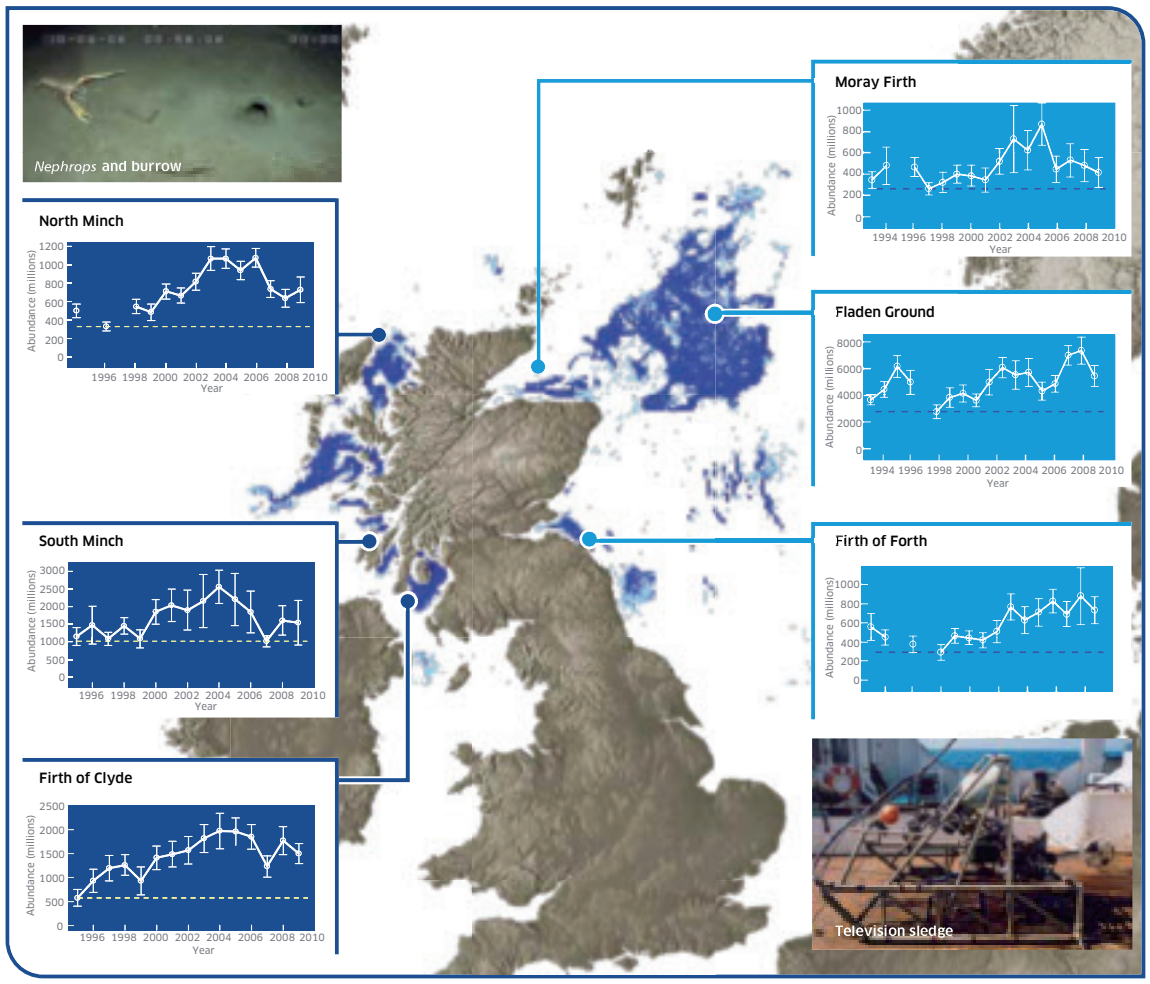
Scallop

© Paul Kay

Scallop dredger

© John M Baxter

***Nephrops* abundance in Scottish stocks**



Conclusions

- There are a number of distinct fisheries in Scottish waters exploiting a wide variety of species.
- The states of stocks of fish presents a mixed picture across and within regions.
- More data are needed on a number of stocks to provide reliable assessments.
- Considerably more data/research would be needed if future reporting was to be carried at the scale of Scottish sea areas.
- There is a mixed picture in terms of current state and future prospects of different industry sectors.
- Overall, trends in fishing mortality levels in relation to precautionary limits show significant improvement.
- In general, trends on fish stock size are more mixed. Of particular concern are West of Scotland demersal stocks which are at very low levels.
- The diversity and variable states of shellfish stocks presents a very mixed picture across the various regions with a tendency for lower exploitation in the north and east.
- Of the stocks for which estimates of Fmsy are available, about 33% are already being fished at this rate.

Creels on quayside at Stromness, Orkney

© John M Baxter

Priority Marine Features

Species	Sea area	Status
Anglerfish *Lophius piscatorius*	Territorial waters and offshore	High risk species taking many years to reach maturity. North sea stock in decline, ICES continue to recommend a reduction in fishing effort and catch. West coast stock stable.
Atlantic halibut *Hippoglossus hippoglossus*	Offshore	Slow growing and late maturing. Seriously affected by overfishing and recognised as Endangered on the IUCN Red List.
Atlantic herring *Clupea harengus*	Territorial waters and offshore	An important food fish for many other species, ICES considers stocks currently managed sustainably in the North Sea.
Atlantic mackerel *Scomber scombrus*	Territorial waters and offshore	Western mackerel stocks considered of regional and possibly global importance. North Sea stock still to fully recover from decline in 1960s.
Black scabbardfish *Aphanopus carbo*	Offshore	Slow growing, long-lived, late maturing susceptible to overfishing. ICES advise no expansion in fishery.
Blue ling *Molva dypterygia*	Offshore	Slow growing, long-lived, late maturing susceptible to overfishing. Stock status uncertain, ICES advise no directed fishery.
Blue whiting *Micromesistius poutassou*	Offshore	Poor recruitment since 2005 has led to declining stocks, ICES consider it to be harvested above Fmsy.
Cod *Gadus morhua*	Territorial waters and offshore	Stocks severely declined, ICES consider stocks in the North Sea, western Scotland and Irish Sea below safe biological limits. Listed as Vulnerable on IUCN Red List.
European hake *Merluccius merluccius*	Offshore	Status cannot be assessed accurately but increasing since 1999 and believed to be within safe biological limits.
Greenland halibut *Reinhardtius hippoglossoides*	Offshore	Long-lived and slow growing, susceptible to overfishing. Current stock status unknown.
Horse mackerel *Trachurus trachurus*	Offshore	Numbers fluctuate depending on scale of annual recruitment. ICES advise that fishery should not expand.
Ling *Molva molva*	Territorial waters and offshore	Scotland has a large proportion of British population, numbers are maintaining a stable low level.
Norway pout *Trisopterus esmarkii*	Territorial waters and offshore	Recruitment is variable but fluctuations in North Sea stocks probably natural rather than due to fishing pressure.
Orange roughy *Hoplostethus atlanticus*	Offshore	Very slow growing, very long-lived, vulnerable to overfishing. ICES advise the fishery is unsustainable in the North-east Atlantic.
Round-nose grenadier *Coryphaenoides rupestris*	Offshore	Slow to reproduce and susceptible to overfishing, currently overexploited.
Saithe *Pollachius virens*	Territorial waters and offshore	Stocks recovering and thought to be fished sustainably.
Sandeel *Ammodytes* spp.	Territorial waters and offshore	Stocks are in decline, an important food fish for many species of seabirds.
Whiting *Merlangius merlangus*	Territorial waters and offshore	Stocks have been stable or declining for last 10 years, and North Sea distribution contracted.

Round-nose grenadier

© Paul Kay

Orange roughy

© JNCC

Sandeels

© Paul Kay

Demersal Fish Community

Over 240 species of fish inhabit the seas around Scotland. Assessing their overall 'health' is difficult: defining 'health' is problematic and there are large gaps in the data. With this in mind, Marine Scotland Science undertook an investigation into the state of the demersal (generally living on or near the sea bed) fish community in Scottish waters. This work was done specifically for this publication. However, it employed a similar approach to comparable assessments for the UK's Charting Progress 2 and OSPAR's Quality Status Report.

Scientific trawl surveys are widely used to assess change in the status of demersal fish communities. The data collected are ideal for generating quantitative measures of particular characteristics of the fish community, and these can be used to monitor change in those characteristics over time and between different places. These measures are referred to as community indicators. OSPAR use a "large fish indicator", defined as the proportion of fish (by weight) in the community that is greater than 40cm in length; simply the weight of demersal fish greater than 40cm in length divided by the total weight of all demersal fish in the sample. The higher the value (varying between 0 and 1), the greater the proportion of large fish in the community. The need to conserve biodiversity has had a strong influence on the development of an ecosystem approach to managing marine natural resources, and this remains a core concern for the EU Marine Strategy Framework Directive and the Marine (Scotland) Act 2010. A range of additional indicators, such as species richness (simply a count of the number of demersal fish species recorded in any survey sample) and species diversity metrics (indices that also take account of the relative abundance of each species in the sample) can also be applied to survey data to act as indicators of change in demersal fish biodiversity.

All three aspects of the composition and structure of the demersal fish community, proportion of large fish, species richness and species diversity, vary markedly across Scottish waters. For example, fish greater than 40cm in length constituted a much greater proportion of the biomass of demersal fish in western waters than in regions to the east of Scotland.

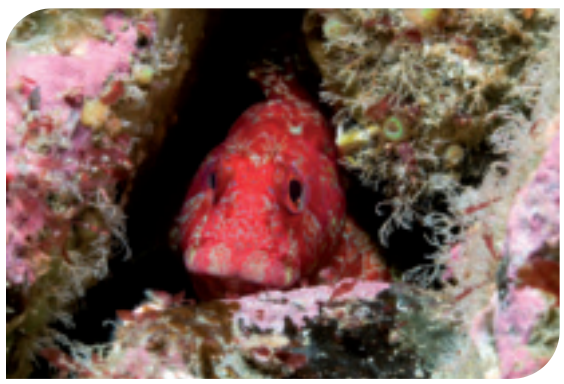
Norwegian topknot

© Paul Kay

Yarrell's blenny

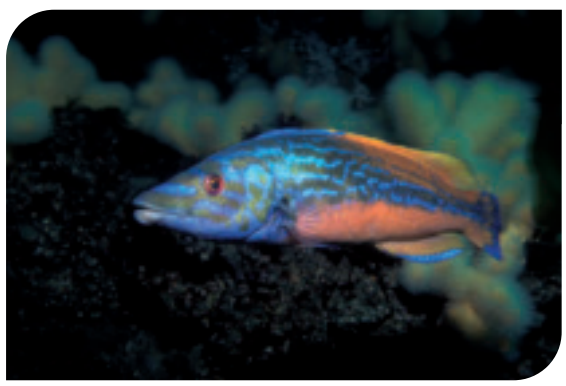
© Paul Kay

Red or Portuguese blenny



© Paul Kay

Male cuckoo wrasse



© Paul Kay

Spatial variation in size composition, species richness and species diversity of demersal fish in waters around Scotland averaged over the period 1999 to 2008

Large fish indicator

Species Richness

Species Diversity

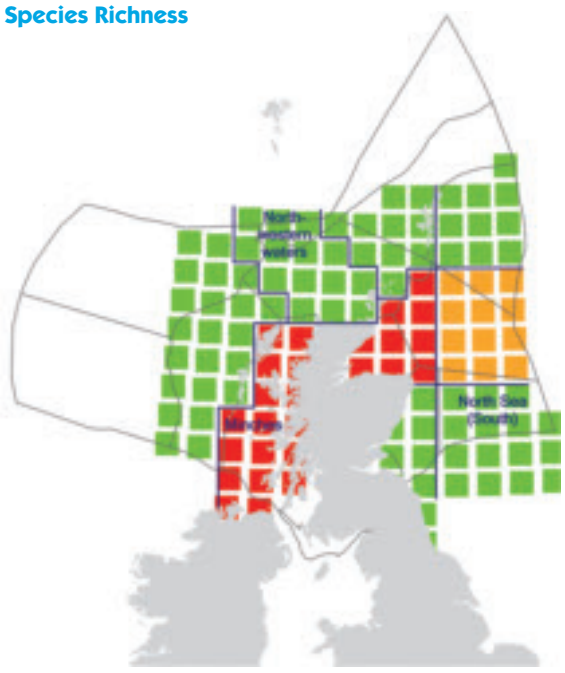
In making any assessment of the state of the fish community, this spatial variation needs to be taken into account, so nine regional assessments (Minches, West of Hebrides, North-western waters, West of Shetland, East of Shetland, Moray Firth, North Sea (north), Firth of Forth, North Sea (south)) were carried out based on the results of two separate analyses. Long-term trends were determined based on comparisons of the average values calculated for each indicator over the first eight (North Sea regions, 1982-1991; western and northern regions, 1986-1995), and last five years (2004-2008) for which data are available for each region. Short-term trends were determined as a regression of the average indicator values calculated over the last ten years (1999-2008) of data for each region. Following the precedent established during development of the OSPAR large fish indicator, the first eight years for which data were available in each region was considered the "reference period". The average indicator value determined for each region during this period was therefore considered to be the baseline value, or minimum aspirational target. The logic underpinning the assessments is described in the table below.

Size composition among demersal fish occupying Scottish waters in the nine regions appeared to give greatest cause for concern; in five regions (West of Hebrides, Moray Firth, North Sea (north), Firth of Forth and North Sea (south)) the large fish indicator suggested a situation where remedial action might be necessary. The situation was generally better for the two biodiversity indicators. Indeed, the species diversity indicator suggested that a cautionary approach was required in just one region (Moray Firth). On the other hand the species richness indicator suggested that some remedial action might be required in two regions (Minches and Moray Firth), and precautionary monitoring required in a third (North Sea (north)). Only in one region, the Moray Firth, did all three indicators suggest the need for either remedial action or precautionary monitoring.

The state of Scotland's demersal fish community is partly influenced by human activities, such as commercial fishing, as well as factors such as climate change. Recent measures to reduce fishing mortality in Scottish waters have clearly benefitted the demersal fish community, but the need for further enhancing an ecosystem approach to marine management remains. The current situation regarding the demersal fish community in Scottish seas suggests the need for continued action and monitoring.

Univariate community indicator assessment scores for the demersal fish community in nine regions around Scotland

Species Richness



Species Diversity

Size Composition

Logic underpinning assessments status scoring

Long term trend	Short term trend	Assessment of "Status"	Reason for "Status" score
Improvement	Improving		Above baseline and improving
	No change		Above baseline and not changing
	Declining		Above baseline, but deterioration indicated – **cautionary**
No change	Improving		At baseline and improving
	No change		At baseline and not changing
	Declining		At baseline but deteriorating – **action**
Decline	Improving		Below baseline but improving – **cautionary**
	No change		Below baseline and no change – **action**
	Declining		Below baseline and deteriorating – **action**

Priority Marine Feature

Sand goby *Pomatoschistus minutus*

The sand goby is found on coarse sandy and muddy sediments in estuaries, lagoons, sea lochs and salt march pools. It is widely distributed around the coastline of Scotland but with most records on the west coast.

Pressure

The main pressure on the species is loss or damage of habitat.

Sand goby

© Paul Kay

Elasmobranchs

Elasmobranchs (sharks, skates and rays) differ from other fish in the sea by having a skeletal structure made out of cartilage as opposed to bone.

Elasmobranchs range throughout the oceans and can be found in all oceanic and coastal zones. Scotland has over 30 species of sharks, skates and rays recorded in its waters of which 25 are found in coastal waters.

All elasmobranchs share life history characteristics which make them vulnerable to overfishing and means that once depleted, populations take a long time to recover. Elasmobranchs are slow growing, late to reach maturity and typically have low fecundity, thus the number of individual fish recruited into a population on an annual basis is low. They have a variety of breeding methods:

Oviparous: Egg laying.

Ovoviviparous: Live young bearing with nutrition from yolk sac.

Viviparous: Live young bearing with maternal nutrition.

Some smaller species such as the small spotted catshark (aka lesser spotted dogfish) can mature as early as 6 years old. Larger, longer lived species such as the common skate do not mature until around 15 years old. Low fecundity can mean that each female only produces between 25-50 eggs/pups per year (some females only produce young every two years). The number of young produced is directly proportional to the size of the female, the larger, older fish producing more young than the smaller recently mature fish. The young are often fully developed and instantly capable of self nurture but they are almost instantly at danger from being taken as bycatch as they are large enough to get caught in trawl nets and dredge gear.

As many elasmobranchs tend to school in sex and age related groups, trawls can often pick up large numbers of juvenile fish in a single haul before they have had a chance to reproduce. Therefore relatively few animals actually reach breeding age, and those that do only produce large enough numbers of young later in life to help rebuild a population.

In 2009 it became compulsory for commercial fisheries to report on elasmobranch landings by species as opposed to family. Historically, skates and rays were recorded under one label, now individual species must be recorded. However, many species of skate and ray are similar in appearance and the variation in morphology within the same species can often lead to confusion and misidentification. This will give false numbers of species being landed and could lead to misrepresentation of stock levels.

Many species are also vulnerable to habitat disturbance and loss and some surface dwelling species such as the basking shark are susceptible to boat strikes and harassment.

All species of sharks and rays are on the OSPAR list of Threatened and Declining Species due to their removal as both target and non-target species.

Priority marine features

Basking shark – *Cetorhinus maximus*
Spiny dogfish – *Squalus acanthias*
Porbeagle shark – *Lamna nasus*
Portuguese dogfish – *Centroscymnus coelolepis*
Leafscale gulper shark – *Centrophorus squamosus*
Common skate – *Dipturus batis* complex
Blue shark – *Prionace glauca*
Sandy ray – *Leucoraja circularis*

Basking shark *Cetorhinus maximus*

The basking shark is the second largest fish in the world and the largest in British waters, growing up to 9.8m in length. They are known to migrate over large distances in both offshore and coastal waters at depths from the surface to over 750m. They are particularly associated with tidal fronts on the continental shelf and shelf edge where they feed on plankton.

They have been recorded from around the whole Scottish coast, with sightings peaking in the summer months especially at a number of hot spots on the west coast.

Pressures

In the past basking sharks were subject to a targeted fishery in Scottish waters and whilst this no longer exists and they are protected in British waters they are still fished elsewhere. They have suffered 50-80% population declines in recent years. Numbers remain low and they are classed as globally Vulnerable on the IUCN Red List.

Sandy ray *Leucoraja circularis*

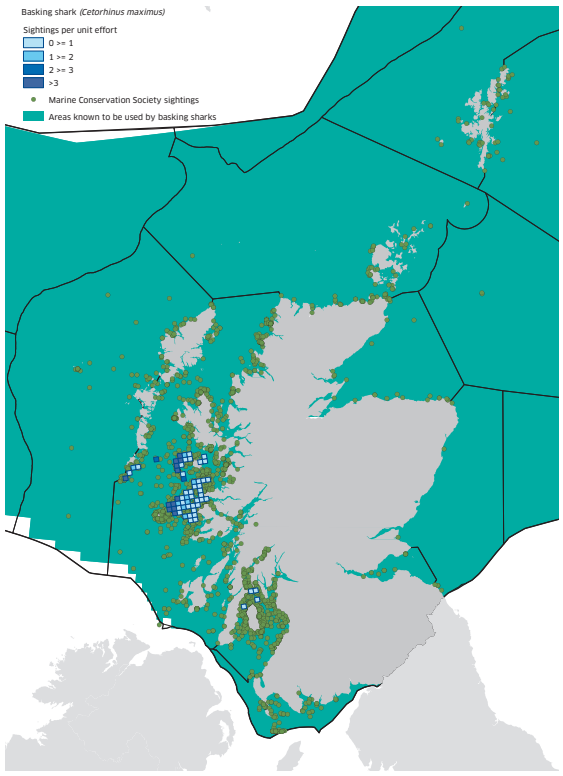
The sandy ray can reach 120cm in length and occurs at depths from 70-275m. It is an offshore species typically found on sandy or muddy sea beds to the north-west of Scotland but can occur elsewhere around the coast.

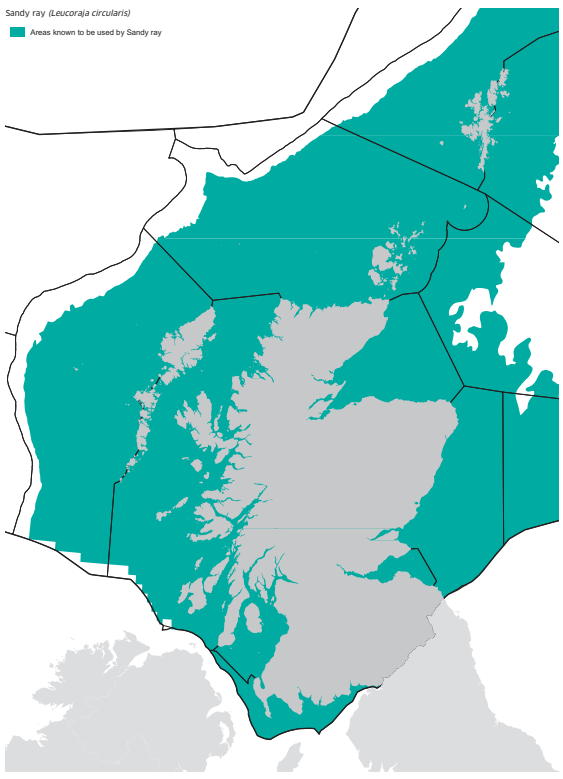
Pressures

The status of the species is unknown and while there is not a target fishery it is often taken as bycatch, leading to declines in its numbers. It is listed as Vulnerable on the IUCN Red List.

Basking shark

© Paul Naylor



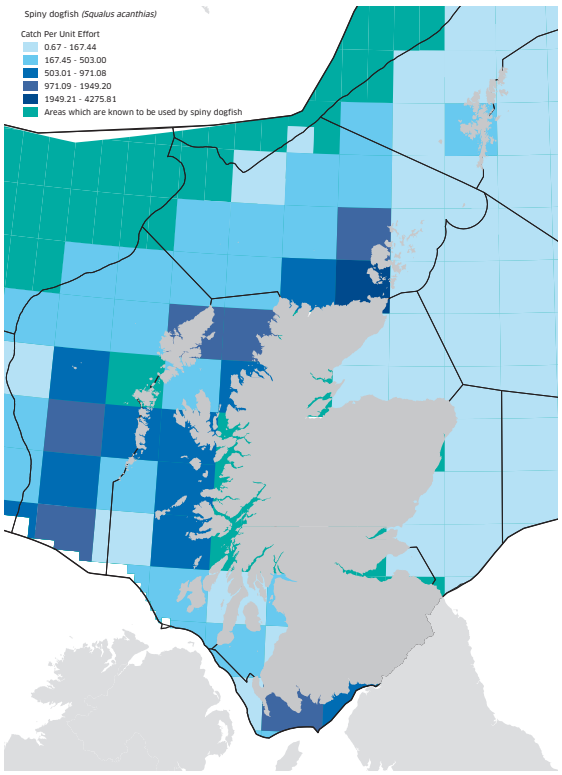


Spiny dogfish
Squalus acanthias

This is a small dogfish reaching 1.6m in length and is one of the most abundant shark species in the world. It is widely distributed in Scottish waters and is found just above the sea bed, typically at depths of 10-200m (but can be as deep as 900m).

Pressures

Most populations are at serious risk from overfishing and the species is classed as Vulnerable internationally and Critically Endangered in the north-east Atlantic, where populations are depleted, on the IUCN Red List. Both directed fishing and accidental bycatch pose threats.



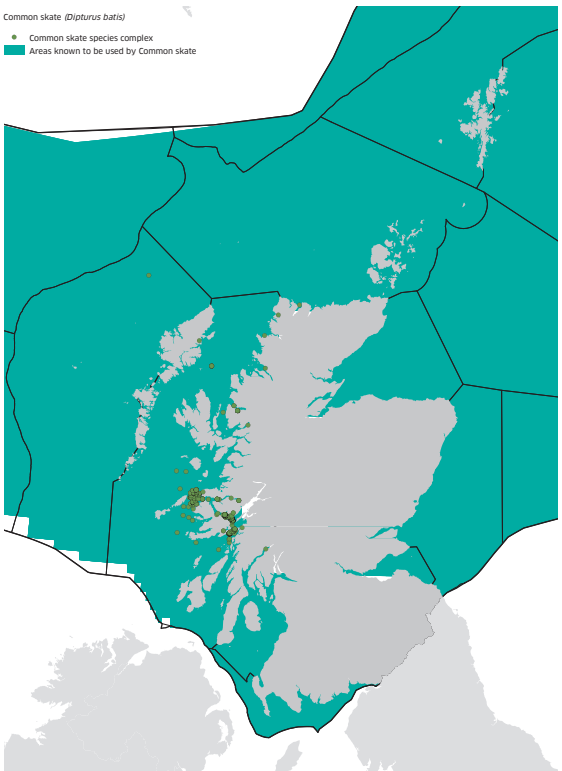
© Paul Kay

Common skate
Dipturus batis complex

The common skate can grow up to 3m in length, and is found at depths down to 600m. It has been recorded from all around Scotland. It was once abundant in north-west Europe but there have been significant declines around the UK over the last century due to overfishing.

Pressure

The waters around the Isle of Mull and Firth of Lorn retain a relatively healthy population but it is classed as Critically Endangered on the IUCN Red List and it is prohibited to land any catch in the EU.



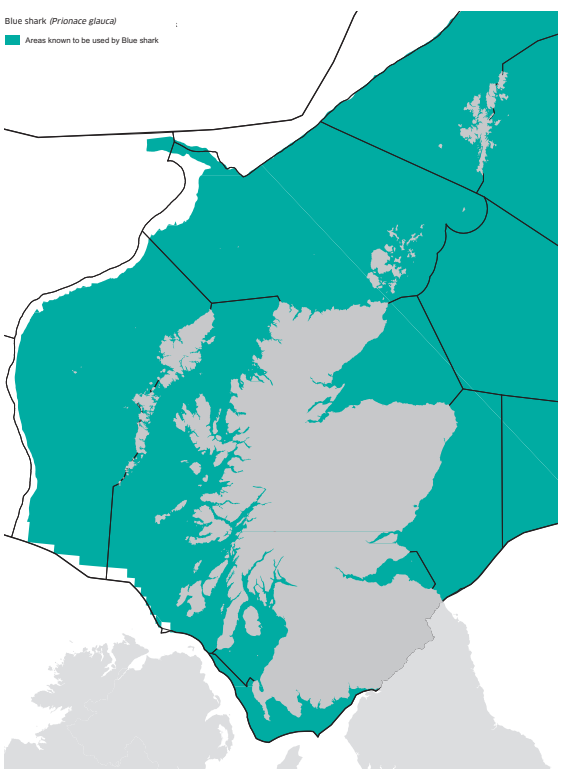
© James Thorburn

Blue shark
Prionace glauca

The blue shark can grow up to 3.8m in length and, as part of their annual migration, can be found especially off the west coast of Scotland during the summer months. It occurs at depths from the surface down to 600m.

Pressures

The blue shark is widely fished either through bycatch of by targeted fisheries. The North Atlantic stock status is unclear due to unreliable catch data but there appears to be a declining trend in recent years. Local legislation to protect it is likely to have only limited impact as they are highly migratory. It is currently listed as Near Threatened on the IUCN Red List.



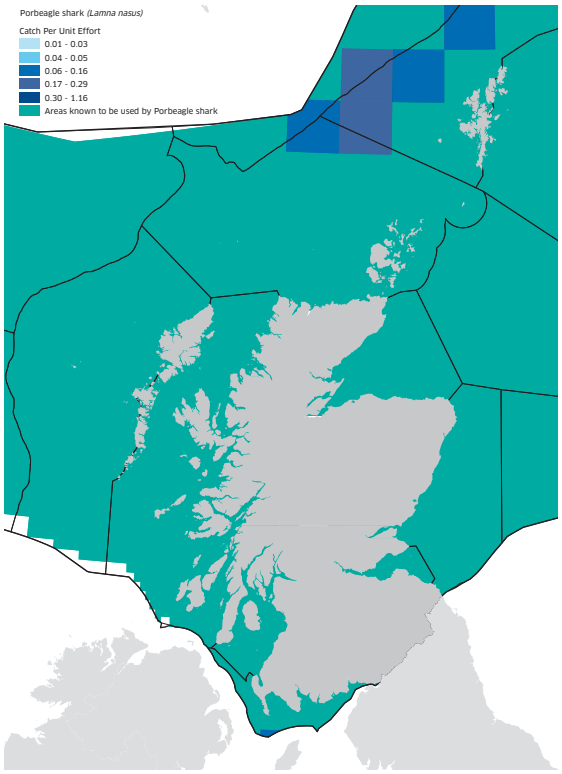
© JNCC

Porbeagle shark
Lamna nasus

The porbeagle shark can reach 3.5m in length and is usually found in mid-water between 200-700m, but sometimes in shallower water close inshore.

Pressure

It is widely distributed around Scotland although considered rare, and is currently listed on the IUCN Red List as Critically Endangered in the north-east Atlantic and Vulnerable internationally. It is fished for human consumption and fishmeal production and is highly susceptible to overfishing. In 2010 an EU-wide zero TAC was introduced.

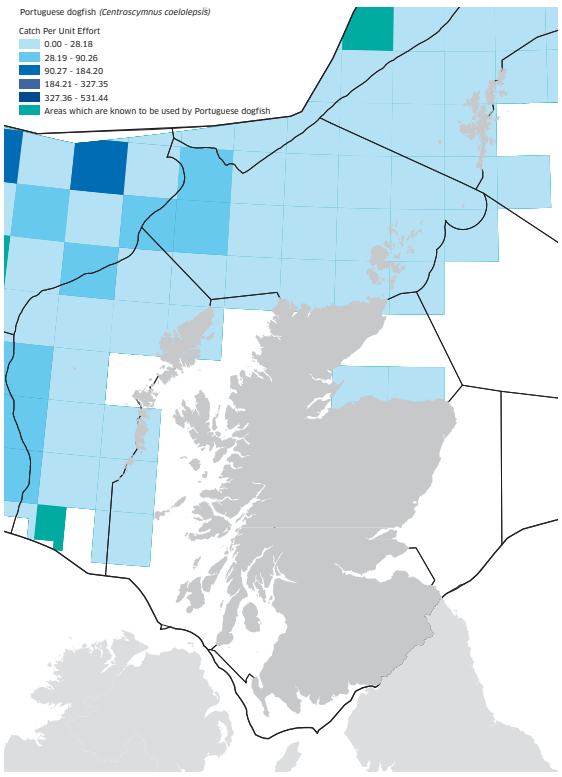


Portuguese dogfish
Centroscymnus coelolepis

This dogfish can reach 1.2m in length and is a deepwater species found between 400-2700m on the continental shelf and abyssal plain. Found off the far west and north coasts of Scotland.

Pressure

It is commercially valuable, susceptible to overfishing and currently classified as Near Threatened on the IUCN Red List.

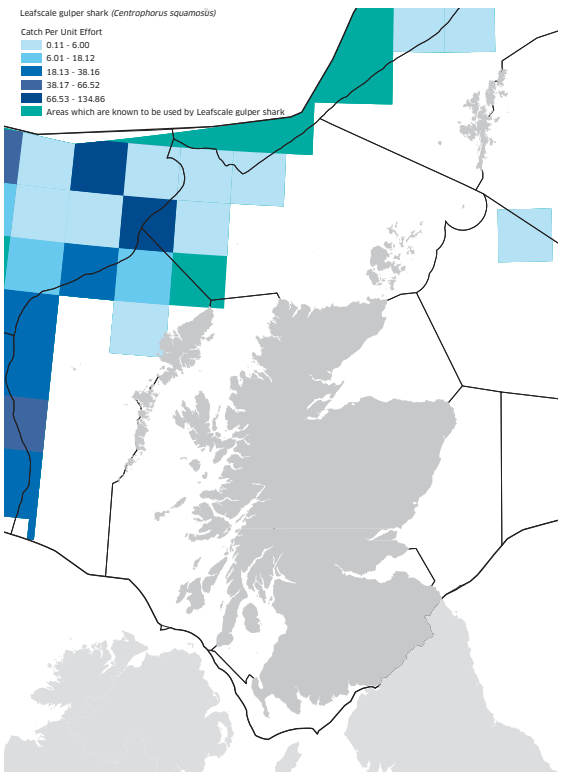


Leafscale gulper shark
Centrophorus squamosus

The leafscale gulper shark can reach 1.6m in length and is found on the continental shelf rarely above depths of 1000m. It is found off the far west and north-west coasts of Scotland.

Pressure

It is commercially valuable, susceptible to overfishing and currently classified as Vulnerable on the IUCN Red List.



Coastal species of skates, rays and sharks not listed as Priority Marine Features

Scientific name/ Common name	Depth range	Habitat	Reproductive strategy	Abundance	Status
Skates and rays					
Amblyraja hyperborea Arctic skate	250 – 2500m	Demersal, soft substrate	Oviparous every two years	A rare visitor.	Least concern no target fishery.
Amblyraja radiate Starry skate	18 – 1400m	Demersal various substrates	Oviparous every two years	One of most abundant in North Sea, also north-east Atlantic.	Least concern no target fishery.
Dasyatis pastinaca Common stingray	Shallows – 200m	Soft substrates	Viviparous annual	Sparsely distributed in North Sea.	Near threatened no target fishery.
Dipturus oxyrinchus Long-nose skate	15 – 900m	Soft substrates	Oviparous every two years	Widely distributed low numbers western Scotland, occasional visitor North Sea.	Near threatened no target fishery.
Dipturus nidarosiensis Black skate	120 – ~1000m	Soft substrates	Oviparous annual	Low abundance, slightly higher numbers in deeper water.	Threatened no current target fishery.
Leucoraja fullonica Shagreen ray	30 – 600m	Rough substrates	Oviparous No data on frequency	Rare species, most common off north-west coast.	Near threatened no target fishery.
Leucoraja naevus Cuckoo ray	20 – 500m	Various substrates	Oviparous annual	Comparatively common throughout.	Least concern no target fishery.
Raja brachyuran Blonde ray	10 – 900m	Soft substrates	Oviparous annual	Found throughout, more common in northern and western regions.	Near threatened no known target fishery.
Raja clavata Thornback ray	10 – 300m	Various substrates	Oviparous annual	One of most abundant throughout, more common in western and northern regions.	Near threatened target fishery within Europe.
Raja montagui Spotted ray	Shallows – 530m	Soft substrates	Oviparous annual	Widespread around northern and western coasts, rare in North Sea.	Endangered no current target fishery.
Sharks					
Alopias vulpinus Thresher shark	Surface – >330m	Epipelagic, Typically 40-75 miles offshore	Ovoviviparous annual	Rare in Scottish waters, mature fish mainly offshore.	Near threatened no target fishery but taken as bycatch.
Galeorhinus galeus Tope	Surface – 550m	Demersal off continental shelf	Ovoviviparous every 2-3 years	Highly migratory throughout Scottish waters, rarer on east.	Classed as Vulnerable on the IUCN Red List, target fishery in England and Wales but not Scotland.
Mustelus asterias Starry smoothhound	Shallow 0 – 100m	Demersal sand and gravel bottom	Annual	Widespread throughout Scotland.	Least concern, unimportant bycatch in multispecies trawls.
Scyliorhinus canicula Small spotted catshark	Shallows – 400m	Demersal coastal and shelf waters	Oviparous annual	Abundant throughout Scottish waters.	Least concern. No target fishery but larger specimens kept for human consumption.
Scyliorhinus stellaris Nursehound	Shallows – 125m	Demersal rough rocky bottom	Oviparous annual	Common throughout coastal and shelf waters, high abundance in places.	Near threatened. Some target fishery.
Somniosus microcephalus Greenland shark	Shallows – >2000m	Demersal	Ovoviviparous unknown	Low abundance, mainly off north-west coast.	Near threatened. No target fishery but taken as bycatch.
Galeus melastomus Blackmouth shark	55 – 1200m	Demersal continental shelf	Oviparous likely annual	Throughout Scottish waters but more abundant in deeper offshore waters.	Least concern. Zero TAC in EU waters.
Hexanchus griseus Bluntnose sixgill	Shallows – >2000m	Semi-pelagic	Ovoviviparous unknown	Patchy abundance, mostly from north and west coast waters.	Near threatened. No target fishery but caught as bycatch in deep water trawls, retained for human consumption.
Squatina squatina Angelshark	5 – 150m	Largely benthic	Ovoviviparous annual	Very rare in Scottish waters, extinct in North Sea.	Critically endangered. Prohibition on retention in All ICES areas.

In addition to the Portuguese dogfish and leafscale gulper shark which are both priority marine features, there are a number of other deep water species of shark that occasionally visit Scottish waters, they mostly occur beyond the continental shelf and are only known due to their occurrence in deep water fisheries.

Little is known about their population numbers or abundance:

Demon catsharks *(Apristurus* spp.*)*
Black dogfish *(Centrophorus fabricii)*
Longnose velvet dogfish *(Centroselachus crepidater)*
Frilled shark *(Chlamydoselachus anguineus)*
Kitefin shark *(Dlarias licha)*
Birdbeak dogfish *(Deania calcea)*
Great lantern shark *(Etmopterus princeps)*
Velvet belly laternshark *(Etmopterus spinax)*
Knifetooth dogfish *(Scymnoden ringens)*

Starry smoothhound shark – *Mustelus asterias*

SEALS

Introduction

Two species of seals (grey seal – *Halichoerus grypus*, and harbour seal – *Phoca vitulina*) are found all around Scotland's coast and inshore waters.

Legislation

The Conservation of Seals Act 1970 has been replaced by the Marine (Scotland) Act 2010 which makes it an offence to shoot seals in Scotland. There is provision for licences to be issued for limited seal management if strict legal tests are met where it is necessary to avoid damage to fisheries or fish farms. For the purposes of considering licence applications to shoot seals the coast has been divided into seven seal management areas: East coast, Moray Firth, Orkney and North Coast, Shetland, Western Isles, West Highlands and South-west Scotland. The number of seals licensed to be shot in any seal management area will be determined on an annual basis, based on the most recent data on seal population size and the underlying trend in their numbers.

It is also an offence to intentionally or recklessly harass seals at their haulout sites.

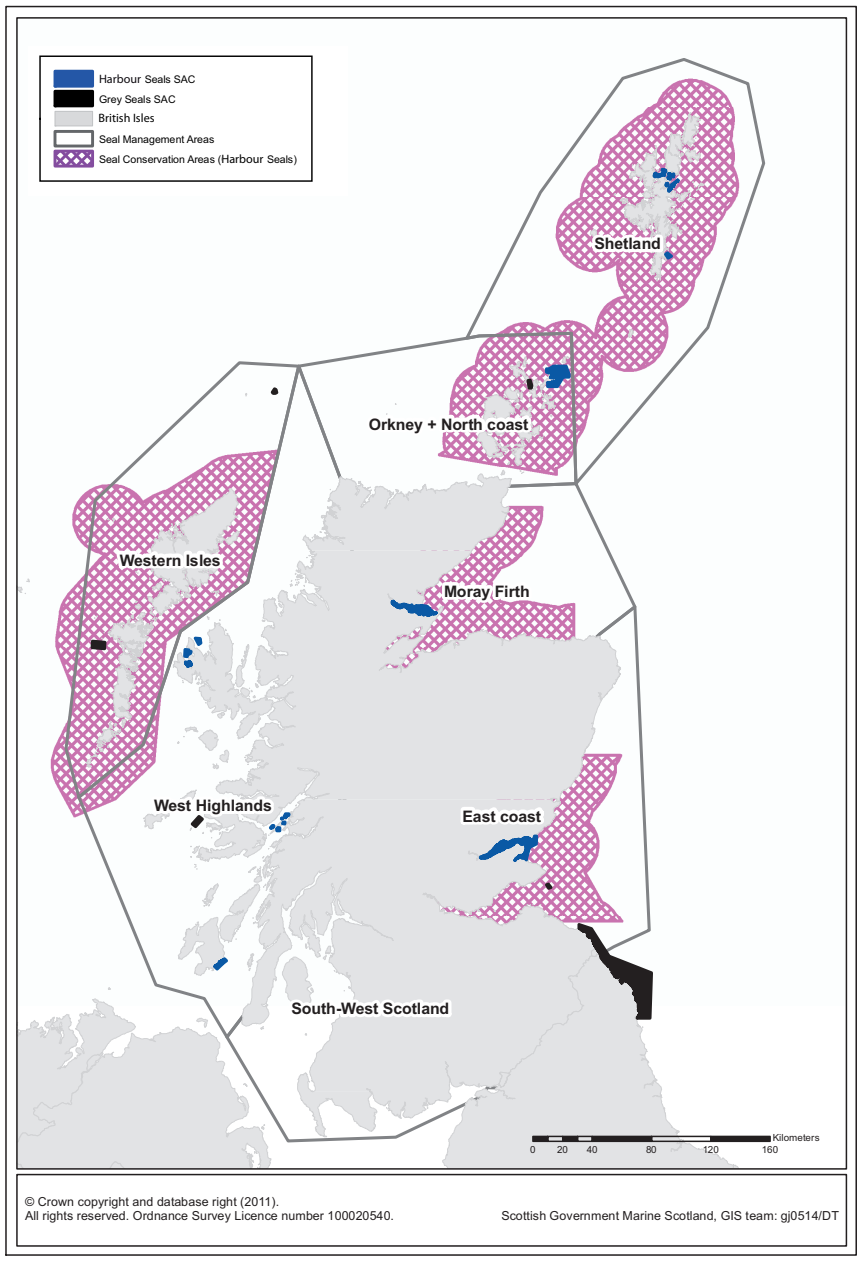
The Council Directive 92/43/EEC of 21 May 1992, commonly known as the Habitats Directive, requires member states to designate Special Areas of Conservation (SAC) for the protection of grey and harbour seals. There are currently five grey seal and eight harbour seal SAC in Scotland.

The OSPAR Convention has set in place Ecological Quality Objectives (EcoQOs) to help assess the state of grey and harbour seal populations in the North Sea.

The EcoQO for grey seals is *'Taking into account natural population dynamics and trends, there should be no decline in pup production of grey seals of ≥10% as represented in a five-year running mean or point estimates (separated by up to five years) within any of nine sub-units of the North Sea. These sub-units are: Orkney; Fast Castle/Isle of May; the Farne Islands; Donna Nook; the French North Sea and Channel coasts; the Netherlands coast; the Schleswig-Holstein Wadden Sea; Heligoland; Kjørholmane (Rogaland)'*.

Up to 2009 grey seal pup production was within these limits. Pup production appears to be stabilising in Orkney, and is increasing at the Isle of May/Fast Castle (entirely due to increases at Fast Castle).

Boundaries of seal management areas and harbour seal conservation areas



The EcoQO for harbour seals is *'Taking into account natural population dynamics and trends, there should be no decline in harbour seal population size (as measured by numbers hauled out) of ≥10% as represented in a five-year running mean or point estimates (separated by up to five years) within any of eleven sub-units of the North Sea. These sub-units are: Shetland; Orkney; North and East Scotland; South-East Scotland; the Greater Wash/Scroby Sands; the Netherlands Delta area; the Wadden Sea; Heligoland; Limfjord; the Kattegat, the Skagerrak and the Oslofjord; the west coast of Norway south of 62°N'*.

In 2009 harbour seal population sizes in all four sub-units in Scotland were outside these limits. Significant declines have been recorded in populations in Shetland, Orkney and South-east Scotland. Numbers of harbour seals in North and East Scotland have also declined on the north coast but have recently shown signs of stabilising in the north-east coast (Moray Firth).

Grey seal Special Areas of Conservation in Scotland (see Protected Areas)
Faray and Holm of Faray (Orkney)
Isle of May (Firth of Forth)
Monach Isles (Outer Hebrides)
North Rona
Treshnish Isles (NW Strathclyde)

Harbour seal Special Areas of Conservation in Scotland (see Protected Areas)
Ascrib Island, Isay and Dunvegan (NW Skye)
Dornoch Firth and Morrich More (E Highland)
Eileanan agus Sgeiran Lois More (NW Strathclyde)
Firth of Tay and Eden Estuary (Fife and Tayside)
Mousa (Shetland)
East Sanday (Orkney)
SE Islay Skerries (W Strathclyde)
Yell Sound (Shetland)

Priority Marine Features

Grey seal *(Halichoerus grypus)*
Harbour seal (*Phoca vitulina*)

Grey seal *Halichoerus grypus*

Approximately 36% of the world's grey seals breed in the UK, of which 90% are from colonies in Scotland. The main concentrations are in the Inner and Outer Hebrides and Orkney. Grey seal pup production monitoring started in the late 1950s. Total numbers increased consistently from then until the late 1990s. In recent years there has been a significant reduction in the rate of increase and pup production in some regions is no longer increasing.

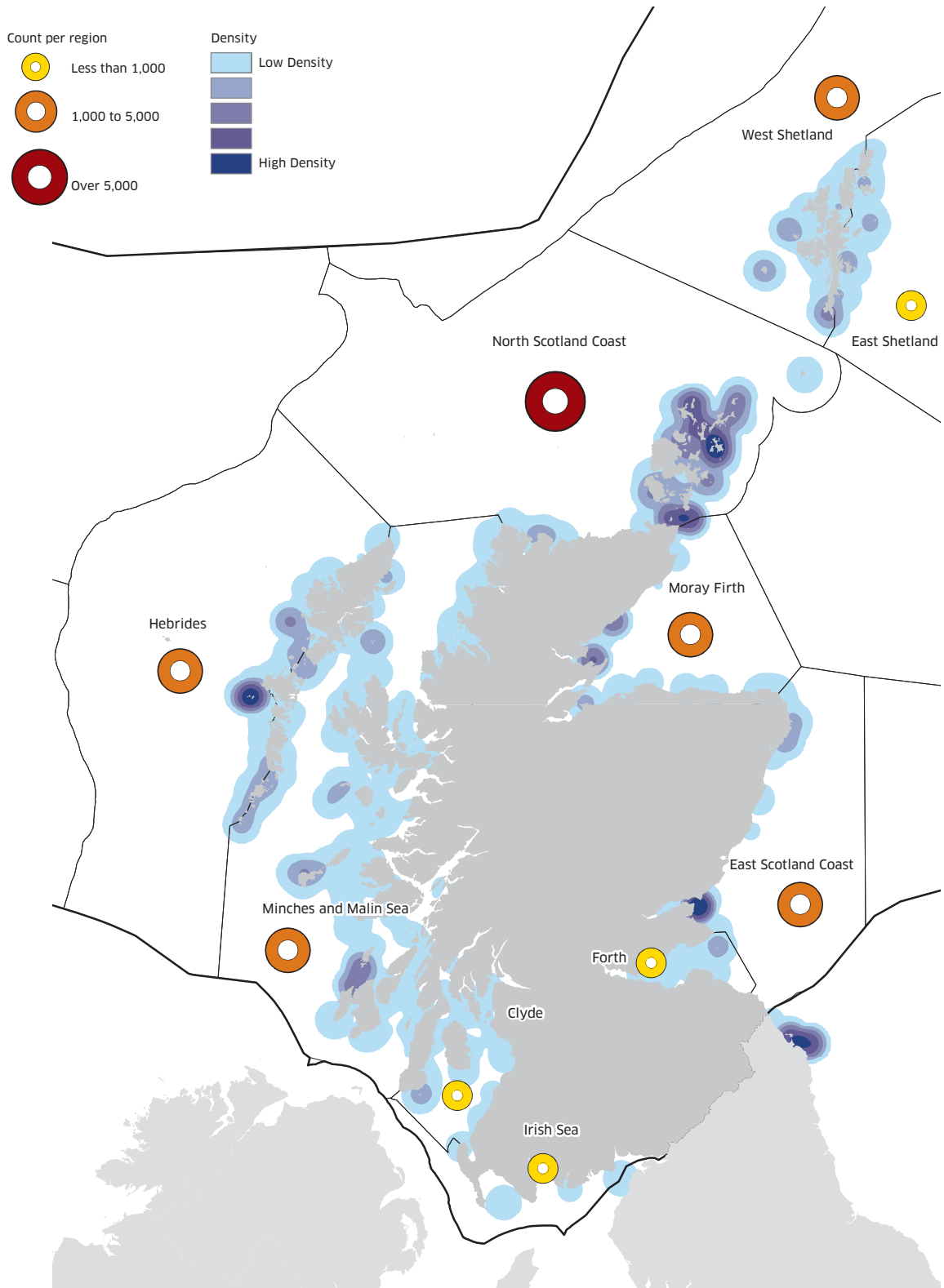
Population estimate for grey seals

Region production	2009 pup production	Change in pup from 08/09
Inner Hebrides	3,396	n/a
Outer Hebrides	12,113	-4.7%
Orkney	19,150	+2.1%
Isle of May/Fast Castle	4,047	+21.0%
All other sites including Shetland	3,247	-5.5%
Total	**41,953**	**+1.0%**

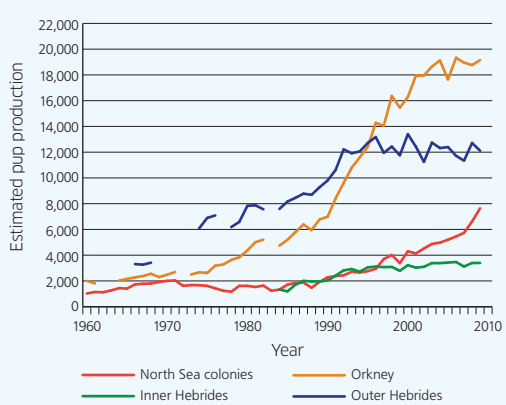
Source: Sea Mammal Research Unit

The estimate of the total grey seal population in the UK in 2009 based on pup production is problematic due to insufficient information on grey seal life history. The best estimate of the UK 2009 grey seal population size is 119,400 (95% CI 92,500 – 156,200) with an estimated Scottish population size of 105,072.

Grey Seals in Scotland by 1km squares, from surveys in August 2007-2009 (Sea Mammal Research Unit)

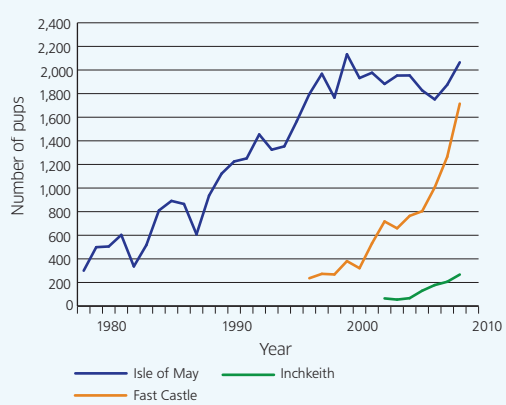


UK grey seal pup production at annually monitored breeding colonies



Source: Sea Mammal Research Unit

Grey seal pup production at North Sea colonies in Firth of Forth



Source: Sea Mammal Research Unit

Grey Seal

© Lorne Gill/SNH

Harbour Seal *Phoca vitulina*

Approximately 4% of the world's population, or 24% of the European subspecies of harbour seal (also known as common seal) are found in Scotland. Over 80% of the UK harbour seal population is found in Scotland.

Harbour seal numbers have declined dramatically by over 50% in Shetland, Orkney and the east coast of Scotland since 2001, with a smaller decline in the Outer Hebrides, whilst on the west coast and Inner Hebrides numbers have remained relatively stable. The cause/s of these declines are as yet unknown but are under investigation and conservation measures have been introduced.

Population estimate of harbour seals

The minimum population estimate for harbour seals in Scotland is:

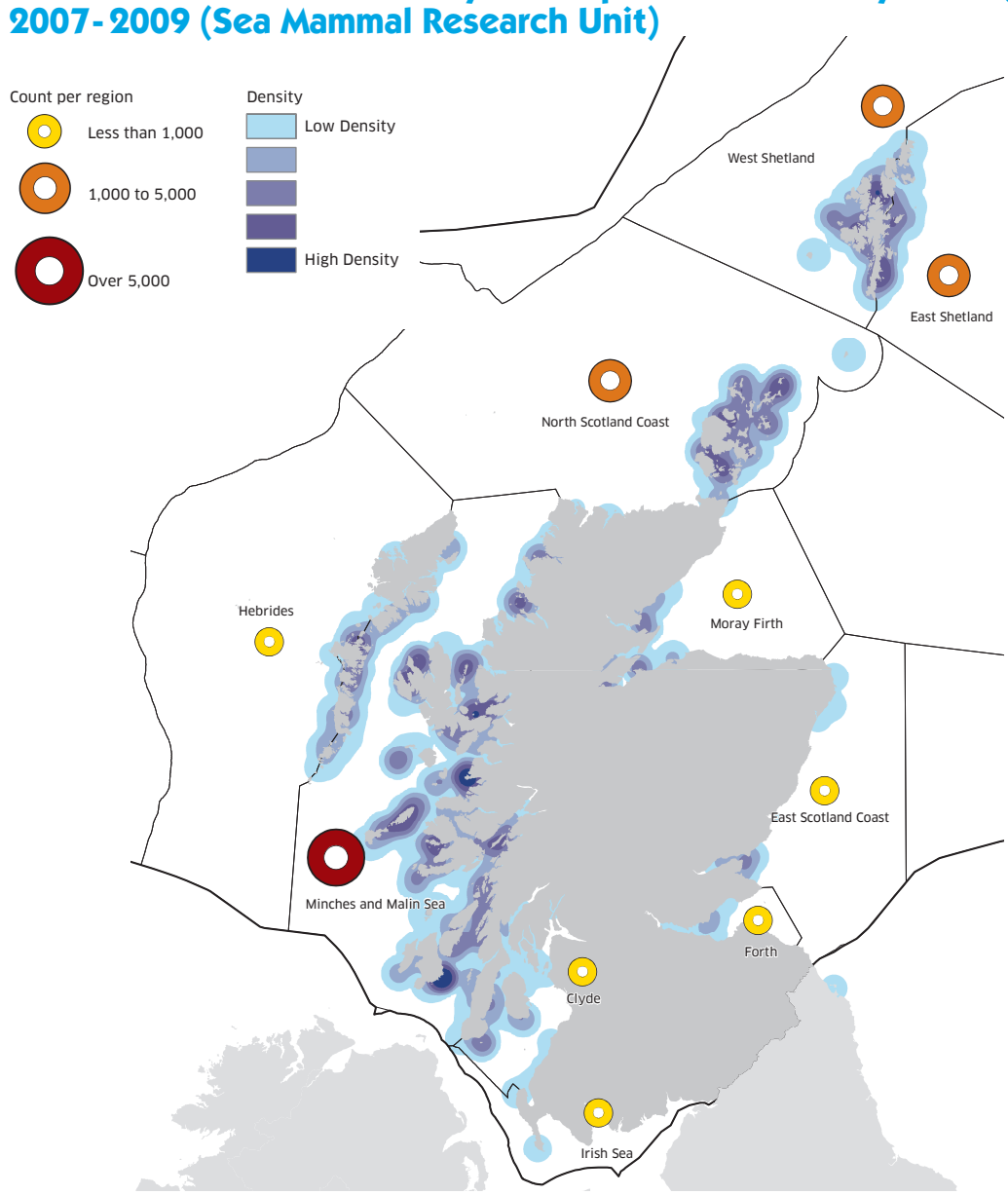
Area	Estimate	Year	Trend
Outer Hebrides	1,804	2008	Declining
Scottish west coast	11,364	2007/ 08/09	Stable/Slight increase
Scottish east and north coast	1,359	2007/ 08	Declining
Shetland	3,003	2009	Declining
Orkney	2,897	2009	Declining
Total	**20,427**		

Source: Sea Mammal Research Unit

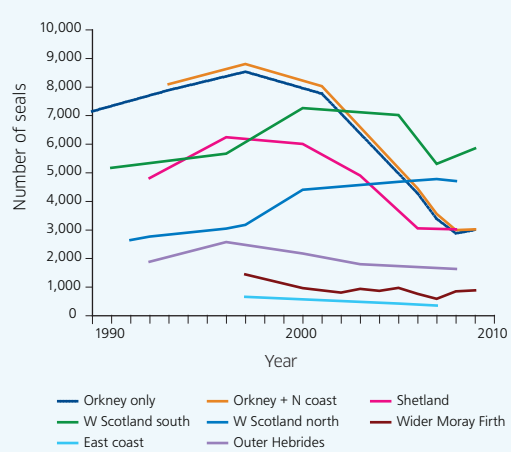
The current estimated total number of harbour seals in Scotland of 20,427 is 31% less than the total of 29,600 for the previous complete survey carried out in 1996/97. The decline in some areas has been much greater than in others, e.g. in Orkney numbers have declined from 8,523 in 1997 to 2,897 in 2009, a decline of 66%, and in the Firth of Tay numbers have declined from a mean of 670 between 1992 and 2002 to 111 in 2009, a decline of 83%.

