

State of the Clyde

Environment Baseline Report

Scottish Sustainable Marine Environment Initiative

SSMEI Clyde Pilot

State of the Clyde

Environment Baseline Report

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1 Introduction

This report is a summary compilation of existing environmental information intended to inform the development of a Firth of Clyde Marine Spatial Plan (the Plan). The Plan is being developed as part of the Clyde Pilot, which sits alongside three other pilot projects within phase III of the Scottish Sustainable Marine Environment Initiative (SSMEI). The SSMEI is developing and testing novel approaches to the sustainable management of Scotland's seas.

The aim of the Clyde Pilot is to assist in delivery of more integrated and sustainable management of marine and coastal areas of the Firth of Clyde (the Firth). The Plan will provide a strategic framework for management of current and future activities across the Firth. The development of the Plan is also informed by a separate socioeconomic review of its coastal communities (EKOS Ltd., 2008)

The sea area covered by the Clyde Pilot is shown in Figure 1. The Plan does not define a geographically fixed landward boundary and includes some policies which are primarily terrestrial in focus, but which are of direct relevance to the management of marine resources and activities.

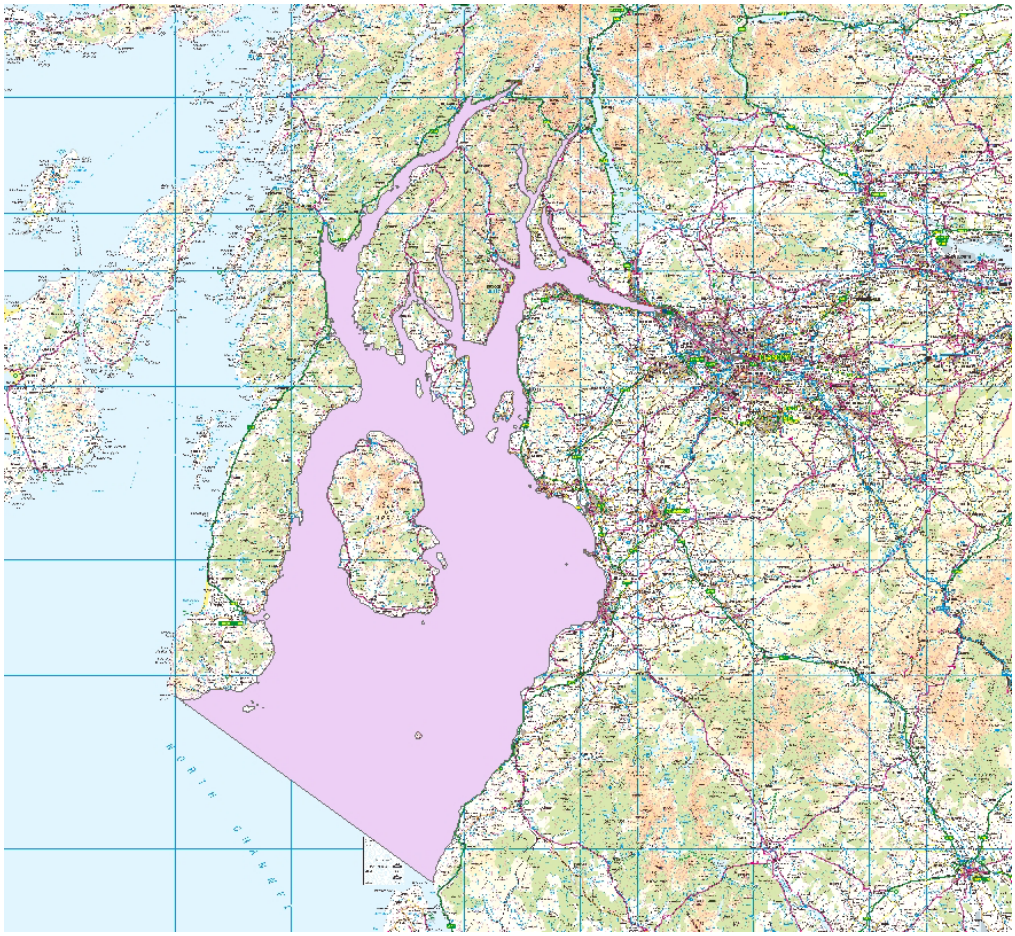


Figure 1: SSMEI Clyde Pilot area (Crown copyright. Licence number 100020538)

This report provides summary descriptions of key aspects of the natural environment of the Firth, including underlying hydromorphology, habitats, biodiversity and

landscapes/ seascapes. In common with the neighbouring Loch Lomond and the Trossachs National Park Authority's *State of the Park Report 2005*, it highlights environmental issues that may be addressed by the Plan in order to improve the management of the area. It also describes the current status, and, where known, trends in status, of some specific environmental components of the Firth. This will inform the selection of monitoring elements to be used to assess the impacts of the Plan.

2 The Physical Environment

The Firth has a coastline of approximately 700km and includes eight sealochs, five estuaries and numerous islands, including Arran, Bute and the Cumbraes. The diverse nature of the area largely results from its underlying geology and the subsequent effects of glaciation during the last ice age. These processes, as well as the action of wind, rain and tide, have helped to create an area rich in biodiversity and ideal for human occupation.

2.1 Geology

The Firth is bisected by the Highland Boundary Fault (
Figure 2). The southern part of the firth is relatively unindented and low in relief, while the coastline in the northern part is more resistant to erosion, resulting in a more indented and dramatic landscape.