The harbour seal population over much of the east coast and the Northern Isles has shown a marked decline in recent years, none more so than in the Firth of Tay where there has been an 83% decline from the high in 1992. The cause/s of this decline are still unknown but it is possible that it is due to a combination of a number of factors such as competition with grey seals, reduced prey availability, disease, increased predation from killer whales, shooting, elevated biotoxin loading, and reduced fecundity. In addition in the Firth of Tay in particular, there were a number of unusual deaths caused by massive traumatic corkscrew injuries, similar to injuries seen in a number of harbour seals off Blakeney Point on the east coast of England. Almost 10% of the Firth of Tay female breeding population of harbour seals may have been affected in 2010.

Harbour Seals in Scotland by 1km squares from surveys in August 2007-2009 (Sea Mammal Research Unit)

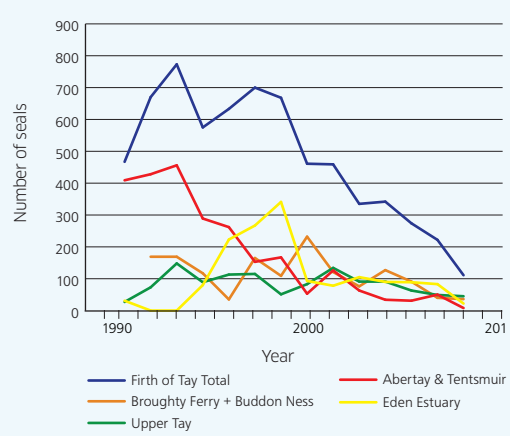


Numbers of harbour seals in Management Areas in Scotland



Source: Surveys by the Sea Mammal Research Unit

Harbour seals in the Firth of Tay



Source: SMRU surveys conducted in August, during the annual moult

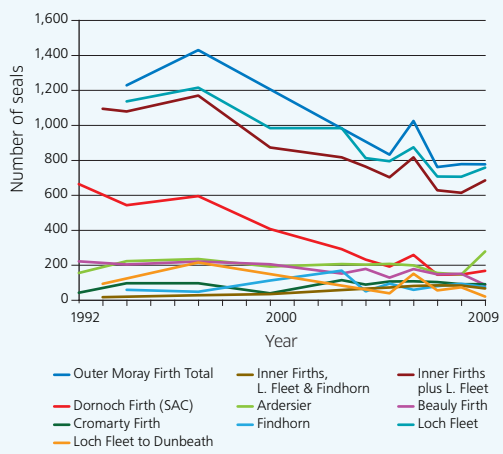
Harbour seals

© Lorne Gill/SNH

Moray Firth Seal Management Plan

The Moray Firth Seal Management Plan was established in 2005 in response to the declining number of harbour seals in the area. Since its inception, numbers have stabilised and begun to rise again. The management plan structure has been considered a success and it has been used as a template for developing the management of seals on other parts of the coast.

Moray Firth harbour seals in August



Source: Sea Mammal Research Unit

Pressures

There are a number of potential pressures and activities that may affect seals but the extent and magnitude of most have not been quantified. These include exposure to a range of hazardous substances including hydrocarbons, pathogens introduced from sewage and persistent pollutants such as PCBs. They are also susceptible to entanglement in marine litter and through by-catch in both active and ghost fishing gear. Habitat damage has resulted in a reduction in prey biomass and some loss of breeding habitat. Collisions with shipping and propeller strikes can be fatal and with the increase in offshore renewable energy developments this could increase. Noise from shipping, anti-predator acoustic devices and recreational activities, both at sea and on land, can cause disturbance at haul-out sites. Unregulated shooting in the past has been a source of mortality that it was difficult to quantify but the new measures contained within the Marine (Scotland) Act mean that this should no longer be a problem. Climate change is an unknown pressure at this time, although there is the potential that with increasing sea temperatures the abundance and distribution of preferred prey species may change.

Female grey seal with young pup

© Lorne Gill/SNH

Harbour seal

© Lorne Gill/SNH

Harbour seal pup

© Lorne Gill/SNH

Grey seal underwater

© Sue Scott

Cetaceans

Whales, dolphins and porpoises are collectively known as cetaceans. Twenty-three species have been recorded in Scottish waters over the last 25 years. Of these 11 are regularly sighted, the remaining 12 are considered to be vagrants or rare visitors.

Cetaceans are very mobile and can range widely with some undertaking large scale seasonal migrations often leaving Scottish waters in the process. Other species are more localised in their distribution. The greatest diversity of species is found off the continental shelf in waters to the north and west of Scotland.

Legislation

Cetaceans are protected by a number of international conventions and agreements. All cetacean species are listed on Annex IV of the Council Directive 92/43/EEC of 21 May 1992, commonly known as the Habitats Directive, *'animal and plant species of community interest in need of strict protection'*. Two species (bottlenose dolphin and harbour porpoise) are also listed on Annex II '*whose conservation requires the designation of Special Areas of Conservation*'. At present there is one SAC designated for the bottlenose dolphin in Scotland but none for the harbour porpoise.

Further obligations under the Habitats Directive require the UK *'to maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest*' and '*establish a system to monitor the incidental capture and killing of the animals species listed in Annex IVa. In the light of the information gathered, Member states shall take further research of conservation measures as required to ensure that incidental capture and killing does not have a significant negative impact on the species concerned.*' and under the Agreement on the Conservation of Small Cetaceans in the Baltic and North Sea (ASCOBANS) the UK is required to '*endeavour to establish an efficient system for reporting and retrieving bycatches and stranding specimens and to carry out … full autopsies in order to collect tissues for further studies and reveal possible causes of death*'.

Pressures

Cetaceans face a number of threats such as noise disturbance from shipping, oil and gas operations, military activities and potentially from other novel activities such as renewable energy developments. They are also vulnerable to pollution although concentrations of many contaminants such as PCBs are declining. Bycatch is the main form of direct human-caused mortality in UK waters. It is seen as a particular threat to harbour porpoises and short-beaked common dolphins although with the reduction in the use of static fishing gear this is declining. Council Regulation 812/2004 lays down measures concerning incidental catches of cetaceans by fisheries and requires member states to report certain cetacean bycatch.

Some species are at risk from entanglement and of death or injury from collisions with vessels. At present this is considered to be slight but with the installation of new renewable energy devices it is possible that this risk could increase. It is not known what the likely impacts of wide scale habitat damage/change are, nor the implications of climate change for cetaceans.

Distribution of cetacean species occurring in Scottish waters

(Species with an asterisk are Priority Marine Features)

Species	UK continental shelf (CS)	UK offshore waters (OS)	Population estimates	Date of estimate
*Phocoena phocoena** Harbour porpoise	✓		385,600 European CS	2005
*Tursiops truncatus** Bottlenose dolphin	✓	✓	12,600 European CS 19,300 OS	2005 CS 2007 OS
*Lagenorhynchus albirostris** White-beaked dolphin	✓		22,700 European CS 10,600 for North Sea	2005
*Balaenoptera physalus** Fin whale		✓	9,000	2007
*Balaenoptera acutorostrata** Minke whale	✓	✓	18,600 European CS 6,800 OS	2005 CS 2007 OS
*Delphinus delphis** Short-beaked common dolphin	✓	✓	63,400 European CS 116,700 OS	2005 CS 2007 OS
*Lagenorhynchus acutus** Atlantic white-sided dolphin	✓ (summer only)	✓	74,600 Faroe-Shetland Channel 21,400 Outer Hebrides	2004 CS
*Grampus griseus** Risso's dolphin	✓		No pop. estimate	
*Globcephala melas** Long-finned pilot whale		✓	25,100	2007
*Orcinus orca** Killer whale	✓	✓	Widespread but pop. size unknown	
*Physeter macrocephalus** Sperm whale		✓	2,100	2007
Stenella coeruleoalba Striped dolphin		✓	67,400	2007
*Hyperoodon ampullatus** Northern bottlenose whale		✓	7,000 for all beaked whales	2007
Ziphius cavirostris Cuvier's beaked whale		✓	7,000 for all beaked whales	2007
*Mesoplodon bidens** Sowerby's beaked whale		✓	7,000 for all beaked whales	2007
Mesoplodon mirus True's beaked whale		✓	No data	
Balaenoptera borealis Sei whale		✓	370	2007
Balaenoptera musculus Blue whale		✓	No data	
Megaptera novaengliae Humpback whale	✓ (summer only)	✓	No data	
Delphinapterus leucas Beluga whale		✓	No data	
Eubalaeana glacialis Northern right whale		✓	No data	
Preudorca crassidens False killer whale		✓	No data	
Kogia breviceps Pygmy sperm whale		✓	No data	

Priority Marine Features

Harbour porpoise *(Phocoena phocoena)*

Bottlenose dolphin *(Tursiops truncatus)*

White-beaked dolphin *(Lagenorhynchus albirostris)*

Minke whale *(Balaenoptera acutorostrata)*

Short-beaked common dolphin *(Delphinus delphis)*

Atlantic white-sided dolphin *(Lagenorhynchus acutus)*

Risso's dolphin *(Grampus griseus)*

Long-finned pilot whale *(Globicephala melas)*

Killer whale *(Orcinus orca)*

Sperm whale *(Physeter macrocephalus)*

Fin whale *(Balaenoptera physalus)*

Northern bottlenose whale *(Hyperoodon ampullatus)*

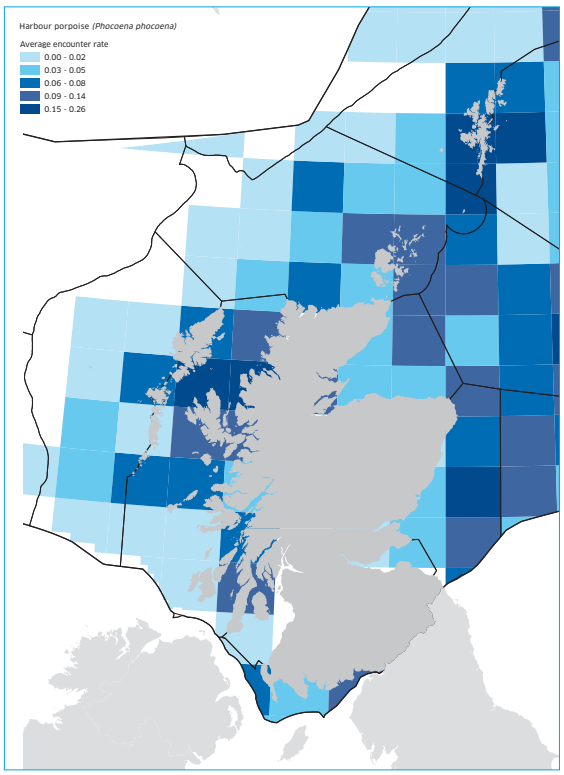
Sowerby's beaked whale *(Mesoplodon bidens)*

Moray Firth – Bottlenose dolphin Special Area of Conservation

© P.S.A. Macdonald/SNH

Harbour porpoise
Phocoena phocoena

Habitat: Open coast, shallow bays, estuaries and sea lochs
Scottish distribution: Abundant in waters all around Scotland
Status: IUCN Red List – Least Concern



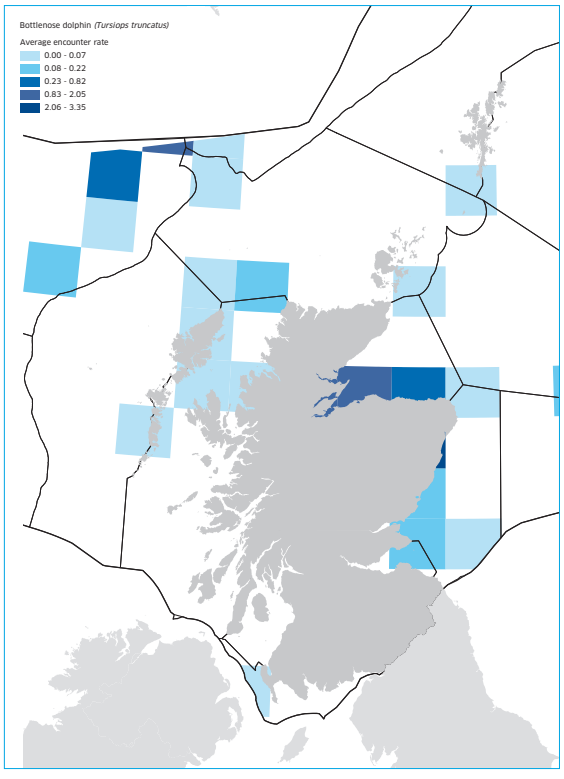
© Peter Evans Seawatch Foundation

Bottlenose dolphin
Tursiops truncatus

Habitat: Open coast, sea lochs, firths and offshore

Scottish distribution: Resident population of around 111 individuals known from Moray Firth and adjacent coastal waters. Also recorded from around Inner and Outer Hebrides

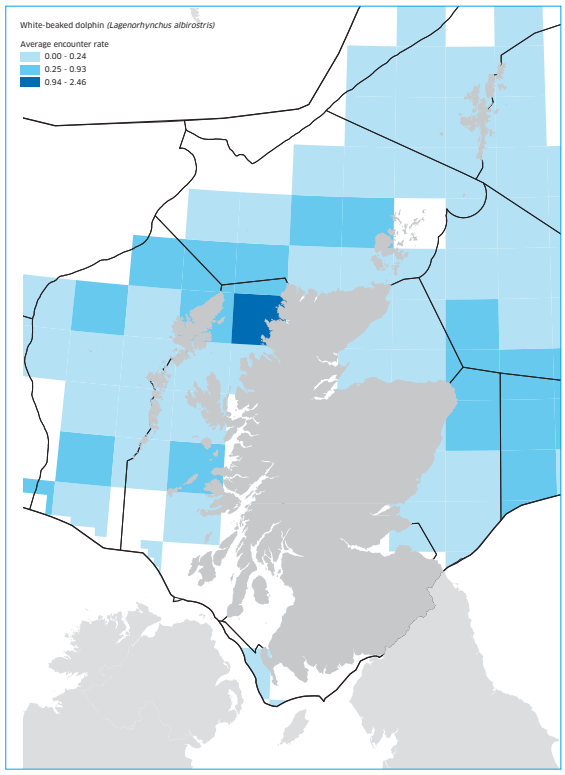
Status: IUCN Red List – Least Concern



© Lorne Gill/SNH

White-beaked dolphin
Lagenorhynchus albirostris

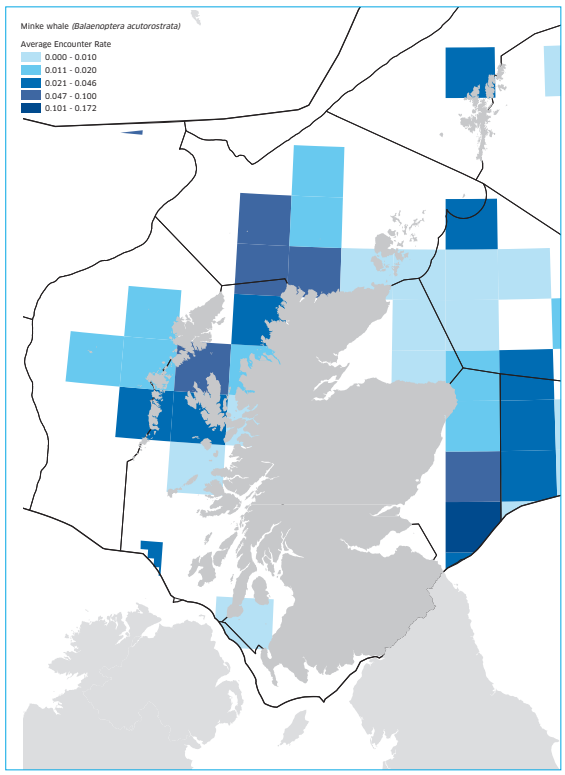
Habitat: Open coast, sea lochs with a preference for waters shallower than 200m and along the shelf edge
Scottish distribution: Abundant in all Scottish waters but concentrated around the Hebrides and Northern Isles
Status: IUCN Red List – Least Concern



© Caroline Weir Seawatch Foundation

Minke whale
Balaenoptera acutorostrata

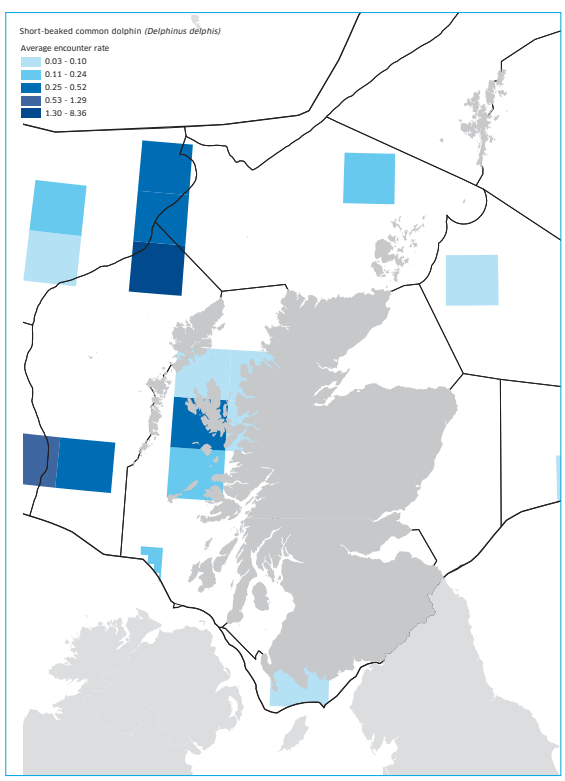
Habitat: Open coast, straits and sounds, sea lochs and occasionally offshore
Scottish distribution: Throughout Scottish waters
Status: IUCN Red List – Least Concern



© Peter Evans Seawatch Foundation

Short-beaked common dolphin
Delphinus delphis

Habitat: Open coast, offshore with a preference for areas of steep seabed
Scottish distribution: Mainly around the Hebrides
Status: IUCN Red List – Least Concern



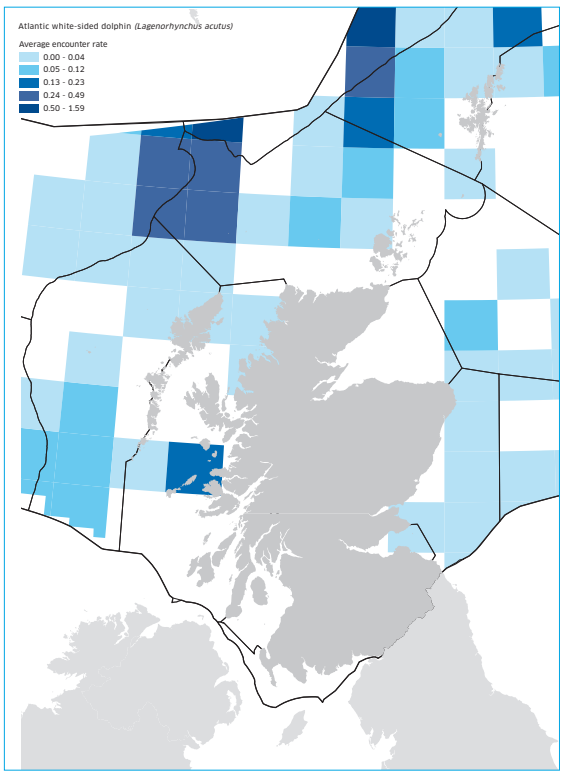
© P Anderwald Seawatch Foundation

Atlantic white-sided dolphin
Lagenorhynchus acutus

Habitat: Offshore along the outer continental shelf and slope

Scottish distribution: Around the Hebrides, Northern isles and North Sea

Status: IUCN Red List – Least Concern



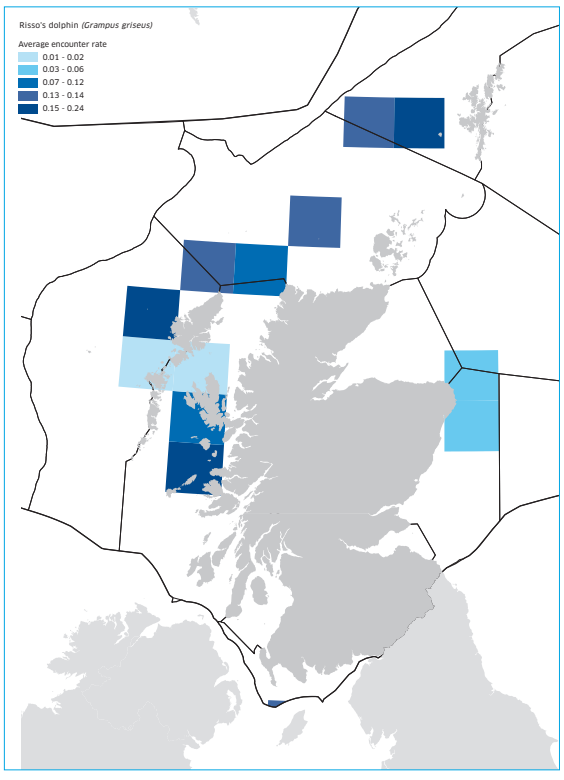
© WDCS/Hal Whitehead

Risso's dolphin
Grampus griseus

Habitat: Open coast, straits and sounds, sea lochs and offshore with a preference for areas with steep sloping sea bed

Scottish distribution: Most sightings around the Outer Hebrides, occasionally from Northern Isles and off the east coast

Status: IUCN Red List – Least Concern



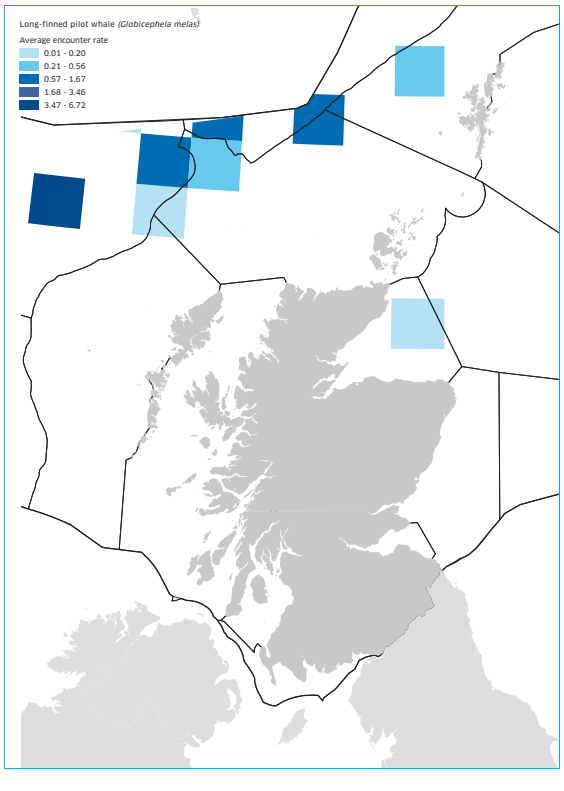
© D Feingold Seawatch Foundation

Long-finned pilot whale
Globicephala melas

Habitat: Deep waters along and seaward of the continental shelf edge

Scottish distribution: Sightings limited to Moray Firth and offshore west of the Hebrides and Shetland

Status: IUCN Red List – Data Deficient



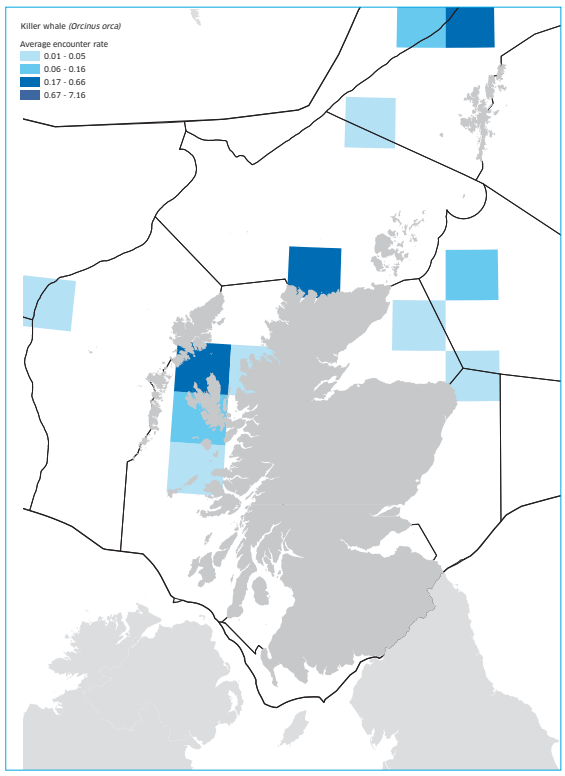
© M Baines Seawatch Foundation

Killer whale
Orcinus orca

Habitat: Open coast, straits and sounds, sea lochs and offshore

Scottish distribution: All around coast but sightings concentrated around Mull, north-east coast and Northern Isles

Status: IUCN Red List – Data Deficient



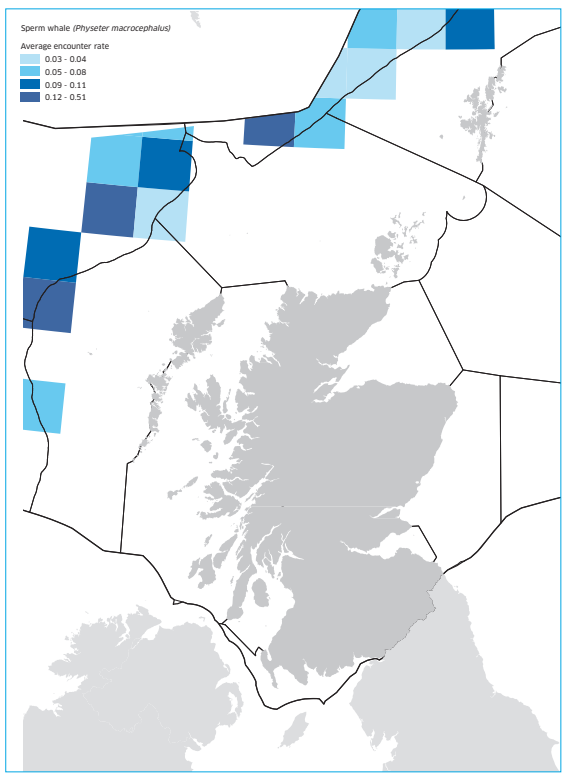
© M Baines Seawatch Foundation

Sperm whale
Physeter macrocephalus

Habitat: Continental slope and oceanic waters >1000m deep

Scottish distribution: Offshore to north and west of Scotland, occasionally seen inshore off Shetland

Status: IUCN Red List – Vulnerable



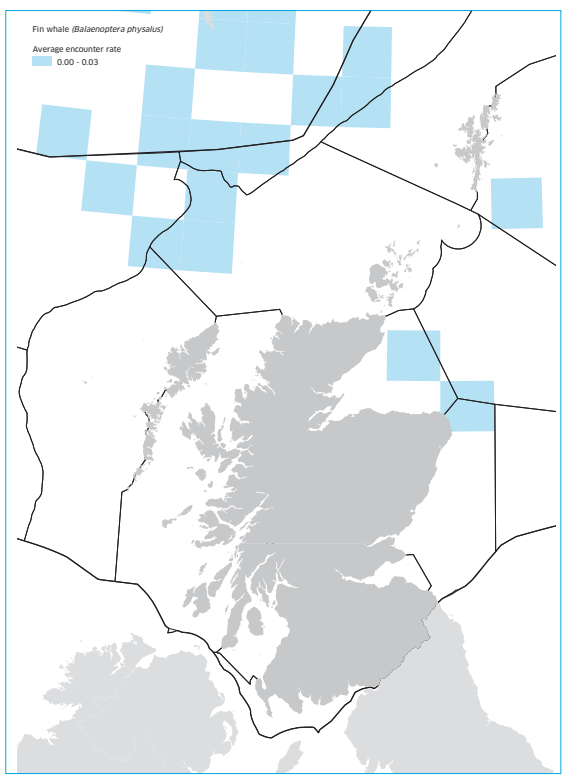
© Peter Evans Seawatch Foundation

Fin whale
Balaenoptera physalus

Habitat: Deepwater (400-2000m) beyond the edge of the continental shelf where they favour banks, mounds and areas of upwelling and frontal zones

Scottish distribution: Beyond the continental shelf margin in northern waters

Status: IUCN Red List – Endangered



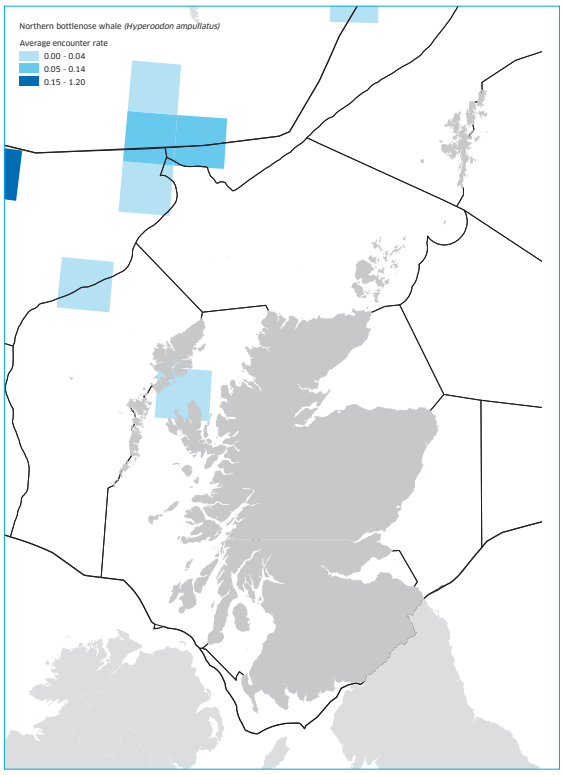
© Seawatch Foundation

Northern bottlenose whale
Hyperoodon ampullatus

Habitat: Cold temperate to subarctic deep waters beyond the edge of the continental shelf at depths of between 500-1500m, often near submarine canyons

Scottish distribution: Most records from beyond the continental shelf edge to the north-west of Scotland in summer months

Status: IUCN Red List – Data Deficient



© Seawatch Foundation

Sowerby's beaked whale
Mesoplodon bidens

Habitat: Occurs almost exclusively in deep waters beyond the continental shelf edge

Scottish distribution: Most records are from north-west and east Scotland

Status: IUCN Red List – Data Deficient

© Seawatch Foundation

Status

Five species (harbour porpoise, bottlenose dolphin, white-beaked dolphin, fin whale and minke whale) are considered to be in favourable condition, with the status of another six (short-beaked common dolphin, Atlantic white-sided dolphin, Risso's dolphin, long-finned pilot whale, killer whale, sperm whale) unknown because of a lack of suitable abundance estimates. The status of the remaining vagrant and rare species also could not be assessed.

As a group cetaceans are considered to be in good condition in the North Sea, but in moderate condition in the Minches and Western Scottish waters. The status of cetaceans in the Scottish continental shelf and offshore waters is unknown.

Species	Range	Population	Habitat	Future prospects	Overall assessment
Harbour porpoise	favourable	favourable	favourable	favourable	favourable
Bottlenose dolphin	favourable	favourable	favourable	favourable	favourable
Minke whale	favourable	favourable	favourable	favourable	favourable
White-beaked dolphin	favourable	favourable	favourable	favourable	favourable
Fin whale	favourable	favourable	favourable	favourable	favourable
Short-beaked common dolphin	favourable	unknown	favourable	unknown	unknown
Atlantic white-sided dolphin	favourable	unknown	favourable	unknown	unknown
Risso's dolphin	favourable	unknown	favourable	unknown	unknown
Killer whale	favourable	unknown	favourable	unknown	unknown
Sperm whale	favourable	unknown	favourable	unknown	unknown
Long-finned pilot whale	favourable	unknown	favourable	unknown	unknown

SEABIRDS

Seabirds

Scotland holds internationally important numbers of 24 species of breeding seabirds that are an important indicator for assessing the state of the marine environment. Seabirds respond to a range of factors, such as changes in food availability, weather, predation and pollution. Their abundance (i.e. number of breeding birds) is determined by how many adults survive from the previous year and how many young birds successfully reach maturity. The productivity (i.e. number of chicks produced) can provide a good indication of food availability as well as levels of predation. Productivity typically changes more quickly than abundance.

Black-legged kittiwake

© Lorne Gill/SNH

Breeding abundance and productivity is assessed for a number of the species that breed in Scotland based on a representative sample of colonies around Scotland, which are monitored as part of the UK Seabird Monitoring Programme. Seabird abundance has been declining since the early 1990s, the lowest abundance (70% of 1986 level) was reached in 2004 and has subsequently increased slightly and has been stable at around 72% for the last three years. The abundance declines were driven by those of black-legged kittiwake, Arctic skua, Arctic tern, herring gull, European shag, great black-backed gull and Sandwich tern and latterly by those of northern fulmar and common guillemot. Seabird productivity has fluctuated over the period but has declined to a low of 57% in 2007, since when there has been a very slight increase.

Breeding seabird numbers

Species	Scotland	UK Total population	Scotland as percentage of UK population
Northern fulmar *Fulmarus glacialis*	485,852	501,609	96.8
Manx shearwater *Puffinus puffinus*	126,545	299,678	42.2
European storm-petrel *Hydrobates pelagicus*	21,370	25,650	83.3
Leach's storm-petrel *Oceanodroma leucorhoa*	48,047	48,047	100
Northern gannet[1] *Morus bassanus*	182,511	218,546	83.5
Great cormorant *Phalacrocorax carbo*	3,626	8,884	
coastal component[2]	3,626	7,238	50.1
European shag *Phalacrocorax aristotelis*	21,487	26,565	80.9
Arctic skua *Stercorarius parasiticus*	2,136	2,136	100
Great skua *Catharacta skua*	9,634	9,634	100
Black-headed gull *Larus ridibundus*	43,191	138,012	
coastal component[2]	6,888	77,324	8.9
Mew gull *Larus canus*	48,113	48,714	
coastal component[2]	20,467	20,883	98.0
Lesser black-backed gull *Larus fuscus*	25,057	111,960	
coastal component[2]	21,565	87,413	24.7
Herring gull *Larus argentatus*	72,130	132,183	
coastal component[2]	71,659	130,228	55.0
Great black-backed gull *Larus marinus*	14,776	16,755	
coastal component[2]	14,773	16,735	88.3
Black-legged kittiwake *Rissa tridactyla*	282,213	378,847	74.5
Sandwich tern *Sterna sandvicensis*	1,068	12,490	8.6
Roseate tern[3] *Sterna dougallii*	5	107	4.7
Common tern *Sterna hirundo*	4,784	11,838	40.4
Arctic tern *Sterna paradisaea*	47,306	53,380	88.6
Little tern *Sterna albifrons*	331	1,927	17.2
Common guillemot[4] *Uria aalge*	1,167,841	1,416,334	82.5
Razorbill[4] *Alca torda*	139,186	187,052	74.4
Black guillemot[5] *Cepphus grylle*	37,505	38,714	96.9
Atlantic puffin *Fratercula arctica*	493,042	580,714	84.9

Breeding seabird numbers in the United Kingdom. Most figures are from the Seabird 2000 survey (1998-2002) but those for Northern gannet and roseate tern include more recent updates. All counts are of pairs unless otherwise stated.
1 Northern gannet figures are from the complete UK and Ireland survey of colonies in 2003-2005.
2 For species which also breed in inland colonies (defined as those >5km from the sea) the coastal component is shown separately.
3 Roseate tern figures are from 2006.
4 Counts are of individuals.
5 Counts of pre-breeding adults.

Abundance and Productivity Indicators

Species	Abundance index		Productivity index	
	1986	2009	1986	2009
Arctic skua	100	47.73	1	0.68
Arctic tern	100	94.08	1	2.43
Atlantic puffin			1	0.95
Black guillemot	100	62.87		
Common tern	100	98.67	1	0.33
Northern fulmar	100	80.47	1	0.79
Great black-backed gull	100	53.62		
Great skua	100	330.02	1	1.11
Common guillemot	100	82.00	1	0.80
Herring gull	100	45.18	1	1.17
Black-legged kittiwake	100	42.79	1	0.84
Lesser black-backed gull			1	1.33
Little tern			1	1.14
Sandwich tern	100	56.83	1	0.0004
European shag	100	57.82		

Northern gannet

© John M Baxter

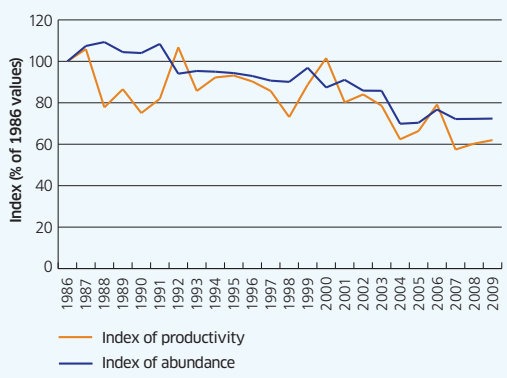
Bass Rock

© John M Baxter

Boreray, St Kilda

© David Donnan/SNH

Productivity and Abundance of breeding seabirds in Scotland (1986-2008)



Source: UK Seabird Monitoring Programme

Northern fulmar

© John M Baxter

Major Seabird Colonies in Scotland

Colony name	Species	Count at last census (Seabird 2000: 1998-2002)
1. Boreray, St Kilda	Atlantic puffin	51,000
	northern fulmar	5,000
	northern gannet	61,000
	Leach's petrel	13,000
2. Rum	Manx shearwater	120,000
	black guillemot	645
3. Dun, St Kilda	Atlantic puffin	55,000
	northern fulmar	11,000
	Leach's petrel	28,000
4. Fair Isle	Atlantic puffin	40,000
	northern fulmar	20,000
	European shag	700
	great skua	140
	Arctic tern	1,300
	common guillemot	39,000
5. Forth Islands – Bass Rock to Haystack (excluding Isle of May)	Atlantic puffin	30,000
	herring gull	6,000
	lesser black-backed gull	5,000
	northern gannet	44,000
6. Shiant Islands	razorbill	8,000
	Atlantic puffin	65,000
	great black-backed gull	300
	European shag	500
	common guillemot	16,000
7. Caithness south-eastern Cliffs	razorbill	7,000
	northern fulmar	7,000
	herring gull	1,400
	European shag	800
	black-legged kittiwake	24,000
	common guillemot	79,000
8. Handa Island	razorbill	17,000
	Arctic skua	42
	great skua	195
	common guillemot	113,000
9. Foula	Atlantic puffin	23,000
	northern fulmar	21,000
	European shag	2,000
	great skua	2,000
	Arctic skua	110
	common guillemot	41,000
10. Caithness north-eastern Cliffs	razorbill	11,000
	northern fulmar	8,000
	herring gull	2,000
	black-legged kittiwake	16,000
	common guillemot	80,000

Note: Colonies ranked on total number of individual breeding seabirds at last census in 1998-2002. A selection of the most notable species is given. Some colonies have been re-counted since last census, but these are not shown. All figures are pairs, except for razorbill, common guillemot and black guillemot, for which individuals are given.

SEABIRDS

Priority Marine Feature

Black guillemot – *Cepphus grylle*

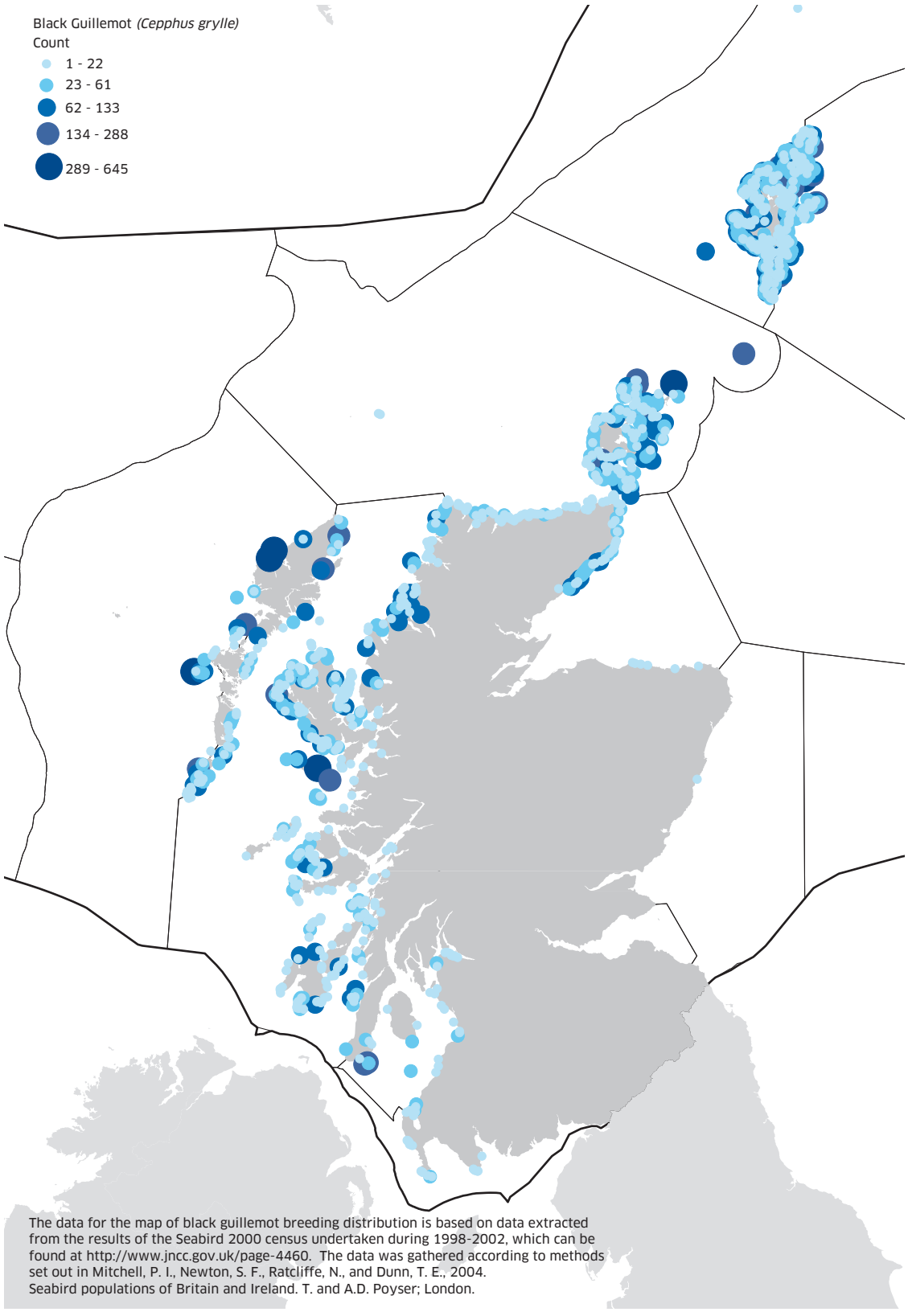
Black guillemots (known as tystie in Shetland) are widely distributed around the Scottish coast, but with the main concentrations in the Northern Isles and west coast. The Scottish population of ~38,000 represents about 87% of the Britain and Ireland population and of these over 50% breed in Shetland and Orkney.

Pressures

Black guillemots are very vulnerable to oil spills and predation at their nests by otters and American mink. Some local declines have been linked to mink predation.

Black guillemot – *Cepphus grylle*

© Lorne Gill/SNH



The data for the map of black guillemot breeding distribution is based on data extracted from the results of the Seabird 2000 census undertaken during 1998-2002, which can be found at http://www.jncc.gov.uk/page-4460. The data was gathered according to methods set out in Mitchell, P. I., Newton, S. F., Ratcliffe, N., and Dunn, T. E., 2004. Seabird populations of Britain and Ireland. T. and A.D. Poyser; London.

Pressures

The key factors affecting the abundance and productivity of seabirds are food availability, weather conditions and the occurrence of predators. Many seabirds, particularly those that have undergone the largest declines, mostly feed on small shoaling fish such as sandeels. In the past commercial sandeel fishing has had a detrimental impact on black-legged kittiwake survival and productivity. There is little sandeel fishing off Scotland currently due to fishery closure and stock collapse. Sandeel abundance appeared to be high again in 2009 and this is reflected in improved productivity in a number of species. Changes lower down the food chain caused by warming sea water temperatures are also thought to have contributed to the reduction in sandeel abundance, size and energy content, especially in the North Sea. Fisheries have also contributed to earlier increases in some seabirds that scavenge offal and discards, such as the northern fulmar and great skua. Great skuas have continued to increase in numbers but northern fulmars have declined in recent years. Predation by non-native mammals has caused reductions in productivity and abundance of ground and burrow nesting seabirds. Successful eradication of these predators at a local scale has started to have benefits for seabirds in recent years.

The traditional guga hunt on Sula Sgeir to the north of Lewis in the Outer Hebrides is licensed to take up to 2000 young northern gannet chicks that are eaten as a local delicacy.

Razorbill

© Lorne Gill/SNH

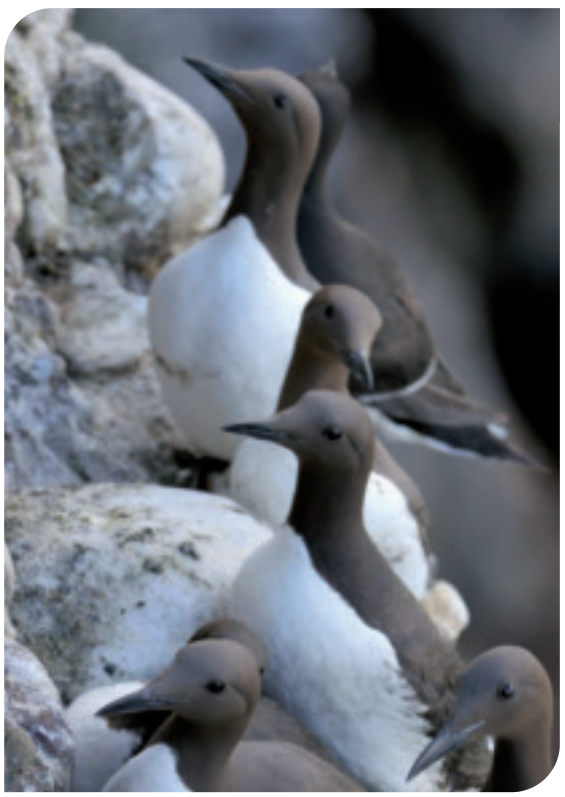
Atlantic puffin

© Lorne Gill/SNH

Northern fulmar

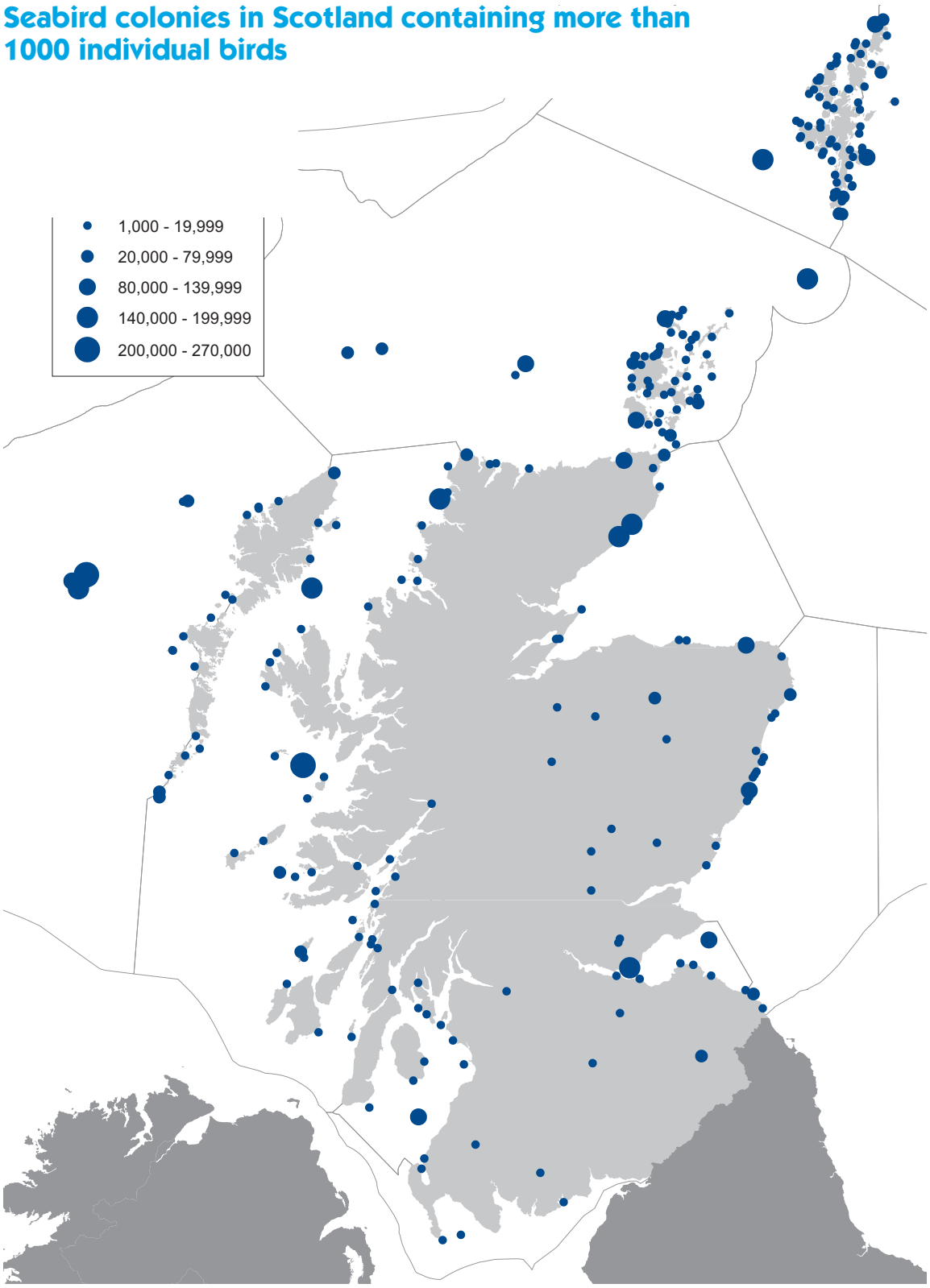
© John M Baxter

Common guillemot



© Lorne Gill/SNH

Seabird colonies in Scotland containing more than 1000 individual birds



Common guillemots on Isle of Noss, Shetland

© Lorne Gill/SNH

WATERBIRDS

Waterbirds

Scotland's coast is of particular importance for waterbirds and there are a number of sites of international importance for the wintering populations of wildfowl, waders and geese that they support. Some species of wader such as Eurasian oystercatcher (*Haematopus ostralegus*), dunlin (*Calidris alpina alpina*), common redshank (*Tringa tetanus*), ruddy turnstone (*Arenaria interpres*) and purple sandpiper (*Calidris maritima*) are associated with coastal environments. Many species are long distance migrant visitors that breed in the high Arctic and winter on Scotland's coasts. Wildfowl such as common shelduck (*Tadorna tadorna*) and Eurasian teal (*Anas crecca*) occur in estuaries whilst species such as common eider (*Somateria mollissima*) are found on more open coasts.

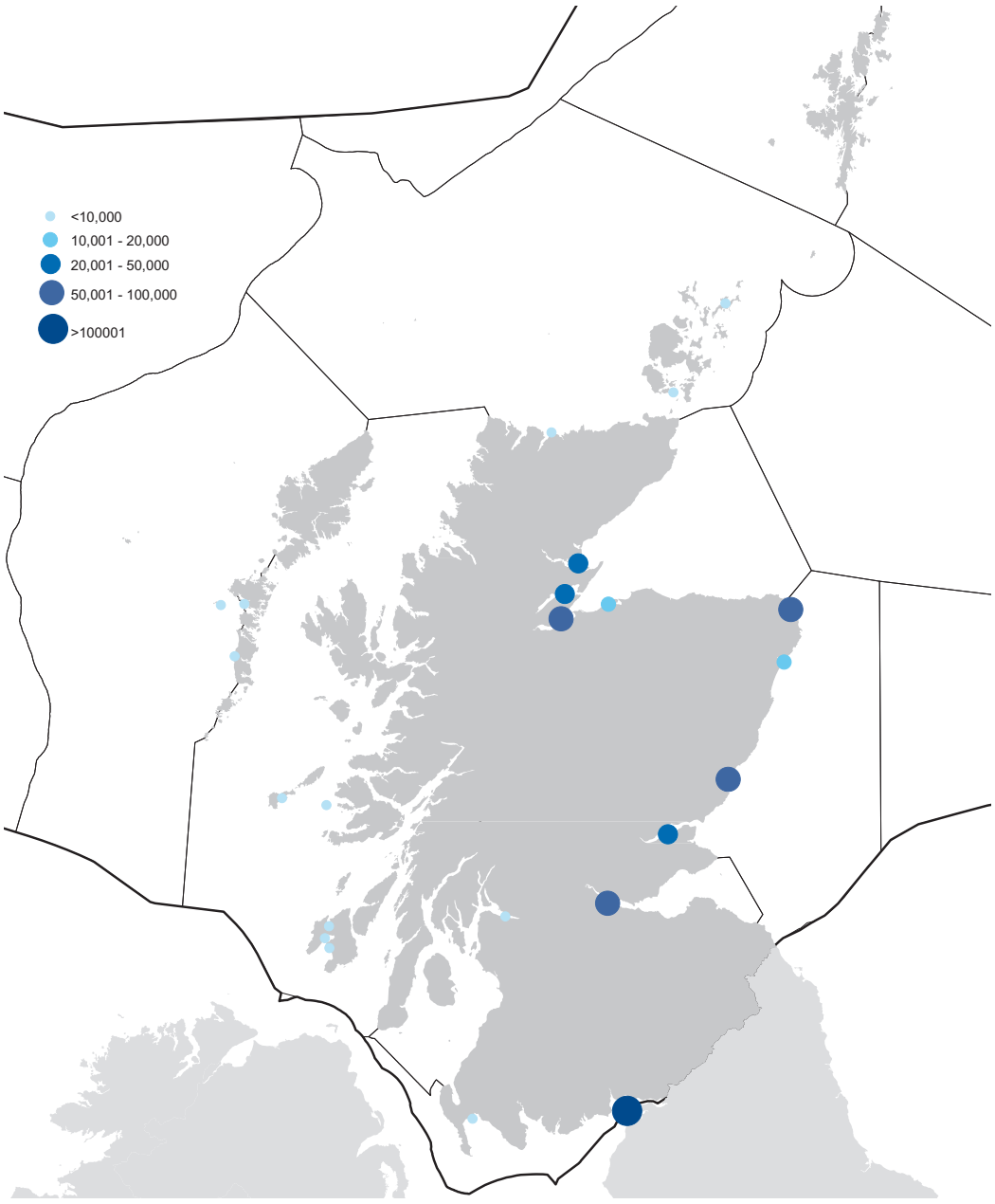
Overall waterbird numbers peaked at 120% in 1995/96 in relation to the 1975/76 baseline, since when there has been a gradual decline. The latest indicator for 2008/09 stands at 102%. Wader numbers which peaked at 102% in 1996/97 have shown an increasing rate of decline and are now standing at 70%, the lowest value since the early 1980s. Wildfowl (ducks and swans) numbers have dropped to 95%, the lowest since 1987/88. In contrast, geese numbers have increased significantly since the baseline was established in 1975/76 and are currently showing a 333% increase.

All waders except Eurasian oystercatcher, grey plover (*Pluvialis squatarola*) and sanderling (*Calidris alba*) have declined in numbers in recent years. There have been long-term declines in seven species, the largest have been seen in dunlin and northern lapwing (*Vanellus vanellus*) numbers (-76%) and a further five species stand at below half of the baseline level (i.e. ringed plover (*Charadrius hiaticula*), purple sandpiper, ruddy turnstone, common redshank and European golden plover (*Pluvialis apricaria*)). The reasons for these declines are still to be fully explained but may be due to redistribution of wintering birds across north-west Europe due to climate change effects.

There is variation in the fortunes of different wildfowl species, eight species show an increase in numbers, with common shelduck and northern pintail (*Anas acuta*) reaching their all time highs, whereas seven species have declined (i.e. tufted duck (*Aythya fuligula*), greater scaup (*Aythya marila*), northern shoveler (*Anas clypeata*), mallard (*Anas platyrhynchos*), common eider, red-breasted merganser (*Mergus serrator*) and common pochard (*Aythya ferina*)), the latter four reaching their all time lows.

1 The WeBS principal site boundaries may cover a larger area than the SPA site boundary. Full details of SPA site counts are available from BTO and site alerts can be downloaded from http://www.bto.org/volunteer-surveys/webs/webs-alerts-spas

Wintering waterbirds average WeBS Count (2004/05 to 2008/09)



Count data were obtained from the BTO Wetland Bird Survey.

Purple sandpiper

© John M Baxter

Dunlin feeding

© John M Baxter

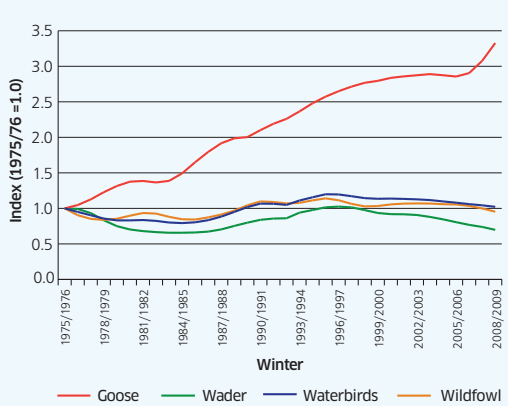
Special Protection Areas for wintering waterbirds containing in excess of 10,000 birds (*counts are the 5 year peak winter mean*).

SPA Site	WeBS Principal Site[1]	WeBS Average Count
Cromarty Firth	Cromarty Firth	32,279
Dornoch Firth and Loch Fleet	Dornoch Firth; Loch Fleet Complex	39,159
Firth of Forth	Forth Estuary	76,981
Firth of Tay & Eden Estuary	Tay Estuary; Eden Estuary	35,884
Loch of Strathbeg	Loch of Strathbeg	66,068
Montrose Basin	Montrose Basin	50,785
Inner Moray Firth	Inner Moray Firth and Inverness Firth	53,947
Moray and Nairn Coast	Moray Firth	11,336
Upper Solway Flats and Marshes	Solway Estuary	107,859
Ythan Estuary, Sands of Forvie and Meikle Loch	Ythan Estuary	16,833

Wintering Waterbird Indicator

Name	Category	Overall Trend from 1975/76 baseline
Mute swan	Wildfowl	Inc
Whooper swan	Wildfowl	Inc
Pink-footed goose	Goose	Inc
Greenland white-fronted goose	Goose	Inc
Icelandic greylag goose	Goose	Inc
NW Scotland greylag goose	Goose	Inc
Nearctic barnacle goose	Goose	Inc
Svalbard barnacle goose	Goose	Inc
Common shelduck	Wildfowl	Inc
Eurasian wigeon	Wildfowl	Inc
Eurasian teal	Wildfowl	Inc
Mallard	Wildfowl	Dec
Northern pintail	Wildfowl	Inc
Northern shoveler	Wildfowl	Inc
Pochard	Wildfowl	Dec
Tufted duck	Wildfowl	Dec
Greater scaup	Wildfowl	Dec
Common eider	Wildfowl	Dec
Common goldeneye	Wildfowl	Inc
Red-breasted merganser	Wildfowl	Sta
Goosander	Wildfowl	Dec
Little grebe	Waterbird	Inc
Great crested grebe	Waterbird	Inc
Great Cormorant	Waterbird	Dec
Coot	Waterbird	Dec
Eurasian oystercatcher	Wader	Inc
Ringed plover	Wader	Dec
Golden plover	Wader	Dec
Grey plover	Wader	Inc
Northern lapwing	Wader	Dec
Red knot	Wader	Dec
Sanderling	Wader	Inc
Purple sandpiper	Wader	Dec
Dunlin	Wader	Dec
Bar-tailed godwit	Wader	Dec
Eurasian curlew	Wader	Dec
Common redshank	Wader	Dec
Ruddy turnstone	Wader	Dec

Abundance of wintering waterbirds in Scotland, 1975/76 – 2008/09



Source: Wetland Bird Survey Results (WeBS)

Coastal Special Protection Areas supporting waterbirds that use the intertidal and sea areas (some sites also support various goose species (*) which are listed for completeness but which tend only to use adjacent coastal habitat for roosting; sites that only support goose species are not included)

Site	Waterbirds features	
Cromarty Firth	Wildfowl assemblage	
Dornoch Firth and Loch Fleet	Greylag goose* Eurasian wigeon	Bar-tailed godwit Waterbird assemblage
East Sanday coast	Purple sandpiper	Ruddy turnstone
Firth of Forth	Red-throated diver Great crested grebe Slavonian grebe Great cormorant Pink-footed goose * Common shelduck Eurasian wigeon Mallard Greater scaup Common eider Long-tailed duck Black (common) scoter Velvet scoter	Common goldeneye Red-breasted merganser Eurasian oystercatcher Ringed plover Grey plover Northern lapwing Dunlin Bar-tailed godwit Eurasian curlew Common redshank Ruddy turnstone Waterfowl assemblage
Firth of Tay and Eden Estuary	Great cormorant Pink-footed goose * Greylag goose * Common shelduck Common eider Long-tailed duck Black (common) scoter Velvet scoter Common goldeneye	Eurasian oystercatcher Grey plover Sanderling Dunlin Black-tailed godwit Bar-tailed godwit Common redshank Waterfowl assemblage
Gruinart Flats, Islay	Barnacle goose * Light-bellied brent goose	Greenland white-fronted goose *
Inner Clyde estuary	Common redshank	
Inner Moray Firth	Greylag goose * Red-breasted merganser	Bar-tailed godwit Common redshank
Loch of Strathbeg	Whooper swan Pink-footed goose * Greylag goose *	Eurasian teal Common goldeneye Waterfowl assemblage
Montrose Basin	Pink-footed goose * Greylag goose * Common redshank Eurasian oystercatcher	Red knot Waterfowl assemblage
Moray and Nairn coast	Pink-footed goose * Greylag goose *	Common redshank Waterfowl assemblage
North Uist machair and islands	Barnacle goose * Ringed plover	Ruddy turnstone
Sieibhtean agus Cladach Thiriodh	Barnacle goose * Ringed plover	Greenland white-fronted goose * Ruddy turnstone
South Uist machair and lochs	Ringed plover	Sanderling
Upper Solway Flats and Marshes	Whooper swans Pink-footed goose * Barnacle goose * Common shelduck Eurasian teal Northern pintail Northern shoveler Greater scaup Common goldeneye Eurasian oystercatcher	European golden plover Grey plover Red knot Sanderling Dunlin Bar-tailed godwit Eurasian curlew Common redshank Ruddy turnstone Waterfowl assemblage
Ythan Estuary, Sands of Forvie and Meikle loch	Pink-footed goose * Waterfowl assemblage	

Pressures

Waterbirds face a range of pressures including various climate change related factors such as temperature changes, salinity changes and sea-level rise. There are already indications that these are resulting in changes in the distribution of certain species with a general north-eastwards shift.

Contamination by hazardous substances also poses a threat. Seaduck, divers and grebes are particularly vulnerable to oil pollution and even a relatively small spill can have a significant impact if it occurs in a particularly important area for a given species. The reduction in the enrichment of many estuarine mudflats, in particular as a result of better regulation of sewage discharges and nutrient runoff, has resulted in a decline in the abundance of some species as the productivity of the mudflats has declined.

The removal of prey species either directly through fisheries or incidentally through disturbance to the seabed can result in reduced availability of food for various waterbird species. Habitat damage and loss due to a variety of coastal activities such as coastal defences, land claim, construction of marinas etc. can also have serious impacts on waterbird numbers.

OCCASIONAL VISITORS

Scottish occasional visitors

There is a variety of mobile species which can be considered part of the Scottish marine fauna although not permanently resident in our waters. These 'occasional visitors' may sit within three different categories.

1. **Species at the edge of their natural range** including those whose frequency of occurrence might change in the future as a result of climate change. Two good examples are the striped red mullet *Mullus surmuletus* and the trigger fish *Balistes capriscus.* The striped red mullet is a member of the goatfish family, easily distinguished by the pair of long chin barbels below the jaw. This is a demersal (bottom-dwelling fish) found usually on sandy or muddy seabeds where the twin chin barbels are employed to probe the surface of the sediment for items of prey such as small molluscs and crustaceans. The trigger fish is a thick-set, grey fish found normally in rocky habitats. It makes use of a strong, beak-like mouth to take a range of prey from the surface of rocks, including barnacles, starfish and sea urchins. Trigger fish have been occasionally taken in creels and photographed by divers at a number of locations on the west coast of Scotland. Both the striped red mullet and the trigger fish are more common in waters further south in the Atlantic and they reach the northernmost limit of their UK distribution in Scotland. The records of each are relatively scarce and come from a variety of sources including fishermen, anglers and divers, usually in the summer months. It is reasonable to assume that increasing water temperatures will lead to a greater frequency of both species in the future and as such they are potentially useful indicators of change.

2. **Seasonal, wide-ranging or migratory species that regularly enter our waters** – particularly in the summer months, e.g. the thresher shark *Alopias vulpinus.* This wide ranging shark is found throughout the temperate waters of the north Atlantic, from Newfoundland to Cuba in the west Atlantic and from Norway to the Mediterranean in the east. In Scotland, it is most frequently encountered in the summer months but these sharks are unlikely to spend their entire lives in one location. Studies of thresher sharks using electronic tags have demonstrated the ability of individuals to travel thousands of kilometres. As a predator of fish the thresher shark is attracted to feed on shoals of mackerel and herring, using its massive tail to stun its prey.

3. **Oceanic species** that, from time to time, can be seen in inshore waters when conditions allow. The 'by-the-wind-sailor', *Velella velella* is a species of the open ocean that when conditions allow may be found in inshore waters, usually along the western coasts and sometimes in vast numbers. There are records of strandings on shores in the southern Clyde from the 1950s while the most recent mass stranding was in 2002, again in the Clyde. These strandings may occur in summer or winter. Although superficially resembling a jellyfish, *Velella velella* is actually a colonial hydroid whose body consists of an oval, disc-shaped float that may be up to 10 cm in length. Some short tentacles hang down into the water below the float while on the top surface is a thin semicircular fin. This fin lies diagonally along the float acting as a sail so that the animal may be propelled, quite literally, 'by the wind'. This sail gives the animal its scientific name (i.e. from velum, a sail) and its common name, 'by-the-wind-sailor'. *Velella velella* feeds on pelagic organisms, including young fish, caught by stinging cells on its tentacles. The sunfish *Mola mola* is a predator of *Velella velella* and, similarly, is another open-ocean dweller which is increasingly seen during the summer months around Scotland. There are records from the North Sea but it is more frequently seen in the west. The sunfish is an unmistakable sight with a body formed into a large, flat disc that may be up to 3m in length and reach a weight in excess of 2000kg. The dorsal and anal fins have become modified to form stiff paddles which propel the fish with a gentle beating motion. The silvery-grey skin is leathery and without scales. The sunfish has a global distribution in both tropical and temperate seas, usually in open water and to a depth of over 400m. The sunfish is most often recorded moving slowly but deliberately at the surface with the paddle-like fin emerging from the water. The sunfish is known to feed on zooplankton and jellyfish.

By their nature, the records for these 'occasional visitor' species tend to be sporadic. However, the mechanisms for reporting, collation and verification of species records have improved in recent years (through initiatives such as MarLIN, Seasearch and the National Biodiversity Network). Consequently, the knowledge base for these 'occasional visitors' is gradually improving, which is essential to provide for their conservation in the longer term.

The following is a list of species that could fall into one or other of the categories of occasional visitor.

This should not be treated as a definitive list but is indicative. There is room for considerable debate over their inclusion (especially in waters > 12miles where the lines between occasional and frequent and resident are quite blurred).

Similarly, there are probably species missed off this list but it is derived from the following sources:

a) those for which there is reasonably good data (e.g. sightings for turtles and cetaceans);

b) those on MarLIN (i.e. records on NBN);

c) those that have been drawn to the attention of SNH when members of the public have sent in a query regarding identification.

Invertebrates:

By-the-wind-sailor – *Vellela vellela*

Goose barnacle – *Lepas anatifera*

Fish:

Oceanic puffer – *Lagocephalus lagocephalus*

Red mullet – *Mullus surmuletus*

Grey trigger fish – *Balistes capriscus*

Ray's bream – *Brama brama*

Albacore tuna – *Thunnus alalunga*

Swordfish – *Xiphias gladius*

Sunfish – *Mola mola*

Moonfish – *Lampris guttatus*

Reptiles:

Leatherback turtle – *Dermochelys coriacea*

Loggerhead turtle – *Caretta caretta*

Green turtle – *Chelonia mydas*

Kemp's ridley turtle – *Lepidochelys kempii*

Cetaceans:

Striped dolphin – *Stenella coeruleoalba*

Northern bottlenose whale – *Hyperoodon ampullatus*

Cuvier's beaked whale – *Ziphius cavirostris*

Sowerby's beaked whale – *Mesoplodon bidens*

True's beaked whale – *Mesoplodon mirus*

Sei whale – *Balaenoptera borealis*

Blue whale – *Balaenoptera musculus*

Humpback whale – *Megaptera novaeangliae*

Beluga whale – *Delphinapterus leucas*

Northern right whale – *Eubalaena glacialis*

False killer whale – *Pseudorca crassidens*

Pygmy sperm whale – *Kogia breviceps*

Pinnipeds:

Bearded seal – *Erignathus barbatus*

Ringed seal – *Phoca hispida*

Harp seal – *Phoca groenlandica*

Walrus – *Odobenus rosmarus*

Northern bottlenose whale

© S. Hooker/Seawatch Foundation

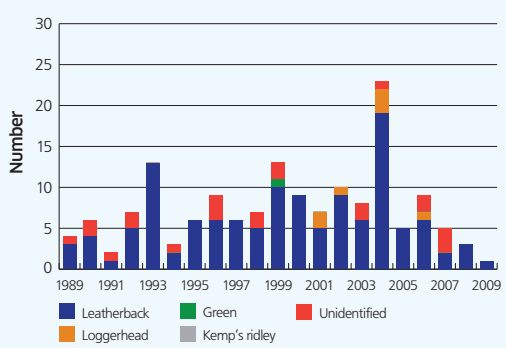
Bearded seal

© Dave Pullan www.davepullan.co.uk

Goose barnacles

© David Donnan

Total number of marine turtles recorded 1989 – 2009 in Scottish Waters



Source: Rod Penrose – data provided by the British Isles & Republic of Ireland 'TURTLE' Database Manager www.strandings.com

Marine turtles

Four species of marine turtle are occasional visitors to Scottish waters:

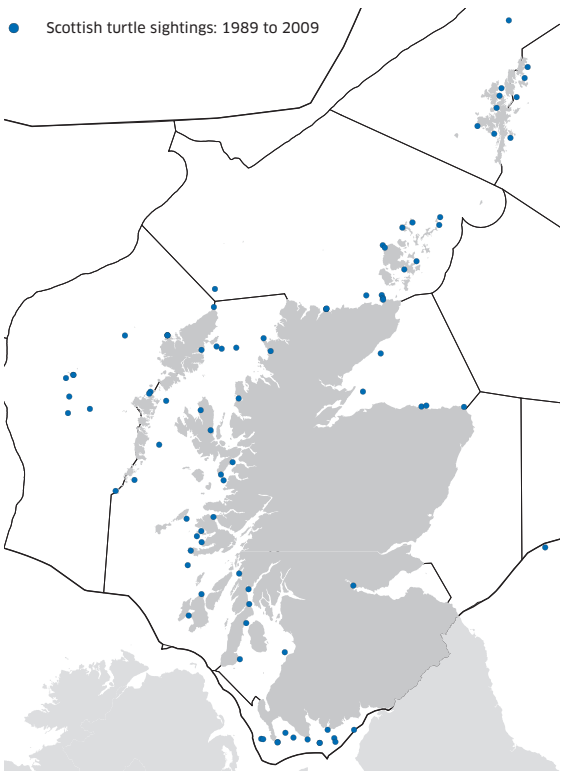
- Leatherback (*Dermochelys coriacea*),
- Loggerhead (*Caretta caretta*),
- Kemp's ridley (*Lepidochelys kempii*), and
- Green (*Chelonia mydas*).

All four species are listed on Annex IV of the Habitats Directive (Council Directive 92/43/EEC of 21 May 1992) thus placing a responsibility on the UK to maintain and restore their favourable conservation status in its waters, as well as considering the risks of incidental capture. All four species also appear on the IUCN Red List of Threatened Species with the leatherback and Kemp's ridley listed as "Critically Endangered," the green as "Endangered" and the loggerhead as "Threatened".[1] Furthermore the leatherback and loggerhead turtles are on the OSPAR list of threatened or declining species.

Leatherback turtle in Firth of Forth

© Richard Erdal

Map of the distribution of marine turtle species strandings and sightings in Scottish waters



Source: Rod Penrose – data provided by the British Isles & Republic of Ireland 'TURTLE' Database Manager www.strandings.com

Records

In total for Scotland there have been 156 sightings of turtles at sea and 74 strandings principally located in the north and west of Scotland since accurate records began in 1989. Incidental records of turtle sightings, however, date back to a record of an animal on the Isle of Coll in 1777. The majority (67%) of sightings and strandings occur between July and November probably associated with the increased abundance of jellyfish during the summer months.

The leatherback is the most commonly sighted species of marine turtle in Scottish waters. Although primarily a tropical nesting species, the leatherback is endothermic allowing it to migrate and feed in cooler waters. They are the largest species of marine turtle in the world, the largest specimen recorded in Scottish waters was estimated at 8ft in length, and was observed inshore between Dunnet Head and Brough in the north-east in 1992.

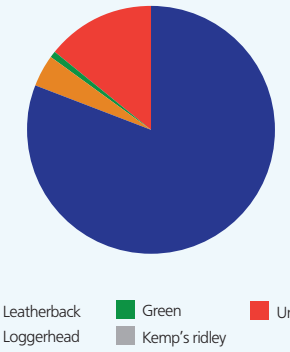
Pressures

Marine turtles face many pressures including drowning in fishing gear which account for a large proportion of Scottish sighting records as well as through collisions with boats and damage caused by propellors. In addition, plastic debris, and plastic bags in particular, are ingested and become lodged in their gut eventually resulting in a long and painful death from starvation.

Protection

The Grouped Species Action Plan for Marine Turtles in UK waters and the UK Overseas Territories[2] prioritises the conservation of the leatherback turtle in UK waters, though little is known about their movements in Scottish waters. The turtle Action Plan is being implemented by a coalition of organisations, government agencies and academic institutions known as the Turtle Implementation Group (TIG).

Species composition of all Scottish marine turtle strandings and sightings



Source: Rod Penrose – data provided by the British Isles & Republic of Ireland 'TURTLE' Database Manager www.strandings.com

NON-NATIVE SPECIES IN SCOTTISH WATERS

Introduction:

Non-native species are those species deliberately or unintentionally introduced into the wild by human action outside their natural distribution. Some become invasive where they establish, proliferate and spread in ways that cause damage to native biological diversity and a range of other activities. Invasive non-native species pose one of the most significant threats to marine biodiversity, especially in the light of climate change.

There are a variety of activities that have the potential to bring non-native species into Scottish waters. These include shipping (commercial and recreational), the seafood industry (aquaculture and certain fisheries), scientific research and escapes from public aquaria. Introduction can be either accidental or intentional. Shipping and aquaculture are the most likely sources of their introduction into Scotland, as well as their natural spread from other areas where they are already established.

Vessels of all sizes have the capacity to transport a wide range of species in a number of ways. Ballast water and associated sediments within ballast tanks are important vectors in the global spread of marine non-native species. Non-native species are also transported in other ways including in seawater pipework, in sea chests, attached or entangled on equipment such as anchors and anchor chains, and as fouling on hulls.

Aquaculture has made a significant contribution to the introduction of invasive species. This can include the intentional cultivation of a non-native species within a 'contained' environment that subsequently results in self-sustaining populations in the wild through the escape of adults or the dispersal of larvae. However, more frequently it is the result of unintentional movement of non-native species with fish or shellfish stock. Up to now the extent to which aquaculture has been a factor in the introduction of non-native species in Scotland is relatively small, although the arrival of the Japanese skeleton shrimp *Caprella mutica* in 2002 illustrates the potential.

Caprella mutica

© Liz Cook/SAMS

Marine non-native species known to be in Scottish territorial waters

A number of non-native species are known to already be present in Scottish waters but a comprehensive list is lacking. Only a few of these species are currently considered invasive (*), but there are a number that have become widespread and well established.

Species	Description
Codium fragile subsp. *tomentosoides* a green alga	A green alga which is now found throughout UK inshore waters.
Spartina anglica common cordgrass*	Originated from North America and, after hybridising with the native UK species, is now the most common saltmarsh grass in the UK.
Heterosiphonia japonica a red alga	Originating from Japan, first sighted in the Moray Firth, was reported in Loch Sunart on the west coast in 2008 and from Loch Gairloch in 2010.
Asparagopsis armata harpoon weed	Occurs throughout western and northern Scotland as far as Shetland but absent from east coast.
Sargassum muticum wireweed*	Originating from Japan, arrived in Scotland in 2004.
Elminius modestus acorn barnacle*	A native of Australia and New Zealand it is well established in Scottish waters, where they can outcompete the native barnacle species.
Caprella mutica Japanese skeleton shrimp	A predator on several native species, and is now widespread in western Scotland.
Styela clava leathery sea squirt*	Originating in the Far East it is a fouling organism that smothers native species and may affect aquaculture equipment if present in high density.
Didemnum vexillum carpet sea squirt*	Found in the Clyde in late 2009.
Botrylloides violaceus a colonial sea squirt	Native of Japan, first recorded in south-west England in 2004 and recorded in Troon yacht haven in 2009 and Wemyss Bay in 2010.
Corella eumyota a sea squirt	Widespread through much of the southern hemisphere was first report from various locations around Oban in 2009.
Tricellaria inopinata a bryozoan	Originating from the Pacific, first recorded in Troon yacht haven in 2009.
Mytilus trossulus a mussel (There is some doubt as to whether this species is a native species or not which is as yet unresolved)	Native to Alaska, Canada and the Baltic Sea, first identified in Loch Etive in 2008 and now known from various location on west coast.
Mytilus galloprovincialis a mussel	Native to the Mediterranean occurring in various west coast sea lochs and north-east coast of Scotland.

Impacts

The potential impact of marine invasive non-native species can be significant, with implications for both biodiversity and the economy.

- These species have the capacity to affect the ecology of native communities of animals and plants, even becoming a dominant species when well established.
- They may be a nuisance species for activities such as shipping and aquaculture by fouling equipment and vessels. This may result in lowered production at fish/shellfish farms and increased costs associated with their control or removal.

Action

Action is needed to minimise the risk of non-natives entering the UK and reduce the risks associated with the movement of species outside their natural range. Priorities will include:

- minimising and managing the negative impact of invasive non-native species in a cost-effective manner;
- continuing to raise awareness (particularly of preventative measures with relevant stakeholders);
- developing effective risk assessments for the potential vector activities; and
- developing best practice in the detection and management of marine non-native species.

Future potential invasions

It is clear that Scotland, in common with other maritime nations, has a growing problem with marine invasive non-native species. This trend seems liable to continue with other species, such as:

- Chinese mitten crab (*Eriocheir sinensis*)
- Slipper limpet (*Crepidula fornicata*)

which are already found in England where they have become well-established and could arrive in Scotland in the near future.

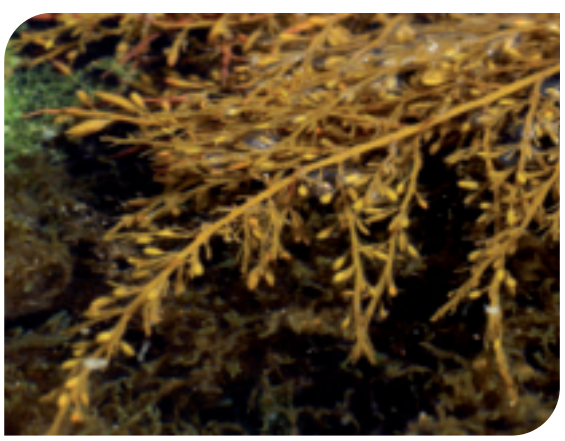
Crepidula fornicata

© Copyright Keith Hiscock

Sargassum muticum

Sargassum muticum, (wireweed), is an invasive non-native brown alga originally from Japan but now found extensively in Europe and North America. It is a fast-growing species able to form dense stands where conditions suit and by virtue of its life-history traits, is ideally suited to spread rapidly once established in a new region. Fronds of the alga readily become detached and can then disperse via natural drift. Crucially, these fronds can remain reproductively active for several weeks enabling dispersal over a wide area. *S. muticum* was first recorded in the UK in 1973 but did not reach Scotland until 2004 when it was found in Loch Ryan. It has subsequently spread up the west coast of Scotland.

***Sargassum* on Cumbrae**



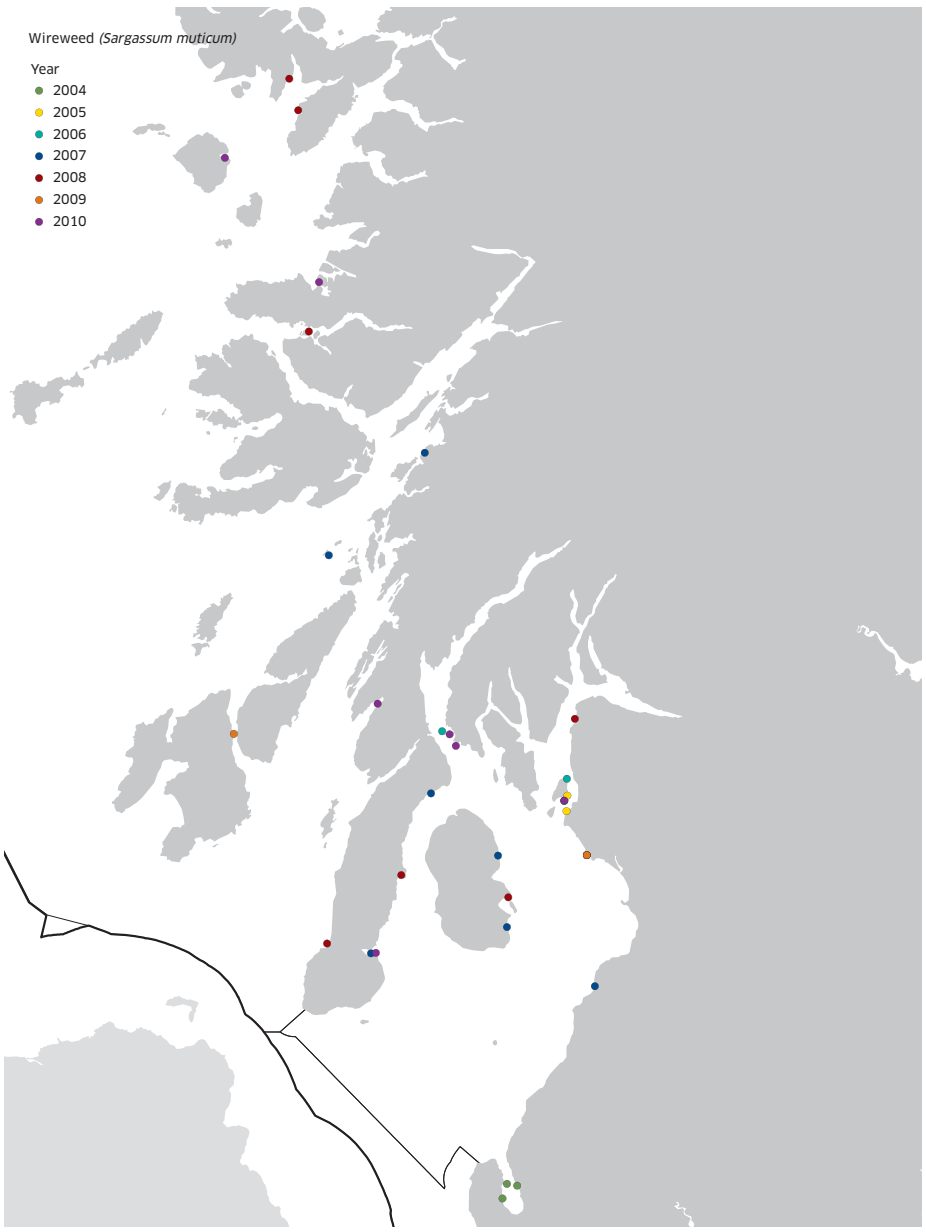
© Lorne Gill/SNH

Didemnum vexillum

Didemnum vexillum (carpet sea squirt) was discovered in the Firth of Clyde in 2009. This fast-growing colonial sea squirt has the potential to cause significant ecological and commercial impacts, based on experience in North America, New Zealand and several European countries. Carpet sea squirts are fouling organisms with a prodigious capacity to form dense and extensive growths on vessels' hulls, marina pontoons, ropes and aquaculture equipment. Their translocation is principally associated with vessel movements. Work is underway to try to eradicate the species before it is able to spread more widely.

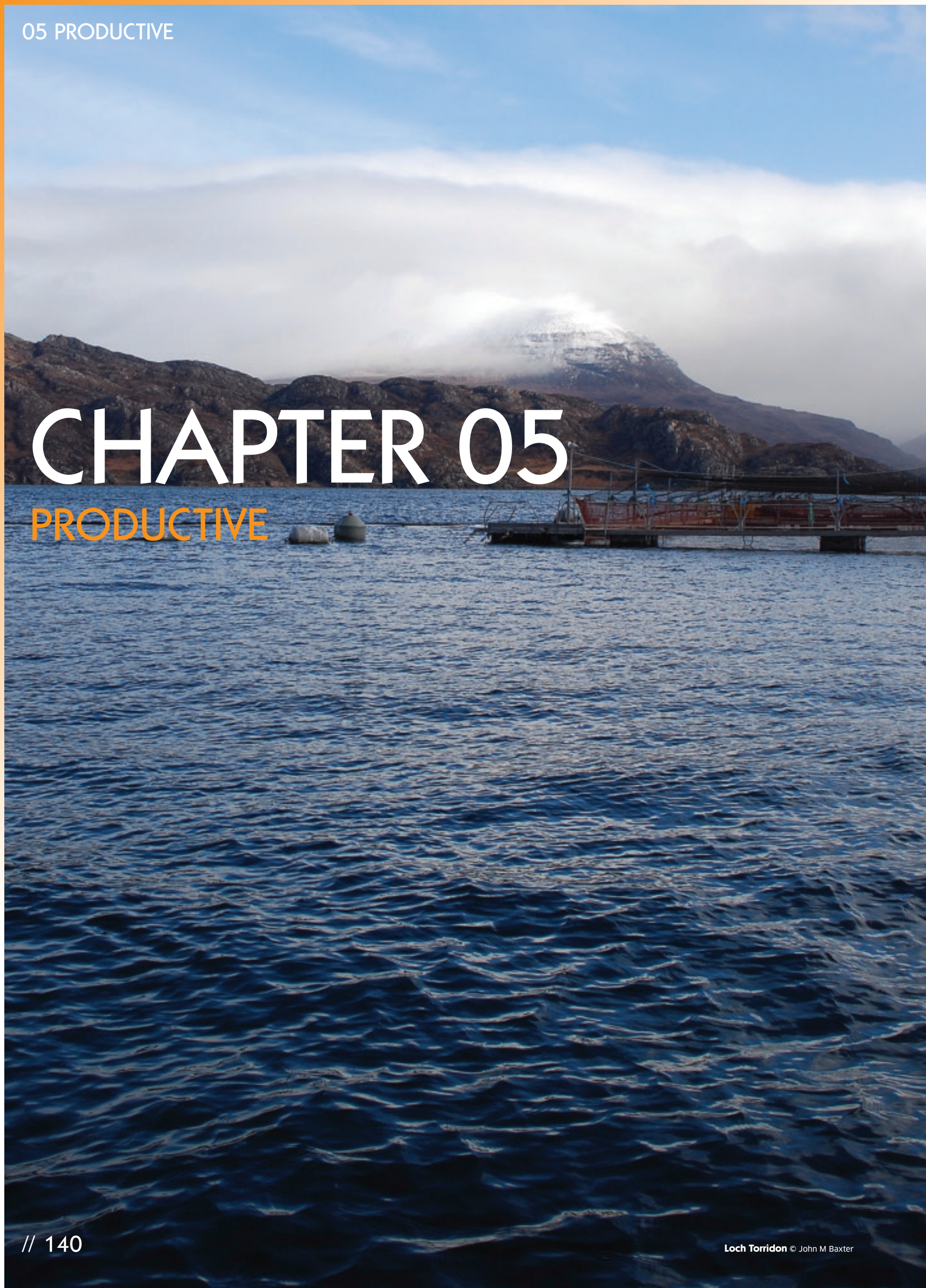
Challenges

- Prevention of new species being introduced.
- Dependence on coordinating action in neighbouring countries.
- Need to respond rapidly to future colonisations.
- Establishment of a mechanism/network to ensure early recording of new arrivals.



Carpet sea squirt growing over a creel

© Copyright SNH/SAMS



CHAPTER 05
PRODUCTIVE

Loch Torridon © John M Baxter

Introduction

The Productive Seas chapter describes and analyses economic and spatial information about human activities in Scotland's seas. It is intended to inform the national marine plan, and is a basis upon which more detailed assessments can be made in future, some of which may be at regional scales.

After an introductory analysis of the 'economic value of Scotland's core marine sector', further sections examine each major activity and the rationale and distribution of it ('**what, why and where?**') using text, tabular data, graphs and maps; essentially giving information about the level of the activity over the period 2005-2009 where possible. In addition, the '**contribution to the economy**', '**social, economic**' and '**environmental**' pressures and impacts are considered. A '**Forward Look**' is also provided to identify factors of relevance to marine planning.

An important feature of this chapter is to identify not just what is known but also what is *not* known, and this is especially the case for the extent to which rational economic valuations can be placed on each activity.

Mapping – the approach

As much spatial information as possible, covering Scotland's seas from the shore to the fishery limits, has been mapped, including some marine-related assets built ashore. Not all activity can be mapped clearly at this level. For example, waste water treatment excludes domestic septic tank outfalls; and areas of individual or blocks of moorings are excluded in the leisure and recreation maps. These data are available and may well be required for regional planning.

The statistical data have been grouped around a map, where appropriate, and this is used to emphasise any spatial differences. The Atlas structure has necessitated taking a high level approach in some instances but all sources of data are included in the online version of the Atlas; **www.scotland.gov.uk/marineatlas**. Official statistical publications have been cited and can be consulted to provide more detail when necessary.

Wherever possible, the Atlas presents information based on Scottish sea areas, rather than the various geographical breakdowns normally adopted within the various data sets. At the time of preparation, Scottish marine regions for marine planning had not been agreed. However, the data presented in this Atlas are probably presented at about the scale suited to marine regions. Also the Atlas demonstrates where data are available and where there may be gaps.

Economic assessment – the approach

There are two approaches used to valuation in this Atlas. The core marine sector approach uses data from the Annual Business Inquiry (ABI), based on the Standard Industrial Classification (SIC).

This analysis examines Gross Value Added (GVA), turnover and employment at the overall core sector, industry and regional levels.

The core marine sector is defined as industries that predominantly rely on the sea to generate their output and is restricted to industries for which official data are available. The core marine sector includes the extraction of crude petroleum and natural gas but due to the size of the sector, it is excluded in the regional breakdowns. Industries such as tourism, that make use of the sea but for which the marine element is not clearly defined by the SIC, are excluded. Non-provisioning ecosystem services are also not included. The core sector approach, therefore, underestimates the overall value of marine economic activity.

In addition, the other 16 sections examine a range of marine activities in detail, including many sectors not covered by the core marine sector approach and for which no ABI data or other official economic data are available, for example water abstraction or telephone cables. In such cases the economic assessment was based on the analysis in *Charting Progress 2*[1], with qualified assumptions.

In some cases data may come from different sources or use different methodologies, for example first sale value, expenditure or investment, rather than GVA, so the economic data in some sections may differ from what is shown in the core marine sector.

Marine aggregate extraction has not been included. The only licence, at Middle Bank in the Firth of Forth, has not been dredged since its last (and only) usage in 2005, as reported in *Scotland's Seas*[2].

The value of ecosystem goods and services is not included here. See Chapter 1 for more information.

Pressures and impacts – the approach

The pressures and impacts of each activity for social, economic and environmental performance are tabulated in terms of positive or negative effects. This draws on both the *Charting Progress 2 Productive Seas Feeder Report*[3] and the *UK Marine Policy Statement*[4]. A quantitative analysis of these has not been possible; quantitative data relate to the level of the activity only, not its impacts. It is acknowledged that current management and regulation seek to minimise the environmental pressures and impacts where possible.

Work on environmental pressures and impacts is currently being developed in the UK Marine Monitoring and Assessment Strategy community as preparation is made for implementation of the Marine Strategy Framework Directive. The tables included have adopted the most recently published pressure themes categories from the *OSPAR QSR*[5] whilst retaining the pressures listed in *Charting Progress 2*.

Pressure themes and pressures in OSPAR QSR[5]

Pressure theme: Climate change and physical pressures
Pressure:
1. Climate change
2. Temperature changes (local)
3. Salinity changes
4. Hydrological changes

Pressure theme: Pollution and other chemical pressures
Pressure:
5. Hazardous substances
6. Radionuclide contamination
7. De-oxygenation
8. Nutrient enrichment
9. Organic enrichment

Pressure theme: Other physical pressures
Pressure:
10. Electromagnetic changes
11. Litter
12. Underwater noise
13. Barriers to species movement
14. Death or injury by ship strikes

Pressure theme: Habitat changes
Pressure:
15. Siltation rate changes
16. Habitat damage
17. Habitat loss

Pressure theme: Biological pressures
Pressure:
18. Visual disturbance
19. Genetic modification
20. Microbial pathogens
21. Non-indigenous species
22. Removal of species

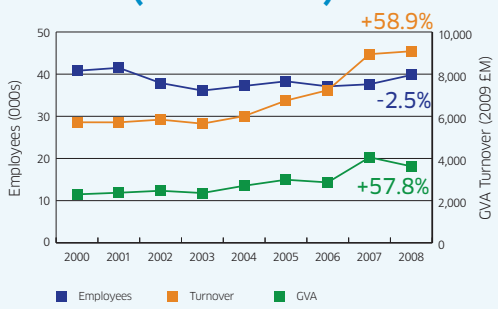
ECONOMIC ANALYSIS OF SCOTLAND'S CORE MARINE SECTOR

Trends in GVA, turnover and employment

This analysis examines the core marine sector in terms of Gross Value Added (GVA), turnover and employment from 2000-2008 with figures extracted from the Annual Business Inquiry (ABI). The industries that form the core marine sector are listed in the table and pie chart. GVA is the value of the output produced minus the cost of all inputs and raw materials used in its production.

The seas have generated a significant amount of economic output and, on this basis, are a valuable asset to the future of the Scottish economy. Overall, the core marine sector, minus the extraction of oil and gas, contributed £3,577M (£3,626M when adjusted to 2009 prices) of GVA in 2008, which amounted to 3.5% of overall Scottish GVA. Extraction of Crude Petroleum and Natural Gas contributed a further £13,334M in 2007.[i] Around 39,800[ii] were employed in the core marine sector in 2008 (1.6% of Scottish employment). Of these, 31% were employed in the Fishing, Fish Farming or Fish Processing sectors.

Trends for 'core marine sector' (2000-2008)



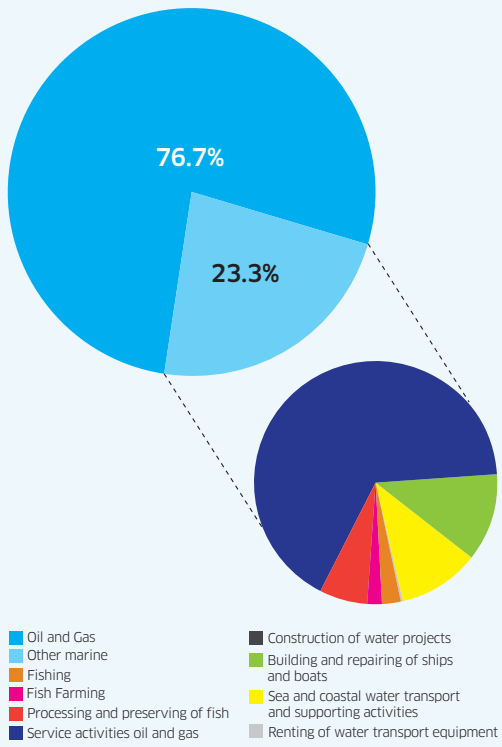
Source: Data from Annual Business Inquiry (ABI)[6]

Note: GVA and turnover at 2009 prices. Excludes Extraction of Crude Petroleum and Natural Gas as data were not available for all the years.

GVA by industry sector

Although displaying data from only one year, *GVA by industry sector 2007* offers a representative picture of the relative size of the core sector industries. 2007 data were used here because figures were not available for all sectors for 2008 due to confidentiality issues. The figure shows that the oil and gas sector contributes the majority of core sector GVA and, while individual sectors may exhibit year-on-year fluctuations, these are not sufficiently large to affect the overall core sector composition.

GVA by industry sector 2007

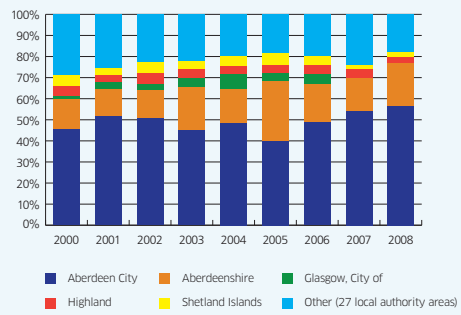


Source: Data from Annual Business Inquiry (ABI)[6]

GVA by local authority

The distribution of core sector GVA among local authorities is influenced by the distribution of the oil and gas sector. Between 2000 and 2008, Aberdeen City and Aberdeenshire combined produced over 60% of the core sector GVA[ii] of all local authority areas and employed around 50% of individuals working in the core marine sector. Glasgow, Highland and Shetland Islands combined contributed an additional 10% of GVA and over 10% of employment. In 2008, five local authorities produced approximately £3,000M of the core sector's £3,600M of GVA with Aberdeen City alone contributing £2,200M.

Core sector GVA contribution by local authority



Source: Data from Annual Business Inquiry (ABI)[6]

Note: Excludes Extraction of Crude Petroleum and Natural Gas as data were not available for all the years.

Industry sector share of core marine sector (2007)*

SIC code	Industry	GVA £m	% All marine GVA	% Core marine sector GVA	Turnover £m	Employment**	% All marine employment	% Core marine sector employment
45.24	Construction of water projects	3	0.0%	0.1%	5	0	<0.1%	<0.1%
71.22	Renting of water transport equipment	8	0.1%	0.2%	15	100	<0.2%	<0.3%
05.02	Fish farms	75	0.4%	1.8%	242	1,600	3.5%	4.3%
05.01	Fishing	111	0.6%	2.7%	247	3,000	6.6%	8.0%
15.20	Processing and preserving of fish and fish products	255	1.5%	6.3%	898	7,800	17.2%	20.7%
61.10 and 63.22	Sea and coastal water transport and supporting activities[iii]	432	2.5%	10.7%	838	4,800	10.6%	12.8%
35.1	Building and repairing of ships and boats	475	2.7%	11.7%	884	5,800	12.8%	15.4%
11.20	Service activities incidental to oil and gas extraction excluding surveying	2,699	15.5%	66.5%	5,819	14,300	31.6%	38.0%
	Total excluding extraction of crude petroleum and natural gas	**4,056**		**100%**	**8,948**	**37,600**		**100%**
11.10	Extraction of crude petroleum and natural gas	13,334	76.7%	N/A	20,671	7,700	17.0%	N/A
	Total Oil and Gas (11.10 and 11.20)	**16,033**	**92.2%**	**N/A**	**26,489**	**22,000**	**48.6%**	**N/A**
	Total core marine sector	**17,390**	**100%**		**29,619**	**45,300**	**100%**	

Source: Data from Annual Business Inquiry (ABI)[6]

*All prices are for 2009, **Rounded to nearest 100. Due to rounding, totals for all columns may differ from the sum of the individual sectors.

Regional employment

The percentage of the population employed in the core marine sector varies significantly between local authorities. The upper map shows core sector employment as a percentage of total employment for each local authority area. In Shetland, the core marine sector provided 10.3% of overall employment in 2008. In Aberdeen, Aberdeenshire, Eilean Siar and Orkney, it accounts for 8.4%, 6.7%, 6.7% and 6.5% of total employment respectively.

Some areas have been more heavily reliant on core marine activities for overall employment than others. The lower map shows employment in fisheries[iv] activities as a percentage of total employment by Travel to Work Area (TTWA)[v], which provides a finer regional breakdown than the local authority level. It shows that Fraserburgh, Berwickshire and the Uists and Barra each have more than 10% of total employment coming from the fisheries sectors. While the proportion of the population employed in fishing activities is generally small in most areas, fishing provides an important source of employment for some local communities.

Conclusion

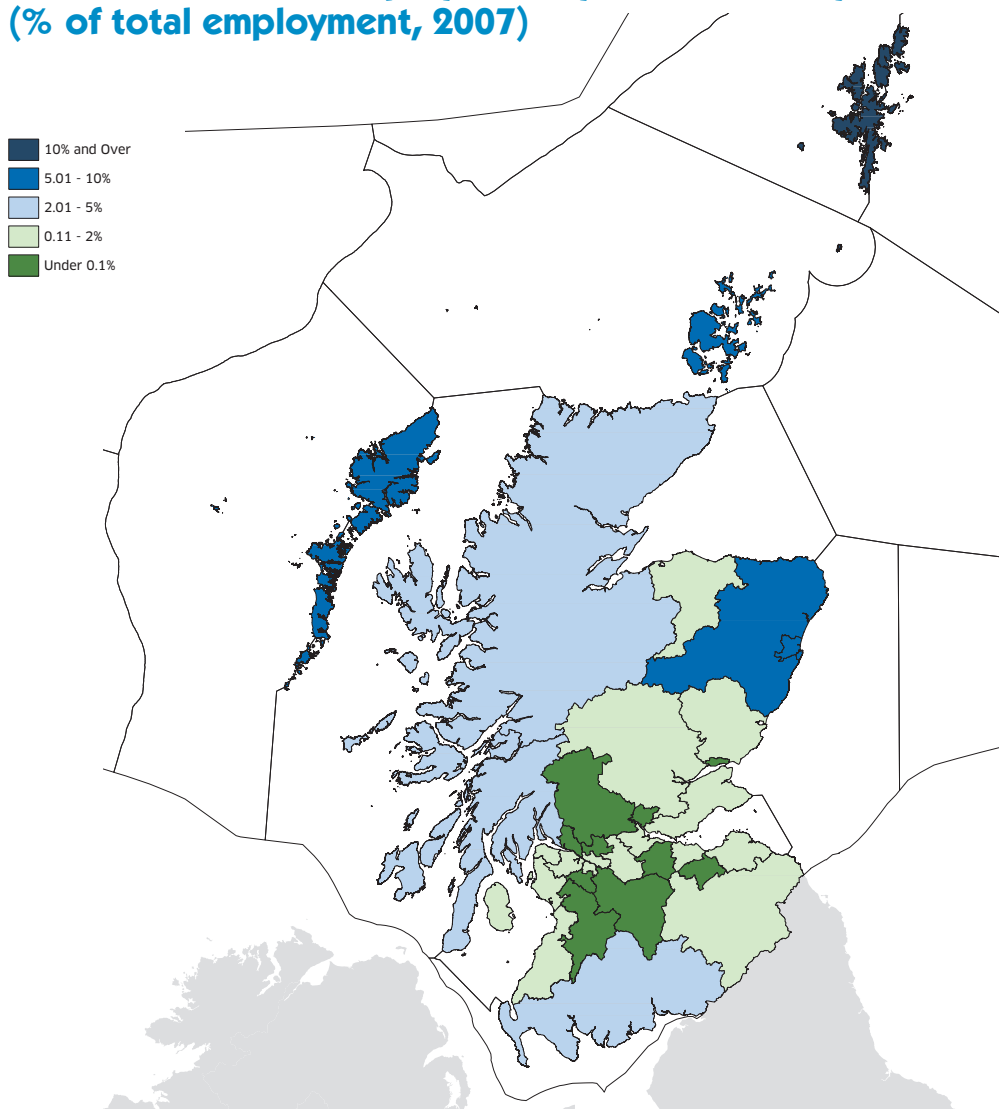
This analysis provides evidence that the seas generate a significant amount of economic output. It does not fully assess the value of economic activity or whether the seas are being used sustainably, nor does it assess the economic value of all activity. Answering these questions would require additional information on the environment or on activities that are currently difficult to quantify using official data. A more detailed assessment will only be possible if more data and information becomes available.

i 2008 data were not separately available for this sector.
ii Not including SIC 11.10: Extraction of Crude Petroleum and Natural Gas.
iii These two sectors had to be combined as data were not available for them individually.
iv Employment in fisheries activities is defined as employment in the fishing (SIC 05.01), fish farming (SIC 05.02) and fish processing (SIC 15.20) sectors.
v Travel to Work Areas are defined as areas where, of the resident economically active population, 75% work in that area and of those working in that area, 75% live in that area. Employment is measured based on people's workplace.

Fraserburgh Harbour

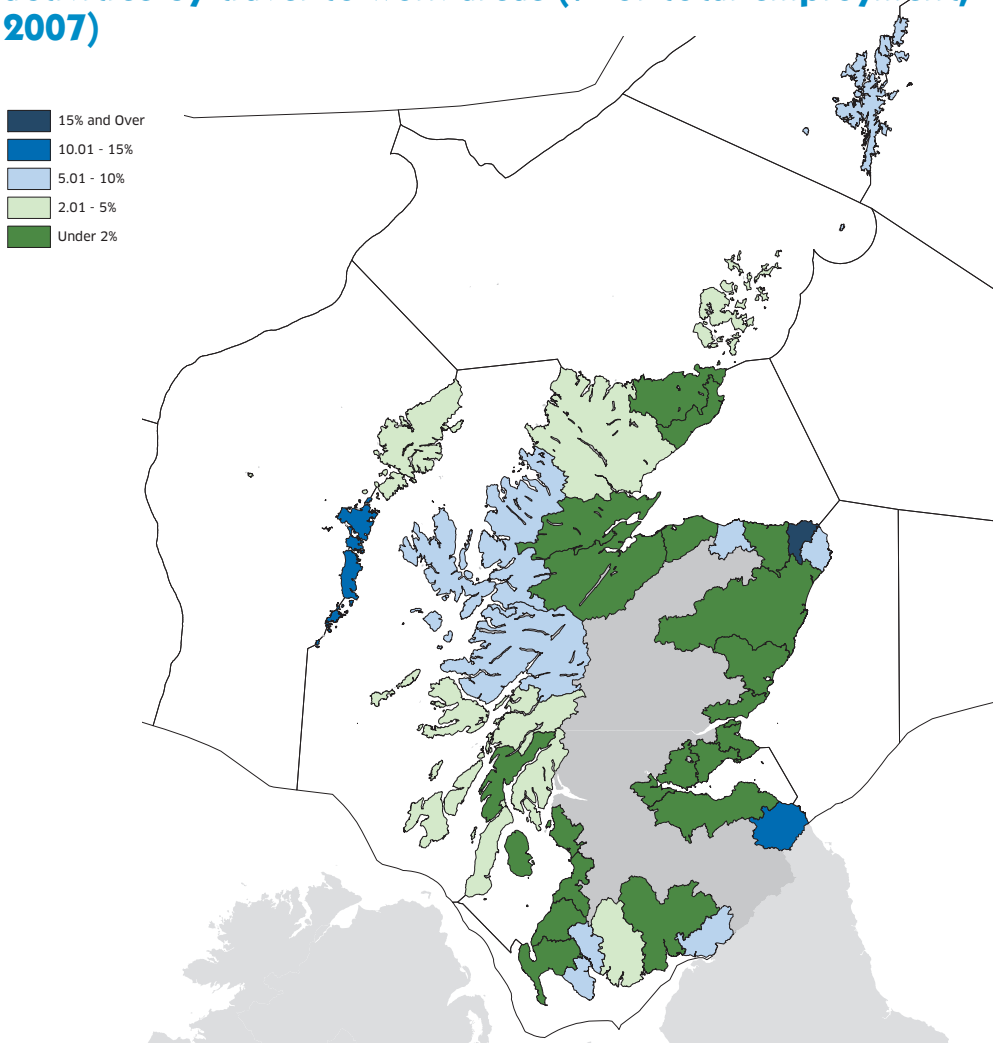
© Fraserburgh Harbour Commissioners

Core marine sector employment by local authority area (% of total employment, 2007)



Source: data from Annual Business Inquiry (ABI)[6][ii]

Direct employment in fishing, processing and aquaculture activities by travel to work areas (% of total employment, 2007)



Source: data from Annual Business Inquiry (ABI) and Marine Scotland Sea Fisheries Statistics[7]

What, why and where?

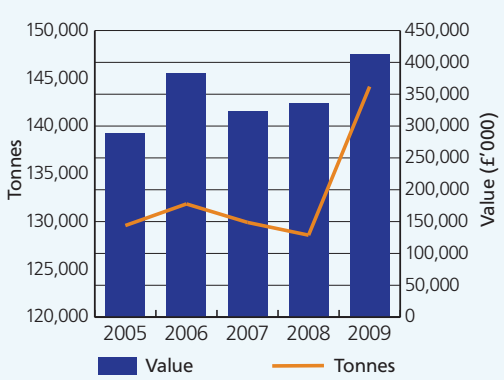
Aquaculture produces Scotland's most valuable food export. It involves the farming or culturing of fish, molluscs, crustaceans or algae. The industry in Scotland is dominated by farming of Atlantic salmon but also has significant rainbow trout and mussel production. It is also important because of its capacity to produce food rich in omega-3 oils that help to promote health. Although much of the production is exported, aquaculture also makes an important contribution to food security.

Scotland is one of the three largest producers of farmed Atlantic salmon in the world along with Norway and Chile, and the largest in the EU. 144,000 tonnes were produced in 2009. Rainbow trout (2,620t), brown trout (157t), halibut (69t) and some Arctic charr are also produced. Cod production in 2009 was negligible compared with 2008 when 1,821t was produced. This change was because of the closure of the major production company.

Shellfish production was dominated by blue mussels in 2009 (7,180t). This was an increase of about 36% since 2006. Pacific oysters (2,911,000 shells) and Native oysters (490,000 shells), King (35,000 shells) and Queen (168,000 shells) scallops have also been cultured. All statistics are from the Scottish Fish Farms and Shellfish Farms, Annual Production Surveys 2009[1][2].

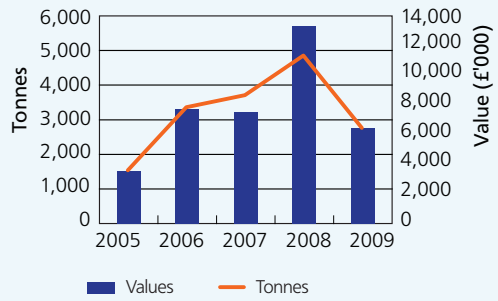
Aquaculture has been the fastest-growing food production sector in the world, with an average worldwide growth rate of 6-8% per year since the millennium. Global aquaculture has increased by a third since 2000, and currently provides around half of the world's seafood for human consumption[3].

Atlantic salmon production and turnover (2005-2009)



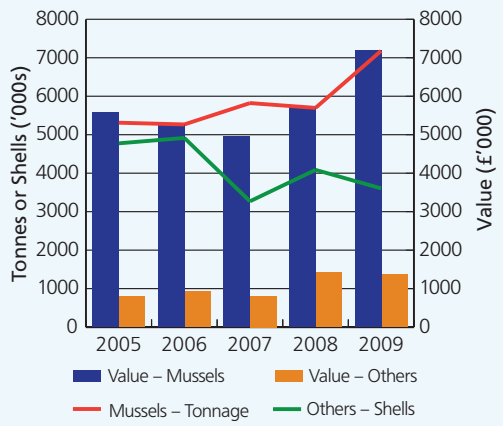
Source: Marine Scotland[1]

Other fin-fish species production and turnover (2005-2009)



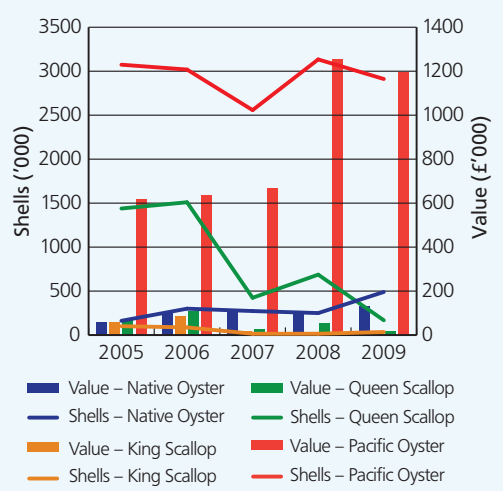
Source: Marine Scotland[1]

Mussel and other shellfish – production and turnover (2005-2009)



Source: Marine Scotland[1]

Other shellfish, by species, production and turnover (2005-2009)



Source: Marine Scotland[2]

Contribution to the economy

Aquaculture is a growing and increasingly important industry, helping to underpin sustainable economic growth in rural and coastal communities in the Highlands & Islands. It has a production value (turnover) worth around £427M per year to the Scottish economy, at farm gate prices in 2009. This was composed of about £412M Atlantic salmon, £6M rainbow and brown trout and £0.5M halibut, with £7M mussels, £1.4M other shellfish. Farmed salmon exports are valued at £285M annually. Exports from fish and aquaculture are Scotland's largest food export.

Key export markets for Scottish salmon include major European countries such as France, Belgium, Netherlands and Luxembourg. The USA became the number one export market for Scottish farmed salmon in 2009.

The provision of jobs in remote and rural areas is a key benefit. Salmon production supports about 874 full-time and 963 part-time jobs. Trout and other finfish production and processing support about 134 full-time and 183 part-time jobs with shellfish supporting about 169 full-time and 345 part-time jobs.[1][2]

A survey of the Scottish Salmon Producers' Organisation members indicates that employees stayed an average of eight years against a UK average for length of service of 5.6 years. 13% of staff were migrant workers.

Production growth in value terms has averaged 4.6% per annum over the period 2000-2009. The salmon sector in particular is now expanding again after several years of contraction, partly in response to the production gap left by the recent collapse in Chilean salmon production, and partly in response to the opening up of new, and strong growth in existing, markets.

Pressures and impacts on Scotland's socio-economics

Positive

- Salmon provides significant food exports
- Employment in remote and rural communities
- Knowledge transfer from university to industry
- Providing healthy food and food security

Negative

- Potentially restricting sea bed use by other users
- Infrastructure may have a visual impact on coastal locations

Source: Based on CP2 PSEG Feeder Report section 3.1.6[4] and UK Marine Policy Statement[5]

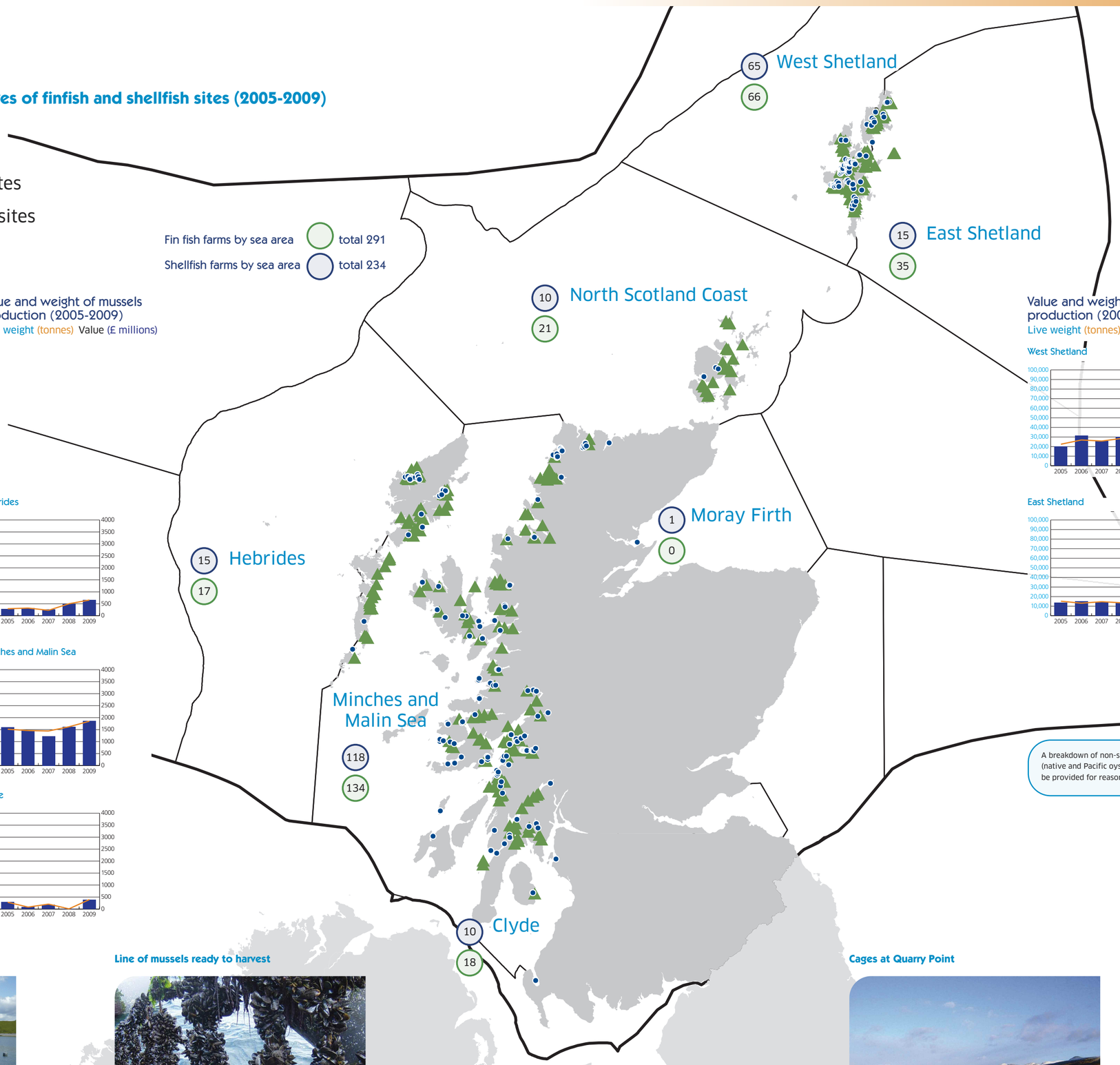
Locations and production figures of finfish and shellfish sites (2005-2009)

▲ Finfish production sites

● Shellfish production sites

Fin fish farms by sea area ○ total 291

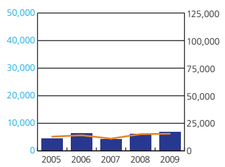
Shellfish farms by sea area ● total 234



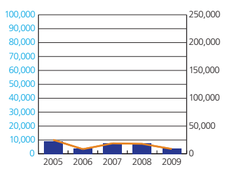
Value and weight of salmon production (2005-2009)

Live weight (tonnes) Value (£'000)

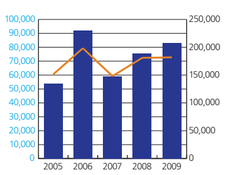
North Scotland Coast



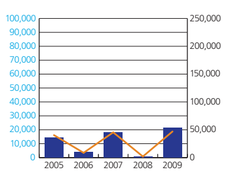
Hebrides



Minches and Malin Sea



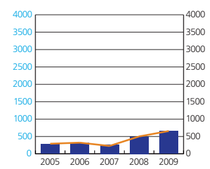
Clyde



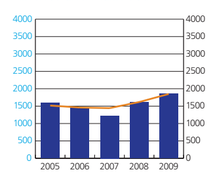
Value and weight of mussels production (2005-2009)

Live weight (tonnes) Value (£ millions)

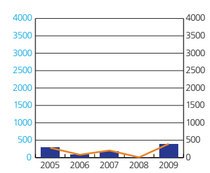
Hebrides



Minches and Malin Sea



Clyde

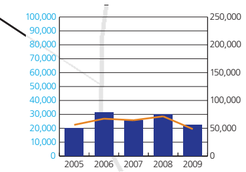


Value Tonnes

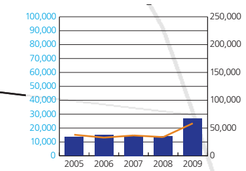
Value and weight of salmon production (2005-2009)

Live weight (tonnes) Value (£'000)

West Shetland



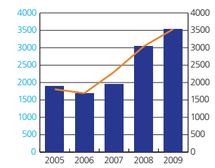
East Shetland



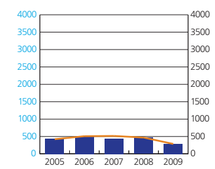
Value and weight of mussel production (2005-2009)

Live weight (tonnes) Value (£ millions)

West Shetland



East Shetland



Value Tonnes

A breakdown of non-salmon fin-fish and other shellfish (native and Pacific oysters, King and Queen scallops) cannot be provided for reasons of commercial confidentiality.

Lismore North

© Marine Scotland

Line of mussels ready to harvest

© Marine Scotland

Cages at Quarry Point

© Marine Scotland

Loch Leven below Ben Nevis

© Marine Scotland

Pressures and impacts on the environment

Pressure theme: Climate change and physical pressures
Pressure: Local water flow rate and wave exposure changes
Impact: Site infrastructure (e.g. pens and floats) has the potential to alter tidal currents and wave conditions.

Pressure theme: Pollution and other chemical pressures
Pressure: Synthetic compound contamination
Impact: The dispersion of chemicals (from treatments, spills, food and faecal matter) has the potential to be toxic to benthic species.

Pressure: Non-synthetic compound contamination
Impact: Antifoulant paints and fish feed have resulted in elevated concentrations of copper and zinc in sediments. Discharges of chemicals can be toxic to benthic species.

Pressure: De-oxygenation (in the sediment and water column)
Impact: Breakdown of organic matter, e.g. uneaten food, can create a Chemical and Biochemical Oxygen Demand (COD and BOD), which can lower oxygen levels and affect local biodiversity.

Pressure: Organic enrichment
Impact: Deposition of particulate waste (faecal material and uneaten food) beneath cages may result in de-oxygenation of sediments. Shellfish species can also produce waste e.g. 'mussel mud' (faeces).

Pressure: Input of nitrogen and phosphorus
Impact: Excretory products and decaying food release ammonia and salts of nitrate and phosphate. This can contribute to eutrophication and possibly to Harmful Algae Blooms.

Pressure theme: Other physical pressures
Pressure: Litter
Impact: Litter, such as broken nets, plastic pipes and metals, impact on marine species through ingestion, entanglement and smothering.

Pressure theme: Habitat changes
Pressure: Habitat structure changes
Impact: Some underwater infrastructure can abrade the seabed; harvesting of shellfish (if dredged) can cause damage; use of materials to encourage settlement of oysters can cause damage.

Pressure theme: Biological pressures
Pressure: Sustainability of fish feed
Impact: Feeding using wild-caught fish from a lower trophic level may deplete wild stocks. UK industry accounts for 4% of total world-wide fish-oil consumption.

Pressure: Introduction or spread of non-indigenous species and interaction with wild species.
Impact: Escapees interbreeding with wild populations resulting in losses of genetic variability, including loss of naturally selected adaptations.
Some mariculture species can cause habitat modification and trophic competition with indigenous species.
Cages provide potential substrate for non-native species such as caprellid shrimps and colonial sea-squirts (e.g. *Didemnum*).

Pressure: Reduction in plankton levels
Impact: Overstocking of shellfish could lead to reduction in the standing stock of phytoplankton.

Pressure: Increased numbers of sea lice
Impact: Infection of wild salmonids by sea lice from farmed fish.

Pressure: Introduction of microbial pathogens (disease)
Impact: Parasites and diseases are part of the natural biology and functioning of ecosystems. Disease can move in both directions between farmed and wild fish.

Pressure: Settlement of cultivated species outside sites
Impact: Shellfish larvae can overspill into the surrounding environment, creating new habitat and biomass for others e.g. waterbirds.

Pressure: Management of other species that impact on aquaculture
Impact: For example, taking or killing of seals to protect salmon stocks and prevent damage of aquaculture cages.

Source: Based on CP2 PSEG Feeder Report Table 3.8[4] and UK Marine Policy Statement[5]

Mussel farm

© Marine Scotland

Forward Look

The immediate prospects for Scottish aquaculture are good. The salmon industry is thriving due to the worldwide effect on demand of the collapse in Chilean production and the opening up of new markets. A recent Institute of Aquaculture report[6] suggests that the prospects for mussel farming are good, in some part due to a decline in Dutch mussel production. Scotland is well positioned to contribute to continued growth in the EU, in line with the EU Aquaculture Strategy.

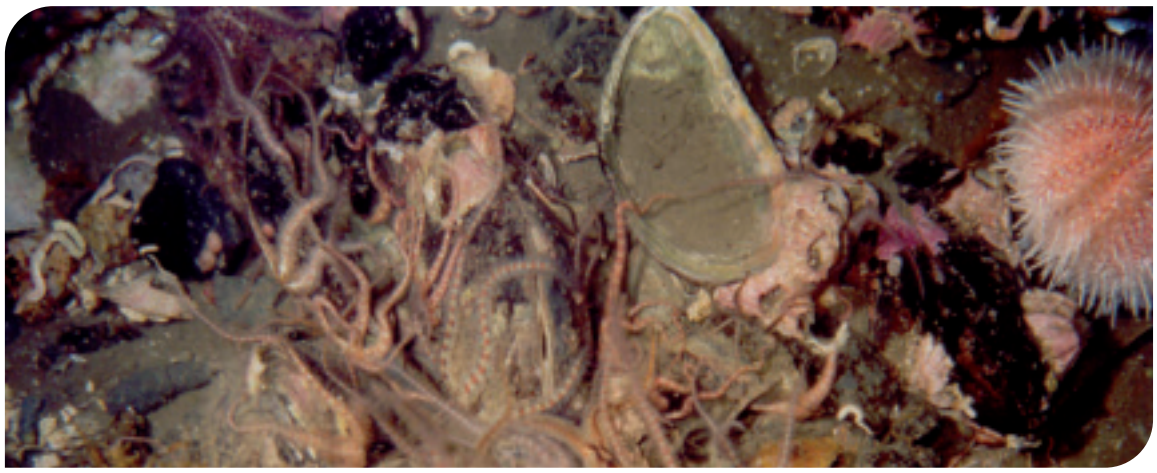
The global demand for seafood, driven by such factors as the need for protein for an expanding population and the need to replace land-based sources suffering from climate change, is likely to increase demand for Scottish production. The salmon industry has identified a significant opportunity for growth in the next five years. In the 2009 European Fisheries Fund awards, grants to the mussel sector were made which could alone lead to a further increase of more than 2,000 tonnes of production.

The stated desire of one company to move to off-shore or exposed salmon farms may remove the main spatial constraint on the industry, and could herald the next stage of aquaculture development. Potential sites could be over twice as large as existing sites and each would therefore represent a significant increase in the value of the Scottish industry.

Given the interest in macro-algae as a basis for biofuel production and other non-food uses over the last five years, and the established Scottish history of macro-algal harvesting, research is underway to assess international progress in this field to inform possible development of this sector.

The proportion of fish meal and fish oil from capture fisheries in farmed fish diets is starting to decline as alternative ingredients are substituted. Most, but not all, of this comes from capture fisheries from stocks primarily from the NE Atlantic and SW Pacific which are considered to be fished at sustainable levels, although there are uncertainties over the sustainability of some. Scottish aquaculture uses about 4% of this global resource.

Unimpacted seabed in the vicinity of a well managed fish farm: brittle stars, common sea urchin, kelp and shell debris present



© Marine Scotland

What, why, where?

Fishing provides a source of fresh, nutritious food and supports remote rural communities around Scotland's coast. There are also strong export markets for Scottish fish.

Most of the fish stocks of interest to the Scottish sea fisheries industry span international boundaries and are often caught in mixed fisheries. This can lead to complicated interactions between regulations applied by different countries to individual species.

Managing stocks

For stocks which occur exclusively in the waters of European Union (EU) Member States, the amount of fish caught is regulated by the EU through the Common Fisheries Policy (CFP). For stocks that move between EU and third country waters, the Commission negotiates fishing opportunities with the relevant country or countries. The key third country agreements for Scotland are with Norway (for the North Sea) and Iceland and the Faroes (for pelagic stocks).

In international waters to the west of Scotland, beyond British Fisheries Limits, management of stocks is agreed through the North East Atlantic Fisheries Commission (NEAFC). Between EU Member States Total Allowable Catches (TACs) are allocated according to historic fishing patterns. For joint stocks shared between EU and non-EU countries, allocations are shared between the signatories to the agreement according to the principles laid down by the United Nations Convention on the Law of the Sea (UNCLOS).

Decisions are based on scientific advice from the International Council for the Exploration of the Sea (ICES).

Fishing activity changes to reflect scientific advice, the location of fish and the need for possible closure of areas. Up-to-date information on temporary closures can be found on the Scottish Government website[1].

Data collection

All landings are reported according to the regions in which fish were caught (known as ICES squares). This catch information, together with independent fish surveys, form the basis of the data used to assess the amount of fish that can be caught each year. Larger fishing vessels (15m and over) are fitted with a Vessel Monitoring System (VMS), which allows for more detailed information about the location of fishing activity. Smaller vessels are currently not covered by VMS. Landings data from Scottish vessels are published annually in the Scottish Sea Fisheries Statistics[2].

Scottish fishing fleet

The Scottish fishing fleet can be split into four broad sectors:

- The pelagic fleet which mainly targets herring and mackerel. It is comprised of a relatively small number of large, profitable vessels.
- The demersal or whitefish fleet targets bottom-dwelling fish in two types of fishery: the roundfish fishery in the North Sea and west of Scotland (which comprises cod, haddock, whiting and saithe) and the species found in the deeper water to the north and west of Scotland.
- The mixed demersal and shellfish fleet are the boats from the whitefish fleet which move between whitefish and Nephrops fisheries (prawn, or langoustine, fisheries).
- The shellfish fleet is those vessels that specialise in shellfish such as scallops and Nephrops. They tend to operate within the inshore waters of the west coast, east coast, Borders, Fife, and south west of Scotland. A high proportion of these vessels are under 10m.

The following species make up the bulk of Scottish catches: mackerel and herring (pelagic); haddock, cod and monkfish (whitefish); Scottish langoustine (*Nephrops*); crabs and scallops (other shellfish).

Fishing ports

The largest part of the commercial fishing industry operates from ports located in the north-east of Scotland, especially around Peterhead and Fraserburgh. This region has both the greatest volume and value of landings, as well as a greater concentration of local fish processors and an important level of local economic dependence on fishing activity (see Economic Analysis Section). Shetland has a fishing sector on a similar scale to that of the north-east and provides important landing facilities for many of Europe's pelagic fleets. The north coast and Orkney support a small local industry and also have some busy fishing ports, notably Scrabster and Wick.

In the north-west, Lochinver and Kinlochbervie are important ports for access to the fishing ground to the north-west of Scotland and often receive landings from fishing vessels from other EU countries that operate to the west of Scotland. The western coast still supports numerous small ports and harbours, the largest of which are Ullapool, Oban, Portree and Mallaig. Elsewhere, in the south-east and south-west, numerous small ports continue to support a small local industry based on small vessels fishing inshore grounds, mostly for shellfish. Most of the fishing industry on the west coast is now dependent upon shellfish.

Fishing effort has decreased significantly since 2000 due to continuing restrictions on fishing activity in order to promote stock recovery.

To obtain a fishing licence for the first time, an entitlement has to be secured from a current licence holder. An entitlement becomes available when a licence is no longer attached to an active fishing vessel or it may be transferred alongside the purchase of a fishing vessel.

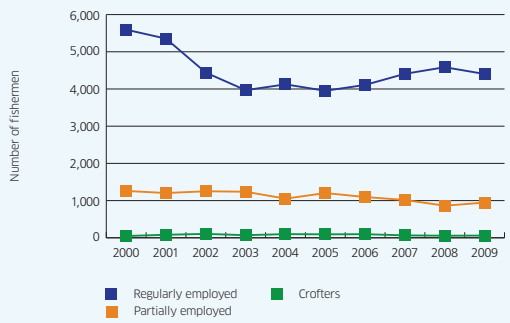
Contribution to the economy

In 2009 366,569 tonnes of fish with a first sale value of £416 million were landed from Scottish waters[3]. This figure includes all fish caught by UK vessels in Scottish waters and fish caught by non-UK vessels in Scottish waters and landed into the UK. Catches by non-UK vessels landing outside the UK are not available below the level of ICES sub-divisions so cannot be attributed to the ICES squares (as shown in the maps) or totalled into Scottish sea areas, as shown on the map opposite.

Pelagic trawler fishing vessel

© SNH

Number of fishermen employed on Scottish based vessels



Source: Scottish Sea Fisheries Statistics, 2009[2]

Pressures and impacts on Scotland's socio-economics

Positive

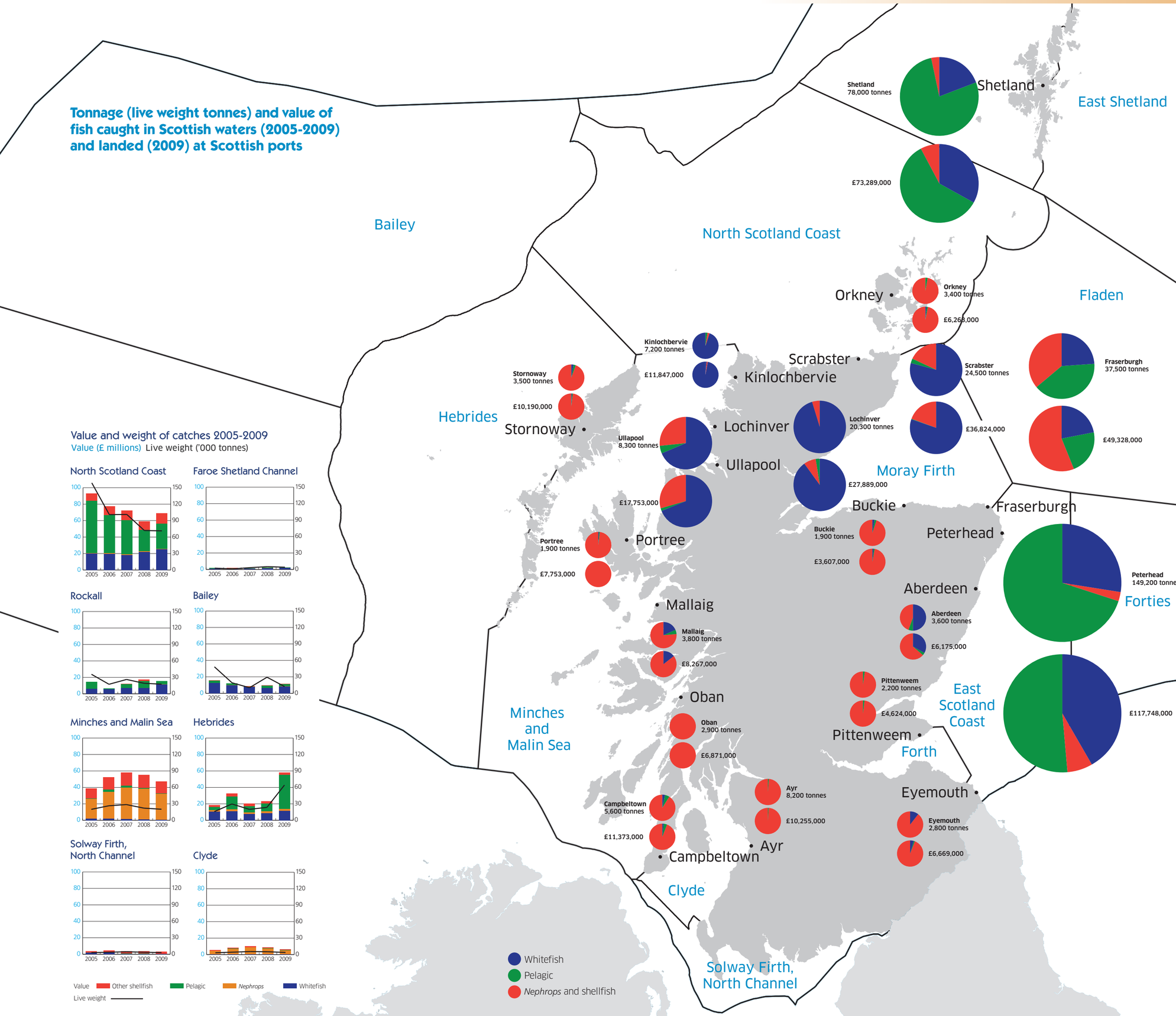
- Long and significant fishing history has large impact on the culture, due to Scotland's proximity to productive fishing grounds
- Employment (full and part time), often in remote communities, for catching and processing sectors
- High quality locally sourced, nutritious source of protein
- Role in achieving food security
- Exports contribute to international trade

Negative

- Fishing often competes for sea space with other marine economic activities
- Most fish caught in Scottish waters is exported while most fish eaten within Scotland is imported

Source: Based on CP2 PSEG Feeder Report section 3.5.6[4] and UK Marine Policy Statement[5]

Tonnage (live weight tonnes) and value of fish caught in Scottish waters (2005-2009) and landed (2009) at Scottish ports



Value and weight of catches 2005-2009

Value (£ millions) Live weight ('000 tonnes)

North Scotland Coast

Faroe Shetland Channel

Rockall

Bailey

Minches and Malin Sea

Hebrides

Solway Firth, North Channel

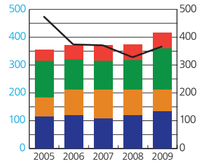
Clyde

Value Other shellfish Pelagic *Nephrops* Whitefish
Live weight

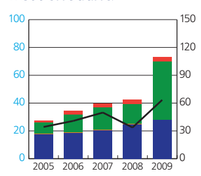
Value and weight of catches 2005-2009

Value (£ millions) Live weight ('000 tonnes)

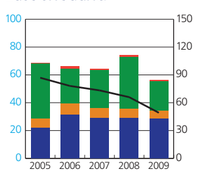
All Scottish waters



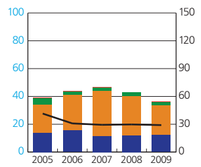
West Shetland



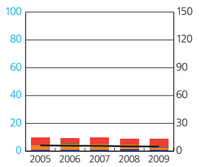
East Shetland



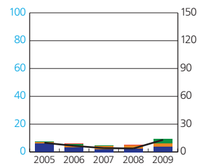
Fladen



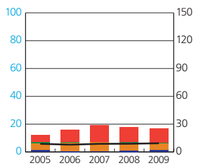
Moray Firth



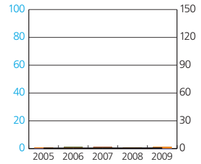
Forties



East Scotland Coast

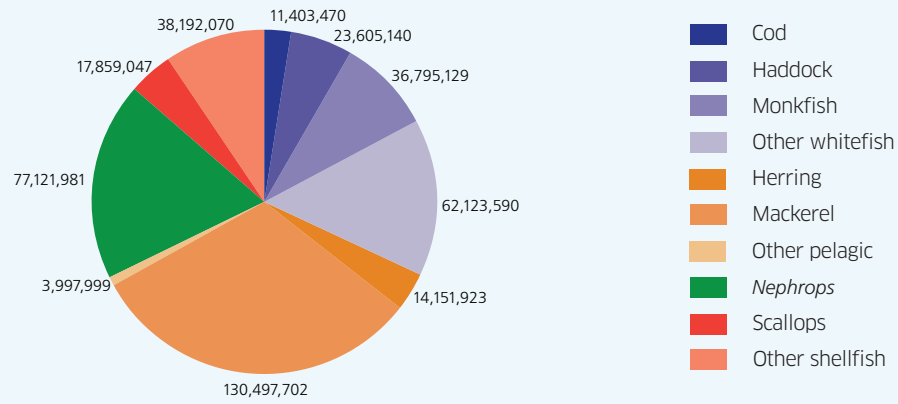


Forth

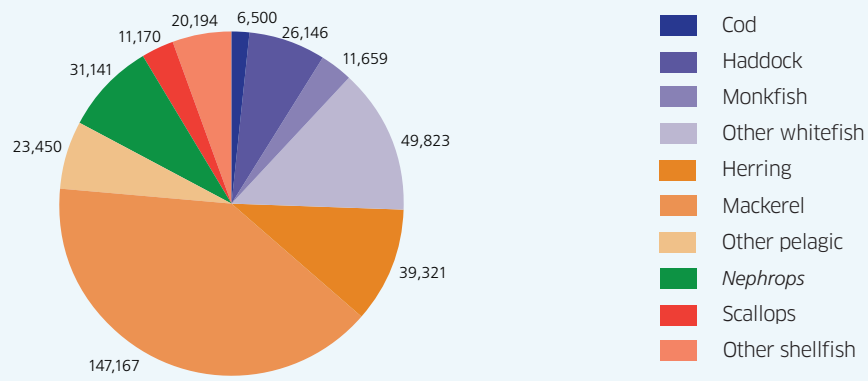


Value Other shellfish Pelagic *Nephrops* Whitefish
Live weight

Value of fish caught in Scottish sea areas, 2009

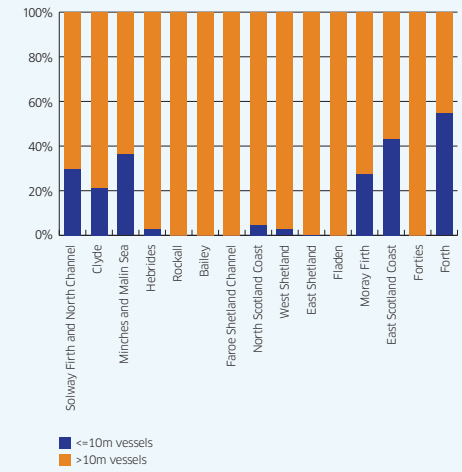


Tonnage of fish caught in Scottish sea areas, 2009



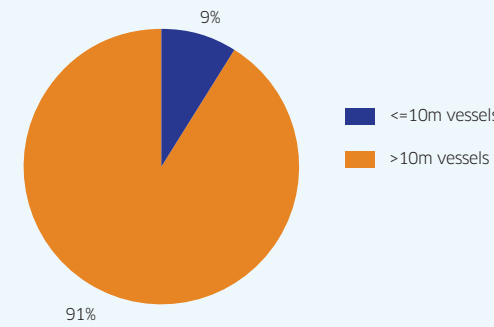
Source: Marine Scotland
Includes landings by all UK vessels (of all lengths) and landings by foreign vessels into the UK. Excludes fish caught in Scottish sea areas by non-UK vessels and landed outside the UK.

% catch by value in each sea area



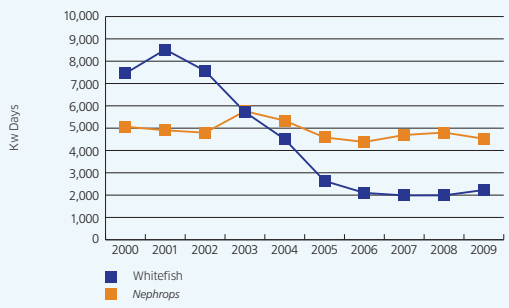
Source: Marine Scotland

% catch by value for all Scottish waters



Source: Marine Scotland

Effort of selected regulated gears (in KwDays) in West of Scotland, Scottish vessels over 10m



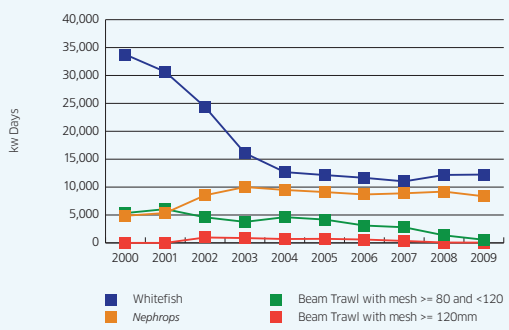
Source: Scottish Sea Fisheries Statistics, 2009[2]
Note: these two gears are the main mobile gears used by the Scottish fleet

Active Scottish based vessels by main fishing method

Vessel Type	2000	2005	2006	2007	2008	2009
10 metres and under	1,593	1,567	1,518	1,494	1,492	1,483
Over 10 metres:						
Demersal	466	308	300	294	295	274
Pelagic	38	25	21	22	24	25
Shellfish	445	386	385	381	394	392
Total	**2,542**	**2,286**	**2,224**	**2,191**	**2,205**	**2,174**

Source: Scottish Sea Fisheries Statistics, 2009[2]
Note: Figures at 31 December each year.

Effort of selected regulated gears (in KwDays) in North Sea, Scottish vessels over 10m



Source: Scottish Sea Fisheries Statistics, 2009[2]
Note: these are the four main gears used in North Sea by Scottish fleet.

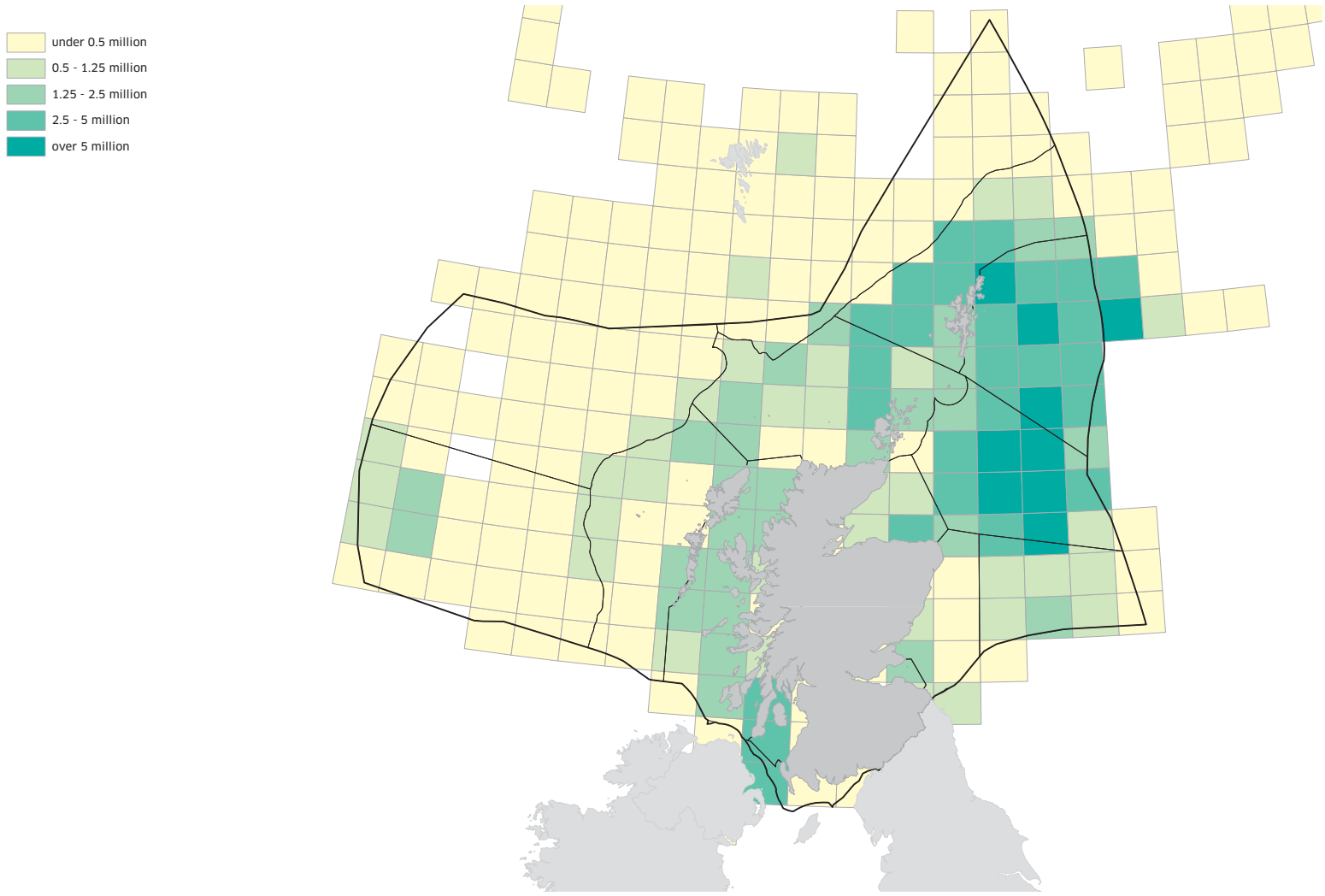
Under 10m fishing vessel

© SNH

Prawn tails

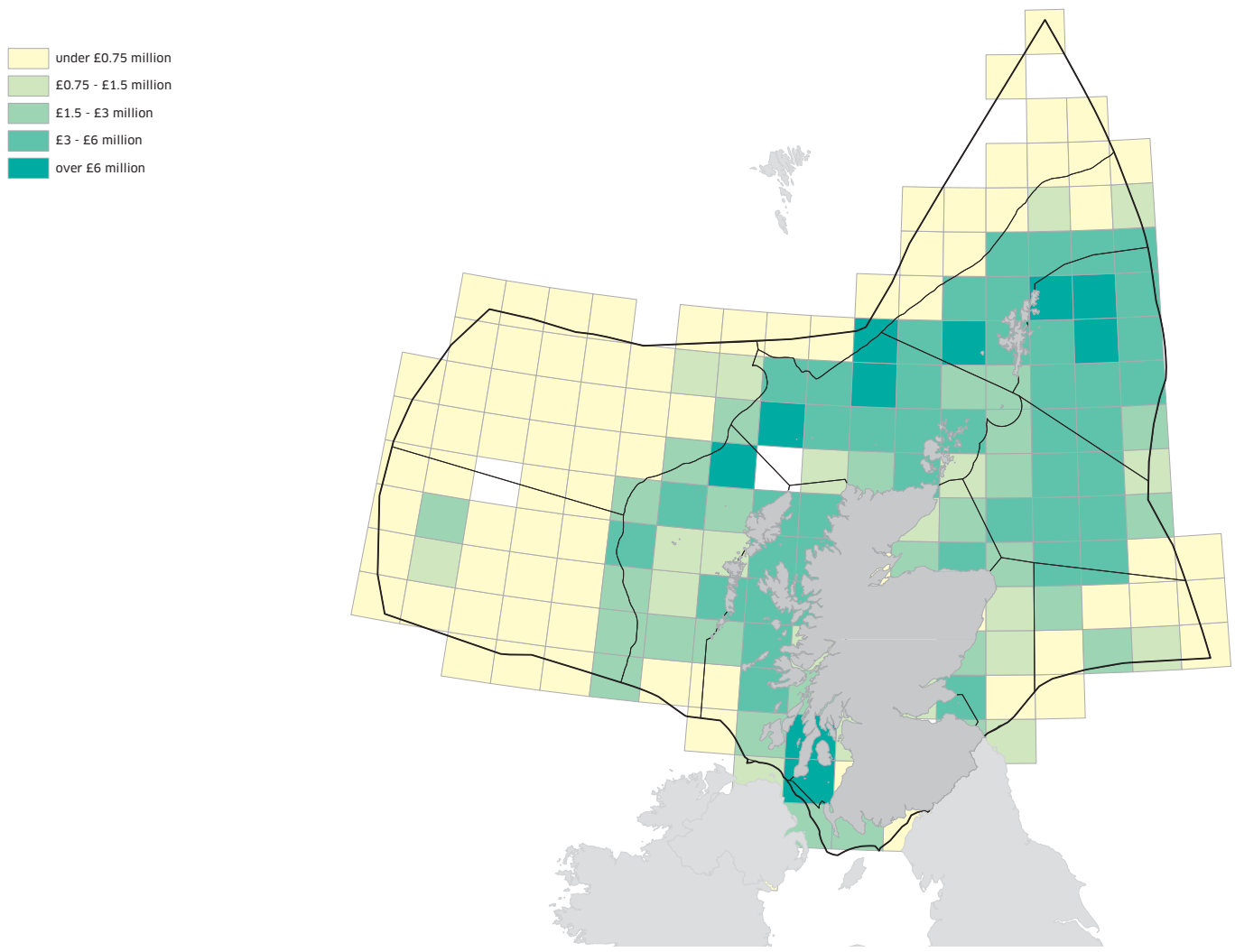
© SNH

Average effort (kw Days) in Scotland's seas by all UK vessels (all lengths) 2005-2009



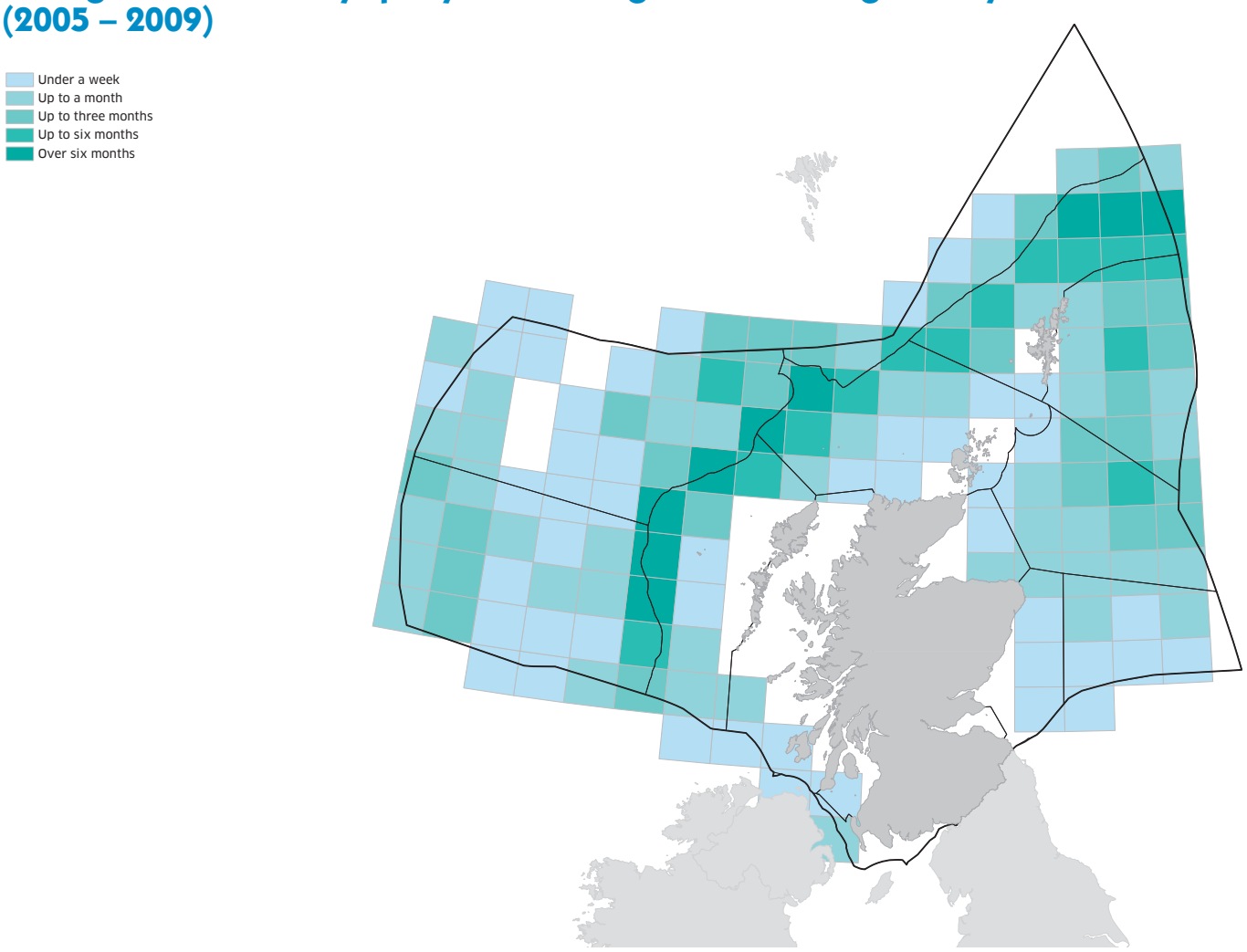
Source: Marine Scotland
Note: no kw Days effort data for non-UK vessels. Rectangles where no effort by UK vessels was recorded are not coloured.

Average value of landings from Scotland's seas 2005-2009



Source: Marine Scotland[3]
Note: excludes landings data for non-UK vessels landing outside the UK. Rectangles where no catch was recorded are not coloured.

Average number of days per year of foreign vessel fishing activity in Scottish waters per ICES square (2005 – 2009)



Source: Marine Scotland

Based on VMS positions received every two hours from EU vessels and every hour from third country vessels.

Pressures and impacts on the environment

Pressure theme: Other physical pressures
Pressure: Introduction of litter, remnants of damaged nets
Impact: Ghost fishing and entanglement of marine animals. Mainly an issue with a static net fishery, rather than trawl fishery pursued by most Scottish vessels.

Pressure theme: Habitat changes
Pressure: Abrasion due to disturbance from fishing gear
Impact: Damage to, or loss of, habitats.

Pressure theme: Biological pressures
Pressure: Selective removal of species
Impact: Individual stock level pressures on distribution and population size. Loss of biological productivity of individual stocks, reduced genetic diversity.

Pressure: Selective removal of species
Impact: Impacts on non-target species (by-catch) due to non-selective extraction.

Pressure: Selective removal of species
Impact: Indirect impacts on community structure and food webs, loss of biological productivity and biodiversity.

Source: Based on CP2 PSEG Feeder Report Table 3.35[4] and UK Marine Policy Statement[5]

Demersal pair trawler fishing vessel

© Marine Scotland

White fish catch coming aboard

© Marine Scotland

Forward look

The fisheries sector is currently, and is likely to remain, important to many rural areas in Scotland. Fisheries management will continue to focus on bringing down rates of exploitation to Maximum Sustainable Yield (MSY) targets. There is increasing downward pressure on the levels of exploitation. Past over-exploitation of some stocks means that current stocks are depleted and require time to become re-established. It is likely that pressure to reduce discarding will increase, though without allowing overall catch to rise. Management measures will need to reduce bycatch and discards, and be more responsive to changing patterns of fish migration and movement.

Currently, Scottish Ministers will not license any expansion in Scotland's existing fishing capacity. So no new fishing licences (which are needed to fish commercially for sea fish and land a catch for profit; and also stipulate authorised seas area, species and gear) are issued.

Reform of the CFP in 2012 may result in significant changes to the aims and objectives of the policy with a consequent effect on management. The outcome of this reform process cannot be predicted with any certainty but one possibility is that EU fisheries may be managed on a regional basis and fishermen may be more directly involved in the management of the fish stocks.

SALMON AND SEA TROUT FISHING

What, why and where?

Scotland is a stronghold of wild salmon *Salmo salar* and sea trout (the anadromous form of brown trout) *Salmo trutta*. These fish spend several years in rivers, migrate to sea then return as adults to spawn. Marine migrations in salmon are generally more extensive than those of sea trout. Salmon usually spawn once whereas sea trout may spawn several times.

All salmon fishing and sea trout fishing rights in Scotland, including in the sea, are private, heritable titles, which may be held separately from any land. They fall into one of three broad categories.

Fixed engine fisheries are restricted to the coast and must be set outside estuary limits. Bag-nets, stake nets and jumper nets are different forms of fishing gear used across Scottish fisheries, with poke nets and haaf nets restricted to the Solway Firth area.

Net and coble fisheries generally operate in estuaries and the lower reaches of rivers.

Rod and line fisheries comprise angling activities which generally take place within rivers and above tidal limits. This method currently accounts for the majority of salmon and sea trout catches.

Catch data are combined geographically into 109 Districts and further aggregated into 11 Regions. Some Regions are not fully covered by the data survey at present. Districts correspond either to a single river catchment together with the adjacent coast or to groups of neighbouring river catchments and their associated coastline. Catch statistics have been collected since 1952 and are published annually as topic sheets by Marine Scotland[1]. Neither the Districts nor the Regions correspond with the sea areas being used in this Atlas.

Net fisheries

Reported annual catches of wild salmon and grilse by fixed engine and net and coble both illustrate the decline of the Scottish net fishing industry over the last 50 years. This decline in catches has been similar in all reporting regions and also mirrored in annual catches of sea trout.

Rod and line fisheries

Rod and line fisheries continue to operate on most of Scotland's rivers. In contrast to the net fisheries, rod catches of salmon have increased slightly over the past 50 years. This is likely, at least in part, to be due to the decline in the netting industry.

Since 1994, the proportion of the total rod and line catch accounted for by catch and release of both salmon and sea trout have shown a general increase.

Reported annual catches, number of salmon (2005 – 2009)

Year	Fixed engine catch	Net and coble catch	Rod and line (caught and retained)	Rod and line (caught and released)
2005	21,016	8,107	37,929	46,069
2006	18,821	6,188	38,476	47,556
2007	13,618	6,279	35,583	55,515
2008	11,703	3,957	32,852	53,139
2009	8,206	4,648	23,690	48,136

Reported annual catches, number of sea trout (2005 – 2009)

Year	Fixed engine catch	Net and coble catch	Rod and line (caught and retained)	Rod and line (caught and released)
2005	3,636	2,930	10,517	9,550
2006	3,239	4,931	10,058	10,617
2007	2,671	2,903	10,383	11,164
2008	2,810	2,732	7,631	9,666
2009	3,742	5,635	8,167	15,508

Source: Marine Scotland[1]

Contribution to the economy

The overall value of these fisheries is difficult to calculate and has many dimensions. Figures for GVA and numbers employed cannot be obtained from the ABI, as it does not separately assess this activity. Rod fishermen cannot sell their catch but contribute to the general tourist economy (spending on accommodation and associated expenditure) and pay for the fishing experience. It has been estimated that anglers fishing in Scotland for salmon and sea trout spend some £73M annually[2]. Net and coble and fixed engine fisheries can sell their catch.

Employment tends to be seasonal particularly in the net fisheries. The numbers fluctuate with July having the most employment in the net fisheries.

Pressures and impacts on Scotland's socio-economics

Positive
- Tourism (for rod fisheries)
- Local employment
- Iconic food product of Scotland (net fisheries only, rods not permitted to sell fish)

Negative
- Possible competition with other amenity users

Source: Based on CP2 PSEG Feeder Report section 3.6.6[3] and UK Marine Policy Statement[4]

Jobs (in July) associated with salmon and sea trout fishing

- Net and coble 117 (2005) and 75 (2009)
- Fixed engine 180 (2005) and 150 (2009)

Data for the whole of Scotland not routinely collected for rod and line.

Source: Marine Scotland

Pressures and impacts on the environment

Pressure theme: Biological pressures
Pressure: Removal of marine fauna and flora
Impact: Potential for reduction in fish stock species through fishing.

Source: Based on CP2 PSEG Feeder Report table 3.46[3] and UK Marine Policy Statement[4]

Salmon and sea trout face various threats and pressures, such as those from predators and fisheries but also those associated with habitat change resulting from catchment management schemes and pollution.

Adult salmon

© Marine Scotland

Forward look

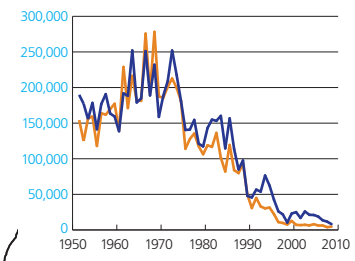
The sector's future very much depends on the status of stocks together with the general economic situation. New coastal salmon nets are rarely opened and the main trend has been for declining catch and fishing effort in the net fisheries. Marine Scotland Science will continue to monitor the status of both stocks and fisheries.

Scottish salmon rivers and salmon and sea trout net fisheries reporting catches in 2009

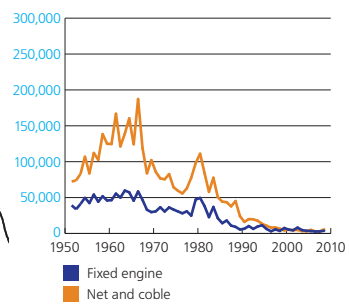
- Net and coble 2009
- Fixed engine 2009
- Main salmon rivers
- Regions

Shetland
Orkney
Outer Hebrides
North
North West
Spey
Moray Firth
Dee
North East
West Coast
Tay
East
Clyde Coast
Tweed
Solway

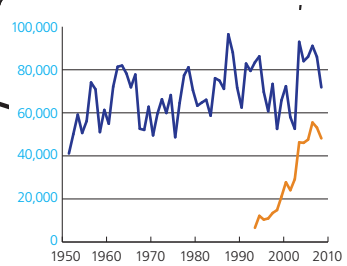
Reported annual catches of wild salmon and grilse (by fixed engine and net and coble) (1952-2009)



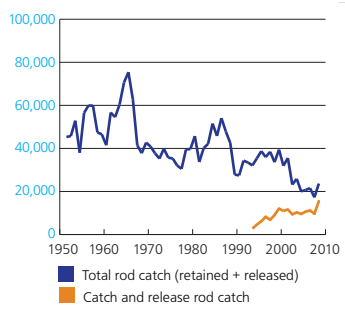
Reported annual catches of sea trout (by fixed engine and net and coble) (1952-2009)



Reported annual catches of wild salmon and grilse by rod and line (1952-2009)



Reported annual catches of sea trout by rod and line (1952-2009)



Source: Marine Scotland[1]

Fixed engine fishery

© SNH

What, why and where?

Marine leisure and recreational activities range from informal walking along a beach or coastal path, to professional participation in extreme water sports. This range of activities contributes to wider tourism.

Sailing in Scotland is concentrated in the Clyde and along the west coast, although new marina facilities have recently created opportunities for cruising around the Northern Isles. Surfing and windsurfing take particular advantage of the Atlantic waves breaking off the Inner Hebrides but surfing is also popular on the east coast.

Diving on wrecks or offshore reefs is an important recreational activity in Orkney and along the Berwickshire coast. Canoeing and kayaking take place around sea lochs and in coastal areas, especially on the west coast, while inland canals provide transit routes between coastal areas.

Sea angling is carried out from most regions of the Scottish coastline. A wide range of species are caught including cod, tope, bass, rays, pollack, mackerel and spurdog. Species caught vary from region to region and at different times of the year. Information about the capture of 'salmon and sea trout' is covered in a separate part of the Atlas.

Coastal and marine wildlife tourism attracts visitors to view, study and/or enjoy wildlife on the coast. This includes viewing birds, mammals and coastal habitats from boats or from land vantage points with a strong emphasis on cliff nesting seabirds or seals at haul-out sites. Marine wildlife tourism specialist operators provide access to offshore areas and certain marine species, for example, dolphins, porpoises, basking sharks and seals.

In the 2010 bathing season, there were 82 designated bathing waters, of which 78 met EU water quality standards. Seven Scottish beaches attained Blue Flag status and a further 56 received Seaside Award status. Monitoring results of designated bathing waters is covered in Chapter 3.

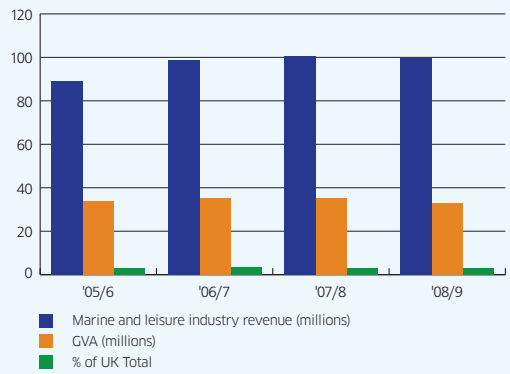
Contribution to the economy

Marine-related leisure and recreation make a particular contribution to the Scottish rural economy, especially on the west coast, the Hebrides and the Northern Isles. The ABI does not categorise this activity separately so other sources are used to obtain economic figures for this atlas. These sources do not collect data based on the atlas sea areas and, being drawn from a variety of studies, are approximate and may include an element of double counting.

Marine leisure

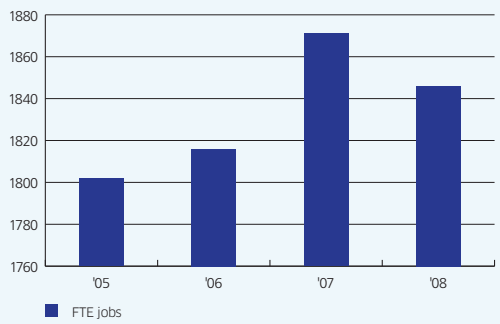
The British Marine Federation calculates that the marine leisure industry (boat building, specialised equipment manufacture, sales, training, insurance services, finance and a wide range of waterborne recreational pursuits) directly supports around 1,800 full time equivalent (FTE) jobs in Scotland through the provision of specialist services through boatyards, marinas and associated chandlery. Pre-2008 figures indicate a significant upwards trend in the development of the industry. The general economic decline has affected some aspects of the marine leisure industry but, on the whole, it is sustained by a strong local market.

Trend in value of Scottish marine leisure industry



Source: British Marine Federation[1]

Trend in FTE jobs



Source: British Marine Federation[1]

Sailing area value and berth numbers

Sailing Tourism study regions	Value	% of total available berthing	No. of pontoons	No. of moorings	Scottish sea areas included
North (Gairloch – Helmsdale – Peterhead, Orkney & Shetland)	£7.9 M	7.8%	1,792	224	North Scotland Coast West Shetland East Shetland Moray Firth
East (Peterhead – Fife Ness – Berwick)	£10.1 M	10%	1,067	480	East Scotland Coast Forth
Clyde (Clyde Estuary & Solway)	£44 M	43.6%	3,333	2,038	Clyde, Solway Firth, North Channel
West (Argyll, Ardnamurchan – Gairloch & Outer Hebrides)	£39 M	38.6%	1,030	2,637	Minches & Malin sea Hebrides
Total	**£101M**	**100%**	**7,222**	**5,380**	

Source: Sailing Tourism in Scotland[2]

Note: excludes offshore areas Fladen, Forties, Rockall, Bailey, Faroe Shetland Channel

Largs Yacht Haven

© British Marine Federation

Kayaking

© SNH

Windsurfing

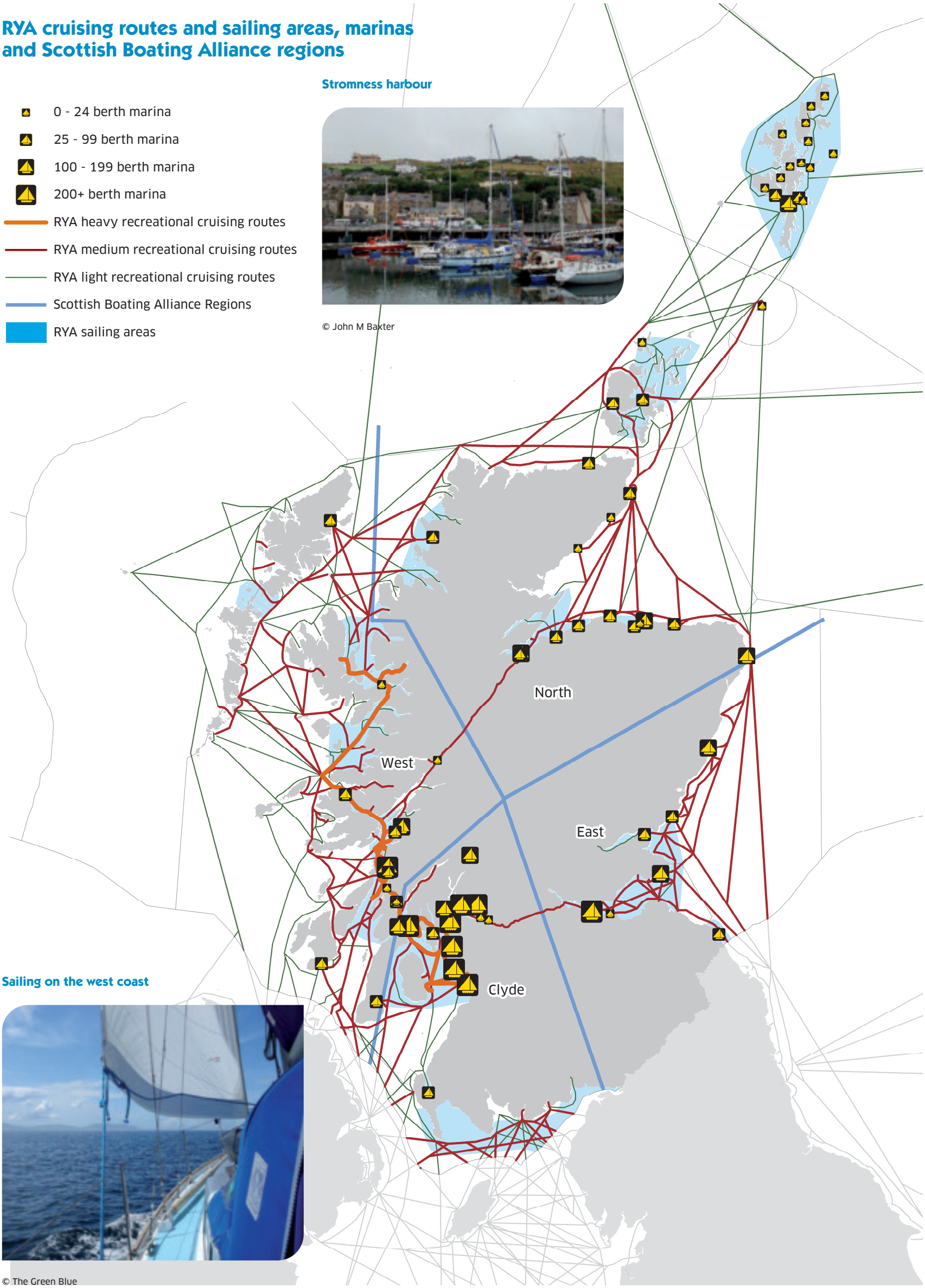
© SNH

RYA cruising routes and sailing areas, marinas and Scottish Boating Alliance regions

- 0 - 24 berth marina
- 25 - 99 berth marina
- 100 - 199 berth marina
- 200+ berth marina
- RYA heavy recreational cruising routes
- RYA medium recreational cruising routes
- RYA light recreational cruising routes
- Scottish Boating Alliance Regions
- RYA sailing areas

Stromness harbour

© John M Baxter



Sailing on the west coast

© The Green Blue

Recreational sea angling

A survey carried out for the Scottish Government in 2009[3] estimated that recreational sea angling generated £140.9 million for the Scottish economy and supported 3,148 FTE jobs.

Dive tourism

Dive tourism is important to the local economies of Orkney and the Berwickshire coastline with the wrecks of the German High Seas Fleet at Scapa Flow and the underwater biological diversity of the Voluntary Marine Reserve off St. Abbs Head and Eyemouth attracting thousands of participants. Data collated by Scottish Enterprise Borders (SEB) in 2007[4] estimated that 25,000 divers visited the two Berwickshire sites and contributed £3.7 million to the local economy. The SEB data suggest that the activity supports 81.7 FTEs in the Scottish Borders area and has a GVA of £1.5 million per annum.

Coastal and marine wildlife - east coast dolphins

A Moray Firth Partnership study in 2009[6] detailed that the total direct expenditure related to the presence of a pod of bottlenose dolphins on the east coast of Scotland was at least £5 million, providing around 202 FTE jobs.

Pressures and impacts on Scotland's socio-economics

Positive

- Contributes to a healthier nation
- Employment (may be seasonal), often in peripheral locations where employment opportunities may be limited
- Underpins longer-term jobs in equipment development and manufacture, marinas and customer service industries
- Major events (e.g. West Highland Week and Tiree Wave Classic) give coastal communities a distinct and global profile
- Improved access to coast possibly attracting more tourists/visitors

Negative

- Variable seasonal employment in peripheral coastal communities could have negative impacts compared with a stable and broader based set of industries
- Sector can be vulnerable to economic downturns
- Activities can compete for space in certain areas at certain times, causing disturbance and, occasionally conflict

Source: Based on CP2 PSEG Feeder Report section 3.6.6[7] and UK Marine Policy Statement[8]

Income, expenditure and employment in Scotland's wildlife tourism

Economic impact of wildlife tourism in Scotland	Expenditure (£M)	Income (£M)	Employment (FTE)
Terrestrial	114	64	3,061
Marine	63	36	1,705
Coastal	100	56	2,681
Total	**277**	**156**	**7,446**

Source: The Economic Impact of Wildlife Tourism in Scotland[5]

Pressures and impacts on the environment

Pressure theme: Other physical pressures
Pressure: Litter
Impact: Including plastic, polystyrene, rubber, metals and glass. Can impact through ingestion, entanglement and smothering.

Pressure theme: Habitat changes
Pressure: Physical disturbance of seabed strata
Impact: Causes alterations to local benthic habitat including trampling and smothering.

Pressure: Coastal erosion and increase in suspended sediments
Impact: Particularly of soft sediment features and an increase in suspended sediments caused by scouring from boat wash or wake.

Pressure theme: Biological pressures
Pressure: Marine wildlife disturbance (visual and acoustic)
Impact: Can stop animals feeding, resting, travelling or socialising, with possible long term effects including changes to reproductive success, weight and condition.

Pressure: Sewage discharge from boats
Impact: Possible human health problems and nutrient enrichment.

Pressure: Introduction of non-native species
Impact: Through fouling on boat hulls can result in contamination of water and sediments with biological impacts on biota.

Pressure: Removal of marine fauna and flora
Impact: Potential for reduction in fish stock species through angling. Possible entanglement of variety of species in lost tackle.

Source: Based on CP2 PSEG Feeder Report table 3.46- and UK Marine Policy Statement[8]

Seal watching on Arran

© SNH

Forward look

Despite the recent downturn, the leisure and recreation sector could have the potential to play an increasingly important role in the Scottish economy. Demand for facilities for formal and informal activities remains on an upward trend, including a demand for new yachting berths in popular sailing and cruising areas. Good maintenance of slipways allows trailer boats and other craft access to the water.

Future targeted marketing campaigns, advertising Scotland's coastal environment and promoting investment in new facilities, could help to support this sector. The 2009 sea angling study[3], for example, identifies a significant potential for growth and other parts of the sector are confident that they will respond positively to a future upturn in economic conditions.

An integrated approach to the planning and management of leisure and recreational activities is required across the land-sea divide. Waterborne sports do not exist in isolation and require both terrestrial and marine planning to be successful. Equally, seascapes, when viewed from the land or afloat, are subject to positive and negative impacts from developments and use. The informality of many of the sector's activities is one of its major attractions but the freedom of where to sail or fish has sometimes been seen as a pressure point in the marine system. Much has been done to reduce conflicts, for example through Codes of Practice and education of those participating. In the event of further expansion of leisure and recreational activity, a review may be required to establish whether or not existing arrangements are sufficient to ensure that their use of the seas does not erode the very aspects that make the seas attractive for these purposes.

Moray Firth dolphin watching

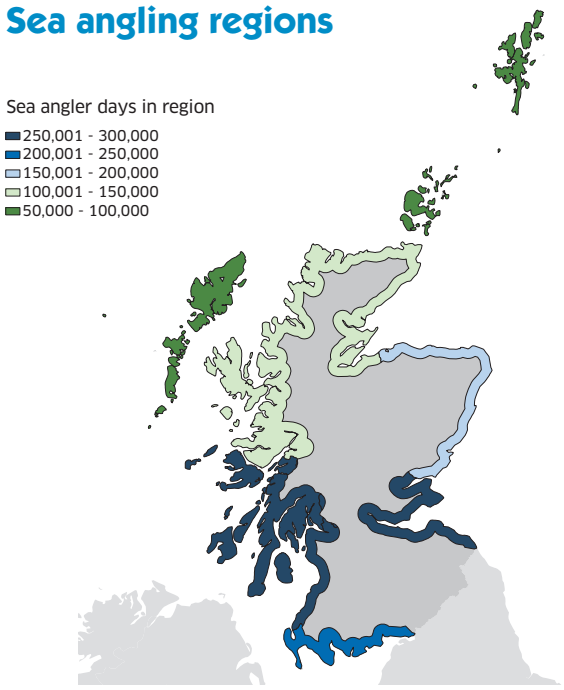
© SNH

Estimated regional sea angling activity and expenditure

Region	No. of resident sea anglers	Annual sea angler days spent in region	Total annual sea angler expenditure (£M)
Argyll & Lochaber	5,825	252,615	£22.6
Dumfries & Galloway	3,224	233,080	£25.2
Glasgow & West	23,548	269,783	£24.1
North East Scotland	8,904	234,307	£15.5
Northern Scotland	7,894	144,346	£11.2
Edinburgh, Fife & South East	20,455	250,868	£26.9
Western Isles	2,515	80,567	£9.2
Orkney & Shetland	2,823	74,640	£6.1
Outwith Scotland	50,000	N/A	N/A
TOTAL	**125,188**	**1,540,206**	**£140.9**

Source: Economic Impact of Recreational Sea Angling in Scotland[3]

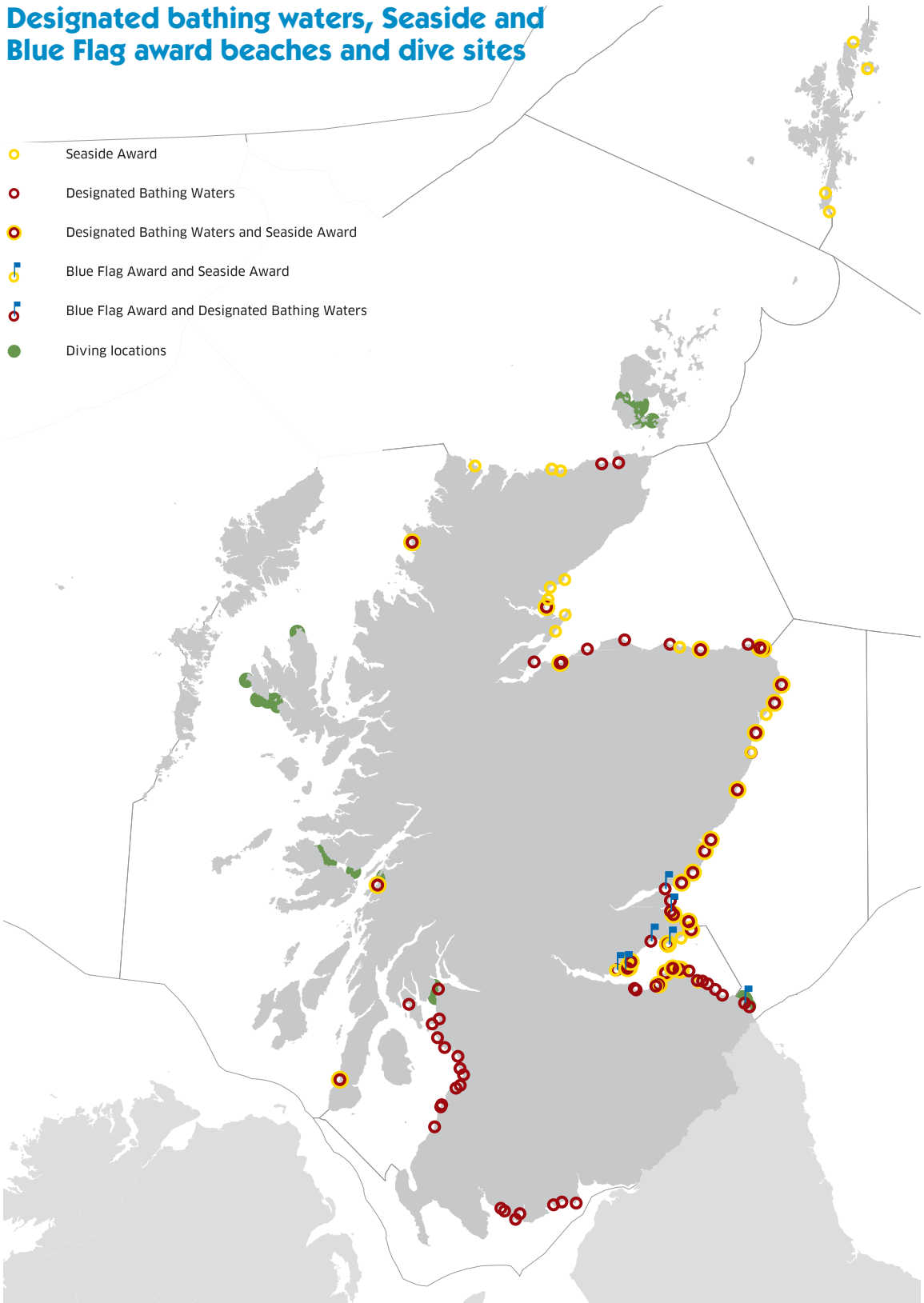
Sea angling regions



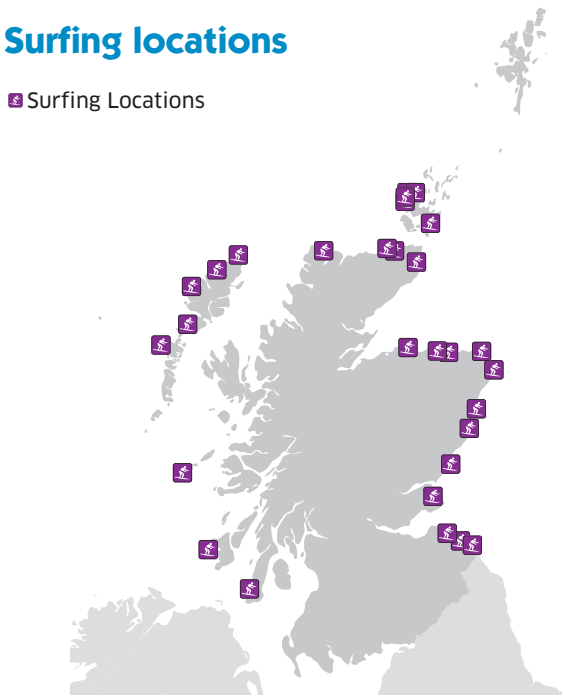
Sea angling at North Berwick

© John M Baxter

Designated bathing waters, Seaside and Blue Flag award beaches and dive sites



Surfing locations



Surfing world series event at Thurso

© www.studiograff-photo.co.uk

HISTORIC ENVIRONMENT AND CULTURAL HERITAGE

What, why, where?

Historic ships, maritime museums, festivals of the sea, world heritage sites, scheduled monuments and designated wrecks are tangible aspects of Scotland's historic environment and cultural heritage. Also included are the remains of settlements from prehistory to the modern day such as harbours, lighthouses and ship-building yards; ecclesiastical buildings and defensive features from castles to war-time defences. They help to create a sense of place, wellbeing and identity, enhancing the distinctiveness of the coast and attracting visitors to Scotland. Scuba divers visit underwater wrecks of ships and aircraft, while in some areas archaeological sites once on land may now be submerged because of changes in the coastline and sea level since the last ice age, offering the potential of fresh insights into the settlement of Scotland.

Contribution to the economy

Cultural heritage sites which make a contribution to the economy fall into two categories. First, those which lie wholly within the marine environment, such as shipwrecks. Second, those on land, where the sea forms an integral part of their identity such as lighthouses, maritime museums, coastal castles and island monasteries. A survey undertaken to obtain data for this atlas[1] reveals a lack of official statistics (for example, from the ABI) for this sector. However, many heritage sites (e.g. historic harbours and lighthouses) are in commercial use and others generate economic value from tourism. Cultural heritage makes a valuable contribution to Scotland's economy, although this is not currently reflected by official data.

Visitor income (ticket sales and other visitor expenditure) was £1.55 million in 2008 for the 20 of 97 managed and visitable coastal heritage sites that provided economic data. Limited availability of these data (due both to commercial confidentiality and the fact that some sites do not keep visitor number data) means that the values shown significantly underestimate the contribution to the economy, so it would not be appropriate to present regional figures. In addition, some sites, including shipwrecks offshore, can be visited for free, so do not contribute directly to the economy, but do contribute to less tangible social benefits such as education, health and well-being. However as a pointer to the wider economic picture, VisitScotland statistics indicate that approximately 83% of visitors come to Scotland primarily to visit historic sites[1].

The heritage tourism sector provides employment for staff with particular skills and knowledge including craftsmen and curators, as well as shop staff and guides. Trend data obtained for the 13 staffed Historic Scotland Properties in Care showed 23 full-time and 21 part-time in 2004 employees and 20 full-time and 23 part-time in 2009[1]. However as employment data have only been obtained for 13 out of the 97 managed and visitable heritage sites, the true number of jobs directly associated with coastal and marine cultural heritage will be significantly greater.

Pressures and impacts on Scotland's socio-economics

Positive

- Full and part-time employment, often in rural areas
- Tourism, for both domestic and international visitors
- Recreation and education, both formal and informal

Negative

- Hazards for other sea users, for example snagging fishing nets, obstructing navigation
- Potential pollution risk
- Restriction on areas for new development

Source: Based on UK Marine Policy Statement[4]

Kisimul Castle, Barra – the sea and coast define the setting

© Historic Scotland

Managed and visitable coastal and marine heritage sites

Type of site	No of managed and visitable sites = 97(*)	Examples	Scottish seas area of example(s)
World Heritage Sites	2	St Kilda	Hebrides
		Heart of Neolithic Orkney	North Scotland Coast
Properties in Care of Historic Scotland	13	Kisimul Castle, Barra	Minches and Malin Sea
		Inchcolm Abbey	Forth
Other managed, visitable heritage assets	21	Ardnamurchan Lighthouse	Minches and Malin Sea
Maritime and coastal heritage museums	43	Discovery Point, Dundee	East Scotland Coast
		Unst Boat Haven	East Shetland
		Scottish Maritime Museum, Irvine	Clyde
Historic ships	9	Royal Yacht Britannia, Leith	Forth
Traditional boat festivals	1	Portsoy Festival	Moray Firth
Designated wreck (designated under section 1 of Protection of Wrecks Act 1973)	8	Duart Point wreck	Minches and Malin Sea

Source: Marine Scotland[1]
Note: * 'Managed and visitable sites' are those assessed by the survey for this atlas as being staffed and/or where visitor or income statistics are likely to have been kept.

Marine cultural heritage statutory designations and other heritage assets

Type of site	No of sites	Examples	Scottish seas area of example(s)
Listed Buildings (*)	4	Bell Rock lighthouse	East Scotland Coast
Scheduled Monuments (*)	9	Marine Crannogs, Beauly Firth	Moray Firth
		7 wrecks of German High Seas Fleet, Scapa Flow	North Scotland Coast
Designated wrecks	8	Kennemerland, Out Skerries	East Shetland
Controlled Sites (**)	6	HMS Royal Oak, Scapa Flow	North Scotland Coast
Vessels designated by name as Protected Places (**)	7	HMS Pathfinder, outer Firth of Forth	East Scotland Coast
Undesignated coastal heritage assets (***)	uncertain	Churchill Barriers, Orkney	North Scotland Coast
Wrecks and documented losses offshore (****)	20,000	James Barrie, Hoxa Sound, Orkney	

Source: Historic Scotland
Notes: (*) identified as entirely in the marine zone – i.e. subtidal or located between high and low water; many other scheduled monuments and listed buildings along the coast have some marine elements
(**) administered by Ministry of Defence under Protection of Military Remains Act 1986
(***) Historic Scotland Coastal Zone Assessment Surveys have recorded c. 12000 sites along 30% of the Scottish coastal zone since 1997. The number of sites around the entire Scottish coast will be significantly larger.
(****) only about 1600 are identified sites where demonstrable remains have been located on the seabed

Key coastal and marine heritage tourism resources

- World Heritage Site
- Property in Care
- Other managed, visitable heritage asset
- Maritime museum
- Coastal heritage museum
- Historic ship
- Traditional boat festival
- Designated wreck
- Scottish sites in Divernet top 100 UK wreck dives

Unst Boat Haven
Mousa Broch
Heart of Neolithic Orkney World Heritage Site
St Kilda World Heritage Site
Portsoy Festival
Kisimul Castle
Ardnamurchan Lighthouse
SS Hispania
Duart Point wreck
Discovery Point
Inchcolm Abbey
Royal Yacht Britannia
Scottish Maritime Museum

St Kilda World Heritage Site

© SNH

Royal Yacht *Britannia*, Leith

© The Royal Yacht Britannia

Pressures and impacts: heritage assets and the wider environment

Pressure theme: Pollution and other chemical pressures
Pressure: Pollution
Impact: From substances within wrecks of ships and aircraft, and some coastal structures

Pressure theme: Habitat changes
Pressure: Impacts on habitats
Impact: Wrecks and coastal heritage site works may cause short term, localised disturbance to species and habitats. Longer term, positive effects can include creation of artificial reefs offshore or shoreline habitats for wildlife. Protected areas, although small, may help deliver biodiversity benefits

Source: Based on UK Marine Policy Statement[4]

A recent study for the MCA, Potentially Polluting Wrecks Project, should provide data on pollution from wrecks in future. The *HMS Royal Oak* (Scapa Flow, Orkney) is known to leak oil but this is monitored and recovered.

Pressures and impacts: heritage tourism and the wider environment

Pressure theme: Other physical pressures
Pressure: Litter/pollution
Impact: Transport to access sites, waste water from visitor facilities and litter can all impact on the environment if not managed properly, Tourism and recreation can be a source of litter. Can impact on wildlife through ingestion, entanglement and smothering.

Pressure theme: Habitat changes
Pressure: Habitat damage
Impact: Visitors and researchers have the potential to disturb or damage habitats (e.g. through boat anchoring).

Pressure theme: Biological pressures
Pressure: Disturbance/visual disturbance
Impact: Presence of visitors may disturb wildlife.

Pressure: Introduction of non-native species
Impact: Visitors may introduce or move species intentionally or unintentionally.

Pressure: Removal of marine fauna and flora
Impact: Visitors may collect marine species as souvenirs or remove for consumption.

Source: Based on CP2 PSEG Feeder Report table 3.46 (See also table in Leisure and recreation for related impacts[5])

The spatial footprint of heritage assets within the marine environment can be difficult to assess as most information is available as point rather than spatial data. However, the majority of heritage assets cover a very small area of seabed. Coastal sites on land are easier to define, but likewise tend to occupy comparatively small and discrete areas, although there can be more dense concentrations of individual sites along some sections of coast. Taking into account the net positive and negative effects outlined above, the overall impact is therefore considered most likely to be neutral[1].

Distribution and visitor statistics for managed and visitable heritage sites in 2008

Scottish seas area (*)	Managed visitable heritage assets	Historic ships and boat festivals	Maritime and coastal heritage Museums	Visitors (2008)(***)	% of visitors
Solway Firth, North Channel	4	0	1	38,800	2%
Clyde	7	5	6	424,950	22%
Minches and Malin Sea	9	2	8	465,400	24%
Hebrides (**)	1	0	2	3,450	<1%
North Scotland Coast	8	0	5	163,200	8%
West Shetland	1	0	0	11,400	<1%
East Shetland	4	0	3	15,750	<1%
Moray Firth	2	1	5	93,450	4%
East Scotland Coast	1	1	8	266,050	13%
Forth	7	1	5	456,800	23%
Total	**44**	**10**	**43**	**1,939,250**	**100%**

Source: Marine Scotland[1]
Note: (*) Bailey, Faroe Shetland Channel, Fladen, Forties and Rockall do not contain any identified visitable sites.
(**) No economic information obtained
(***) Rounded to the nearest 50

Public involvement

Scottish Traditional Boat Festival
An annual festival held in Portsoy, Banff to celebrate maritime heritage. 70 traditional vessels took part in 2009, watched by approx. 20,000 visitors.

The SCAPE Trust
The Shorewatch initiative has involved the public in monitoring the risk posed by erosion on archaeological sites along the coast, for example at the Brora Saltpans, Sutherland.

The Nautical Archaeology Society
Encourages public participation in the recording and conservation of coastal and marine heritage and organises internationally recognised training courses.

Wrecks and diving tourism
Scotland has 16 wrecks listed in the top 100 UK wreck dives[2] (for example *SS Hispania*, Sound of Mull) and an estimated 15,260 dives were carried out on the wrecks of the German High Seas fleet (Orkney) in 2006[3].

Lord of the Isles Galley Trust
In 1991 the Trust built the 'birlinn' (west highland galley) *Aileach*. *Aileach* is used as a sailing and training vessel and has appeared in eight television programmes.

Between 1994 and 2009, 1,640 scuba divers visited three of Scotland's eight designated wrecks under 'visitor licence' from Historic Scotland.

Forward look

Far less is known about marine cultural heritage than about sites on land. Understanding more about the resource is a priority for effective management. Evidence from the 17th-century Duart Point wreck suggests that outstanding levels of preservation can occur where seabed conditions allow and disturbance is avoided. However, large numbers of relatively recent wrecks are in a phase of irreversible decay. Also coastal erosion for some of the Scottish coast is likely to continue to pose a significant threat to coastal heritage.

Heritage assets are vulnerable to a wide range of man-made and natural processes. Careful management is needed to ensure that future marine activities and developments are carried out in a way that respects the historic and cultural heritage, the setting of important coastal heritage assets and protects these for the benefit of future generations. Where natural processes present the risk, the challenge is to develop and prioritise effective responses to help conserve the most important sites and to mitigate loss where necessary and possible.

There has been a general increase in visitors to historic sites but this trend may reverse in the short term given the current economic climate. Underwater heritage remains accessible to relatively few, but digital technology is presenting new opportunities to promote this resource beyond the diving world.

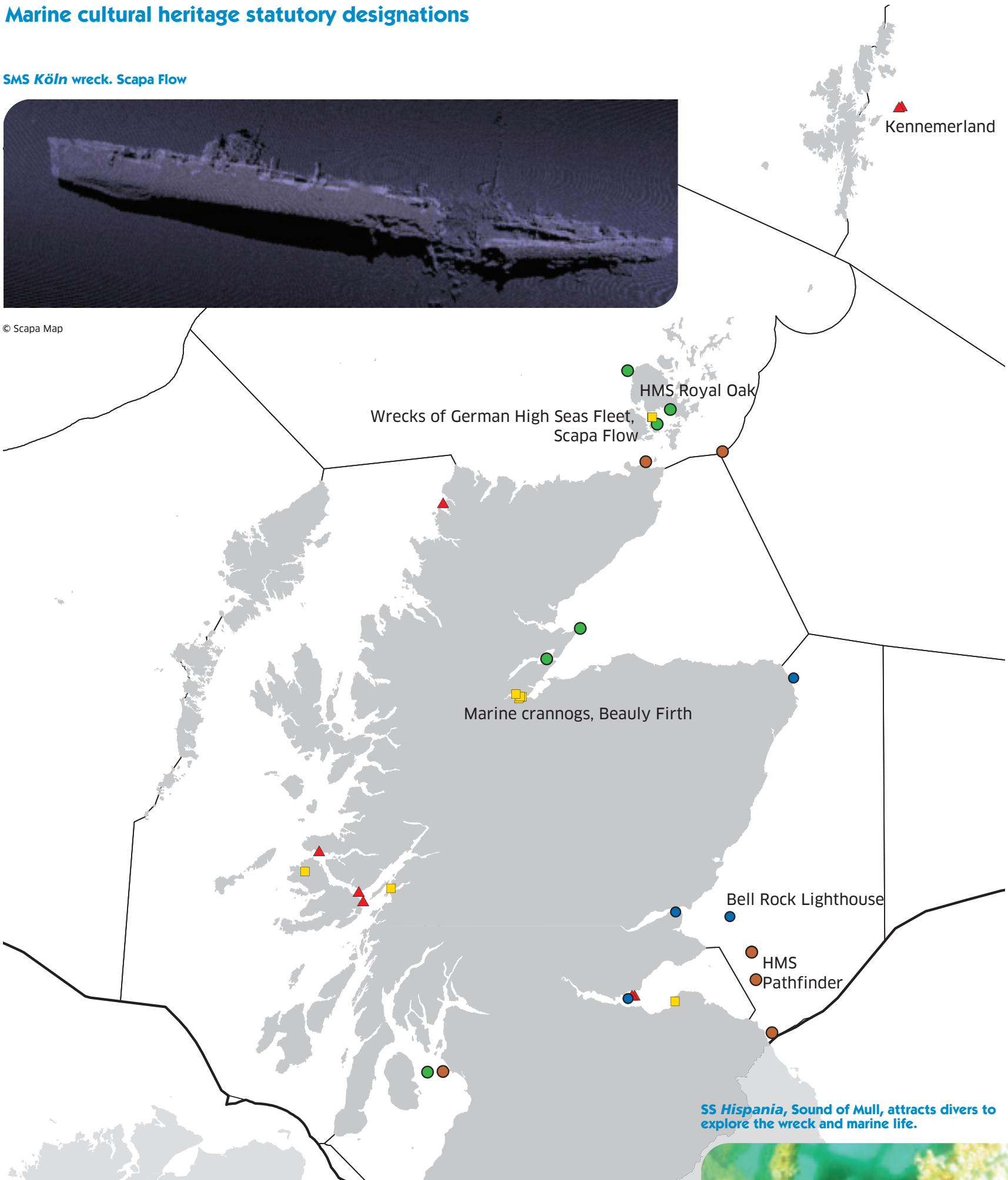
Visitor open day at Brora Saltpans, Sutherland

© SCAPE/University of St Andrews

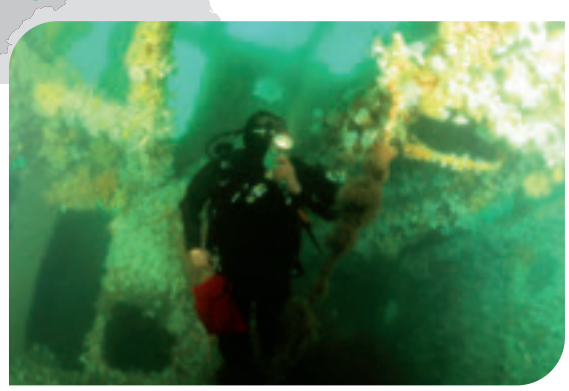
Marine cultural heritage statutory designations

SMS *Köln* wreck. Scapa Flow

© Scapa Map



SS *Hispania*, Sound of Mull, attracts divers to explore the wreck and marine life.



© Simon Volpe Underwater Text and Photography

- Scheduled Monuments
- Listed Buildings
- Designated wrecks
- Vessels designated by name as Protected Places under the Protection of Military Remains Act 1986
- Vessels designated as Controlled Sites under the Protection of Military Remains Act 1986

COASTAL PROTECTION AND FLOOD DEFENCE

What, why and where?

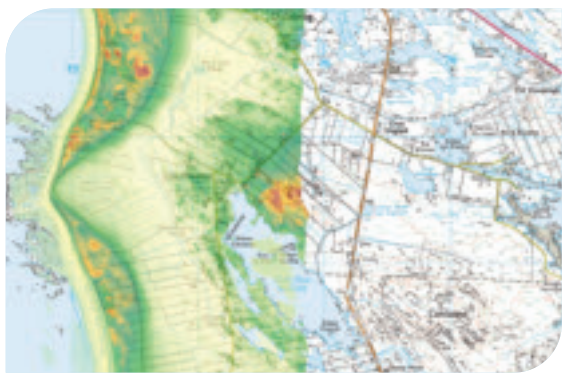
Coastal erosion and flooding pose a threat to people and their property at the coast. For generations, society has built defences to prevent erosion and protect land from flooding. Examples of these include groynes, sea walls and embankments (termed hard engineering).

Present day approaches also include soft engineering such as replenishing eroding beaches with sand, referred to as beach nourishment. Also, nature is occasionally allowed to take its course through managed retreat or coastal realignment, where existing hard defences are intentionally or naturally allowed to breach so recreating natural saltmarsh. This provides a place for high tides to spread out and would be most effective in firths.

There is no central record of all historic coastal management schemes, although aerial survey would indicate where the coast had most likely been altered. SNH estimate that 429km of mainland Scotland's coast is artificial, 307km of this is coastal defences, the rest being other developments such as piers and harbours[1].

Light Detection and Ranging (LIDAR) can produce a high-resolution map of terrain, from which it is possible to identify man-made structures. LIDAR also allows for the monitoring of changes in coastal structures.

Digital elevation model from LiDAR super-imposed on Ordnance Survey map of southern South Uist



Source: SNH[2]
Note: shading shows changes in altitude; lighter colours are lower, darker colours are higher ground. The gradual narrowing and lowering of the dune reach towards Cille Pheadair is clear in the LIDAR image, as is the extensive low-lying area inland of the dune ridge, which is the bed of a drained loch.

Defences at Aberdeen

© Aerial Photography Solutions

Contribution to the economy

The key contribution of coastal protection and flood defence schemes is through the protection of assets and infrastructure. They do not contribute directly to economic output, providing no measurable GVA and the number of jobs associated with this sector is difficult to measure accurately. The expenditure on these projects, where known, is shown in the tables, total £56M, with the main benefits being to protect property and reduce damage to economically important land. Costs to society are avoided through the existence of the schemes.

Pressures and impacts on the environment

Pressure theme: Climate change and physical pressures
Pressure: Beach replenishment/nourishment to mitigate erosion
Impact: Change in beach profile leading to hydrographic changes.

Pressure: Hydrographic change from the presence of the structures
Impact: Change in sedimentation pattern may lead to erosion/sedimentation processes in adjacent areas. Defences may also lead to accelerated erosion in front of the defences[6].

Pressure theme: Pollution and other chemical pressures
Pressure: Beach replenishment/nourishment to mitigate erosion
Impact: Changes in beach morphology and replenishment material may contain contaminants.

Pressure theme: Other physical pressures
Pressure: Introduction of noise
Impact: Noise related to construction activities, including sediment addition for soft schemes, can cause disturbance and changes to behaviour of certain species e.g. to foraging birds; movement of material may cause disturbance to fish[7].

Pressure theme: Habitat changes
Pressure: Beach replenishment / nourishment to mitigate erosion
Impact: Habitat changes where deposited material is different from current beach material; shelly material may prevent erosion – important for dunes; coarser material may slow down vegetation successions enhancing habitat value for nesting shore birds; any change may alter suitability for burrowing species, food supply (including to shorebirds).

Pressure: Physical presence of structure
Impact:
Hard coastal defences
Fragment and replace sedimentary habitats, leading to habitat changes and species level pressures. Diversity and abundance of species has been found to decrease on artificial structures[8][9]. Structures can be a barrier to species movement.

Soft engineered schemes
Smothering by new layer of material. Possible erosion of fine particles causes increased turbidity which can alter primary productivity within sub tidal areas. Nourished beaches have less diverse ecosystems than natural[10] beaches, with reductions in dominant macro invertebrate species[11]. Loss, reduction and replacement by other types of habitats.

Source: Based on CP2 PSEG Feeder Report Table 3.16 and 3.17[5]

Coastal realignment at Nigg Bay, Cromarty Firth[3][4]

In 2003, an inner sea wall was restored at Nigg to withstand a 1 in 50 year tidal event. This allowed the outer sea wall to be breached letting high tides onto land that was previously improved grassland. This created 25ha of intertidal habitat: a combination of mudflat, and low, mid and upper saltmarsh, and some dry grassland.

Up to 2,000 waterbirds now use the site as a mid tide feeding area and high tide roost; approximately 20% of the waterbird population of Nigg Bay. The Firth supports internationally important numbers of knot, bar-tailed godwit, pink-footed goose and greylag goose and nationally important numbers of redshank, curlew, oystercatcher, red-breasted merganser, scaup, pintail, wigeon, mute swan and Slavonian grebe.

The environmental benefits can be stated in qualitative terms but it is difficult to attribute a financial value to them. The scheme cost £53,840. The RSPB have been monitoring the area to assess its impact on species assemblages, vegetation and sedimentation.

Nigg Bay managed realignment scheme, Cromarty Firth

© N Russell, RSPB

Forward look

With the rise in global sea-levels and a predicted increased risk of storm surges, Scotland's coastal infrastructure and habitats may be placed under increasing threat[12][13]. Rising sea levels and changes to wave conditions may alter erosion rates, increase the incidence and severity of flooding events, and affect intertidal profiles [12]. This may well increase demand for coastal defences.

Long-term tide gauge measurements (see Chapter 2) at Aberdeen show a rising trend over the last 100 years of around 0.7 mm/year, whereas a tide gauge in Lerwick, Shetland Islands, has recorded a fall in relative sea level since 1957 [13]. Global sea-level rise is offset in some areas by the isostatic rise in the Scottish landmass, which has continued since the melting of the ice sheets at the end of the last ice age [14].

There is potential resource for beach nourishment material from the seabed although this would be subject to obtaining consent. Beneficial re-use of maintenance dredging spoil is an alternative source.

Some local authorities have developed Shoreline Management Plans to guide the management of their coasts. The Flood Risk Management (Scotland) Act 2009, which repeals the Flood Prevention (Scotland) Act 1961, establishes a framework within which sustainable flood risk management of coastal flooding will operate more effectively.

Flood defence schemes (since 1961) and coast protection schemes (since 2000)

Flood defence schemes since 1961

Number on map	Location	Cost (£M) (where known)
1	Ayr South Pier	
2	Saltcoats	1.8
3	Largs	0.7
4	Clydesmill Stage 1	
4	Clydesmill Stage 2	
5	Dalmarnock	
6	Rothesay	1.6
7	North Renfrew	6.6
8	Conon Bridge Village	0.1
9	River Ness Tidal Section	23.6
10	Carnoustie	0.5
11	Tayview Caravan Park Monifieth	
12	Kincardine-on-Forth	0.7
13	Bo'ness Foreshore	7.5
14	Prestonpans	

Source: Scottish Flood Defence Asset Database
Coastal schemes undertaken under the Flood Prevention (Scotland) Act 1961

Coast protection schemes since 2000

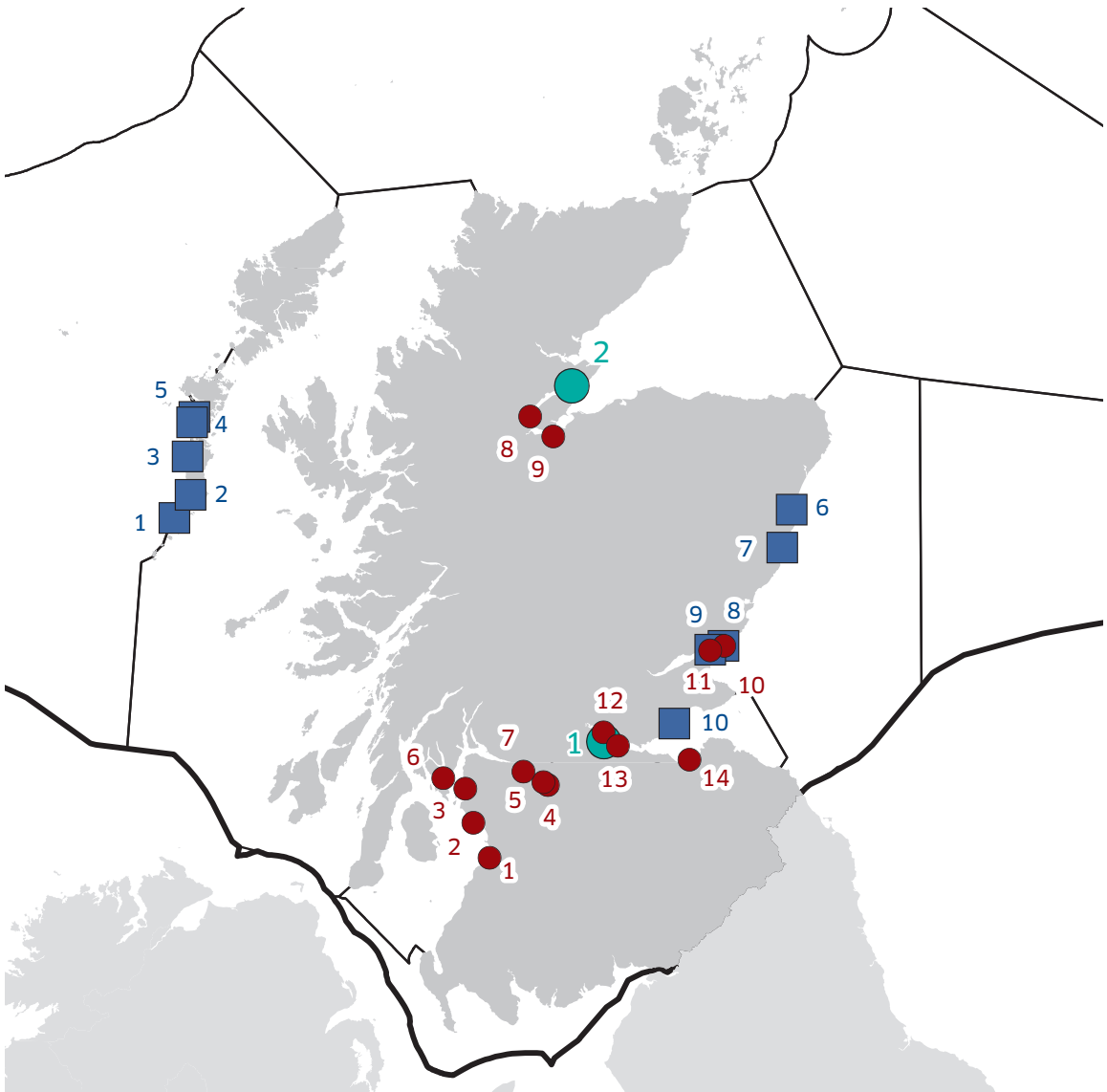
Number on map	Location and year approved	Length of scheme (km)	Cost (£M)
1	Craigston (2007)	0.3	0.9
2	Ludag (2007)	1.15	2.3
3	Stoneybridge (2007)	0.5	0.2
4	Pol na Craan (2007)	0.5	0.1
5	Balivanich (2007)	0.15	0.5
6	Aberdeen Bay (2006)	0.5	2.5
7	Stonehaven Bay (2000)	No data	0.2
7	Stonehaven Bay (2005)	No data	0.2
8	Carnoustie (2003)	0.54	0.6
9	Tayview Caravan Park Monifeith (2003)	0.4	0.4
10	Wemyss & Dysart (2000)	No data	4.8

Source: Scottish Government

Managed re-alignment schemes

Number on map	Location	Construction Date	Area (ha)	Cost
1	Skinflats	2010	12	N/A
2	Nigg Bay	2003	25	£53,840

Source: RSPB

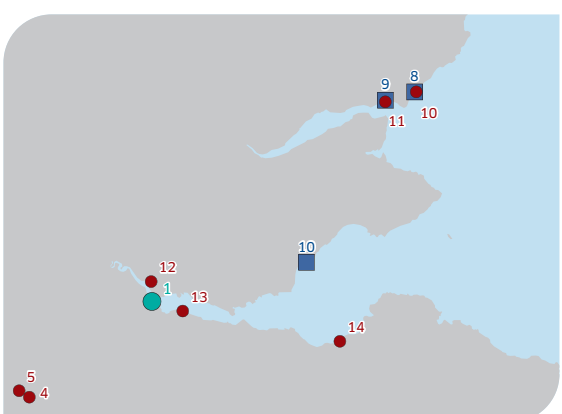


Pressures and impacts on Scotland's socio-economics

Positive
- Protection of property and business
- Employment in construction
- Conserving or enhancing amenity value of coastal land
- Salt marsh habitat creates defence with lower maintenance cost

Negative
- Long term sustainability issues of hard engineering in face of rising sea level and increased storm surges
- Short term loss of amenity, and possible road congestion, during construction
- Encourages coastal development in low lying areas

Source: Based on CP2 PSEG Feeder Report section 3.2.6[5]



RENEWABLE ENERGY AND POWER CABLES

What, why and where?

Renewable energy is widely regarded as a cleaner source of energy than fossil fuels. Scotland's traditional energy sources, such as oil and gas, are also finite and securing sustainable clean energy from the marine environment could help meet Scotland's future energy demands.

Development of an offshore green energy industry is also being driven by the EU 2020 target of 20% of EU's energy consumption from renewable sources by 2020. The Scottish Government has a commitment to meet 80% of Scottish demand for electricity from renewable sources by then.

Development of offshore renewable energy will help to provide Scotland with a secure energy supply and could lead to Scotland becoming a major energy supplier to other parts of the UK and Europe. However, there are significant challenges associated with meeting the targets both in terms of engineering and of ensuring that there are net environmental benefits. The infrastructure required for grid connection also requires a major upgrade to support developments.

Robin Rigg in the Solway Firth, Scotland's first offshore wind development, has a capacity of 180 MW from 60 turbines. Offshore wind demonstration sites have also been established in the Moray Firth (at Beatrice, two 5MW turbines) and off the Aberdeen and Fife coasts, not currently operational. Wave and tidal demonstration sites have been established in Islay and Orkney; a demonstration site off the Western Isles is also under consideration.

Scottish renewable energy generation capacity (October 2010)

Sector	Output (MW)
Wind (on and offshore)	2,319.04
Hydro	1,387.66
Energy from Waste	99.68
Biomass Electricity	79.09
Biomass Heat	34.12
Wave	0.80
Tidal	0.25
Total	**3,920.64**

Source: Scottish Renewables[1]

Offshore energy potential and location

It is estimated that Scottish waters have the potential to generate around 10% of Europe's wave power and possess 25% of the potential European offshore wind and tidal resource. Scotland has almost 40% of the total UK resource.

The Crown Estate awarded the world's first commercial leases for wave and tidal energy generation in 11 sites in the Pentland Firth and Orkney Waters (see case study). It also granted exclusivity agreements to offshore wind energy developers for ten areas in territorial waters and similar agreements, for two wind farm development areas beyond 12 nautical miles under the Round 3 for wind farm leasing.

The Scottish Government has prepared a draft development plan for offshore wind in territorial waters which has identified 25 medium term options with potential for development. The plan identified the ten areas subject to exclusivity agreements as short term development options.

Estimated available energy in Scotland's seas

Source	Available energy (estimated) (MW)
Offshore Wind	169,000
Wave	15,000
Tidal	22,000

Source: Scottish Government[2]

Pressures and impacts on Scotland's socio-economics

Positive
- Increased local jobs (both full and part time)
- Diversity of electricity supply and meeting energy objectives and climate change targets
- Opportunities for manufacturing and construction
- Industrial tourism through potential use of visitor centres
- Potential economic growth of remote and rural areas
- Transferable technology and skill development
- Possibility of structures providing some coastal defence benefit

Negative
- Impacts on or displacement of other users of the marine environment, for example, fishing
- Potential conflict in competition for sea space

Source: CP2 PSEG Feeder Report section 3.12.6[4] and UK Marine Policy Statement(5)

Socio-economic studies

A socio-economic assessment and regional locational guidance are being developed to ensure the full impacts (socio-economic and environmental) of development are considered. A number of studies undertaken by the Scottish Government indicate that the development of the sector will have a positive effect on jobs in the manufacturing and engineering supply chain, particularly in remote communities. The National Renewables Infrastructure Plan (NRIP)[6] has identified that the size, design and transport issues of many of the offshore renewable devices mean that it will be preferable to manufacture and assemble as close to the development sites as possible.

Pressures and impacts on the marine environment

Pressure theme: Climate change and physical pressures
Pressure: Hydrographic changes (due to extraction of energy and/or presence of structures in the sea)
Impact: May alter energy distribution at the sea bed and in the water column. Most relevant for species and coastal features that are strongly correlated with or dependent on particular wave or current speed environments.

Pressure theme: Pollution and other chemical pressures
Pressure: Spillage of fuel oil and construction materials.
Impact: Effects on sediment or water quality potentially impacting on benthic communities.

Pressure theme: Other physical pressures
Pressure: Risk of collision with turbines
Impact: Moving blades of turbines (wind and tidal) may strike mobile animals, injuring or killing them.

Pressure: Changes to physical environment
Impact: Species may be displaced by, or attracted to, new structures in and above the sea.

Pressure: Noise (semi-continuous) from exploration, construction, decommissioning activities, cable laying or vessels
Impact: Potential impacts on noise sensitive species, such as marine mammals and some fish, particularly from pile driving and the use of explosives. May result in permanent or temporary hearing damage or displacement from critical habitat for some species in close proximity to activity. In shallow water, noise fields could act as a barrier to movement for some species.

Pressure: Noise (semi-continuous or continuous) from sub-sea turbines
Impact: Potential impacts on noise sensitive species, resulting in avoidance behaviour and/or exclusion from critical habitat.

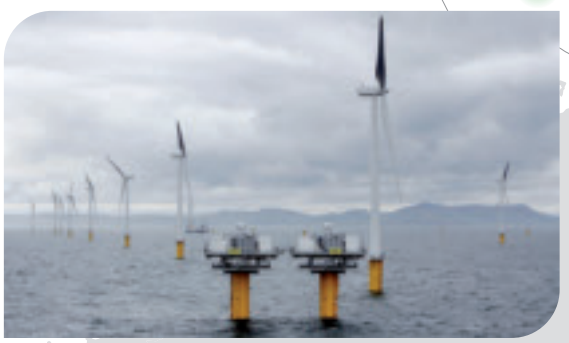
Pressure: Changes to electromagnetic fields (EMF)
Impact: Avoidance or attraction responses in EMF sensitive species resulting in behavioural changes

Current sites and identified areas for wave, tidal and offshore wind energy and infrastructure sites

- NRIP sites
- EMEC Tidal Power Test Facility
- EMEC Wave Power Test Facility
- Beatrice Wind Farm Zone
- Grid infrastructure (> 132kV)
- Pentland Firth and Orkney Strategic Area
- Robin Rigg Windfarm
- Wind Demonstration Sites
- Tidal Areas of Interest
- Wave Area of Interest
- Leased tidal area
- Leased wave area
- Offshore wind - Territorial Waters Round
- Offshore wind - Round 3 Zones
- Offshore wind - SEA Medium term options

Arnish
Nigg
Ardersier
Kishorn
Peterhead
Aberdeen
Dundee
Methil
Leith
Hunterston
Machrihanish

Robin Rigg windfarm



© E.on

Regional locational guidance areas of opportunity for wave and tidal development

Location	Device Type
West Shetland	Wave
South West Shetland	Wave
West of Lewis	Wave
Mull of Kintyre	Tidal
West of Islay	Tidal

Source: Scottish Government[6]

Pressures and impacts on the marine environment

Pressure theme: Habitat changes
Pressure: Habitat loss
Impact: Loss of habitat and species in the footprint of the devices.

Pressure: Habitat damage from construction activities
Impact: Increased suspended sediments and turbidity, smothering, disturbance of contaminated sediments and direct disturbance from devices and/or power cables.

Pressure: Smothering
Impact: Sediment may settle after cable laying and result in changes to local biota and habitat.

Pressure: Habitat introduction
Impact: Alteration in substrate type, habitats, hydrodynamics and sediment dynamics and introduction of new hard surfaces.

Pressure theme: Biological pressures
Pressure: Biological disturbance
Impact: Possible scour around device disturbing seabed communities.

Pressure: Biological disturbance
Impact: Potential barrier effects of structures on marine migratory pathways. Behavioural changes, especially in mobile species, from the presence of devices. Beneficial effects caused by introduction of new habitat leading to greater local biodiversity and protection of local regions from damage by displaced activities, such as fishing.

Source: CP2 PSEG Feeder Report section 3.87 and 81[4] and UK Marine Policy Statement[5]

The uncertainties in current assessments of the environmental effects are being investigated through a joint Marine Scotland and SNH £2M research programme[7].

Submarine electricity cables

Sea area	Length (kms)
East Shetland	197.6
Minches and Malin	193.1
North Scotland Coast	190.2
Clyde	100.3
Fladen	97.9
Moray Firth	30.1
Forties	27.6
West Shetland	27.6
Solway Firth and North Channel	20.5
Hebrides	7.1
East Scotland Coast	1.6
Forth	1.4
Total	**895.2**

Source: Seazone[3]

Forward look

The Offshore Valuation Study[2], May 2010, estimates that Scotland has 206 Gigawatts of practical wind, wave and tidal resources: almost 40% of the UK total resource. The study has also estimated that harnessing just a third of this practical resource off Scotland's coast by 2050 would mean installed offshore capacity of up to 68 GW: enough to power Scotland seven times over. However, at present it is not known what proportion of the overall resource is exploitable with technology that is likely to become available in the foreseeable future. Neither wave nor tidal technologies are mature compared to current wind power technologies.

The map shows areas of possible offshore renewable energy wind resource. They have been identified through a variety of methods, investigation, analysis and assessment. This assessment is ongoing to find the areas that are most suitable for development, avoiding areas of high use and environmental sensitivity. As technology and knowledge improves, areas will be refined or new areas may be identified.

Marine Scotland has published Regional Locational Guidance[8], under The Saltire Prize Programme, which identifies the five least sensitive areas for wave and tidal developments although development could occur elsewhere. The European Marine Energy Centre (EMEC) in Orkney is testing and monitoring the environmental and operational effects of new wave and tidal power generating systems in the sea, although it is likely that the effects of each system will need to be understood at each site.

The Scottish Government's second National Planning Framework[14] identifies the future development of a sub-sea electricity transmission super-grid, as well as sub-sea cables to Orkney, Shetland and the Outer Hebrides.

Future contribution to the economy

It is not possible to obtain individual sector data (GVA and jobs) for marine renewable energy from the ABI. However, other studies show that the potential is large although these cannot be attributed to specific sea areas yet. Submarine power cables are an integral part of the electricity supply chain and it is not appropriate to value these separately.

To investigate the required investment for infrastructure the Scottish Government, Highlands and Islands Enterprise and Scottish Enterprise have published a National Renewables Infrastructure Plan (NRIP)[6]. This aims to support the development of a globally competitive offshore renewables industry based in Scotland. It sets out the investment that port owners estimate is needed fully to develop 11 port sites for use for offshore wind manufacturing.

Beatrice Windfarm Demonstrator Project adjacent to Beatrice oil platforms

Pelamis test wave device

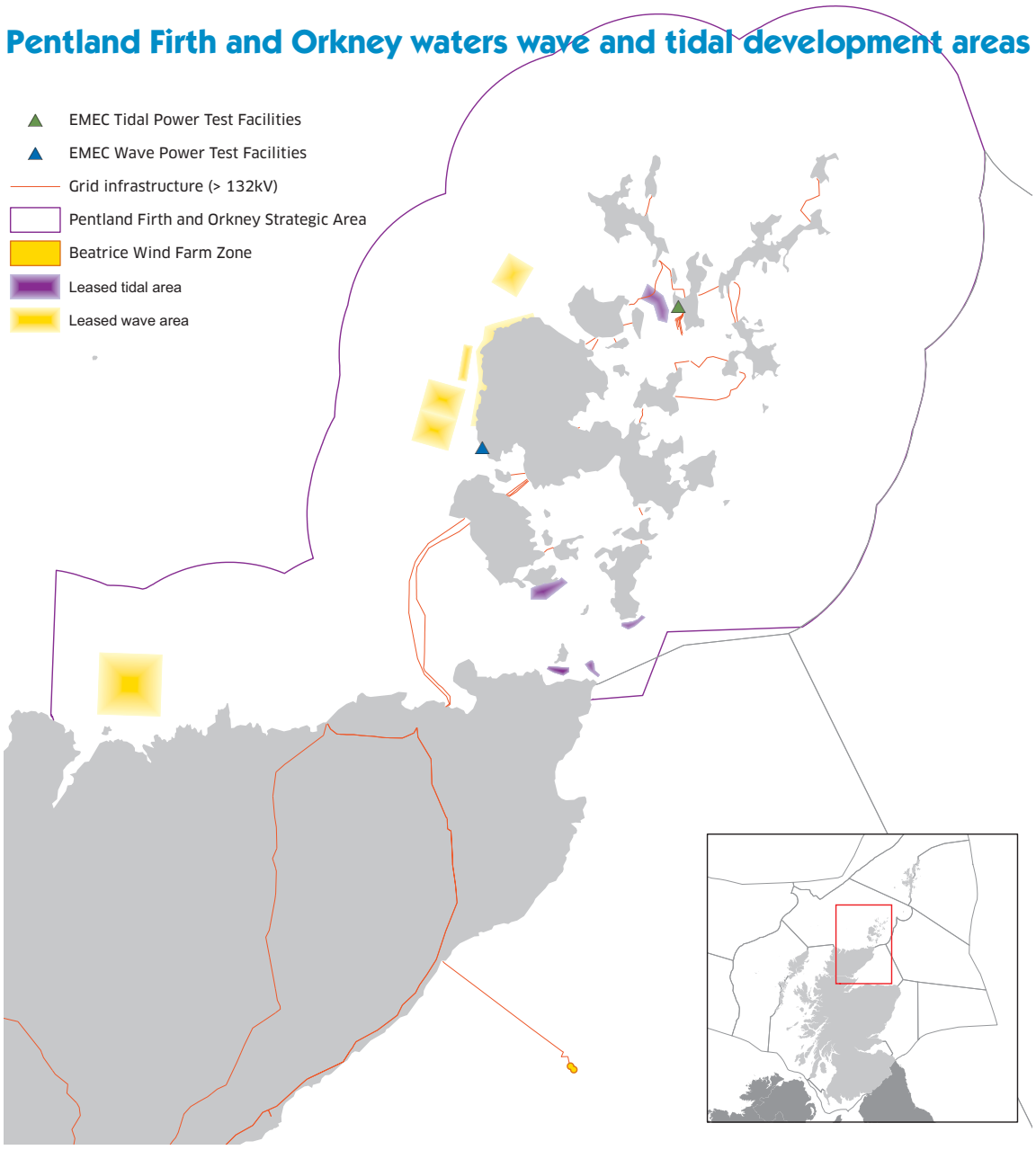
© Pelamis Wave Power Ltd

Capacities for Pentland Firth & Orkney Waters leasing round

Type	Capacity (MW)	Location
Wave	200	Costa Head
Wave	200	Brough Head
Wave	50	Marwick Head
Wave	50	West Orkney South
Wave	50	West Orkney Middle South
Wave	50	Armadale
Tidal	200	Westray South
Tidal	200	Cantick
Tidal	100	Brough Ness
Tidal	100	Duncansby
Tidal	400	Inner Sound

Source: The Crown Estate[9]

Pentland Firth and Orkney waters wave and tidal development areas



Predicted employment and investment opportunities for renewable energy development in Scotland

Year	Sector	Direct jobs	Indirect jobs	Potential investment
2010	Offshore wind[10]	463	894	
2010	Wave & tidal[11]	300	-	
2013/14	Ports and associated infrastructure[6]	5180		£223m
2020	Offshore wind[10]	28,000	20,000	£7.1bn
2020	Wave & tidal[11]	5,300	-	£2.5bn

Source: Scottish Renewables[6][10][11]

Installed and proposed test wave and tidal areas

Name	Status	Potential capacity (MW)	Location
Islay Wave Energy Plant[12] (land based 'Limpet' energy transformer)	Partly operational (since 2000)	0.61*	The Rhinns of Islay
Siadar Wave Energy Generation Scheme[12]	Under consideration	4*	North coast of Lewis
Fall of Warness Tidal Scheme (EMEC)[12]	Partly operational (since 2007)	4*	Eday, Orkney
Billia Croo Wave Test Site[13]	Partly operational (since 2004)	*	Western Edge, Orkney

Source: Offshore SEA[12] and EMEC[13]

Note: (*) no current output

Pentland Firth & Orkney waters

The Crown Estate has awarded 11 lease agreements to marine energy developers in the Pentland Firth and Orkney Waters. This is the world's first commercial leasing round for wave and tidal renewable energy generation. 11 agreements were signed for six wave and five tidal projects with a potential capacity to generate 1.6 GW of marine energy, sufficient capacity to power over one fifth of Scottish households. The capital investment required within the Pentland Firth and Orkney waters is estimated to be between £2-3 billion between 2010 and 2020. The Crown Estate has also estimated that this could build up to £300 million per annum of operation and maintenance service requirements by 2020.

The award of leases was an important milestone for the global sector and shows Scotland's position at the forefront of marine energy development. The Pentland Firth and Orkney waters projects will be an important contribution to UK and European renewable energy targets. Scottish Ministers are responsible for licensing and consenting the projects, utilising the new streamlined marine planning and consenting regime in the Marine (Scotland) Act 2010.

CARBON CAPTURE AND STORAGE

What, why and where?

Carbon capture and storage (CCS) is an approach being developed to manage emissions of CO_2. If it proves to be feasible and economically viable, CCS could capture approximately 80-90% of CO_2 emissions produced by fossil fuel power plants and heavy industry, transport them in liquid form by pipeline or ship, and subsequently inject them into geological formations deep underground where they are stored permanently below the earth's surface[1].

Scotland has vast potential for the geological storage of carbon under the seabed of the North Sea[1]. CO_2 capture technologies could be applied to coal or gas-fired power generation. However the technology involved uses energy, which means it will probably reduce the efficiency of the power plant. CCS represents a major technological challenge and there are cost uncertainties and regulatory issues that still need to be resolved.

The amount of CO_2 produced from industrial sources within Scotland is about a tenth of that of the UK as a whole. Scotland is likely to produce between 300 and 700M tonnes of CO_2 from 2010 to 2050. This, on average, is between 8 and 18M tonnes per year (Mt/year) depending on the proportions and types of power generation, it is expected this will be mitigated through the progressive fitting of CCS to power generation, so that it is decarbonised by 2030.

Geological reservoirs suitable for storage of CO_2 are classified according to whether they contain (or have contained) oil, gas, or saline water. Saline aquifers have the largest storage potential but there is uncertainty about the storage capacity of individual sites. A study has investigated more than 80 saline aquifers and 10 have been identified for potential use. These have a potential capability to store more than 200 years of Scotland's current CO_2 output from its major fixed industrial sources[1].

Contribution to the economy

As an emerging technology CCS's potential value is unknown. Economic value is not yet available from the ABI. However, a research study *Opportunities for CO_2 around Scotland* published in May 2009[1], showed that Scotland has the storage capacity, the natural resources, the technology and opportunity to develop a significant CCS industry. There is potential capacity to store industrial CO_2 emissions from Scotland for the next 200 years.

The size of the potential storage opportunities under the North Sea could also be of importance to the whole EU, and to growing economies such as China and India, as a future carbon store. Although the technology requires development, Scotland is well placed to take a lead in this subsequent commercialisation.

An estimate of 10,000 jobs in clean fossil fuels, CCS in Scotland and the export of technology and services has been made but a breakdown of the marine related jobs is not available[2]. Economic values cannot be attributed to sea areas for future CO_2 storage at this stage but there could be considerable benefits in the future, such as cost savings for organisations attempting to reduce emissions.

Pressures and impacts on Scotland's socio-economics

Positive
- Helps reach climate change targets
- Strengthens security of energy supply by enabling continued use of coal within the energy mix
- Contributes to economic growth by placing Scotland in a lead role in an emerging sector
- Uses existing pipelines and infrastructure no longer required for oil and gas

Negative
- None identified

Source: Based on CP2 PSEG Feeder Report s. 3.14.6[3]

Pressures and impacts on the marine environment

The nature of environmental impacts may depend on the extent to which it is possible to use existing pipelines, installations and wells.

Pressure theme: Climate change and physical pressures
Pressure: Salinity increase
Impact: Use of salt caverns involves the injection of water and the possibility that brine (salt in solution) could flow up the well, forming a dense layer across the seabed. This may be highly toxic to marine organisms.

Pressure theme: Pollution and other chemical pressures
Pressure: CO_2 leakage into subsurface microbial systems
Impact: Leakage could cause local acidification with a permanent effect on marine habitats if it persists. Leakage into sea could change pH and affect microbial ecosystems and plankton dynamics.

Pressure: Introduction of non-synthetic substances and compounds
Impact: Solvents used in CCS and any discharged waters may carry contaminants. Produced water and scale volumes should be much less than for oil and gas production.

Pressure theme: Habitat changes
Pressure: Smothering and siltation rate changes
Impact: Physical loss /damage from construction (e.g. dredging) and decommissioning activities which may also reduce water quality.

Source: Based on CP2 PSEG Feeder Report Table 3.100[3] (See also oil, gas, pipelines and gas storage section) and UK Marine Policy Statement[4]

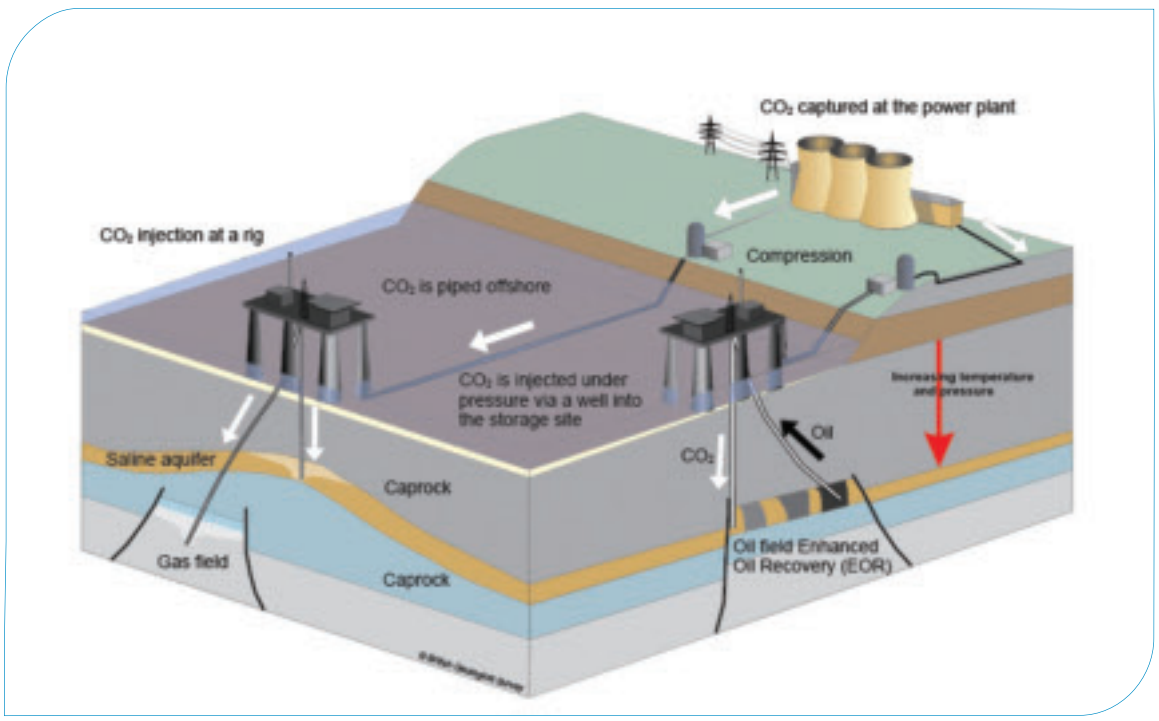
Forward look

The energy sector is important to economic growth. To meet Scotland's climate change target of 80% reduction in greenhouse gas emissions by 2050, the electricity generation sector will need to be decarbonised by 2030. CCS could have an important role to play along with a substantial increase in renewable energy. New coal-fired power stations will need to demonstrate CCS on at least 300MW (net) of capacity from the beginning of operation. Further new builds from 2020 would be expected to have full CCS.

There are three immediate challenges facing this emerging technology. The first is to demonstrate its economic and technical feasibility which, having been proven on a pilot scale at Longannet Power Station, will be taken forward through funding from the UK Government's CCS Demonstration Competition. The second is to ensure that the storage of CO_2 in geological formations is, in effect, permanent because the concept will not work if CO_2 leaks back to the surface even after many hundreds of years in storage. The third challenge is to develop the technology on a time scale that will allow it to capitalise on the oil and gas infrastructure within the North Sea in the form of pipelines and platforms before these are decommissioned and removed.

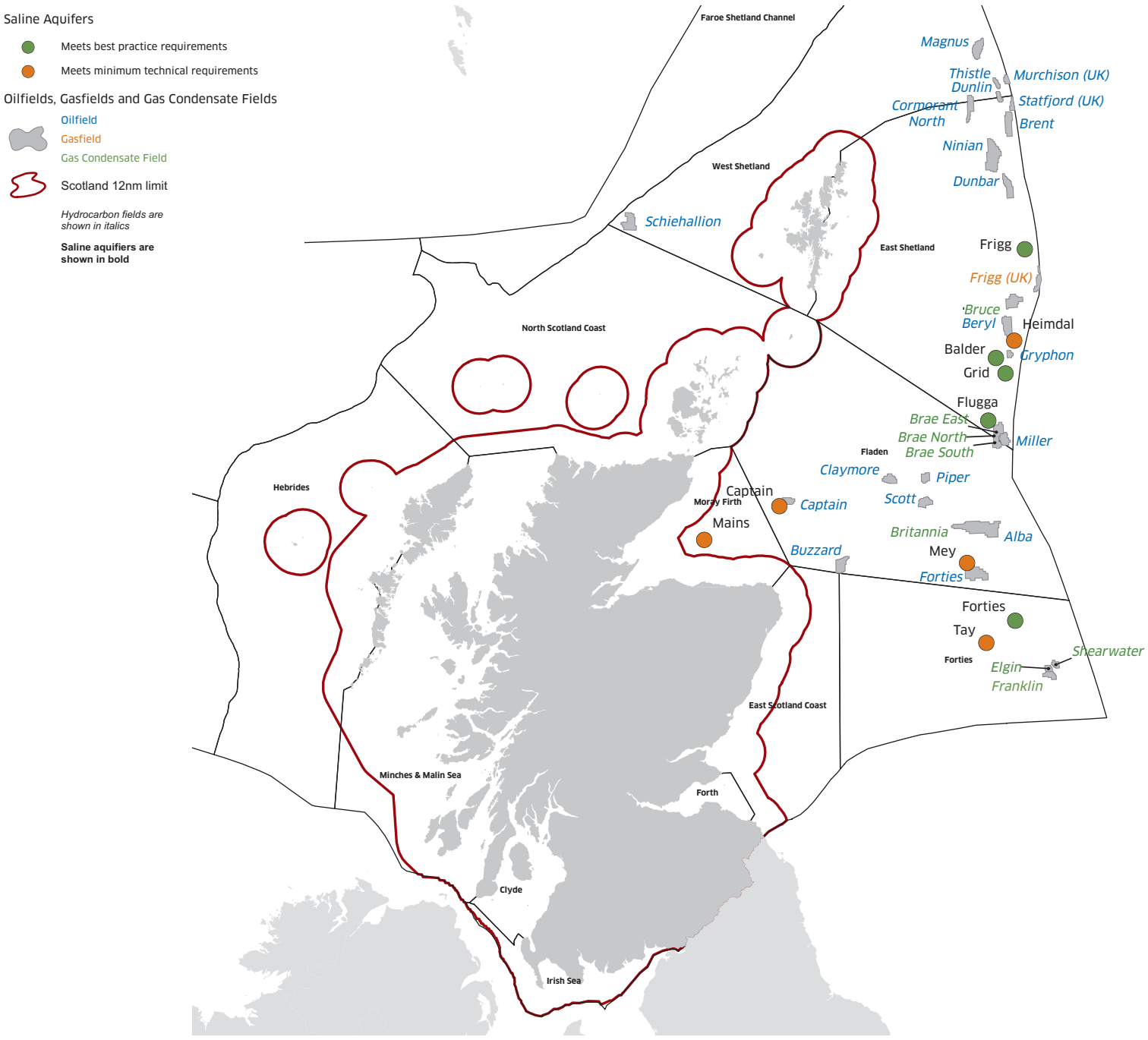
There are real economic opportunities in developing CO_2 storage hubs and pipeline networks for Europe. The Scottish Government published a *Carbon Capture and Storage roadmap* in March 2010. A follow up study to *Opportunities for CO_2 storage around Scotland* will be published in 2011.

The CCS process from power station to seabed



© NERC, British Geological Survey

Location of 29 hydrocarbon fields and 10 saline aquifers identified as potential CO_2 storage sites



Hydrocarbon fields assessed as having potential for CO_2 storage

Field name	Close of production (year)	Average water depth (m)	Estimated CO_2 storage (Mt)
Brae North GC	2015 +	99 +	52
Franklin GC HPHT	2030 –	93 +	62
Elgin GC HPHT	2030 –	93 +	63
Shearwater GC HPHT	2015 +	92 +	66
Brae East GC	2020 =	116 =	111
Britannia GC	2030 –	136 =	181
Bruce GC	2020 =	122 =	197
Frigg (UK) Gas Field	2008 +	112 =	171
Brent Oil Field	2015 +	140 =	456

\+ Parameter is technically or economically favourable
= Parameter is technically or economically borderline
– Parameter is technically or economically unfavourable

Source: 'Opportunities for CO_2 storage around Scotland'[1]

Note: GC = gas condensate field; HPHT = high pressure high temperature field

Saline aquifers assessed as having potential for CO_2 storage

Saline aquifer	CO_2 storage capacity (Mt CO_2) Assuming 0.2% storage efficiency	CO_2 storage capacity (Mt CO_2) Assuming 2% storage efficiency
Forties	886 +	8,856 +
Grid	785 +	7,847 +
Balder	347 +	3,465 +
Flugga	61 +	611 +
Frigg	58 +	575 +
Mey	1,655 =	16,549 =
Heimdal	618 =	6,177 =
Tay	133 =	1,328 =
Captain	36 =	363 =
Mains	24 =	241 =

Note: table shows range of potential storage capacities calculated from storage efficiencies derived from regional studies and regional modelling

OIL, GAS, PIPELINES AND GAS STORAGE

What, why and where?

Oil and gas exploration and exploitation has been a major activity in Scottish offshore waters since the late 1960s. Most oil and gas fields on the United Kingdom Continental Shelf (UKCS) are located in the North Sea. Only the Beatrice Field in the Moray Firth is close to shore and within the 12 nautical mile Territorial Sea limit. The remainder are much further offshore, within the 200 nautical mile limit. Since 1977 there has also been activity to the area west of Shetland following the discovery of the Clair Field.

There is extensive infrastructure associated with these oil and gas developments including seabed and platform-mounted production facilities and networks of pipelines bringing oil and gas ashore for processing. The shore-side reception facilities include the gas terminal at St Fergus in Aberdeenshire and the Sullom Voe oil terminal in Shetland, the largest oil terminal in Europe. There are three interconnector pipelines in the south west which take gas across the Irish Sea. There is no gas storage activity in Scottish waters, currently.

Oil and gas are Scotland's principal sources of fuel and power. They met more than 58% of primary energy demand in 2008 and are forecast still to meet up to 70% in 2020. Oil and gas provided 21% of the energy required for Scotland's electricity generation in 2009[1]. While oil and gas continue to make a significant contribution to electricity generation, the Scottish Government aims to meet 80% of electricity demand from renewable sources by 2020.

Producing platforms and pipeline lengths

Scottish sea area	Pipeline length (kms)	Number of platforms (2009)
Solway Firth, North Channel	91.75	
Clyde	9.45	
North Scotland Coast	150.79	2
West Shetland	1,565.86	8
East Shetland	3,087.22	32
Fladen	4,491.58	39
Moray Firth	84.61	3
East Scotland Coast	583.90	
Forties	2,755.87	19
Forth	33.87	
Total	**12,804.83**	**103**

Source: based on SeaZone and DEAL data

Aerial view of St Fergus terminal, Aberdeenshire

© Ken Taylor

Contribution to the economy

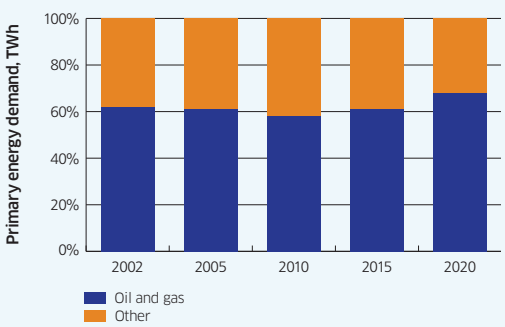
Responsibility for the oil and gas sector is reserved to the UK Government and all taxes go to the UK Treasury. The industry is the largest industrial contributor to the UK's GVA. Its' value to the UK economy was estimated to be £37 billion in 2008[3]. Based on the ABI figures, the GVA of the oil and gas sector in Scotland has been calculated as £16.033 billion in 2007 (at 2009 prices). The economic contribution of pipelines is included in the overall oil and gas value as they are part of the production process.

Offshore activity is supported by a highly specialised supply chain which supports a large downstream manufacturing sector. In 2008, supply chain exports were in the range of £4 billion to £5 billion.

Production from the UKCS has also contributed significantly to UK tax revenues, with approximately £283 billion (2010-11 prices) paid since production began in the 1960s. Research by the University of Aberdeen[4] suggests that since 1980-81, approximately 90% of North Sea production occurred in Scottish waters, raising approximately £242 billion in tax revenue for the UK Exchequer (at 2010-11 prices).

The oil and gas industry continues to be a major employer. Oil & Gas UK estimates that in 2010 some 196,000 Scottish based jobs were supported by the servicing of activity on the UKCS and in the export of oil and gas related goods and services. This includes not just direct employment but also wider effects on the supply chain.

% contribution of oil and gas to primary energy demand in Scotland (2002 – 2020)



Source: Scottish Energy Study[2]

Revenues and production from Scottish sea areas (2005-2008)

	2005	2006	2007	2008
Oil (£M)	£12,165,241,506	£13,388,862,880	£14,805,137,378	£20,137,179,023
NGL (£M)	£1,237,510,169	£1,528,300,660	£1,596,415,911	£1,672,490,269
Gas (£M)	£4,406,219,873	£5,580,566,901	£5,052,189,556	£6,934,189,380
Total (£M)	**£17,808,971,549**	**£20,497,730,443**	**£21,453,742,846**	**£28,743,858,673**
Oil (tonnage)	56,751,985	51,734,343	54,900,487	53,081,406
NGL (tonnage)	5,439,147	5,458,028	5,551,411	4,435,130
Gas (therms)	18,217,736,788	16,310,774,884	17,199,518,394	19,605,699,625

Source: DECC production figures split into Scottish sea areas

Scottish oil and gas employment

No. jobs	Type
110,000	Activity on the UK Continental Shelf
45,000	Export of goods and services
41,000	Supported by the economic activity induced by employees' spending.

Source: Oil & Gas UK 2010 Economic Report[5]

Tanker at Hound Point, Firth of Forth

© SNH

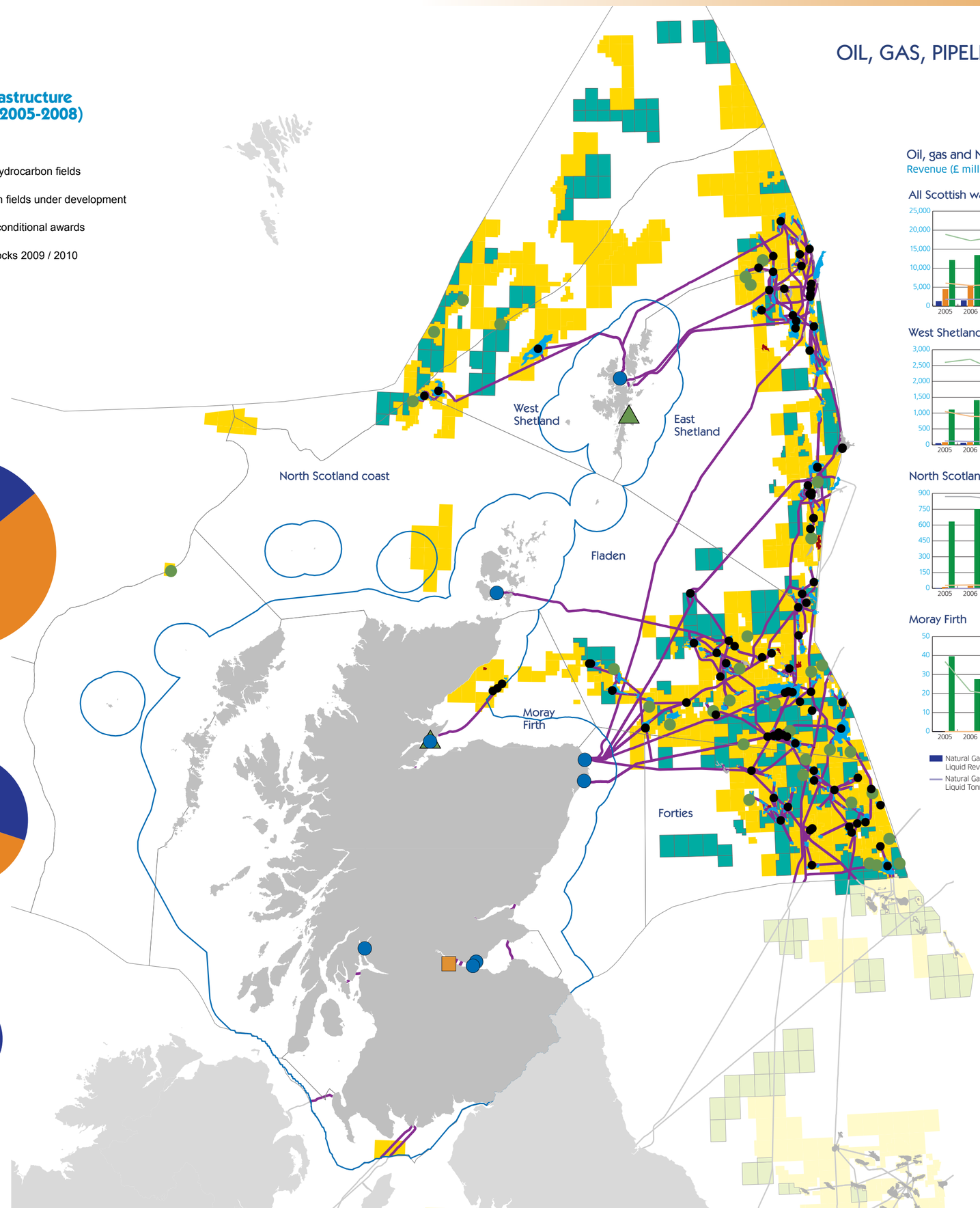
Supply vessel approaching a jack up rig

© Oil & Gas UK

Hydrocarbon fields, platforms, pipelines, coastal infrastructure and production (tonnage) and revenue per sea area (2005-2008)

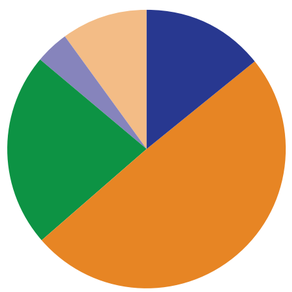
- Offshore platforms
- Significant discovery not yet developed
- Refinery
- Terminal
- Decommissioning yard
- Pipelines
- 12nm limit

- Producing hydrocarbon fields
- Hydrocarbon fields under development
- 26th round conditional awards
- Licensed blocks 2009 / 2010



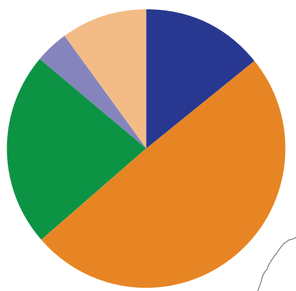
Share of production and revenue between sea areas (2008)

Oil Production



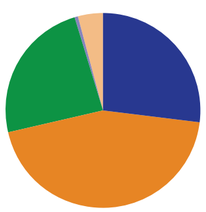
Total 53.1m tonnes

Oil Revenues



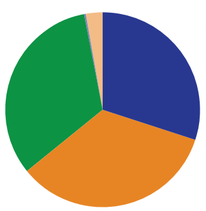
Total £20.1bn

Gas Production



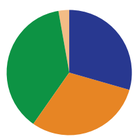
Total 19.6bn therms

Gas Revenues



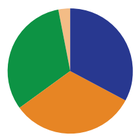
Total £6.9bn

NGL Production



Total 4.4m tonnes

NGL Revenues



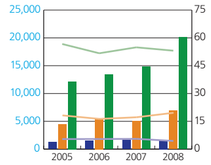
Total £1.6bn

East Shetland, Fladen, Forties, Moray Firth, North Scotland Coast, West Shetland

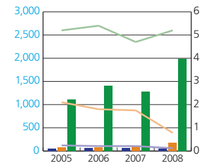
Oil, gas and NGL production and revenue (2005-2008)

Revenue (£ millions) Tonnage (millions) gas therms (billions)

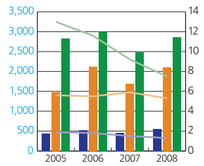
All Scottish waters



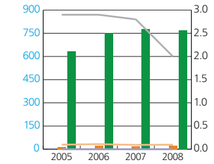
West Shetland



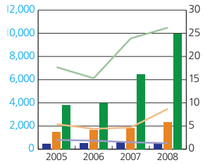
East Shetland



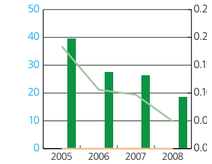
North Scotland coast



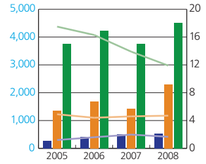
Fladen



Moray Firth



Forties



Natural Gas Liquid Revenues, Gas Revenues, Oil Revenues, Natural Gas Liquid Tonnages, Gas Therms (billions), Oil Tonnages

Pressures and impacts on the environment

Pressure theme: Pollution and other chemical pressures
Pressure: Oil contamination from accidental spills
Impact: Oil spills may contaminate sediments, water and marine fauna with resultant knock on effects on food chains.

Pressure: Introduction of non-synthetic substances and compounds
Impact: Pollution and other chemical changes. Increase in naturally occurring radio-active material (NORM).

Pressure: Chemical or oil contamination
Impact: Pollution and other chemical/oil discharges from accidental spills, exploration or production operations, including produced water, and from drill cutting piles.

Pressure theme: Other physical pressures
Pressure: Electromagnetic fields
Impact: Behavioural changes to electro-sensitive and magneto-sensitive species, for example, sharks and rays.

Pressure: Noise from seismic exploration activities
Impact: Potential impacts on noise sensitive species such as cetaceans and some fish species.

Pressure: Noise from drilling rigs, production facilities or vessels
Impact: Potential impacts on noise sensitive species (construction, operation and decommissioning).

Pressure: Noise and vibration
Impact: Burial of pipelines has the potential to cause noise and vibration causing avoidance of an area during installation.

Pressure theme: Habitat changes
Pressure: Smothering/siltation rate changes or abrasion
Impact: Physical loss/damage from construction and decommissioning activities, including laying of new pipelines.

Pressure: Physical presence of structures
Impact: Loss of species and habitat within the footprint of the structure. Colonisation of structures by organisms. Behavioural changes, death or injury of birds through interactions/ collisions with surface structures.

Pressure: Habitat damage
Impact: Loss of habitat and species in the 'footprint' of the pipeline. Physical disturbance of seabed substrata causing sediment re-suspension and increased turbidity.

Pressure: Habitat change
Impact: Seabed pipelines and vertical concrete and steel jacket structures provide a hard substratum for a variety of sessile epibenthic species to colonise and provide shelter for fish. Many of these changes may be beneficial.

Source: Based on CP2 PSEG FR table 3.68, 3.76 (See also table in Carbon capture and storage for related pressures and impacts)[5] and UK Marine Policy Statement[6]

Pressures and impacts on Scotland's socio-economics

Positive
- Employment, both offshore and onshore Transferable skills of use to other sectors, in particular the offshore renewable energy industry
- Exports of both crude hydrocarbons and refined products
- Research that can be transferred to other sectors
- Supply chain benefits to a global market
- Energy security from indigenous resource

Negative
- Impacts on other sea users for example:
  - Fisheries
  - Renewable energy developments
  - Telecommunications cables
  - Shipping

Source: Based on CP2 PSEG FR section 3.9.6 & 3.10.6[6] and UK Marine Policy Statement[7]

BP Clair production platform

© BP

Sullom Voe terminal, Shetland

© Shetland Islands Council (Ports and Harbours Operations)

Forward look

Scottish waters are a mature oil and gas province but there could be up to 24 billion barrels of oil still to be recovered from the UKCS[5], compared with 39.5 billion so far recovered. These are mainly in discoveries awaiting development, areas under current licence or regions where oil can be expected to be found, but has not yet been explored. Based on the average price of oil and gas forecast by the Energy Information Administration between 2009 and 2030, the wholesale gross value of these remaining reserves may be between £650 billion and £1.1 trillion.

A significant area with unexploited gas reserves lies to the west of Shetland. A new gas export pipeline from this area is currently being built to support the output from the Laggan and Tormore fields which are scheduled to start production in 2014. The amount of oil and gas imported into the UK is also likely to increase[5], requiring further gas pipeline import projects but none of the currently planned pipelines are in Scottish waters.

The longevity of the industry will depend on commodity prices, exploration and operational costs over the medium to long term and the ability to secure investment to fund new exploration and extraction activities.

Over the next thirty years decommissioning the offshore infrastructure will be a significant activity. Its timing will be influenced by a range of factors including long term trends in oil and gas prices, increased recovery of oil and gas from existing fields, future fiscal and regulatory regimes, reduction of decommissioning costs and technical innovations.

Oil & Gas UK estimates the decommissioning costs to be £2.4bn (west of Shetland), £8.8bn (northern North Sea) and £11.7bn (central North Sea – approx 90% of platforms are in Scottish waters)[4].

A potential new activity will be the use of depleted fields to store carbon dioxide captured onshore (see CCS section). When the geological conditions allow, depleted fields can be used as sites for the storage of gases generally (as a holding area) although these have not been developed in Scottish waters.

The skills and knowledge developed in the North Sea are still vital for the oil and gas sector but can also be transferred to other sectors such as renewable energy.

What, why, where?

Abstraction involves taking water, via pipe, from the sea, using it for an industrial process and then returning it to the sea. Most abstracted water is used for cooling. There is a limit placed on the temperature at which water can be returned. The majority of coastal water abstractions, by volume, are for power stations (98% or 20.2M m^3 per day). The remainder 2% or 0.4M m^3 per day are for use by the fish processing and manufacturing industries. Cooling water used by ships is not included here.

A large power station may abstract up to 200m^3/second or more during peak load for cooling from either coastal or estuarine waters. In most cases non-evaporative cooling is used where the steam turbine exhausts are cooled via the main condensers before the water is discharged back to the sea. Evaporative cooling is often used by power stations located inland which use cooling towers to recycle the water.

Other uses include the operation of fish farms and fish processing factories, manufacture of food, wood and chemical products, agriculture, marine animal sanctuaries and navigation abstractions to maintain water levels in impounded docks. Use is also made by the construction industry (for use as a raw material) and by the defence industry.

There are 20 abstractions from transitional waters (i.e. water from estuary or river mouths that is partly salty but substantially influenced by freshwater flows) and 36 abstractions from coastal waters (i.e. waters from highest tide to 3 nautical mile limit but not transitional water). Putting this in context, the Clyde and Forth sea areas daily abstractions represent about 0.002% and 0.00045% of the volumes of the sea areas. Abstractions from the other sea areas are significantly less than these. If industry could not abstract water from the sea, the alternative would be to abstract water from rivers or land based groundwaters, if available.

Cooling water discharge at Peterhead

© SEPA

Contribution to the economy

Water abstraction can create efficiency savings but does not generate a measurable economic value by itself. It is therefore not possible to measure its contribution in terms of GVA or employee jobs. However, it is clear that such abstractions are fundamental to sustaining certain key economic activities. The *Charting Progress 2* approach[1] calculates the UK annual market value of electricity sales from coastal power stations as between £5 billion and £10 billion and attributes £100-200 million to coastal station production based on a 2% energy efficiency advantage over air cooled power stations. As there are about 25% of UK stations in Scotland, a value of between £25M and £50M per annum has been estimated. There are many other industries which abstract water, and other assumptions, that have not been taken into account in the assessment of economic value. However, the valuation highlights that coastal waters have an economic value for industry, even if there is difficulty in calculating it. Given the assumptions, it would not be appropriate to split this figure between the sea areas.

Pressures and impacts on Scotland's socio-economics

Positive
- Power stations directly support the economy through the provision of electricity
- Recreational angling may benefit from wild sea bass feeding in the plume of discharged waters – anecdotal evidence from Torness power station

Negative
- Fish caught on intake grilles may reduce efficiency of industrial process
- Possible restrictions on certain uses of the sea near large intakes

Source: Based on CP2 PSEG section 3.17.6[2]

Fish trapped at Longannet

Fish entrapment is a commercially sensitive subject and there have been few studies on the matter. 'Fish Mortality by impingement on the cooling water intake screens of Britain's' largest direct-cooled power station', estimated that nearly 1.25 x 107 (95%c.i.: 7.10 x 106 – 2.21 x 107) fish weighing almost 74 t (43.0 – 127.8 t) were trapped at Longannet Power Station in 1999. Of these, the clupeids sprat and herring comprised 85%. However, inter-annual variation can be large. At nearby Kincardine the mass of dead fish increased from 10 t between June 1961 and November 1962 to 150 t in December 1962. A fish return system is being installed at Longannet to reduce mortality and return all fish (alive and dead) to the estuary to mitigate the impact on the estuarine ecosystem[5].

Pressures and impacts on the environment

Pressure theme: Climate change and physical pressures
Pressure: Thermal changes
Impact: Water returned at higher temperatures. Not considered to be a major threat in coastal waters due to rapid mixing in coastal waters, e.g. Longannet Power Station return channel is 1.7kms long so reducing thermal effect.

Pressure: Water flow changes (local)
Impact: Changes in water flow due to water intake pipes. Any scour effects are predicted to be localised. The main impact would be the removal of species.

Pressure theme: Pollution and other chemical pressures
Pressure: Pollution
Impact: Chlorine biocides and oxidants used to limit biofouling organisms. Studies have shown that fish livers may accumulate chlorinated by-products but harmful effects have not been discovered.[3]

Pressure theme: Biological pressures
Pressure: Species level pressures
Impact: Removal of species via cooling water inflows, number of fish impinged on the intake screens is proportional to the volume of water abstracted. Biological impingement and entrainment typically consists of fish, seaweeds, jellyfish, other macro-invertebrates and planktonic species. Considered less of a threat at coastal abstractions due to larger water body.

Source: Based on CP2 PSEG table 3.118[2] and UK Marine Policy Statement[4]

Cooling water intake at Cockenzie

© SEPA

Forward look

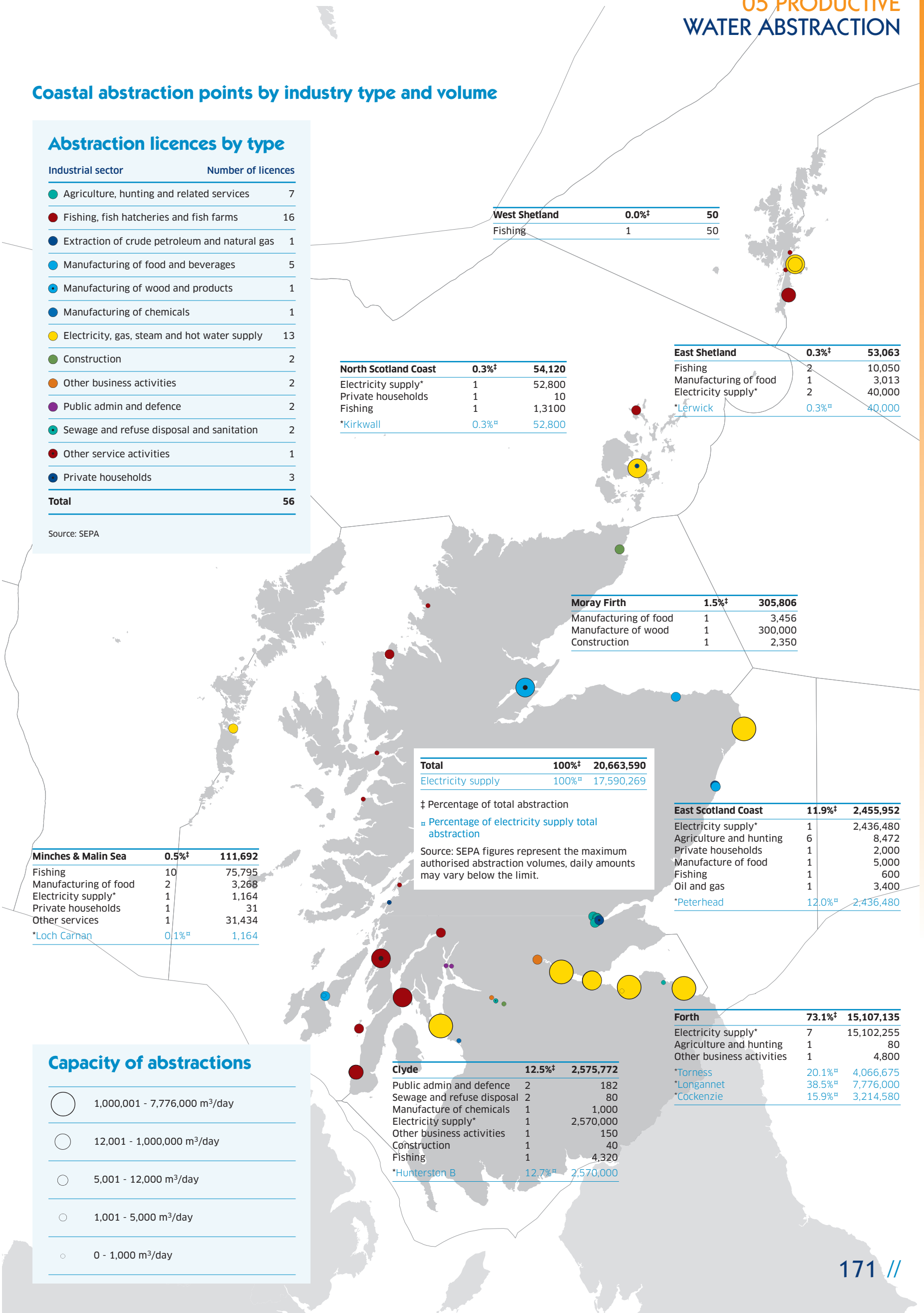
Water abstraction is generally important for industry and for economic growth but new development is led by the needs of industry and markets. Water abstraction is likely to continue at close to its current level and may increase in future. There is a strong possibility that electricity generation capacity will be built in future, so the need for abstraction for energy production is likely to continue even though the current emphasis is on renewable energy production. The Scottish Government's second National Planning Framework[6] identifies opportunities for generation at Longannet, Cockenzie, Boddam and Hunterston. Locations of future water intakes may need careful consideration, particularly if proposed for narrow estuaries that are important for protected habitats and species.

Coastal abstraction points by industry type and volume

Abstraction licences by type

Industrial sector	Number of licences
Agriculture, hunting and related services	7
Fishing, fish hatcheries and fish farms	16
Extraction of crude petroleum and natural gas	1
Manufacturing of food and beverages	5
Manufacturing of wood and products	1
Manufacturing of chemicals	1
Electricity, gas, steam and hot water supply	13
Construction	2
Other business activities	2
Public admin and defence	2
Sewage and refuse disposal and sanitation	2
Other service activities	1
Private households	3
Total	**56**

Source: SEPA



West Shetland	0.0%‡	50
Fishing	1	50

North Scotland Coast	0.3%‡	54,120
Electricity supply*	1	52,800
Private households	1	10
Fishing	1	1,3100
*Kirkwall	0.3%¤	52,800

East Shetland	0.3%‡	53,063
Fishing	2	10,050
Manufacturing of food	1	3,013
Electricity supply*	2	40,000
*Lerwick	0.3%¤	40,000

Moray Firth	1.5%‡	305,806
Manufacturing of food	1	3,456
Manufacture of wood	1	300,000
Construction	1	2,350

Total	100%‡	20,663,590
Electricity supply	100%¤	17,590,269

‡ Percentage of total abstraction

¤ Percentage of electricity supply total abstraction

Source: SEPA figures represent the maximum authorised abstraction volumes, daily amounts may vary below the limit.

Minches & Malin Sea	0.5%‡	111,692
Fishing	10	75,795
Manufacturing of food	2	3,268
Electricity supply*	1	1,164
Private households	1	31
Other services	1	31,434
*Loch Carnan	0.1%¤	1,164

East Scotland Coast	11.9%‡	2,455,952
Electricity supply*	1	2,436,480
Agriculture and hunting	6	8,472
Private households	1	2,000
Manufacture of food	1	5,000
Fishing	1	600
Oil and gas	1	3,400
*Peterhead	12.0%¤	2,436,480

Forth	73.1%‡	15,107,135
Electricity supply*	7	15,102,255
Agriculture and hunting	1	80
Other business activities	1	4,800
*Torness	20.1%¤	4,066,675
*Longannet	38.5%¤	7,776,000
*Cockenzie	15.9%¤	3,214,580

Clyde	12.5%‡	2,575,772
Public admin and defence	2	182
Sewage and refuse disposal	2	80
Manufacture of chemicals	1	1,000
Electricity supply*	1	2,570,000
Other business activities	1	150
Construction	1	40
Fishing	1	4,320
*Hunterston B	12.7%¤	2,570,000

Capacity of abstractions

- 1,000,001 - 7,776,000 m³/day
- 12,001 - 1,000,000 m³/day
- 5,001 - 12,000 m³/day
- 1,001 - 5,000 m³/day
- 0 - 1,000 m³/day

MARITIME TRANSPORT (PORTS AND SHIPPING)

What, why and where?

Ports and shipping provide for the transport of freight and passengers. This includes key international and coastal shipping routes including ferry services to the Scottish islands. A few ports specialise in specific cargos, for example, Sullom Voe for oil, and Glensanda for crushed stone. The majority are multi-purpose even if they are well known for one particular commodity, such as Peterhead for fish. Other ports may play an important role for a particular industry such as Aberdeen in supporting North Sea oil and now for the developing offshore renewable energy industry.

Cargo and passenger port traffic figures are published each year in Scottish Transport Statistics[1] and Department for Transport Maritime Statistics Compendium[2]. In 2009, 85.5Mt of cargo was handled through all Scottish ports, being reductions of 11.2% since 2008 and 21.4% since 2005. 98.4% of this was handled by the 16 major ports (96.0% by the top 11), with the Forth ports accounting for 43.6%.

In 2009, 10,048,738 passengers were carried on ferries (3.2% down since 2005), with 2,873,611 cars (1.5% up) and 213,936 commercial vehicles and buses (11.8% down)[1]. The busiest sea areas were Clyde and Solway Firth/North Channel (passengers 64% of overall traffic in Scotland, cars 59% and commercial vehicles 39%) followed by the Minches and Malin Sea (22%, 28% and 35%).

The movement of vessels is recorded by the Maritime and Coastguard Agency, Lloyds List Intelligence and others, such as individual ports. Data sets are not always comparable, with a different range of categories being used and certain types of ports or vessels, for example, fishing, recreational, local ferries, not featuring in all types of statistics.

Lloyds' data show that in 2009, there were 15,225 vessel arrivals at the main Scottish ports (excluding Cairnryan, Stranraer and Glensanda), a 3.9% fall since 2005. 82.2% of these were at 3 ports: Aberdeen (45.8%: 1.0% up since 2005), Forth ports (19.3%: 27.6% fall) and Lerwick (17.1%: 52.6% up). The 15,225 vessels represented 128.3Mt of shipping deadweight tonnage (13.6% fall since 2005) with the Forth ports (38.7%: 1.5% fall) and Aberdeen (17.7%:8.5% up) positions reversed due to the different nature of shipping: fewer but much larger vessels in the Forth.

Scotland has three major ship building yards: BAE Systems Surface Ships (Scotstoun/Govan), Babcock Marine Warships (Rosyth), Babcock Marine Clyde (Helensburgh) and a range of smaller yards.

Types and examples of Scottish ports

Port type	Number	Examples of ports (top 11, additional 5)[i]
Private or commercial company	63	Cairnryan, Ayr, Clyde (Ardrossan, Glasgow, Greenock, Hunterston), Glensanda, Dundee, Forth (Burntisland, Grangemouth, Granton, Inverkeithing, Leith, Methil, Rosyth)
Local authority owned	122	Stranraer, Orkney (Scapa Flow, Kirkwall, Stromness), Sullom Voe, Perth
Trust port	32	Lerwick, Cromarty Firth (Invergordon), Inverness, Peterhead, Aberdeen, Montrose
Ministry of Defence	2	HMNB Clyde, Coulport
Caledonian Maritime Assets Ltd and British Waterways	25	Terminals such as Oban, Brodick, Port Ellen, Kennacraig Ardrishaig

Source: Marine Scotland (table excludes many small slipways, jetties and harbours).

Note: (i) top 16 ports in Scottish Transport Statistics; top 11 are defined as regularly handling over 1Mt per year.

Ship-to-ship oil transfer operations 2005-2009

	Number of transfer operations					Oil tonnage				
Port and Scottish sea area	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Scapa Flow (north Scotland coast)	17	8	7	10	27	1,746,715	993,759	930,136	582,097	2,599,461
Sullom Voe (west Shetland)	3	1	0	1	5	284,702	137,948	0	59,394	298,395
Nigg (Moray Firth)	14	11	16	12	14	1,201,467	853,431	1,246,146	970,459	1,015,832
Total	34	20	23	23	46	3,232,884	1,985,138	2,176,282	1,611,950	3,913,688

Note – Scapa Flow hosted one LNG transfer of 56,827 tonnes in 2007.

Source: Marine Scotland

Contribution to the economy

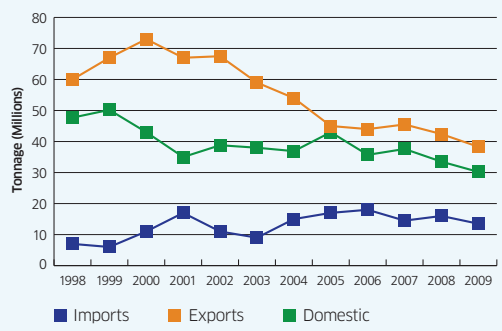
All Scotland's ports contribute to their local and regional economies as employers and by providing essential facilities for users such as the fishing industry and ferry operators. In many cases they also contribute to the national economy and economic growth.

From the ABI the GVA (2009 prices) and number of jobs for sea and coastal water transport and supporting activities was £432M and 4,700, and for building and repairing of ships and boats the equivalent GVA was £475M, with the number of jobs at 5,800, all in 2007. These values cannot be disaggregated to individual sea areas.

There are other sources of economic data. Oxford Economics reports for the Chamber of Shipping[3] have estimated that from a turnover of £9.5 billion the shipping industry contributes about £4.7bn GVA to the UK. A further report for the UK Major Ports Group[4] suggests that ports contribute around £7.7bn to UK GDP. Neither report presents a breakdown for Scottish shipping or ports. However, Scottish ports handle about 17% of UK trade by volume.

It was estimated (in 2006) that port activities account for around 18,000 jobs in Scotland[5].

Foreign (imports and exports) and domestic traffic (million tonnes) through major Scottish ports 1998-2009



Source Scottish Transport Statistics[1]

Note: Largest % of exports to Netherlands, USA, Germany, France. Imports from Norway, Russia.

Shipbuilding

Hull sections of two new aircraft carriers are currently being constructed at five UK sites (including the Clyde and at Rosyth). All vessels will be assembled at Rosyth. All six Daring class Type 45 destroyers are being built on the Clyde (some parts come from outside Scotland).

Source: Scottish Enterprise

International and domestic ferry routes

- Cross Region Northeast
- North Scotland Coast
- West and East Shetland
- Forth and East Scotland coast
- Solway Firth, North Channel and Clyde
- Minches and Malin Sea
- Additional Routes without Statistics

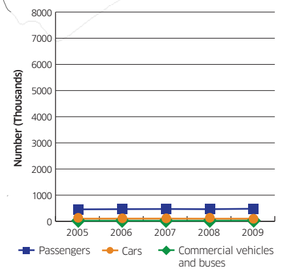
Isle of Lewis Ferry

© CalMac Ferries Ltd

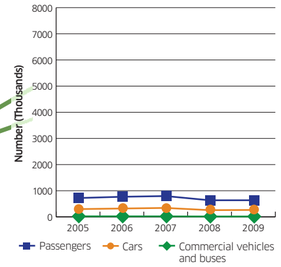
Port development in Loch Ryan, January 2011

© Stena Line

North Scotland Coast



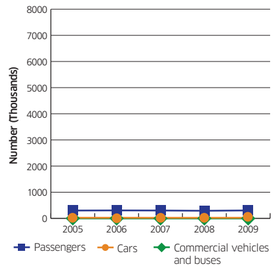
West and East Shetland



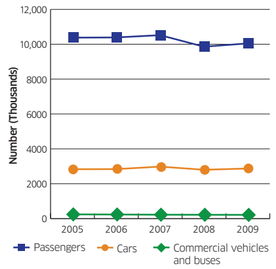
Ferry *Hamnavoe* passing the Old Man of Hoy, Orkney

© NorthLink Ferries Ltd

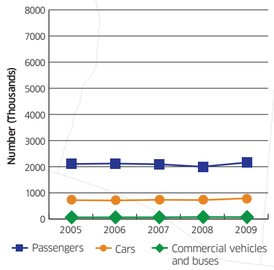
Northeast (cross region)



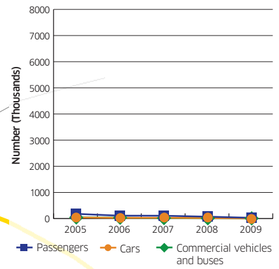
All Scotland



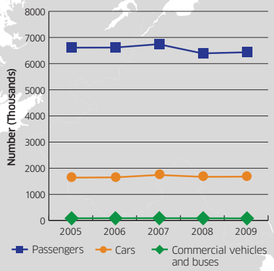
Minches and Malin Sea



Forth and East Scotland Coast



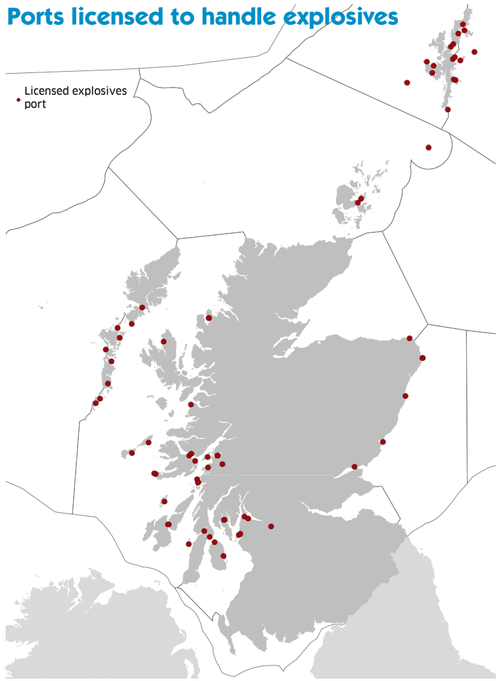
Solway Firth, North Channel and Clyde



Loch Ryan and Stranraer harbour looking north

© Stena Line

Ports licensed to handle explosives



Source: Health and Safety Executive

Pressures and impacts on Scotland's socio-economics

Positive

- Relative environmental benefits of moving goods by sea compared with other forms of transport
- Employment (direct and indirect)
- Providing skilled people for shore-based jobs, shipbuilding and repair
- Wider, societal benefits by enabling the movement of people, goods and services to and from island communities and providing access to education, healthcare and social activities
- Provision of infrastructure for offshore industries

Negative

- Ports use large areas of coastal land and often require hard coastal defences
- There is often competition for sea space e.g. coastal water shipping lanes near ports, where ships are restricted in their ability to move

Source: Based on CP2 PSEG Feeder Report section 3.7.6[6] and UK Marine Policy Statement[7]

Ship-to-ship oil transfer at Sullom Voe

© Shetland Islands Council, Ports and Harbours Operations

HMS *Dragon* launch on the Clyde

© BAE Systems Surface Ships

Peterhead

© Peterhead Port Authority

Greenhead base at Lerwick

© Lerwick Port Authority

Invergordon, Cromarty Firth

© Scotavia Images

Pressures and impacts on the environment

Pressure theme: Pollution and other chemical pressures
Pressure: Release of antifouling substances
Impact: Result in contamination of water and sediments and biological impacts on biota.

Pressure: Introduction of non-synthetic substances and compounds
Impact: Accidental release of oil and other hazardous substances, (either cargo or fuel, discharges from port facilities and shipbuilding/ship repair yards) may result in contamination of water and sediments and ecological impacts on wildlife, mariculture and tourism (see Chapter 3).

Pressure theme: Other physical pressures
Pressure: Noise Impacts
Impact: Noise from, for example, construction, ship movements, other operations.

Pressure: Noise from dredging
Impact: Potential impacts on noise sensitive species, such as cetaceans and some fish species.

Pressure: Noise impacts
Impact: Noise from construction, ship movements can cause disturbance of behaviour, damage to hearing, worst-case fatality.

Pressure: Litter
Impact: Litter poses a risk of harm/death to marine wildlife through ingestion of, or entanglement.

Pressure: Death or injury by collision
Impact: May kill or injure individuals e.g. cetaceans.

Pressure theme: Habitat changes
Pressure: Smothering by sediment plume
Impact: Results in habitat change and loss. May reduce water quality.

Pressure: Habitat damage, loss and/or abrasion
Impact: Infrastructure, e.g. ports, replaces natural coastline with man-made structures. Navigational dredging can damage marine benthic habitats. Vessel wash can damage habitats.

Pressure: Abrasion from passage of dredge head
Impact: Habitat change and damage.

Pressure: Removal of substratum
Impact: Changes to sediment characteristics. Significance depends upon habitat sensitivity, recovery rates and magnitude of impact.

Pressure: Disturbance of seabed
Impact: Can reduce sediment and water quality and change benthic fauna.

Pressure theme: Biological pressures
Pressure: Introduction or spread of non-native species
Impact: Non-native species may be carried in ballast water and as fouling organisms on hulls. These may cause habitat modification and competition with native species.

Pressure: Microbial pathogens
Impact: Release of sewage introduces pathogens and nutrients into the water, affecting water quality and potentially passing on diseases to humans through contact with contaminated water or consumption of contaminated shellfish.

Source: Based on CP2 PSEG Feeder Report tables 3.53 and 60[6] and UK Marine Policy Statement[7]

There are environmental benefits. Transport by water is a key part of the transport infrastructure, providing economies of scale and produces less CO_2 than comparable modes of transport per tonne-kilometre/per passenger-kilometre. Navigational dredging can provide material for beach replenishment schemes. Artificial shoreline infrastructure may provide habitat for colonisation.

MARITIME TRANSPORT (PORTS AND SHIPPING)

Traffic through Pentland Firth (2009)

Type of traffic	Dead Weight Tonnes	Dead weight % of all traffic	No. of vessels passing	No. of vessels passing % of all traffic	Average deadweight per vessel
All traffic	275,564,241	100%	7,955	100%	34,640
Traffic not stopping in UK	144,721,925	53%	3,888	49%	37,222
Traffic stopping at a UK port	130,842,316	47%	4,067	51%	32,171
Traffic starting or finishing at a Scottish port	74,520,400	27%	2,019	25%	36,909
Traffic starting and finishing at a Scottish port (domestic traffic)	8,300,648	3%	598	8%	13,880

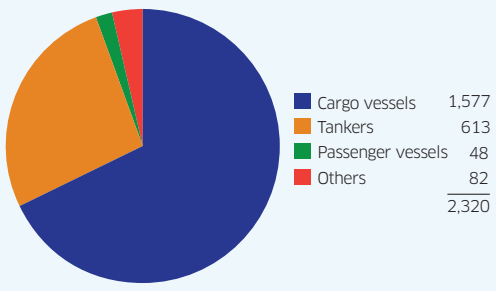
Source: Lloyds List Intelligence

Monthly vessel traffic through the Minches in 2009

	J	F	M	A	M	J	J	A	S	O	N	D	Total % over year	Number of vessels
Northbound (%)	52.1	59.3	50.0	54.8	52.7	50.5	54.8	55.0	54.9	55.9	50.8	49.1	53.4%	1,238
Southbound (%)	47.9	40.7	50.0	45.2	47.3	49.5	45.2	45.0	45.1	44.1	49.2	50.9	46.6%	1,082
% per month	7.0	7.6	8.7	9.1	9.5	8.4	8.6	8.1	8.9	8.8	8.0	7.4	100.0%	2,320

Source: MCA, Stornoway Maritime Rescue and Co-ordination Centre – excludes local ferry traffic and fishing vessels

Traffic through the Minches by type of vessel (2009)

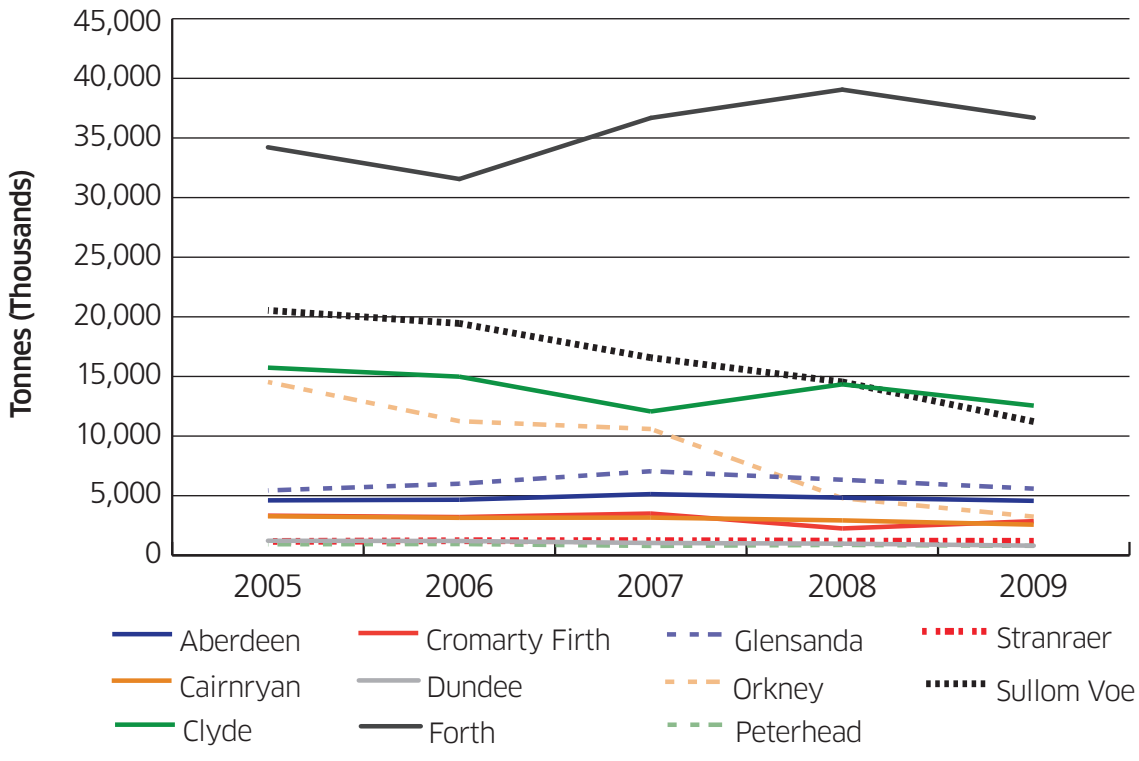


Source: MCA Stornoway MRCC

Ullapool

© Ullapool Harbour Trustees

All traffic for 11 major ports (2005-2009)



Source: DfT Maritime Statistics Compendum[2]

Pentland Firth and the Minches traffic

Shipping traffic through the Pentland Firth and the Minches is of particular interest since much of this does not stop at Scottish ports. However, not all traffic, for example fishing vessels and recreational craft, are counted.

Forward look

The Scottish Government has devolved responsibilities for ports, and has developed its own ports policy under the Scottish National Transport Strategy.[8] The sector is important to the economy and for economic growth. There are no robust data available on any future expansion, ports' policy follows a market driven approach to port development. 95% of goods moving in and out of the UK go by sea and there is little scope to use alternative means to do this. New ship technology and larger ships will tend to lower the costs per tonne-kilometre but may require ports with new or improved access to deeper water.

Forecasts for the UK have led the Department for Transport to conclude in its draft National Policy Statement for Ports covering England and Wales, that 'there is a compelling need for substantial additional port capacity over the next 20-30 years, to be met by a combination of development already consented, and development for which applications have yet to be received'.[9] There are substantial opportunities for some of this additional capacity to be met in Scotland. The Scottish Government's Second National Planning Framework (NPF2)[10] identifies development opportunities to accommodate container traffic along the Firth of Forth, Scapa Flow and Hunterston. It also supports improvements to facilities for ferry services at Loch Ryan. Existing and potential facilities at Cromarty Firth and Nigg Fabrication Yard are identified within the Framework as being of strategic importance.

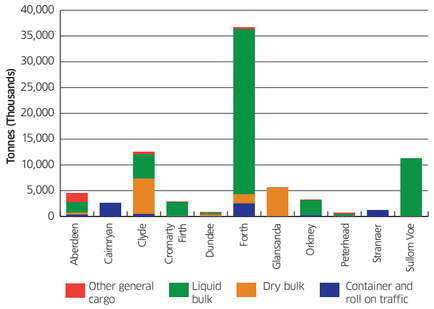
Ports and shipping will continue to play an important role in the movement of goods and people. As well as the environmental benefits of this, for example contributing towards climate change targets, the industry will have a significant role to play in making the most of opportunities offered by offshore renewable energy.

The importance of ports to provide infrastructure that can be adapted to meet the needs of the emerging offshore renewable energy industry is highlighted in the National Renewables Infrastructure Plan (N-RIP).[11] Gathering data on shipping movements and densities is needed for marine planning and offshore renewable energy deployments.

The Scottish Government is undertaking a comprehensive review of ferry provision throughout Scotland. The Review is considering how ferries should be funded and procured, on what basis fares should be set, what kind of services should be supported with public money and who should be responsible for providing these services. The Ferries Review will result in a long-term Plan for ferry services to 2022.

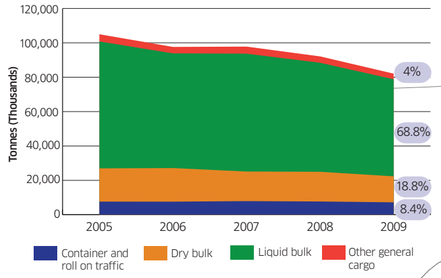
Scotland's ports, cargo tonnages (2005-2009) and identified navigation areas

Type of cargo at main Scottish ports in 2009



Source: DfT Maritime Statistics Compendium[2]

Traffic, by type, in major 11 ports (2005-2009)



Source: DfT Maritime Statistics Compendium[2]
Note: Liquid bulks includes gas, oil, oil products; Dry bulk includes ores, coal, grains.

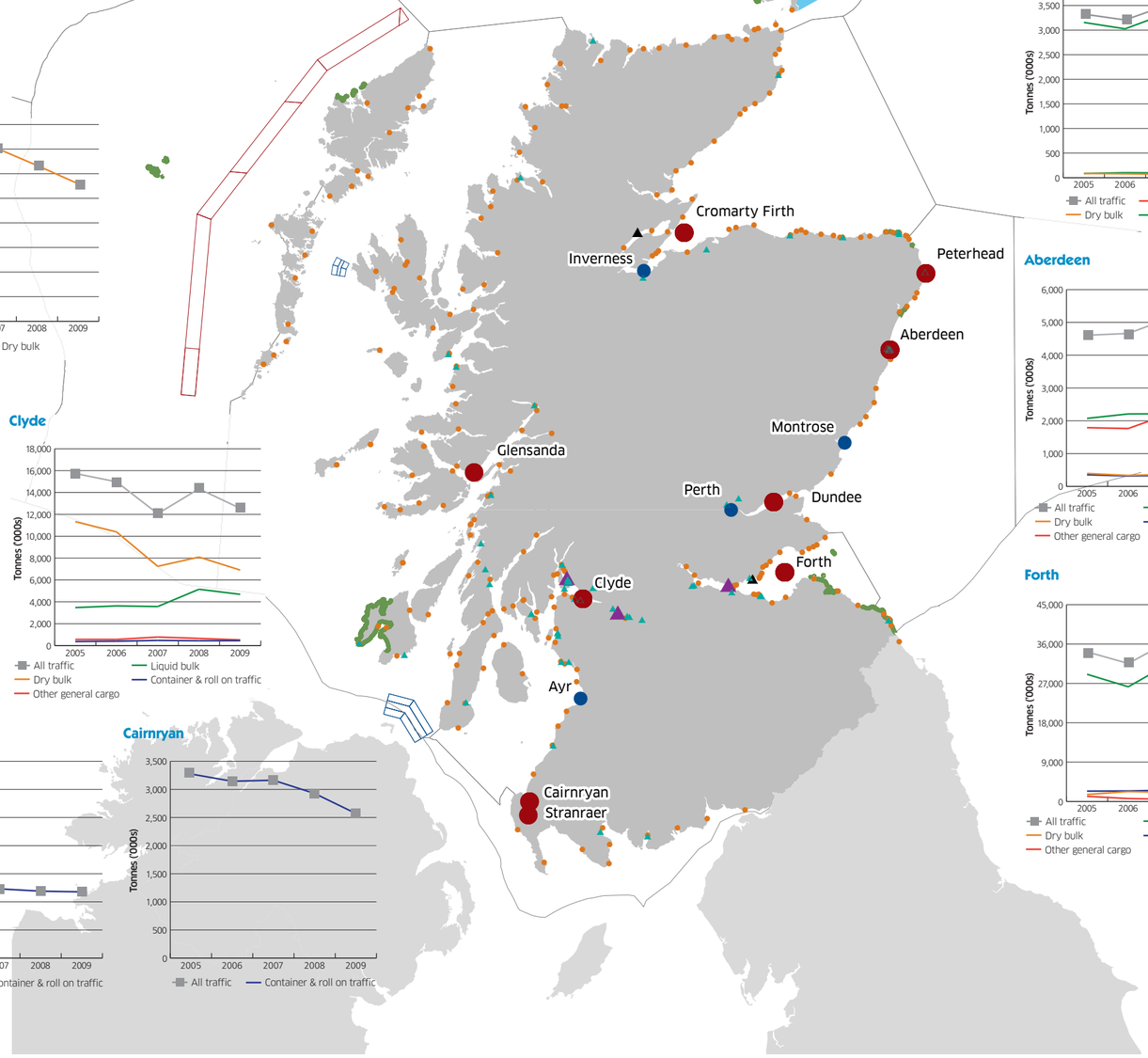
Glensanda quarry, Loch Linnhe

© Aggregate Industries UK Ltd

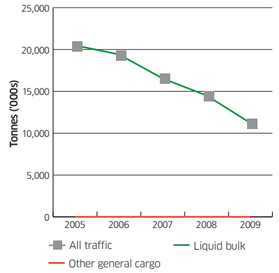
- Major Ports > 1 million tonnes per year
- Other major ports
- Other ports and harbours
- Shipbuilding and repair yards (1000+ employees)
- Offshore structures yards
- Boatbuilding / shipbuilding and repair yards
- Marine Environmental High Risk Areas
- Deep water route
- Traffic separation scheme
- Precautionary area
- Area to be avoided

Container vessels at Greenock, Clyde

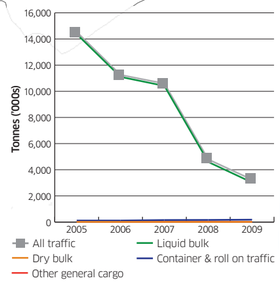
© Clyde Port PLC



Sullom Voe



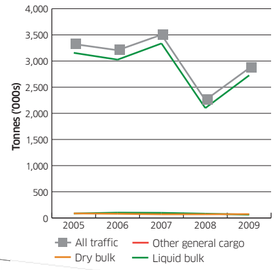
Orkney



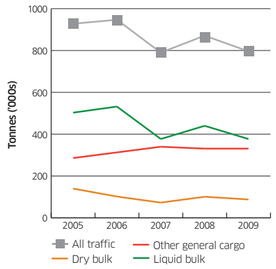
Lerwick South Harbour

© Lerwick Port Authority

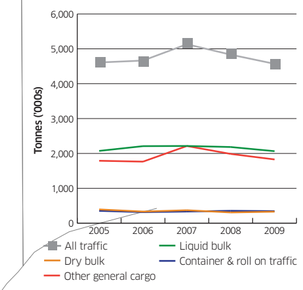
Cromarty Firth



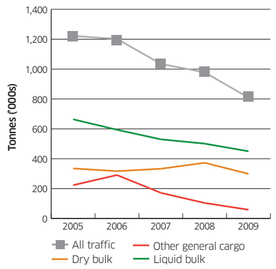
Peterhead



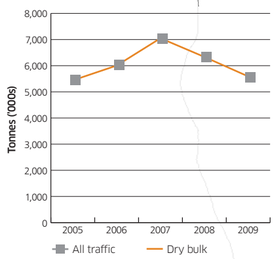
Aberdeen



Dundee

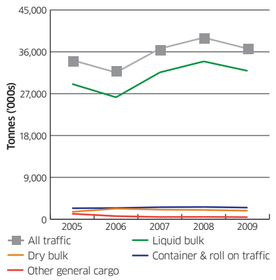


Glensanda



Clyde

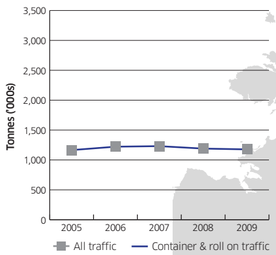
Forth



Grangemouth port and refinery in the Forth

© Forth Ports PLC

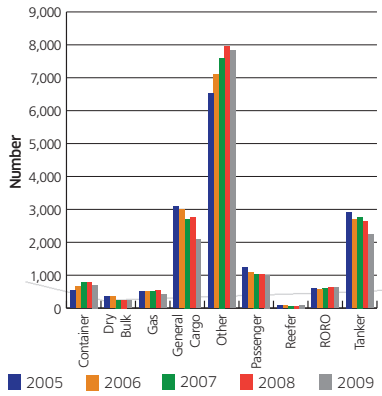
Stranraer



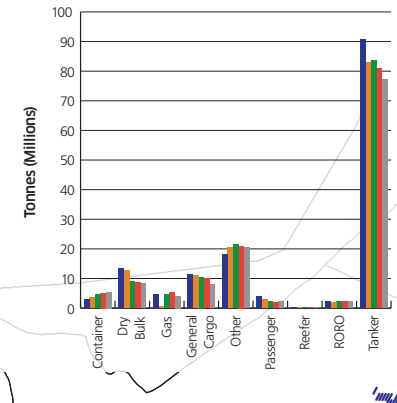
Cairnryan

Shipping traffic: number of vessels in a given area during 1st week January 2010 based on Maritime and Coastguard Agency AIS data

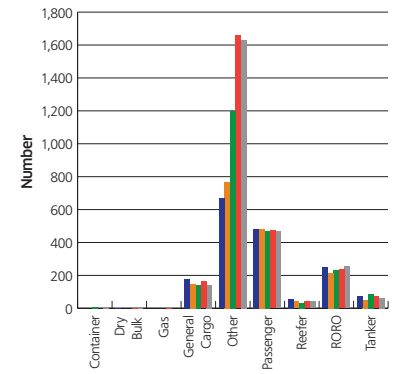
All Scotland – Vessel count trend



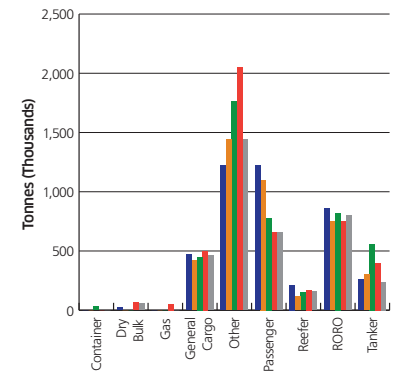
All Scotland – Deadweight trend



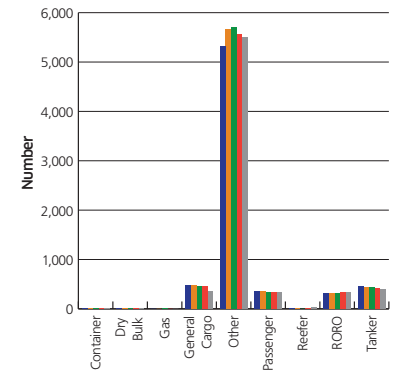
Lerwick – Vessel count trend



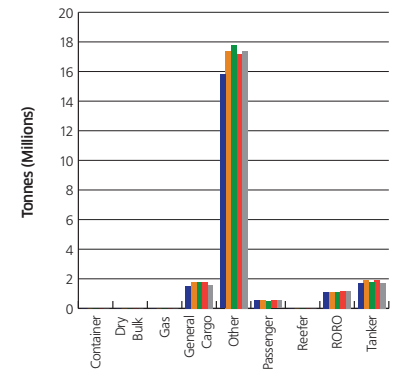
Lerwick – Deadweight trend



Aberdeen – Vessel count trend



Aberdeen – Deadweight trend



Lighthouses

Limits for traffic through the Pentland Firth table

Marine Environmental High Risk Areas

151+

51 - 150

21 - 50

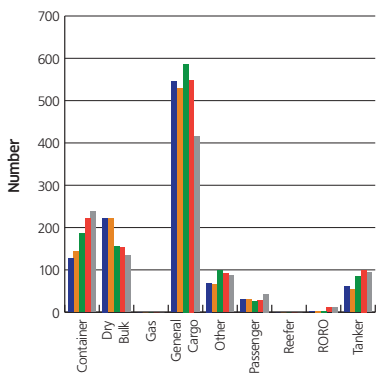
6 - 20

1 - 5

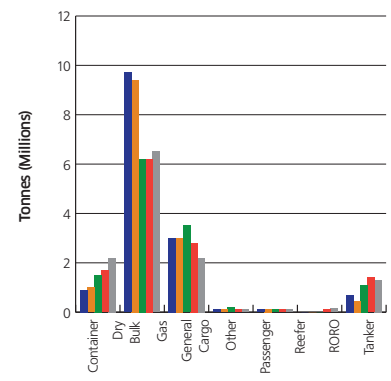
Map shows number of vessels using class A AIS (vessels >300t, AIS working and not switched off, position info is accurate) and excludes vessels <300t, fishing vessels, recreational craft, vessels carrying class B AIS.

All graph data from Lloyds List Intelligence. "Other" includes fishing vessels, offshore supply vessels, research vessels, tugs, warships, recreational craft, dredgers.

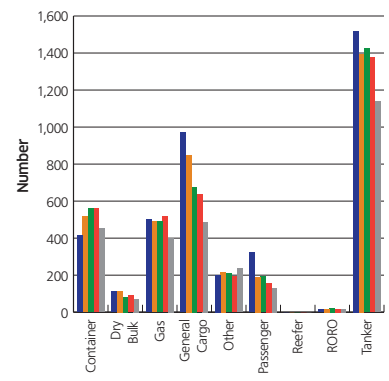
Clyde ports – Vessel count trend



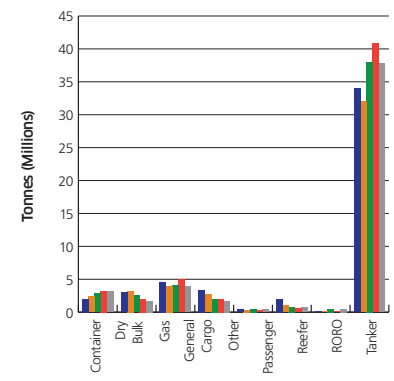
Clyde ports – Deadweight trend



Forth ports – Vessel count trend



Forth ports – Deadweight trend



WASTE DISPOSAL (DREDGE MATERIAL)

What, why and where?

Since the 1980s disposal at sea of radioactive wastes (stopped in 1982), industrial wastes (1992), colliery mine-stone (1995) and sewage sludge (1998) has been progressively reduced, and is now prohibited. Only the disposal of dredged material from ports, harbours and marinas is presently allowed. This activity is essential to maintain navigation in ports and harbours as well as for the development of new port facilities.

There are 66 open sites routinely used for disposal. A further 50 sites are either closed (not having been used for at least 10 years) or disused (not having been used for at least five years). Sea disposal sites are selected based on a number of criteria including their location in relation to amenities and other uses of the sea in the area, economic and operational feasibility and physical, chemical and biological characteristics.

The aim is to minimise seabed disposal and seek alternative, beneficial use by conducting a Best Practicable Environmental Option (BPEO) assessment and considering practicable alternative options before granting a licence. Dredged material may be re-used for land reclamation or beach nourishment where it is uncontaminated and physically suitable. Biologically inert or natural materials may also be considered for disposal. Fish waste (from land based processing) is sometimes disposed but this has not occurred in the period 2005-2009.

Dredged material is assessed for contaminants before disposal to reduce environmental impacts. In general, dredged material with contaminant levels below a certain threshold can be disposed of at sea. Above this, but below a higher threshold, may require further consideration and testing before a decision can be made, whilst above the higher threshold there is a presumption against disposal at sea.

During 2009 a total of 2,901,499 tonnes was dredged and deposited of a total of 5,743,882 tonnes that could be allowed under licence. The amount of disposal has remained relatively constant over time. Most disposal occurs in the sea areas adjacent to the highest densities of human population and industry. Tonnages deposited are recorded by Marine Scotland and reported to OSPAR[1].

Largest operation

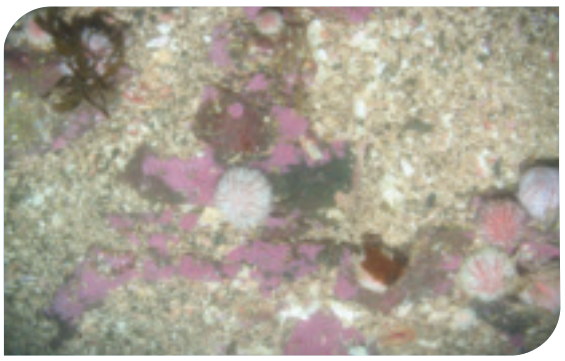
Grangemouth, the largest dredging operation, is licensed to dispose of 1.15M tonnes equivalent (Te) of sediment annually. The actual quantity disposed is nearer 1.05m Te, based on an average over 2005-2009.

Contribution to the economy

It is not possible to calculate the GVA and number of jobs associated with dredge spoil disposal from the ABI, as it does not separately assess this activity. However, it is clear that without dredging, supported by disposal at sea, access to ports and harbours would either be limited or face costly alternative means of disposal, which could affect the maritime transport sector's contribution to the economy. Dredged material can also save costs, when of suitable material, to replenish sand on beaches providing coastal protection and supporting recreational uses of the coastline, thus enhancing economic performance.

From 2005-2009, 112 one year licences were issued for the disposal of dredged material at sea. These were mainly for ports and generated a total licence revenue of £276,035.

Seabed within Wick sea disposal site



© Marine Scotland

Pressures and impacts on Scotland's socio-economics

Positive
- Employment
- Disposal allows industries/ports to function, alternative would be higher cost land disposal, requiring additional treatment/storage prior to use
- Suitable dredged material can be used for construction projects, beach replenishment/ nourishment and enhancement of flood defences or salt marsh

Negative
- Possible obstruction on seabed for other seabed users
- Possible sediment plumes could affect users requiring high water quality

Source: Based on CP2 PSEG Feeder Report section 3.16.6[2] and UK Marine Policy Statement[3]

Seabed within the Scrabster sea disposal site

© Marine Scotland

Pressures and impacts on the environment

Pressure theme: Climate change and physical pressures
Pressure: Hydrological changes
Impact: Possible changes to local tidal current and wave conditions (if area has limited dispersion).

Pressure theme: Pollution and other chemical pressures
Pressure: Disposed material contaminants
Impact: Dredged materials may contain a number of contaminants known to have an adverse effect on marine organisms. Dredging could lead to re-suspension of contaminants that have been sequestered through sedimentation.

Pressure theme: Habitat changes
Pressure: Introduction of waste at disposal point – changes in siltation rates
Impact: Disposed material spreads laterally and there will also be some short-term turbidity in the water column leading to changes in siltation rates at adjacent seabed locations.

Pressure: Introduction of waste at disposal point – changes to substrate and habitat type
Impact: Habitat damage and smothering causing possible burial of seabed flora and fauna.

Source: Based on CP2 PSEG Feeder Report Table 3.112[2] and UK Marine Policy Statement[3]

Marine Scotland undertakes a regular monitoring programme of sea disposal sites (see chapter 3) and records are maintained of the material deposited.

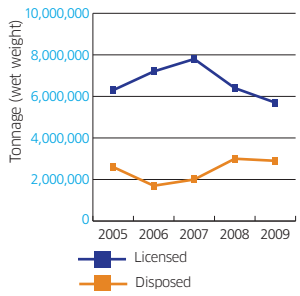
Forward look

Dredging is an essential activity to keep ports and harbours open and it is therefore economically important. Dredging and disposal will continue to be undertaken in order to maintain existing shipping channels and to improve, develop and protect the coastline. The Scottish Government's Second National Planning Framework[4] identifies future port developments at Grangemouth, Rosyth, Scapa Flow, Hunterston, Loch Ryan, Cromarty Firth and Nigg. Associated dredging may be required.

New dredging to re-open old ports or further develop existing ports could result in an increase in the amount of material dredged. As a consequence there may be a need to develop new sea disposal sites as existing sites reach capacity. However, the hydrodynamic nature of most disposal sites within Scottish waters results in the natural dispersion of finer material leaving only larger, bulkier material such as rocks and boulders. It is likely that there will be reduced contamination loads in dredge spoil because of greater control on leaching of contaminants from land-based industry and also from those using harbours.

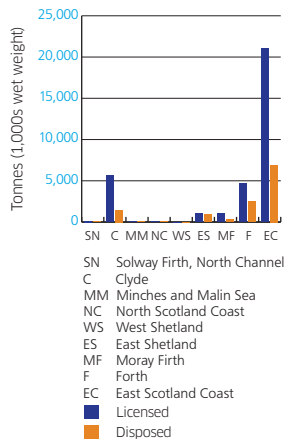
Locations and average tonnage disposed at open sites (2005 and 2009)

Total tonnage (wet weight) of dredged material licensed and actual disposal (2005-2009)



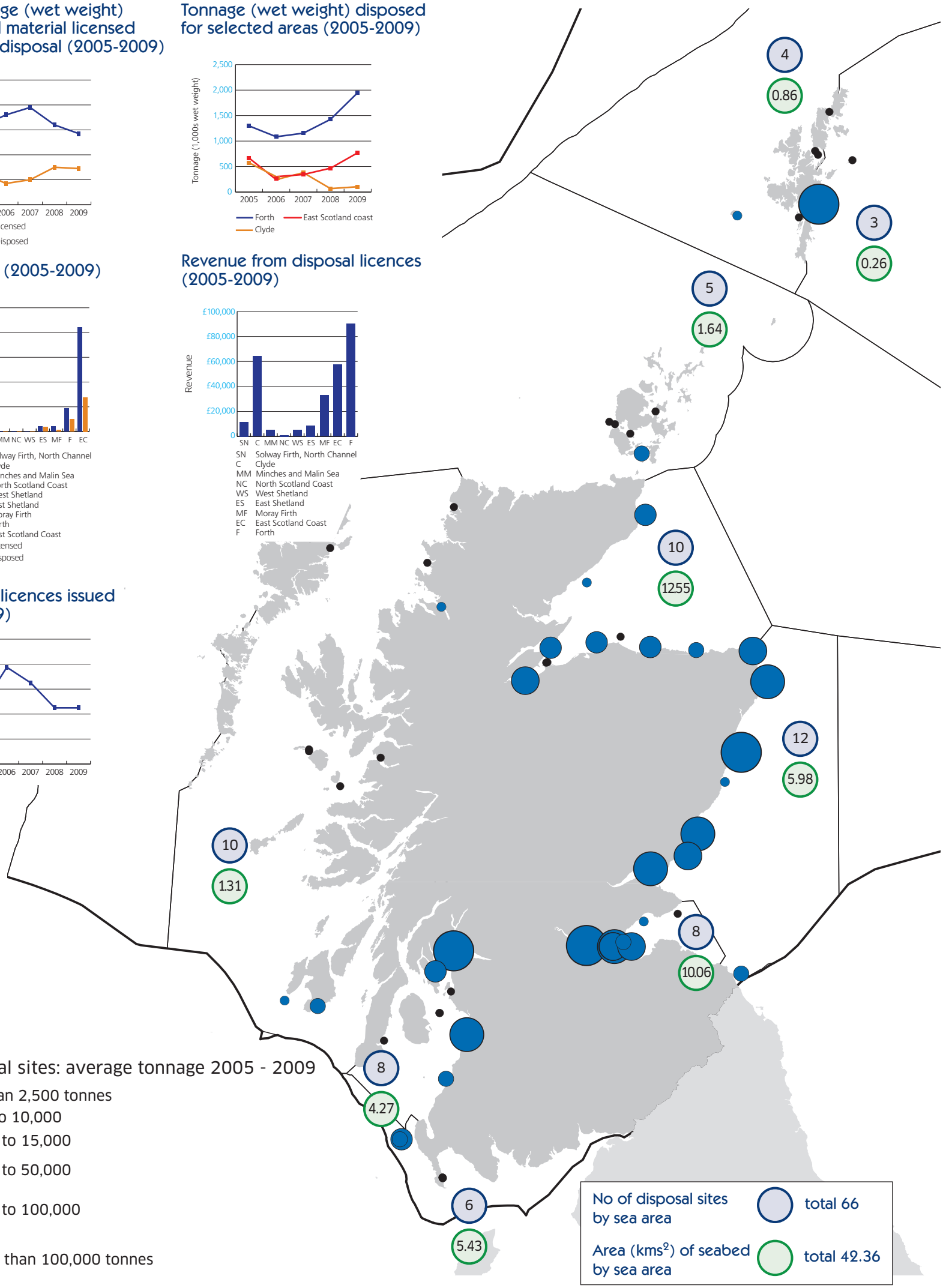
Tonnage (wet weight) disposed for selected areas (2005-2009)

By sea area (2005-2009)



Revenue from disposal licences (2005-2009)

Number of licences issued (2005-2009)



WASTE DISPOSAL (WASTE WATER TREATMENT AND INDUSTRIAL OUTFALLS)

What, why and where?

Waste water treatment is designed to process waste water whilst protecting the environment and maintaining public health. Outfalls to the marine environment fall into three categories. Outfalls from waste water treatment (WWT) plants which process waste water from the mains sewerage system; industrial sites which take waste from manufacturing plants; and some private domestic sources. These categories of outfall also discharge to the riverine freshwater environment which eventually reach the sea.

All sewerage systems that also collect rainwater (combined sewers) need overflow outlets (combined sewer overflows) that deal with the extra water collected during some rainstorms. Without these safety valves there would be a flooding risk at both the sewerage works and in other properties. Sewage in these overflow discharges is diluted with significant amounts of rainwater.

Treatment

There are four types of treatment undertaken at waste water treatment plants:

Preliminary treatment is the first stage of the process and involves the removal of coarse solids and large materials.

Primary treatment is a physical and/or chemical process involving settlement of suspended solids.

Secondary treatment is a process generally involving biological treatment either with secondary settlement or another process. Secondary treatment is designed to reduce the suspended solids and oxygen demand. It also reduces the bacterial content of sewage.

Tertiary treatment is the final stage of the process and can include filtration, removal of nutrients such as phosphorous and nitrogen, and disinfection, for example by UV light.

The Urban Waste Water Treatment Directive 1991 sets out treatment levels for waste water based on the population equivalent of the plant catchment and the sensitivity of the water receiving the discharges.

WWT plants and outfalls are found all around the coastline near villages, towns and cities. Those with the larger capacity and higher treatment levels being concentrated in the major firths, near large cities or near sensitive receiving waters.

Scottish Water provides sewerage services to the majority of households in Scotland, although some households have private discharges. Data on private discharges such as septic tanks are not included in this Atlas.

Industrial effluent discharges are licensed if the volume of effluent is >10m^3/day and has a population equivalent >15 and are subject to control placed on the amount and nature of the discharge. SEPA regulates such outfall discharges through The Water Environment (Controlled Activities) (Scotland) Regulations 2005 (CAR Regulations).

Details of substances recorded in the seas, from both waste water and industrial outfalls are in Chapter 3.

Numbers of outfalls discharging at the coast

Sea area	No. of industrial outfalls	No. of WWT outfalls	Total
Solway Firth, North Channel	8	24	32
Clyde	26	61	87
Minches and Malin Sea	12	86	98
Hebrides		25	25
North Scotland Coast	4	26	30
West Shetland	2	33	35
East Shetland	6	37	43
Moray Firth	9	39	48
East Scotland Coast	16	20	36
Forth	29	33	62
Total	**112**	**384**	**496**

Source: SEPA SPRI database[1]

Types of treatment per sea area for waste water treatment

Sea area	Total WWT outfalls	preliminary	primary	secondary	tertiary
Solway Firth, North Channel	24	1	15	8	
Clyde	61	2	44	15	
Minches and Malin Sea	86		72	13	1
Hebrides	25		23	2	
North Scotland Coast	26		21	5	
West Shetland	33		33		
East Shetland	37		36	1	
Moray Firth	39	2	14	15	8
East Scotland Coast	20	3	3	12	2
Forth	33	5	9	16	3
Totals	**384**	**13**	**270**	**87**	**14**

Source: SEPA

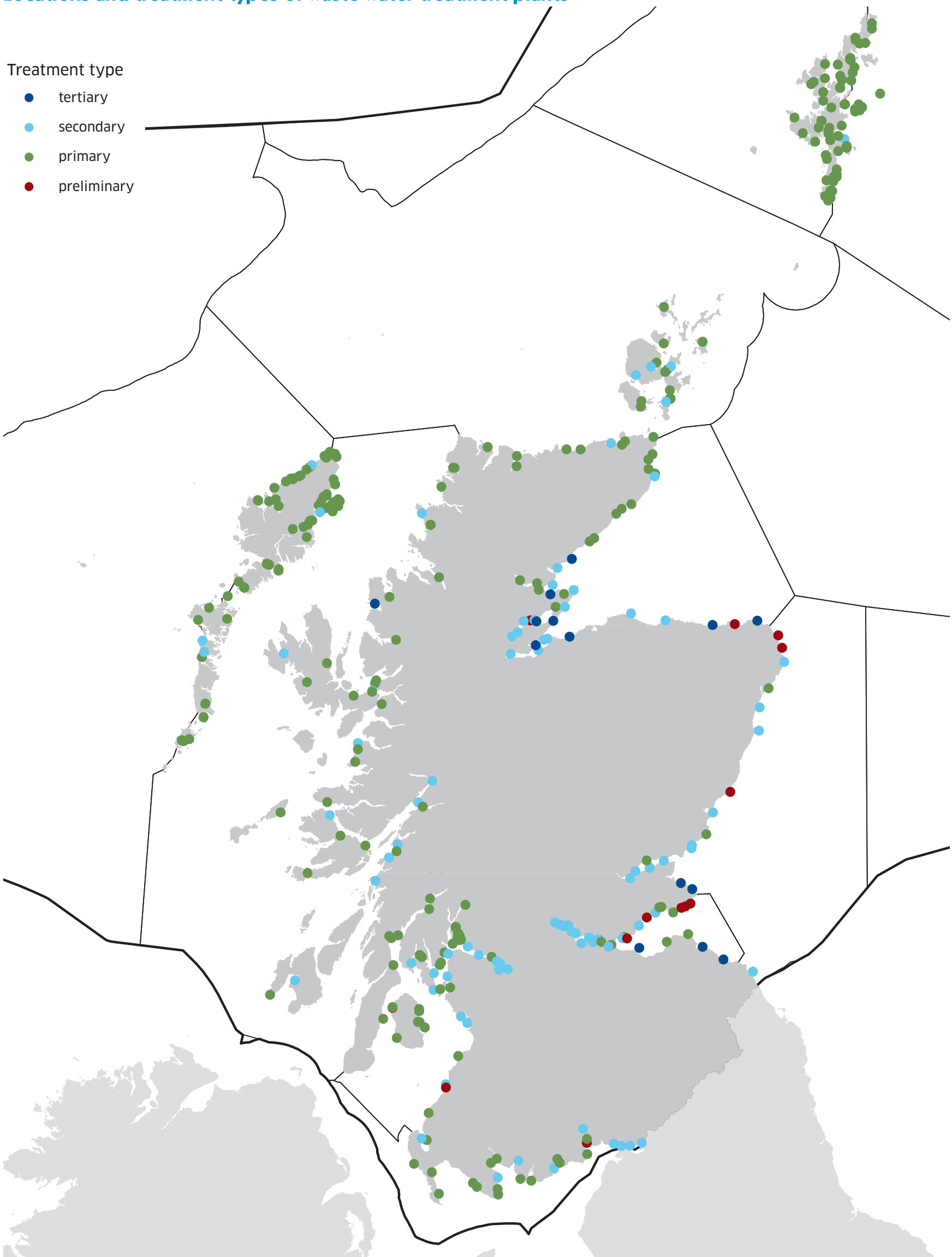
Volumes of outfalls per sea area for waste water treatment

Sea area	Total WWT outfalls	Volumes per day							
		0 to 5m^3	> 5 to 20m^3	> 20 to 100m^3	> 100 to 1000m^3	> 1,000 to 10,000m^3	> 10,000 to 50,000m^3	> 50,000 to 150,000m^3	> 150,000m^3
Solway Firth, North Channel	24			2	11	8	3		
Clyde	61		9	16	21	6	5	1	3
Minches and Malin Sea	86	2	8	44	24	7	1		
Hebrides	25	1	2	15	7				
North Scotland Coast	26	1	3	9	11		2		
West Shetland	33	1	15	13	4				
East Shetland	37	3	9	21	3	1			
Moray Firth	39		1	7	10	14	6	1	
East Scotland Coast	20			2	7	4	5		2
Forth	33				4	17	6	4	2
Totals	**384**	**8**	**47**	**129**	**102**	**57**	**28**	**6**	**7**

Source: SEPA

WASTE DISPOSAL (WASTE WATER TREATMENT AND INDUSTRIAL OUTFALLS)

Locations and treatment types of waste water treatment plants



WASTE DISPOSAL (WASTE WATER TREATMENT AND INDUSTRIAL OUTFALLS)

Contribution to the economy

The disposal of waste water at sea is an ecosystem service, creating the benefit of costs saved compared to alternative means of disposal. The value of this benefit cannot be calculated with certainty. In economic terms, waste water treatment and industrial outfalls do not generate a measurable output and their contribution can therefore not be measured, from ABI data, in terms of GVA or employee jobs provided.

It has been estimated that £5.83M of SEPA's income is generated by licences issued for disposal in coastal waters[2]. Between 2003/04 and 2008/09, Scottish Water invested £292M in activity, including new waste water treatment plants, to comply with the Urban Waste Water Treatment Directive requirement for all urban areas to have appropriate waste water treatment collection systems by 2005. During the same period a further £41M was invested to improve treatment facilities to meet the requirements of the Bathing Waters Directive.

Pressures and impacts on Scotland's socio-economics

Positive
- Allows industries to function by providing a service
- Employment
- Provides clean seas for other activities e.g. bathing, aquaculture, public health
- Reduces risk of flooding
- Provision of infrastructure for waste water collection

Negative
- Potential pollution especially if systems fail
- Possible obstruction on seabed
- Local nutrient enrichment affecting fisheries and other uses of coastal waters
- Release of pathogens including some that can have adverse health consequences for marine wildlife and for human health.

Source: Based on CP2 PSEG Feeder Report section 3.16.6[2] and UK Marine Policy Statement[3]

Pressures and impacts on the environment

Pressure theme: Pollution and other chemical pressures
Pressure: Hazardous substances
Impact: Risk of pollution, reduced water and sediment quality. Possible mortality of organisms from organic, metal and radioactive contaminants, from industrial discharges.

Pressure: Addition of nutrients e.g. nitrogen, phosphates and derivatives
Impact: Risk of eutrophication, potentially resulting in changes in the species composition of phytoplankton communities, toxin producing and harmful algal blooms. Possible loss of submerged vegetation through shading, development of hypoxic conditions due to decomposition of excess plant biomass, changes in benthic community structure due to hypoxia or toxic algae, fatalities of fauna due to oxygen deficiencies.

Pressure: Addition of organic matter
Impact: Removal of oxygen from the water column and deposition of organic matter on the seabed leading to fatalities of fauna due to oxygen deficiencies and changes in benthic community structure.

Pressure theme: Other physical pressures
Pressure: Litter in wastewater
Impact: Risk of harm to wildlife through ingestion or entanglement.

Pressure theme: Biological pressures
Pressure: Addition of faecal material
Impact: Pathogens (bacteria, viruses or parasites) may cause illness/infection if ingested through recreational water use or shellfish consumption.

Source: CP2 PSEG Feeder Report table 3.112[2]

Chapter 3 reports on the impacts of the discharges on the marine environment.

Lerwick waste water treatment plant (Shetland)

© Scottish Water

Forward look

Scottish Water has been set objectives for 2010-2015. Relevant to the marine environment these include improving the quality of wastewater treatment works discharges to ensure compliance with the environmental standards set out in all appropriate directives. There is also a requirement to plan for the provision of new strategic capacity to meet the needs of all new housing development until 2020. Work is ongoing to identify what this means for new treatment works and outfalls at the coast. However, there are requirements in various directives to ensure minimal impact and a sustainable co-existence with other existing marine activities such as aquaculture, fishing and bathing.

Seafield, Edinburgh waste water treatment works

© Aerial Photography Solutions

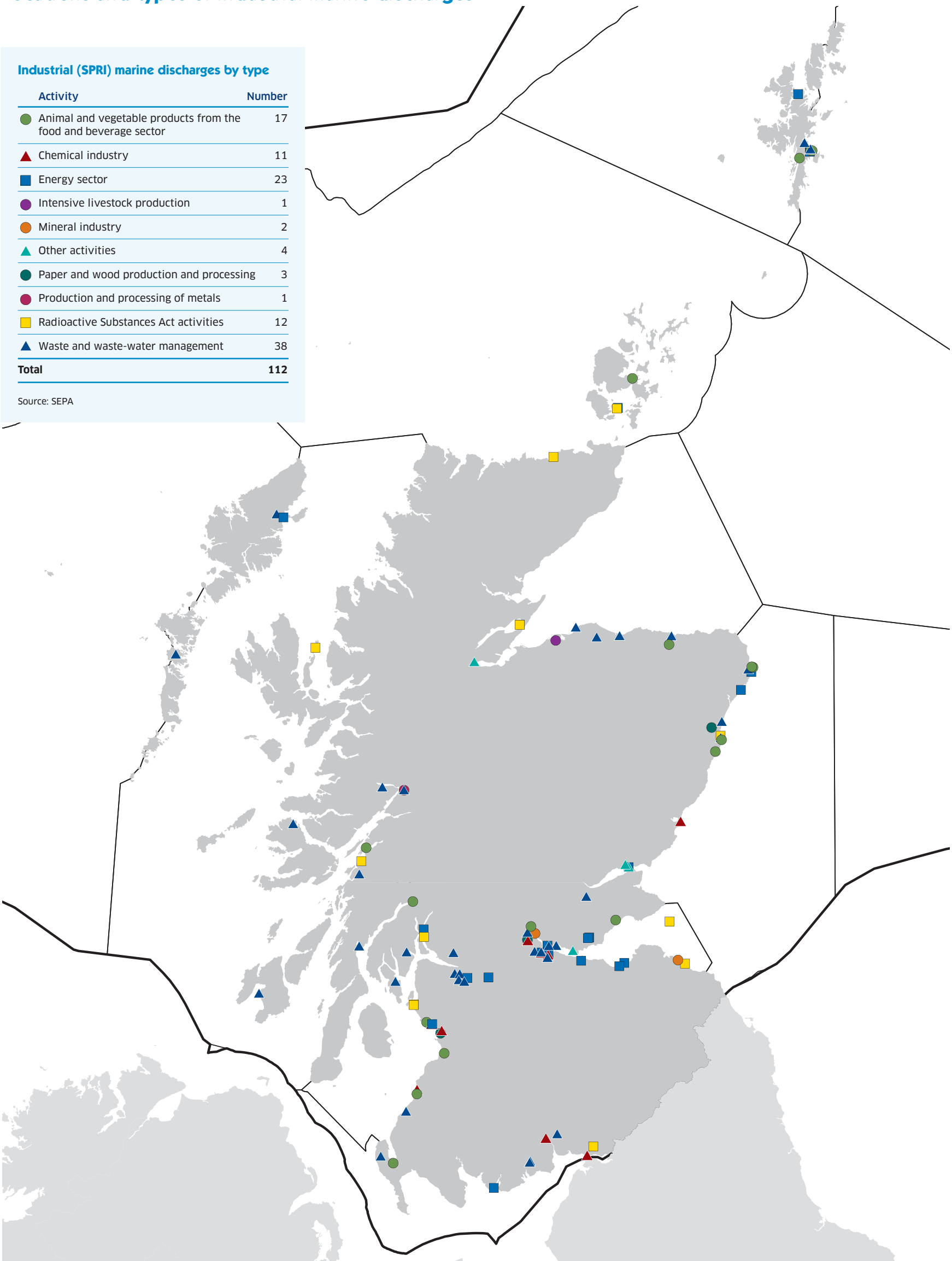
WASTE DISPOSAL (WASTE WATER TREATMENT AND INDUSTRIAL OUTFALLS)

Locations and types of industrial marine discharges

Industrial (SPRI) marine discharges by type

Activity	Number
Animal and vegetable products from the food and beverage sector	17
Chemical industry	11
Energy sector	23
Intensive livestock production	1
Mineral industry	2
Other activities	4
Paper and wood production and processing	3
Production and processing of metals	1
Radioactive Substances Act activities	12
Waste and waste-water management	38
Total	**112**

Source: SEPA



DEFENCE (MILITARY)

What, why and where?

The Ministry of Defence uses Scotland's coasts and seas. The coasts are mainly used for training and locating bases and the seas, while also used for training, are important for test and evaluation activities as well as surveillance and monitoring of potential threats, and for combating these threats.

Most use of the coasts and seas is by the Royal Navy (submarine base, jetties and exercise areas), but coastal locations for both the Army (training camp and firing ranges), Royal Air Force (bases, coastal Air Weapon Ranges and Danger Areas) and Defence Test and Evaluation Ranges (used by the MOD to trial weapon systems) are also important. Detailed information about the intensity of defence use of the seas is not available for reasons of national security. However, the firing ranges, for example, are not in constant use but vary depending on operational requirements.

The major training activity each year is the Joint Maritime Course (JMC) with navy, army and air force exercises conducted off the Scottish north west coast. These waters, with the Inner Hebrides, form the Navy's Scottish Exercise Areas (SXAs), part of the overall practice exercise areas (PEXA)[1]. These are marked on navigation charts and cover large areas of sea although actual exercises are restricted to a limited number of weeks per year and cover only a proportion of these areas at any one time. The areas marked on the chart shows the full area of the marine environment available for military training and other defence activities.

HMNB Clyde

Her Majesty's Naval Base Clyde at Faslane is home for UK's four Vanguard class submarines and is the largest single site employer in Scotland with a workforce of 6,500, drawn from the Royal Navy, MoD civilians, Babcock Naval Services and external contractors.

Source: CP2[2]

Employment

At January 2010, 11,920 personnel Ministry of Defence and Armed Forces personnel were based in Scotland. Royal Navy = 4,230; Army = 3,300; RAF = 4,390. 25% of these were in Argyll & Bute.

A further 5,830 civilians were employed. 29% of the were in Argyll & Bute and 18% were in Glasgow.

Source: DASA[3]

Contribution to the economy

Defence facilities are important sites which contribute to the national and local economy. As this sector produces no measurable output, it is not possible accurately to measure the GVA for marine related defence for Scotland.

HMS *Brocklesby* sails from HMNB Clyde

© Crown Copyright/MOD 2006

Pressures and impacts on socio-economics

Positive
- Full and part time employment
- Economic impact near bases with personnel active in the local community
- Law enforcement within UK seas
- Protection of offshore activities, such as fishing, oil and gas and shipping
- 150 ship visits each year bringing more people to the area
- Search and rescue services

Negative
- Exercise areas and live firing ranges may restrict other uses
- Historic munition dump sites can restrict other seabed users, for example Beaufort's Dyke site (last used 1976) required cables and pipeline routes to be diverted

Source: Based on CP2 PSEG Feeder Report section 3.3.6[4] and UK Marine Policy Statement[5]

Environmental Improvements

The US navy used the Holy Loch as a base from 1961 to 1992. Following their departure the MoD cleaned up the seabed in the late 1990s and it has since been re-opened for fishing.

Tornado aircraft completing a bombing run at Cape Wrath

© Crown Copyright/MOD 2005

Pressures and impacts on the environment

Pressure theme: Pollution and other chemical pressures
Pressure: Release of antifouling substances and other synthetic substances
Impact: Release of chemicals may result in contamination of water and sediments and biological impacts on biota. Potential legacy issues around some munitions dump sites where there was disposal of chemical weapons.

Pressure: Introduction of non-synthetic substances and compounds
Impact: Release of oil and other hazardous substances (from accidental and incidental discharge of cargo or fuel, munitions, discharges from port facilities and shipbuilding/ship repair yards) may result in contamination of water and sediments and ecological impacts on wildlife, mariculture and tourism.

Pressure: Introduction of radio nuclides
Impact: Radionuclide contamination.

Pressure theme: Other physical pressures
Pressure: Litter
Impact: Introduction of litter (e.g. spent shells and explosives) poses a risk of harm/death to marine wildlife through ingestion of, or entanglement. Little information on this available centrally but local ranges know what has been fired.

Pressure: Noise impacts
Impact: Noise from construction, ship movements, sonar activity and use of live explosives for training purposes. Can cause disturbance of behaviour, damage to hearing, and in the worst-case fatality.

Pressure: Death or injury by collision
Impact: Collisions with vessels, missiles may kill or injure.

Pressure theme: Habitat changes
Pressure: Habitat damage, loss and/or abrasion
Impact: Infrastructure associated with military activity, such as ports, replaces natural coastline (habitat loss) with man-made structures. Capital and maintenance dredging associated with shipping can damage marine benthic habitats. Ship wash can damage habitats.

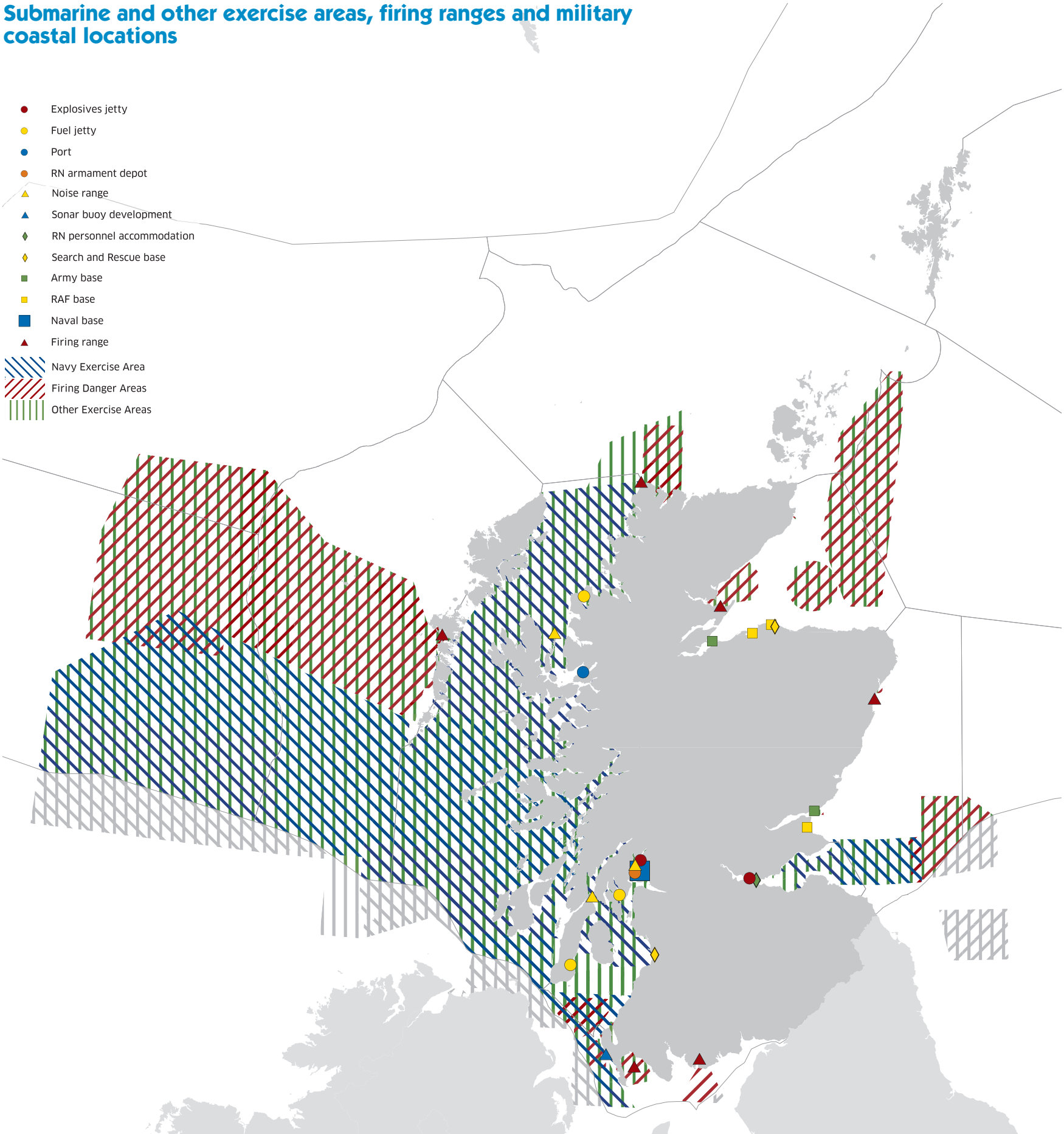
Pressure theme: Biological pressures
Pressure: Microbial pathogens
Impact: Release of sewage from vessels introduces pathogens and nutrients into the water, affecting water quality and potentially passing on diseases to humans through contact with contaminated water or consumption of contaminated shellfish.

Pressure: Introduction or spread of non-native species
Impact: Non-native species may be trans-located or spread through the UK in ballast water and as fouling organisms on ships' hulls. These may cause habitat modification and competition with native species.

Source: Based on CP2 PSEG Feeder Report table 3.24 and 3.53[4] (See also table in Maritime Transport section for shipping related pressures and impacts) and UK Marine Policy Statement[5])

To reduce the impacts of its activities, the Ministry of Defence has a Policy Statement on Safety, Health, Environmental Protection and Sustainable Development, as well as a Climate Change Strategy. It is required to carry out sustainability appraisals and environmental assessments, as appropriate, for new or revised activities.

Submarine and other exercise areas, firing ranges and military coastal locations



HMNB Clyde

© Crown Copyright/MOD 2009

HMS *Dauntless* on sea trials

© BAE Systems Surface Ships

Forward look

It is difficult to assess levels of future defence plans. It is reasonable to assume that training, surveillance and monitoring will continue. The operation of Scottish bases and the use of Scottish seas for military purposes is reserved to the UK government.

05 PRODUCTIVE
TELECOMMUNICATION CABLES

What, why and where?

Telecommunication cables carry telephone calls, internet connections and data.

An international network passes north and south of Shetland connecting Europe to North America, Faroe Islands, Iceland and Greenland. Scottish islands are generally connected to the mainland network by a combination of seabed cables and microwave transmission.

Cables tend to be laid on seabed with a shallow gradient and soft sediment, often meandering to find the most suitable route around any seabed obstructions.

Today, international cables are exclusively fibre optic which carries many thousands of simultaneous transmissions. Domestic inter-island cables are still normally copper wire. There are 4,802.33 kms of active cable in Scottish seas. During the last five years, a number of new cables have been laid to extend internet access to Orkney, Shetland, Faroes, Iceland and Greenland. These include the CNS Fibre Optic, Northern Lights, SHEFA and DANICE. The remaining cables on the map were laid between the late 1980s and 2004.

The alternative method of communication to using cables would be via satellite. A transatlantic call from Scotland costs approximately 17.3p/minute via cable and 72p/minute by satellite phone[1]. It is also reported that cable connections are more reliable.

Contribution to the economy

It is difficult to estimate the direct use value of the cables in the marine environment. A calculation based on the throughput of telephone calls has been made although this ignores the enormous potential value of internet traffic.

Approximately 40% (4,163 kms of 11,000 kms) of all the UK's active international cables are on the Scottish seabed. Adopting the methodology in *Charting Progress 2*, the estimated value of the telecommunications industry in Scottish waters is £1.02 billion[2] but it is inappropriate to attribute this between the Scottish sea areas. It is also not representative of the direct contribution to the Scottish economy as the traffic does not necessarily start or end in Scotland. What it shows is that Scotland's seabed has a significant value because of the amount of telecommunications traffic passing through cables laid on it. Further, the figure underestimates the potential strategic and economic benefit of the data carried, including internet traffic. More generally, the economic and social benefits of the internet underpin the Scottish Government's Digital Strategy. The number of jobs associated with submarine cables is not known.

Pressures and impacts on Scotland's socio-economics

Positive
- Internet provision
- Business and social communication (domestic and international)
- Employment and research

Negative
- Possible restrictions other seabed uses
- Potential seabed hazard, for example, for fishermen

Source: Based on CP2 PSEG Feeder Report section 3.15.6[3]

Pressures and impacts on the environment

Pressure theme: Other physical pressures
Pressure: Electromagnetic changes
Impact: Electromagnetic fields, equivalent or less than the Earth's magnetic field, may have some effects on electro-sensitive and magneto-sensitive species.

Pressure: Noise and vibration
Impact: Burial of cables (during installation) has the potential to cause noise and vibration causing avoidance of an area by, for example, cetaceans.

Pressure theme: Habitat changes
Pressure: Abrasion
Impact: Deployment and burial of cables (during installation) has the potential to damage some sea bed communities.

Pressure: Habitat loss
Impact: Loss of habitat and species in the 'footprint' of the cable.

Pressure: Habitat damage
Impact: Physical disturbance of seabed substrata, during installation, can be minimal, causing sediment re-suspension and increased turbidity leading to possible wider-scale benthic disturbance.

Source: Based on CP2 PSEG Feeder Report table 3.105[3] and UK Marine Policy Statement[4]

Lengths of active cable in Scottish sea areas

Sea area	International cables (kms)	Inshore cables (kms)	Total (kms)	Scottish cables (% of total)
Solway Firth, North Channel	102.22	NIL	102.22	2.1%
Clyde	213.18	178.21	391.39	8.2%
Minches and Malin Sea	46.34	250.68	297.02	6.2%
Hebrides	NIL	1.51	1.51	0%
Rockall	209.94	NIL	209.94	4.4%
Bailey	790.53	NIL	790.53	16.5%
North Scotland coast	875.79	122.00	997.79	20.8%
Faroe Shetland channel	687.33	NIL	687.33	14.3%
West Shetland	333.19	0.92	334.11	7.0%
East Shetland	388.91	1.12	390.03	8.1%
Fladen	236.49	NIL	236.49	4.9%
Moray Firth	115.97	6.11	122.08	2.5%
Forties	106.75	NIL	106.75	2.2%
East Scotland Coast	57.00	0.40	57.40	1.2%
Forth	NIL	77.73	77.73	1.6%
Total	**4,163.64**	**638.69**	**4,802.33**	**100%**

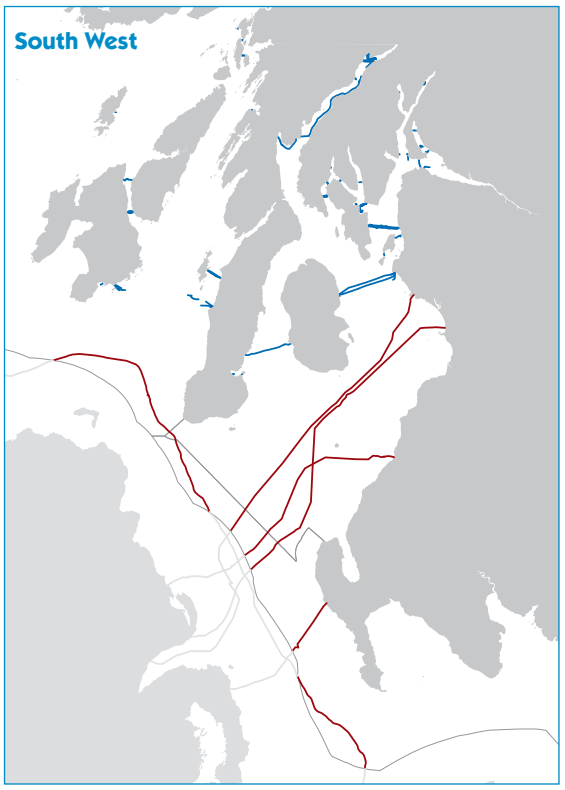
Source: Marine Scotland based on BT and Kingfisher Charts data.

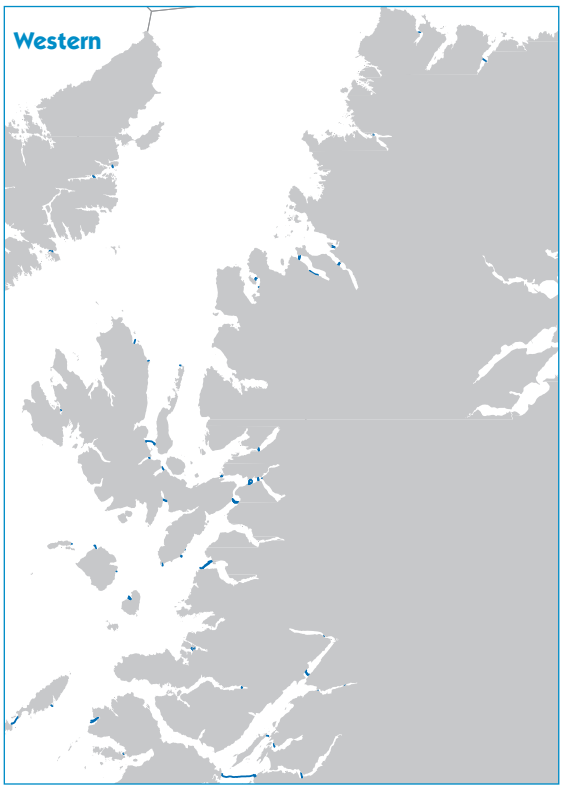
Forward look

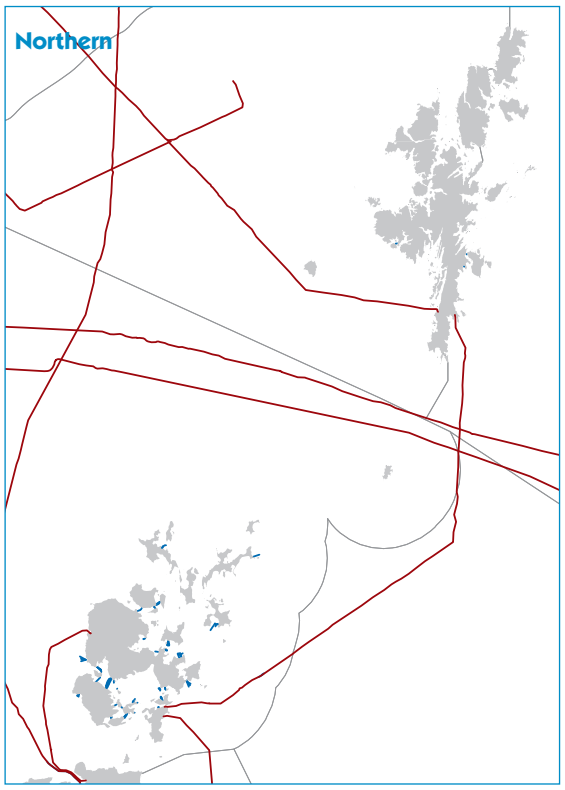
In today's world of electronic media the importance of the communications sector and its contribution to the economy is widely recognised. UK Cable Protection Committee data show that 95% of international trans-ocean traffic is carried by cable. Submarine cables will be vital for the foreseeable future. The extent to which any new cables will be laid in Scottish waters is not known. The number of additional submarine cables on the Scottish seabed will depend on a variety of factors such as the destination countries and the most suitable starting point for such a cable.

New cable laying technology means that future cables could be buried deeper, so lessening the restriction of other seabed users, but this will have to be balanced against ease of access for maintenance.

International and inshore telecommunications cables







CS *Sovereign* laying the Orkney shore end of the Northern Lights cable in 2008

© Global Marine Systems Ltd

CANTAT 3
FARICE
DANICE
Faroe Shetland Channel
West Shetland
SHEFA
SHEFA
East Shetland
ATLANTIC CROSSING
Bailey
North Scotland Coast
NORTHERN LIGHTS
Fladen
Hebrides
Moray Firth
CNS FIBRE OPTIC
Rockall
Forties
TAT 14(K)
East Scotland Coast
Minches & Malin Sea
Forth
SIRIUS NORTH
HIBERNIA 'A'
LANIS 3
Clyde
SCOTLAND-N.IRELAND 2
SCOTLAND-N.IRELAND 1
Irish Sea

International cables
Inshore cables
Cables outside Scottish Marine Areas

MARINE MANAGEMENT, EDUCATION, RESEARCH AND DEVELOPMENT

What, why and where?

As a maritime nation with responsibility for about 6 times as much sea as land, Scotland has a long history of marine management, monitoring, research and education.

Marine management

Marine Scotland, a directorate of Scottish Government established in April 2009, is responsible for the integrated management of Scotland's seas out to the fisheries limits, generally 200 nautical miles. Its' duties cover marine planning, policy development, licensing and enforcement, as well as scientific research, monitoring and assessment of the state of the seas.

Marine Scotland is the guardian of the marine vision of 'clean, healthy, safe, productive, biologically diverse marine and coastal environments, managed to meet the long-term needs of people and nature' and is implementing the Marine (Scotland) Act 2010. It also licenses a variety of activities which will be under the new Marine Licence regime from April 2011.

Marine Scotland works with stakeholders through the **Marine Strategy Forum** established in July 2009. The Forum provides advice on Marine Scotland's key strategies and priorities.

There is a range of other management structures which have a marine element, including:

- *inshore fisheries:* the Inshore fisheries advisory groups
- *coastal management:* the Scottish Coastal Forum and local coastal partnerships
- *water management:* the river basin management area advisory groups

The **Scottish Environment Protection Agency** (SEPA), a non-departmental public body established in 1996, is Scotland's environmental regulator and accountable through Ministers to the Scottish Parliament. SEPA's aim is to provide an effective and integrated environmental protection system which will both improve the environment and contribute to sustainable economic growth and a greener and healthier Scotland. It works with Marine Scotland and others to achieve the marine vision and has powers from the coast out to 3 nautical miles. The main marine legislation used by SEPA includes various EC Directives, such as the Water Framework Directive, which aims to achieve good ecological status for all waters out to 3 nautical miles.

There are two bodies providing nature conservation advice. The main role of **Scottish Natural Heritage** (SNH), an agency established in 1992, is to promote, care for and improve the natural heritage, help people enjoy it responsibly, enable greater understanding and awareness of it and promote its sustainable use, now and for future generations. It has responsibilities for the marine environment from the coast out to the limits of territorial waters.

SNH works closely with the **Joint Nature Conservation Committee** (JNCC). JNCC delivers the UK and international responsibilities for SNH and the other Great Britain conservation bodies, including their offshore marine nature conservation responsibilities. JNCC advises the Scottish Government on marine conservation from 12 nautical miles out to the limits of jurisdiction and on international nature conservation issues.

There are also two national cultural heritage bodies with complementary functions. **Historic Scotland** is an executive agency of the Scottish Government charged with safeguarding the nation's historic environment and promoting its understanding and enjoyment. **The Royal Commission on the Ancient and Historical Monuments of Scotland** (RCAHMS) collects, records and interprets information on the architectural, industrial, archaeological and maritime heritage of Scotland.

The Crown Estate Commissioners is a UK public body that manages about 55% of the foreshore and all the seabed in Scotland out to the 12 nautical mile limit on behalf of the Crown. They also manage the rights to minerals, except hydrocarbons, beyond 12 nautical miles.

Many other bodies exercise marine management and consenting roles in Scottish waters. For example, the **Department of Energy and Climate Change** has responsibility for the oil and gas regime, the **Department for Transport** for shipping and the **Ministry of Defence** for military activity.

KnowSeas

The Knowledge-based Sustainable Management for Europe's Seas (KnowSeas) project is supported by the European Commission under the Environment (including climate change) Theme of the 7th Framework Programme for Research and Technological Development. The 4 year project, started in April 2009, has 30 partners from 15 countries and is coordinated by the Scottish Association for Marine Science.[1]

Research, survey and management vessels

Organisation	Vessel
Marine Scotland	FRV *Scotia*
	FRV *Alba na Mara*
	MV *Temora*
	MPV *Minna**
	MPV *Jura**
	MPV *Hirta**
SEPA	SV *Sir John Murray*
Scottish Association for Marine Science (SAMS)	RV *Calanus*
	RV *Seol Mara*
University Biological Station Millport	RV *Aora*
	RV *Actinia*
NAFC Marine Centre, Shetland	MV *Moder Dy*
	MV *Atlantia II*

Note: *fisheries protection vessels

Education, research and development

The **Marine Alliance for Science and Technology for Scotland** (MASTS) was established in 2009 and pools the work of around 700 researchers in marine science from across Scotland. This includes much of the marine research in Scottish universities. MASTS' objective is to ensure coordination across marine science in Scotland so that it can remain internationally competitive. One of the policy related initiatives underway, at the Scottish Association for Marine Science (part of the UHI Millennium Institute), is *KnowSeas*. Non-environmental marine expertise is provided at university centres such as engineering at Robert Gordon, Strathclyde, Heriot Watt and marine law at Dundee.

MASTS research themes

9 joint research themes

1. Biodiversity and ecosystem function
2. Coastal zone
3. Fisheries
4. Genomics of marine organisms
5. Marine predators
6. Modelling
7. Physical oceanography
8. Platforms and sensors
9. Sustainable mariculture

Supporting

- Sustainable marine management and exploitation of the marine environment including
  - Renewable energy
  - Coastal development
  - Exploitation of bioresources
  - Marine spatial management
  - Conservation of living resources
  - Predicting the effects of climate change

Marine environmental research, advice and management activity

The International Association of Maritime Institutions is primarily an association of colleges and other organisations involved in providing education and training for personnel involved in the Merchant Navy, Towing and Fishing Industries. It includes **Lewis Castle College** (Stornoway), **Department of Maritime Studies Orkney College** (Stromness), **Shetland School of Nautical Studies** (Scalloway), **Banff & Buchan College of Further Education** (Fraserburgh) and **Glasgow College of Nautical Studies** (Glasgow).

There is a range of other education structures for various sectors. For example:

- the **Sector Skills Council for Science, Engineering and Manufacturing Technologies** supports businesses in achieving global competitiveness through investment in skills. The marine sector covers shipbuilding and repair, boat building and repair, and marine equipment manufacture. There are a number of courses in Scottish colleges.[2]
- the **Royal Yachting Association** provides a number of training centres for sailing.[3]
- **EMEC** (European Marine Energy Centre) is the first centre of its kind to be created and offers the opportunity to test full scale grid connected renewable energy prototype devices in realistic wave and tidal conditions.[4]

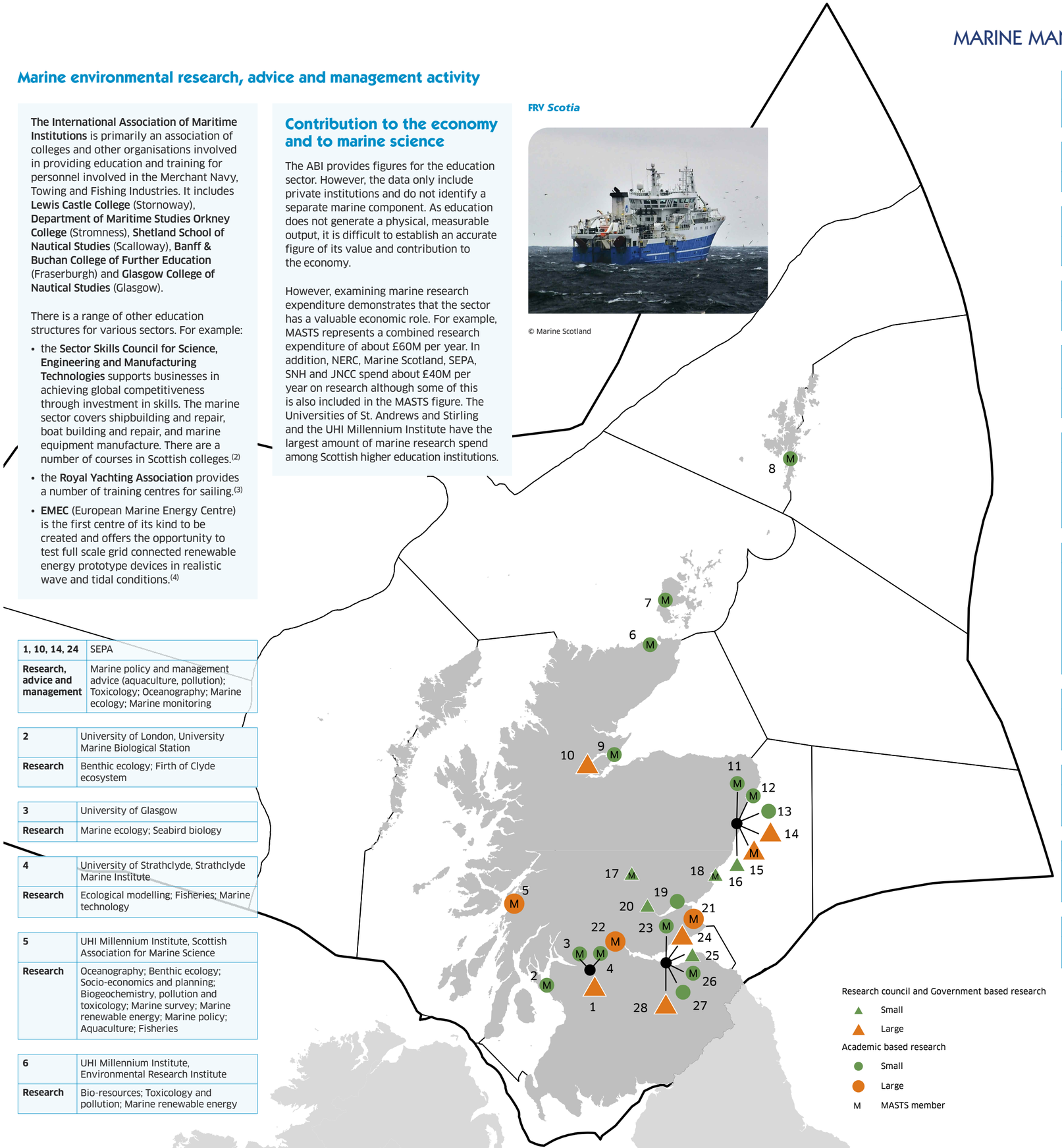
Contribution to the economy and to marine science

The ABI provides figures for the education sector. However, the data only include private institutions and do not identify a separate marine component. As education does not generate a physical, measurable output, it is difficult to establish an accurate figure of its value and contribution to the economy.

However, examining marine research expenditure demonstrates that the sector has a valuable economic role. For example, MASTS represents a combined research expenditure of about £60M per year. In addition, NERC, Marine Scotland, SEPA, SNH and JNCC spend about £40M per year on research although some of this is also included in the MASTS figure. The Universities of St. Andrews and Stirling and the UHI Millennium Institute have the largest amount of marine research spend among Scottish higher education institutions.

FRV *Scotia*

© Marine Scotland



1, 10, 14, 24	SEPA
Research, advice and management	Marine policy and management advice (aquaculture, pollution); Toxicology; Oceanography; Marine ecology; Marine monitoring

2	University of London, University Marine Biological Station
Research	Benthic ecology; Firth of Clyde ecosystem

3	University of Glasgow
Research	Marine ecology; Seabird biology

4	University of Strathclyde, Strathclyde Marine Institute
Research	Ecological modelling; Fisheries; Marine technology

5	UHI Millennium Institute, Scottish Association for Marine Science
Research	Oceanography; Benthic ecology; Socio-economics and planning; Biogeochemistry, pollution and toxicology; Marine survey; Marine renewable energy; Marine policy; Aquaculture; Fisheries

6	UHI Millennium Institute, Environmental Research Institute
Research	Bio-resources; Toxicology and pollution; Marine renewable energy

7	Heriot-Watt University, International Centre for Island Technology
Research	Marine management; Marine renewable energy

8	UHI Millennium Institute, NAFC Marine Centre
Research	Fisheries; Aquaculture; Planning

9	University of Aberdeen, Lighthouse Field Station
Research	Marine mammal and seabird biology; Marine renewable energy

11	University of Aberdeen, Oceanlab
Research	Deep-sea biology; Marine biodiversity; Fisheries science; Ecosystem science

12	University of Aberdeen, School of Biological Science and the Department of Chemistry
Research	Fish genomics; Biological oceanography; Bio-prospecting; Fish genetics

13	Macaulay Land Use Research Institute, Coasts @ Macaulay
Research	Water quality; Coastal governance; Climate change impacts; Socio-economics; Deep sea carbon cycling; Ecosystem functioning; Analytical services

15	Marine Scotland Science
Research, advice and management	Marine policy and management advice (aquaculture, climate change, fisheries, marine spatial planning, pollution, renewable energy); Ecosystems; Ecotoxicology; Fish disease; Ocean system science; Oceanography; Human impacts; Modelling (ecological and hydrographic); Plankton ecology

16	JNCC
Research, advice and management	Marine management advice (including Marine Protected Areas); Seabird and cetacean monitoring

17	Marine Scotland Science
Research, advice and management	Fresh water fisheries and water quality

18	Marine Scotland Science
Research, advice and management	Salmon fisheries

19	University of Dundee
Research	Coastal systems; Marine policy and planning

20	SNH
Research, advice and management	Marine policy and management advice (aquaculture, marine spatial planning, MPAs, Natura, oil pollution, renewable energy, seals licensing, impacts of fisheries and climate change); Biodiversity survey; Marine ecology; Marine monitoring

21	University of St Andrews, Scottish Oceans Institute including: Sea Mammal Research Unit, Centre for Research in Ecological and Environmental Modelling, Facility for Earth and Environmental Analysis
Research	Marine mammals; Coastal ecology; Statistical ecology; Ecological modelling; Environmental economics; Marine survey; Marine geology; Marine renewable energy; Human impacts; Oceanography; Marine policy advice; Fish genetics

22	University of Stirling, Institute of Aquaculture
Research	Fish disease; Aquaculture production; Environmental economics; Fish genetics

23	Heriot-Watt University, School of Life Sciences
Research	Marine survey; Benthic biology; Marine planning

25	Natural Environment Research Council (NERC), Centre for Ecology and Hydrology
Research, advice and management	Seabird ecology

26	Edinburgh Napier University
Research	Ecological modelling; Marine ecology; Marine pollution

27	University of Edinburgh
Research	Marine geology

28	Natural Environment Research Council (NERC), British Geological Survey
Research, advice and management	Marine geology; Marine survey

SV *Sir John Murray*

© SEPA

Research and development partnerships with industry

SARF – Scottish Aquaculture Research Forum is a registered charity and an independent company whose main aim is to support research into aquaculture and related areas. It was established as a priority action under the Strategic Framework for Scottish Aquaculture in 2004 and receives Scottish Government financial support.[5]

SISP – Scottish Industry/Science Partnerships – Marine Scotland works to improve cooperation between the Scottish catching sector and fisheries science providers, ensuring industry is closely involved in the development of scientific research.[6]

Pressures and impacts on Scotland's socio-economics

Positive

- Employment and training
- Supporting economic growth
- Enhancing well being
- Developing new technology
- Research to underpin sustainable use

Negative

- None identified

MPV Hirta

© Marine Scotland

Forward look

Existing work in the research community will inform future marine policy development and implementation. The Scottish Marine Science Strategy will identify government's priority areas to investigate and there is likely to be a need for collaborative research and effort and a new emphasis on understanding the socio-economics of marine activities. It is likely that knowledge will emerge on:

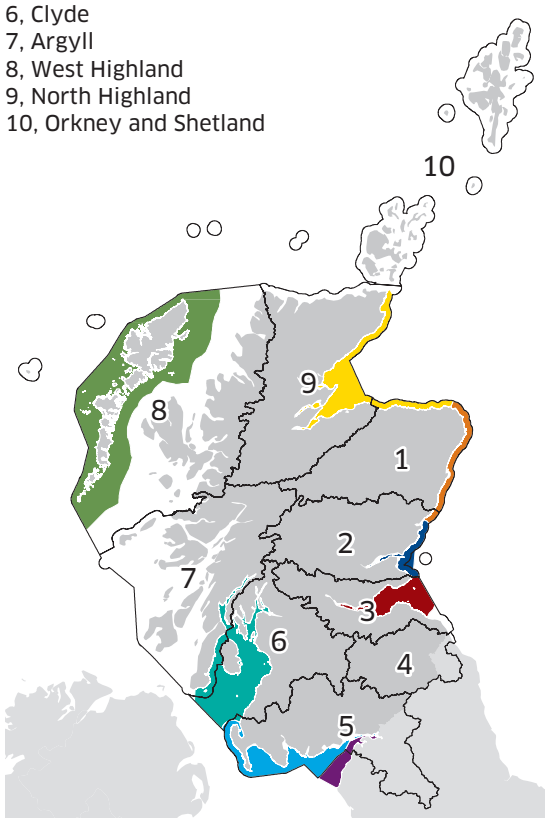
- marine bio-resources, including novel chemicals, new and sustainable food supplies and bio-energy
- increased and new forms of sub-sea oil and gas recovery (e.g. from gas hydrates, and CO_2 storage) and the potential re-use of oil and gas fields for carbon capture and storage
- new technologies for the expansion of wave, tidal and wind power
- the seabed and its resources, especially in deep waters through increasingly detailed maps
- new approaches to marine planning.

Local coastal partnerships & WFD management areas

Local Coastal Partnerships:
- Coast Hebrides
- East Grampian Coastal Partnership
- Firth of Clyde Forum
- Forth Estuary Forum
- Moray Firth Partnership
- Solway Firth Partnership (English Waters)
- Solway Firth Partnership (Scottish Waters)
- Tay Estuary Forum

WFD Area Advisory Groups:

1, North East Scotland
2, Tay
3, Forth
4, Tweed
5, Solway
6, Clyde
7, Argyll
8, West Highland
9, North Highland
10, Orkney and Shetland



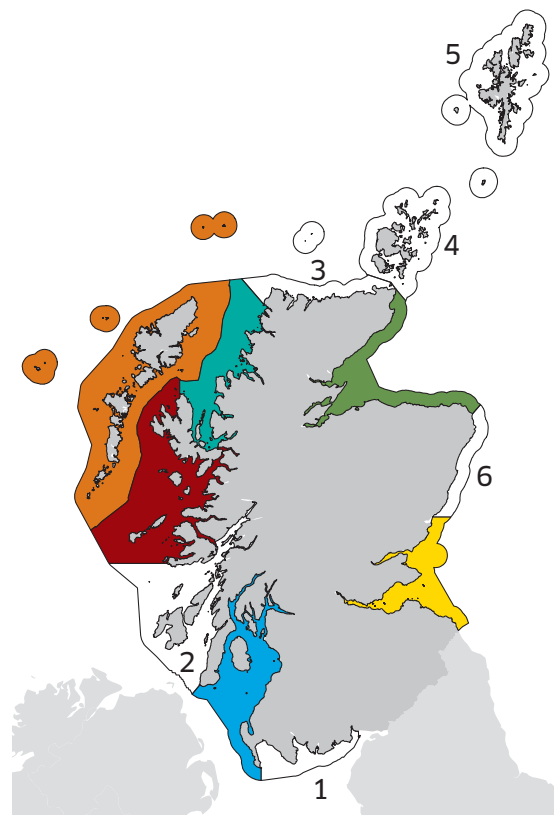
Inshore Fishery Group areas

Inshore Fishery Groups

Pilot groups:
- Clyde
- Small Isles & Mull
- Nan Eilean Siar
- North West
- Moray Firth
- South East

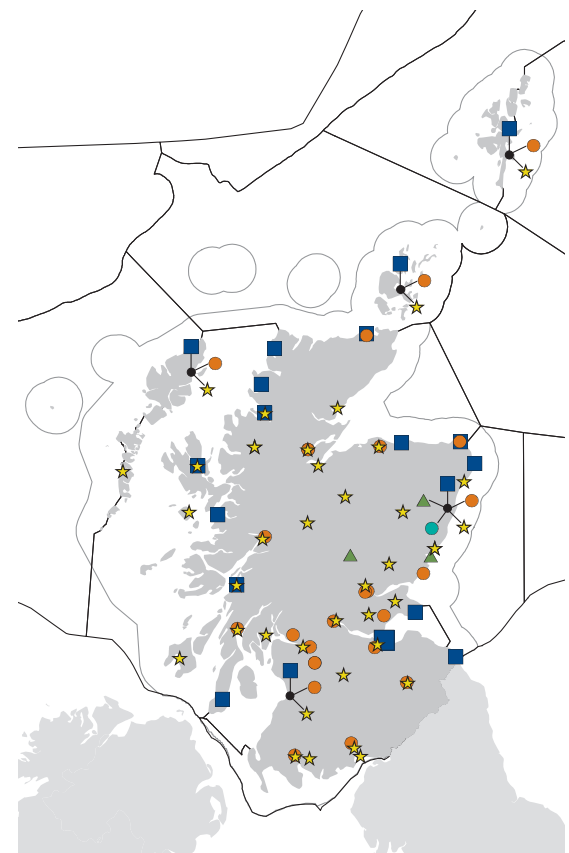
Possible groups:

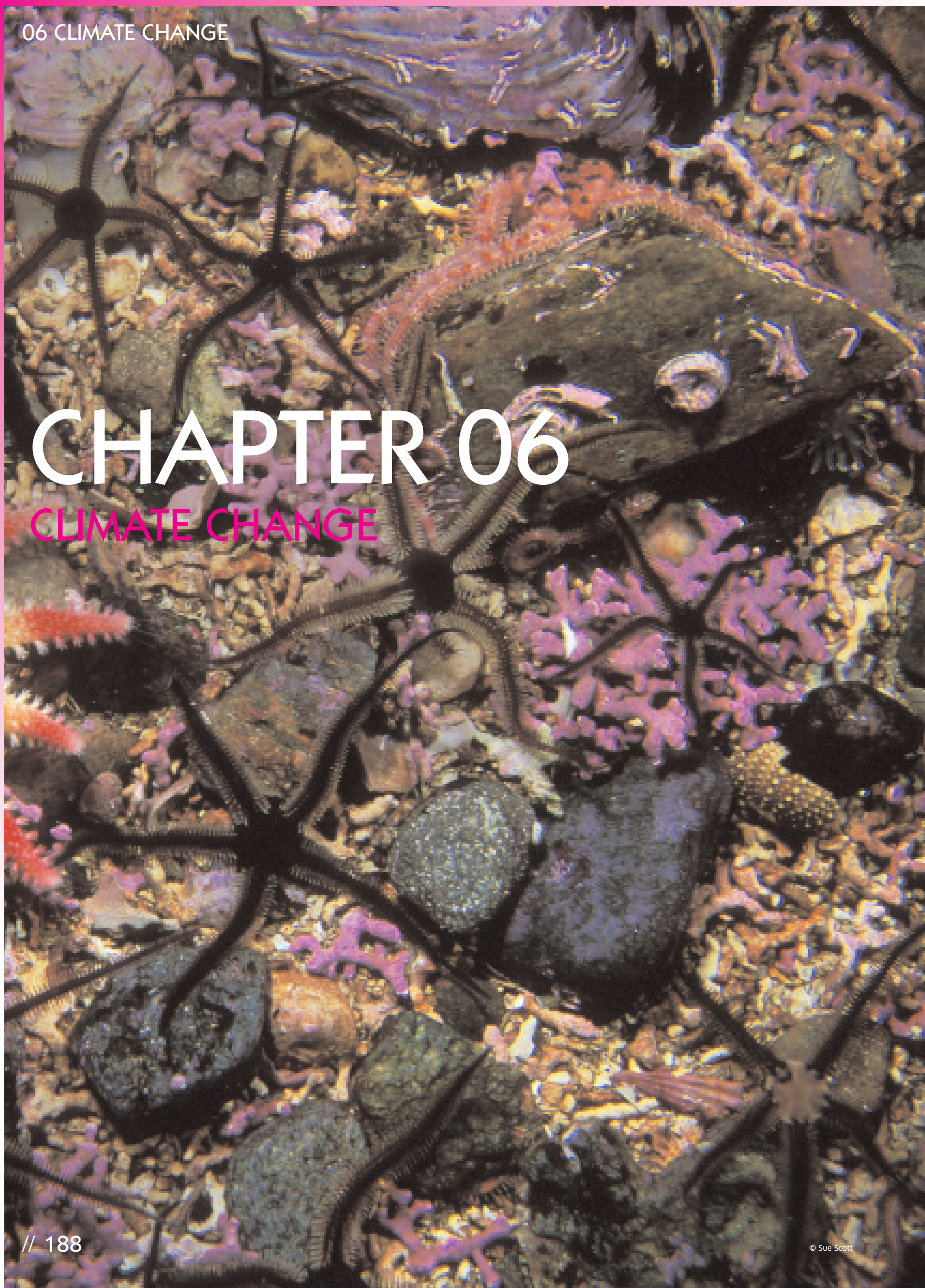
1, Solway
2, South West
3, North Coast
4, Orkney
5, Shetland & Fair Isle
6, East Coast



Marine science and regulatory offices

- SNH
- SEPA
- JNCC
- Marine Scotland Science
- Marine Scotland
- 12 nautical mile limit



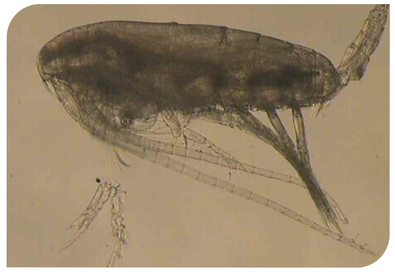


CHAPTER 06

CLIMATE CHANGE

© Sue Scott

***Calanus finmarchicus* is vulnerable to changing conditions**



© Marine Scotland

Maerl is relatively intolerant of sea temperature rises

© Sue Scott

What Is Already Happening

Since 1970 waters between 0 and 600 m have warmed and waters between 0 – 800 m have become more saline

Rising sea temperature has caused changes in phytoplankton growth and distribution

What Could Happen

Surface layers are likely to be stratified for a longer period during the year by the end of the century

Increased tendency for stratification could lead to offshore blooms, including *Kerenia mikimotoi*, which has been associated with fish kills and benthic mortalities in coastal waters

Black-legged kittiwake (*Rissa tridactyla*) has shown a decline in breeding success

© Anke Addy (www.ankeaddy.com)

What Is Already Happening

Since 2000 breeding success of seabirds such as Arctic skua, black-legged kittiwake and shag has declined due to decreased food availability linked to climate change

Rising sea temperature is leading to an extension of the northern limit of seabed animals

Rising sea levels do not pose a risk to the coast which is rocky and rising

What Could Happen

Increase tendency for stratification could lead to offshore blooms, including *Kerenia mikimotoi*, which has been associated with fish kills and benthic mortalities in coastal waters

Shag (*Phalacrocorax aristotellis*) has shown a decline in breeding success

© Mark Newell

What Is Already Happening

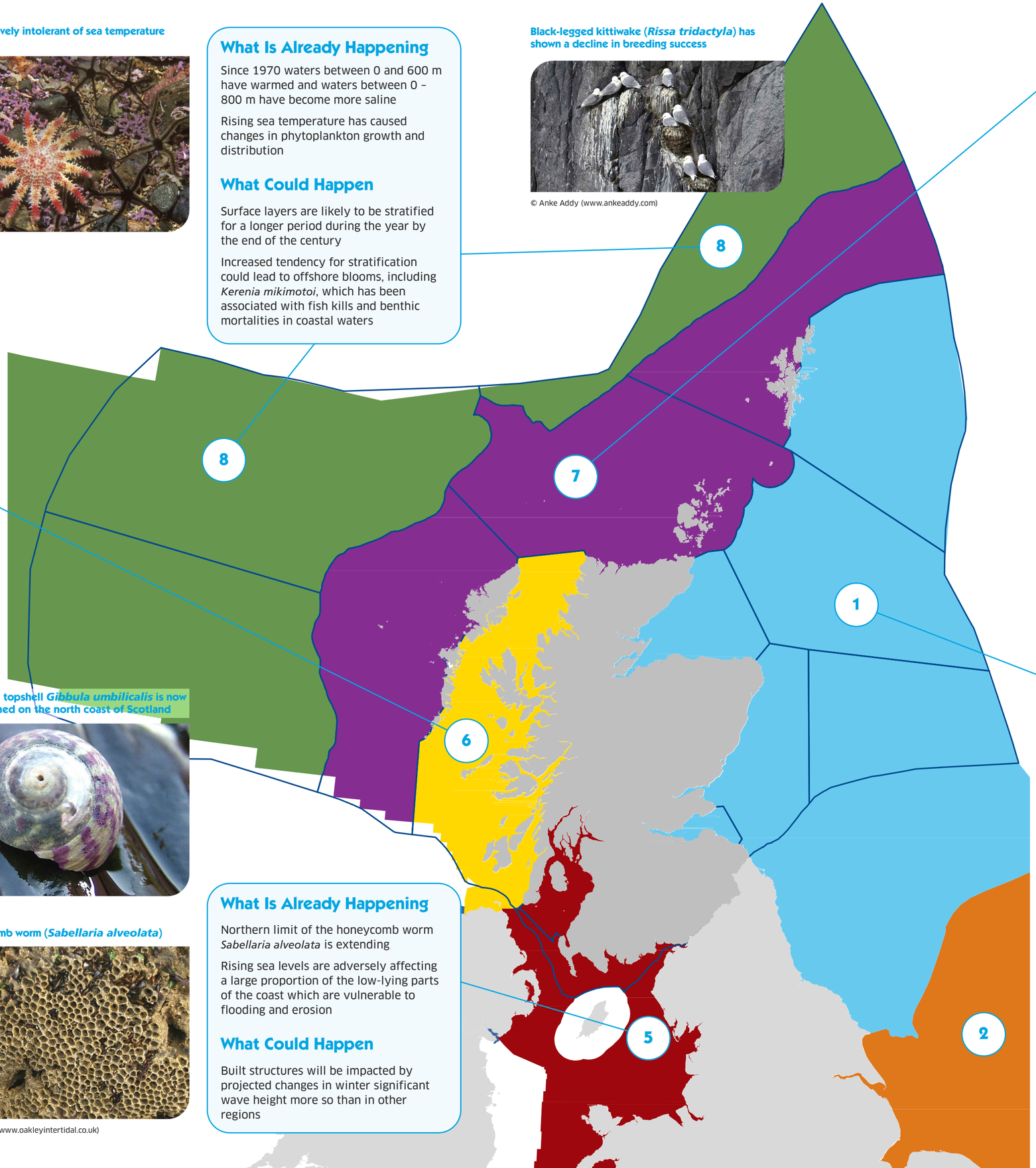
Since 2000, breeding success of seabirds such as Arctic skua, black-legged kittiwake and shag has declined due to decreased food availability linked to climate change

Relict populations of the cold-water copepod *Calanus finmarchicus* persist in some sea lochs but are vulnerable to changing conditions

Rising sea levels are only adversely affecting a small proportion of the coast

What Could Happen

Increased tendency for stratification could lead to offshore blooms, including *Kerenia mikimotoi*, which has been associated with fish kills and benthic mortalities in coastal waters



What Is Already Happening

Squid are becoming more abundant off north-east Scotland creating new opportunities for fisheries

Rising sea temperature has caused changes in the plankton community and the distribution of some fish species

The length of the phytoplankton growing season has increased

Rising sea levels are only adversely affecting a small proportion of the coast

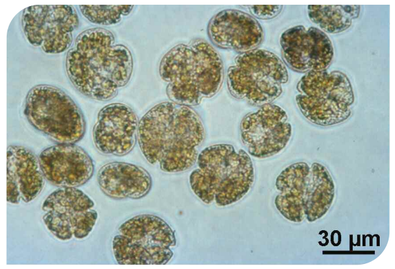
What Could Happen

7 – 54 cm sea-level rise projected in Edinburgh between 1990 and 2095 under a medium greenhouse gas emission scenario

Charting Progress 2 Regions

- (1) Northern North Sea
- (2) Southern North Sea
- (5) Irish Sea
- (6) Minches & Western Scotland
- (7) Scottish Continental Shelf
- (8) Atlantic North-West Approaches
- Shared waters between N Ireland and Rep of Ireland
- Scottish Sea Areas

Kerenia mikimotoi

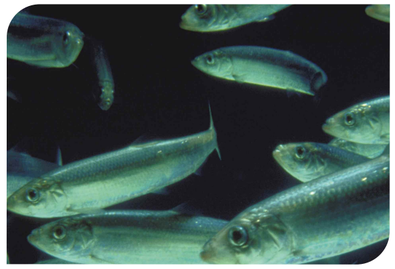


© Marine Scotland

The intertidal topshell *Gibbula umbilicalis* is now well established on the north coast of Scotland

© Marlin

Herring (*Clupea harengus*) may move northwards



© Marine Scotland

The honeycomb worm (*Sabellaria alveolata*)

© Judith Oakley (www.oakleyintertidal.co.uk)

What Is Already Happening

Northern limit of the honeycomb worm *Sabellaria alveolata* is extending

Rising sea levels are adversely affecting a large proportion of the low-lying parts of the coast which are vulnerable to flooding and erosion

What Could Happen

Built structures will be impacted by projected changes in winter significant wave height more so than in other regions

Climate Change

The climate of Scotland's seas is largely defined by their temperature, salinity, circulation patterns (see Chapter 2) and exchange of heat, water and gases with the atmosphere. The functioning of Scotland's seas is dependent on changes in these climatic factors as well as chemical parameters such as acidity.

The most up-to-date assessment of the implications of climate change for Scotland's seas is provided by the Marine Climate Change Impacts Partnership (MCCIP), which produces a Report Card at regular intervals based on evidence from the leading scientists in the field. This highlights what has already been observed and forecasts possible future challenges and opportunities. In coming years it will also promote best practice for different sectors on adapting to climate change through its Climate Smart Working project. In 2011 MCCIP will publish a report card that will provide a comprehensive review of the information available on the implications of climate change for fish, fisheries and aquaculture.

Marine air and sea surface temperatures have risen in the last 25 years although interannual variability is still high. Under a medium greenhouse gas emissions scenario, UKCP09 projects that the shelf seas will be 1.5 to 4.0 °C warmer by the end of the 21st century. The shelf seas and ocean waters to the north and west of Scotland have become relatively more saline over the last 40 years. Sea-level rise of between 12 and 76 cm by 2095 is projected by the UKCP09. Models and measurements suggest about a 30% increase in acidity of surface water (i.e. a decrease of 0.1 units of pH) and a 16% decrease in carbonate ion concentrations since the start of the industrial revolution around 1750. This change is continuing and at a rate not experienced in the last 55 million years. Without a significant reduction in atmospheric CO_2 concentrations it is likely that acidification of our seas will continue. This is of considerable concern for marine ecosystems and calcifying organisms in particular.

The marine ecosystem is highly interconnected through a web of predator prey relations and as such any direct impacts on a single species will have knock-on effects up the food chain. Recent warmer conditions in the North Sea have resulted in changes in plankton abundance and distribution (see Plankton section in Chapter 4). These changes have led to reduced availability of prey fish for some seabirds species which have consequently suffered through poor breeding success and reduced survival rates (see Seabird section in Chapter 4).

There has been a northward shift in distribution of around 10° latitude over the last 50 years in many species of plankton, and the timing of plankton production has also altered. Some fish species have moved northwards by between 50 and 400 km over the last 30 years. The cold-water species such as monkfish and snake blenny have moved furthest. It is likely that new species will move into Scottish waters in greater numbers as the seas continue to warm.

By 2050 it is possible that pelagic species such as herring and anchovy may move northwards by an average of 600 km, and demersal species such as haddock and cod by as much as 220 km.

There is currently too little information on the overall changes in conditions that might be expected and the responses of individual species or ecosystems to confidently predict exactly what might occur. There are some clear indications, however, that changes are happening and in some cases relatively rapidly. The intertidal topshell *Gibbula umbilicalis* is now well established with breeding populations on the north coast of Scotland where before it was only very occasionally recorded. Other species such as cold water corals and maerl, both of which have been identified as Priority Marine Features, are relatively intolerant of sea temperature rises and altered sea water chemistry and as a result their distributions may contract northwards.

The impacts of climate change are potentially very far reaching on both commercial and non-commercial species. There are likely to be some major impacts on the aquaculture industry as a result of sea temperature rise including an increase in the prevalence of illness and parasites, and a greater frequency of harmful algal and jellyfish blooms. Likewise the additional stresses imposed by climate change on already heavily exploited fish stocks could be significant, but at the same time it may create opportunities to exploit new stocks such as seabass and John Dory.

Box 1

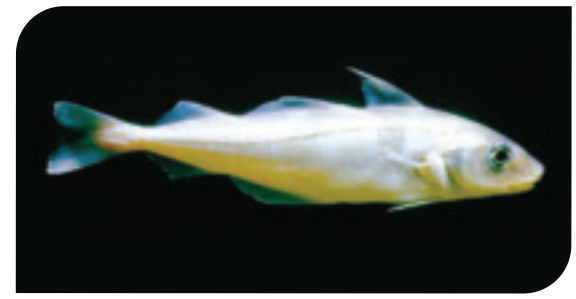
While many of the changes that are observed are consistent with increasing levels of atmospheric carbon dioxide (CO_2) and a warming climate (e.g. rising sea temperature and acidification) there remains a lack of understanding of many of the causative links to climate. For example, it continues to be difficult to predict the rate and magnitude of future change for factors such as sea-level rise, Atlantic circulation, acidification and stratification. In other cases, for example the extent to which oceans will continue to take up CO_2, or changes in storminess or salinity, there is uncertainty which direction the change in marine climate will take.

© Paul Weychan, Marine Scotland

Renewable Energy - part of our efforts to mitigate climate change

The observed increases in sea surface temperature, and the associated effects such as the northerly movement of species, can only be limited by a global reduction in greenhouse gases. Reducing Scotland's emissions can, in part, be achieved by harnessing Scotland's renewable energy potential including wind, wave and tidal energy. The Scottish Government has set ambitious emissions targets and is supporting the development of renewable energy in Scottish waters. This represents a relatively new use of the seas with areas of the sea bed and water column being exploited in new ways. There are therefore a range of both known and unknown impacts associated with such developments. These are currently being investigated and include the impact on the sea bed, the consequences of the removal of significant amounts of energy from the system and the risk of collision for mobile species. There may also be benefits beyond the generation of power and consequent reduction in CO_2 emissions, for example, some developments could become refuges from other human activities such as fishing.

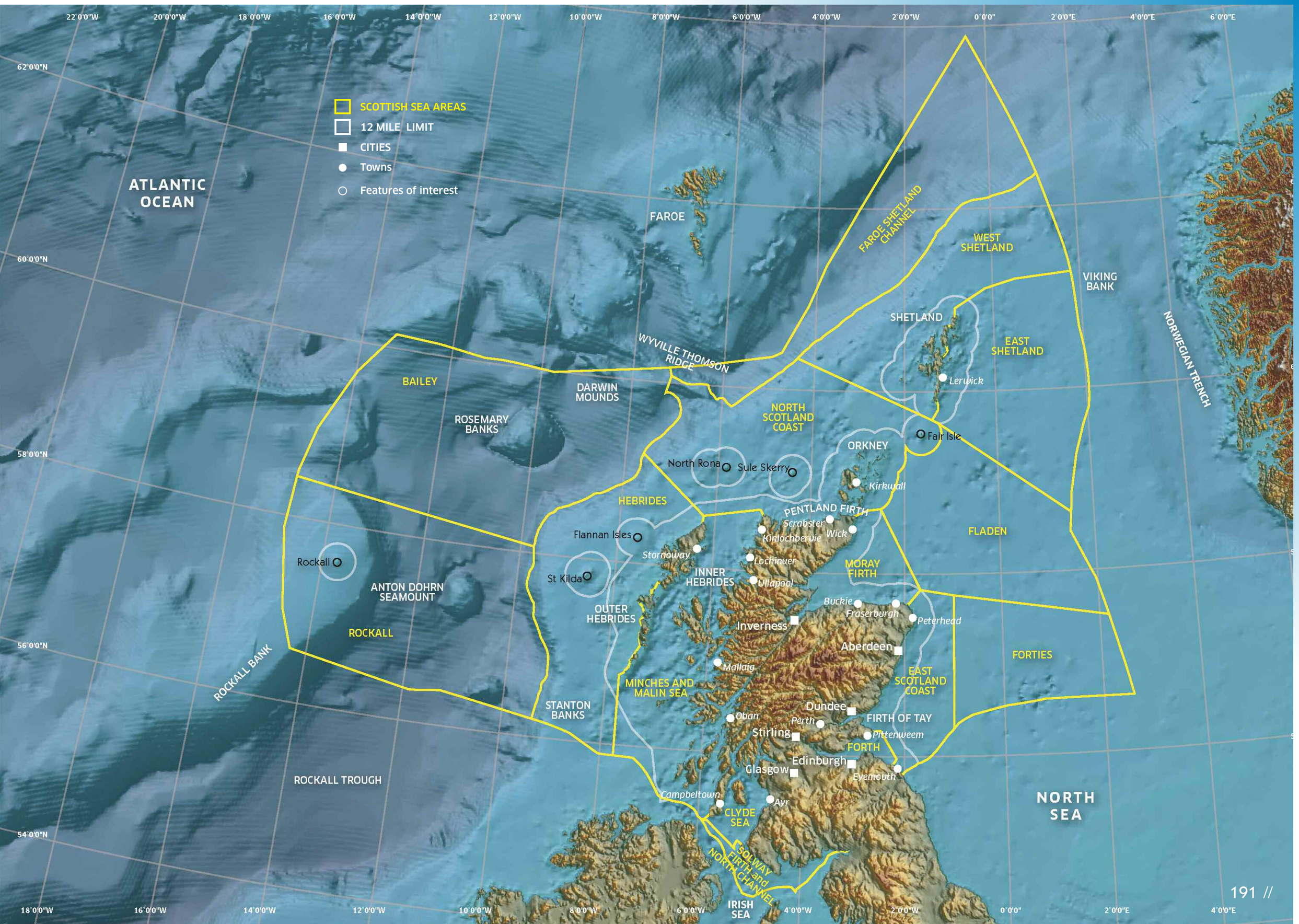
Haddock (*Melanogrammus aeglefinus*) may move northwards



© Marine Scotland

Tidal device

© John M Baxter


SCOTTISH SEA AREAS
12 MILE LIMIT
CITIES
Towns
Features of interest
ATLANTIC OCEAN
FAROE
FAROE SHETLAND CHANNEL
WEST SHETLAND
VIKING BANK
NORWEGIAN TRENCH
SHETLAND
EAST SHETLAND
Lerwick
WYVILLE THOMSON RIDGE
BAILEY
DARWIN MOUNDS
ROSEMARY BANKS
NORTH SCOTLAND COAST
ORKNEY
Fair Isle
North Rona
Sule Skerry
Kirkwall
HEBRIDES
PENTLAND FIRTH
Scrabster
Wick
Kinlochbervie
FLADEN
Flannan Isles
Stornoway
Lochinver
MORAY FIRTH
Rockall
St Kilda
INNER HEBRIDES
Ullapool
ANTON DOHRN SEAMOUNT
OUTER HEBRIDES
Buckie
Fraserburgh
Peterhead
Inverness
ROCKALL
Aberdeen
FORTIES
ROCKALL BANK
Mallaig
EAST SCOTLAND COAST
MINCHES AND MALIN SEA
STANTON BANKS
Dundee
Oban
Perth
FIRTH OF TAY
Stirling
Pittenweem
FORTH
Edinburgh
Glasgow
Eyemouth
ROCKALL TROUGH
Campbeltown
Ayr
CLYDE SEA
NORTH SEA
SOLWAY FIRTH and NORTH CHANNEL
IRISH SEA
22°0'0"W
20°0'0"W
18°0'0"W
16°0'0"W
14°0'0"W
12°0'0"W
10°0'0"W
8°0'0"W
6°0'0"W
4°0'0"W
2°0'0"W
0°0'0"
2°0'0"E
4°0'0"E
6°0'0"E
62°0'0"N
60°0'0"N
58°0'0"N
56°0'0"N
54°0'0"N

© Crown copyright 2011

This document is also available on the Scottish Government website:
www.scotland.gov.uk

and on the atlas website: www.scotland.gov.uk/marineatlas

Published by the Scottish Government March 2011

ISBN 987-0-7559-8254-7