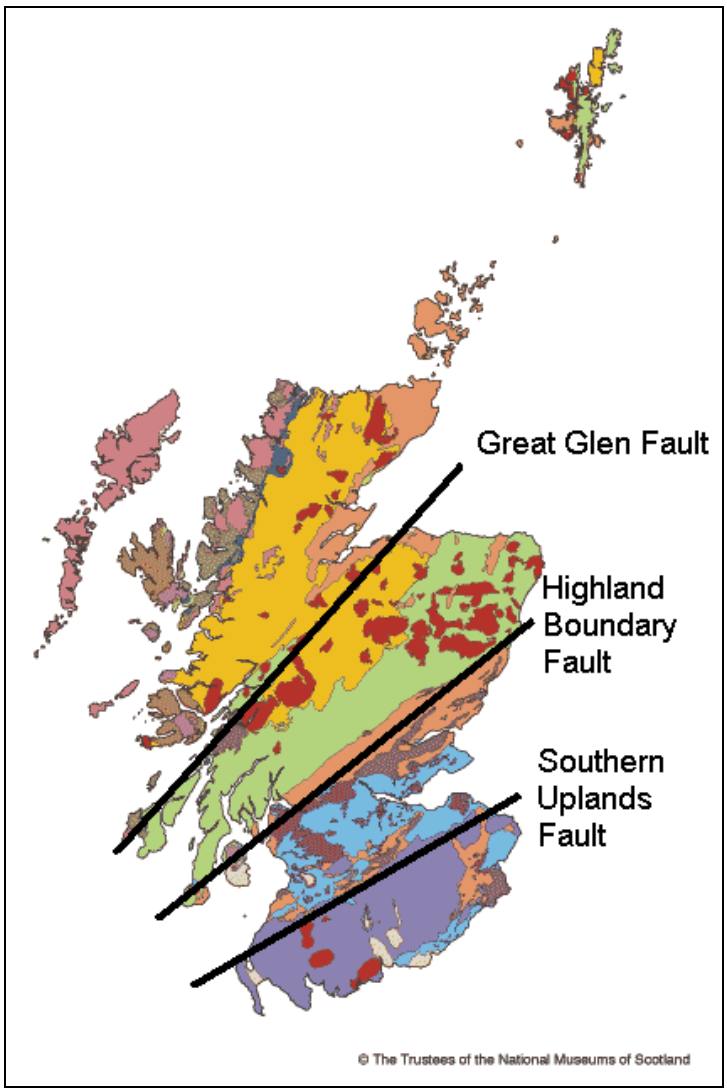


Figure 2: The geological fault lines of Scotland

Like much of the rest of the UK, the land surface of this area was completely covered by ice for most of the last ice age. The subsequent melting of the ice after 1.6 million years resulted in the upward movement of the land, which continues to this day. In this region the ice sheets were probably at their thickest and the depression of the land surface greater than anywhere else in the UK. As a consequence the land is still rising and evaluation of tide gauge data by Emery & Aubrey (1985) showed a fall in sea level across the Firth relative to the land surface, ranging from 2-6mm.

The Firth's complex geological structure has led to the designation of a number of Sites of Special Scientific Interest (SSSI) around its coast (Figure 3).



Figure 3: The locations of coastal SSSIs designated for geological features in the Firth of Clyde (Crown copyright. Licence number 100020538)



These geological SSSIs are detailed in Table 1, which also indicates the condition of each site as at summer 2008.

Table 1: Details of the SSSIs designated for geological features in the Firth of Clyde

Name	Feature	Site Condition[1]
Largs Coast Section	Non-Marine Devonian	Favourable Maintained
Strone Point, North Loch Fyne	Dalradian, structural and metamorphic geology	Favourable Maintained
Ardrossan to Saltcoats Coast	Permo-carboniferous igneous	Favourable Maintained
Maidens to Doonfoot	Dinantian, Permo-carboniferous igneous, Old red sandstone igneous	Favourable Maintained
Turnberry Lighthouse to Port Murray	Old red sandstone igneous	Favourable Maintained
Girvan to Ballantrae Coast Section	Stratigraphy and Igneous Petrology	Unfavourable
Sgavoch	Igneous petrology	Favourable Maintained
Drumadoon to Tormore	Stratigraphy and igneous petrology	Favourable Maintained
South Coast of Arran	Igneous petrology	Not known
Dippin Head	Igneous petrology	Favourable Maintained
Clauchlands Point	Igneous petrology	Favourable Maintained
Corrie Foreshore and Limestone Mines	Stratigraphy	Favourable Maintained
Laggan	Palaeozoic palaeobotany	Favourable Maintained
North Newton Shore	Non-Marine Devonian Stratigraphy	Favourable Maintained

Notes: 1 site condition as shown on Sitelink at http://www.snh.org.uk/SNHi/ June 2008

The Firth may be characterised into four broad physical types on the basis of underlying geology, tidal aspects and exposure to wind and wave, namely: sealochs; estuaries; sheltered coastal waters (Inner Firth); and, moderately exposed coastal waters (Outer Firth).

2.2 The Sealochs

The Firth contains eight sealochs, as shown in Figure 4. Seven of these (The Gareloch, Loch Long, Loch Goil, Holy Loch, Loch Striven, Loch Riddon and Loch Fyne) branch from the northern shore of the Firth into the mountains of Argyll and Dunbartonshire, with Loch Goil branching from Loch Long. Campbeltown Loch is located in the Outer Firth on the Kintyre Peninsula.

Several of these sea lochs are fjordic in character, being long, narrow basins, which are extremely deep in places. Some lochs (e.g. Striven and Goil) have shallow sills at their mouths, which restrict the circulation of water and reduce the horizontal exchange of water with the main channel of the Firth. Others, such as Loch Long and Holy Loch, are simple glaciated channels.

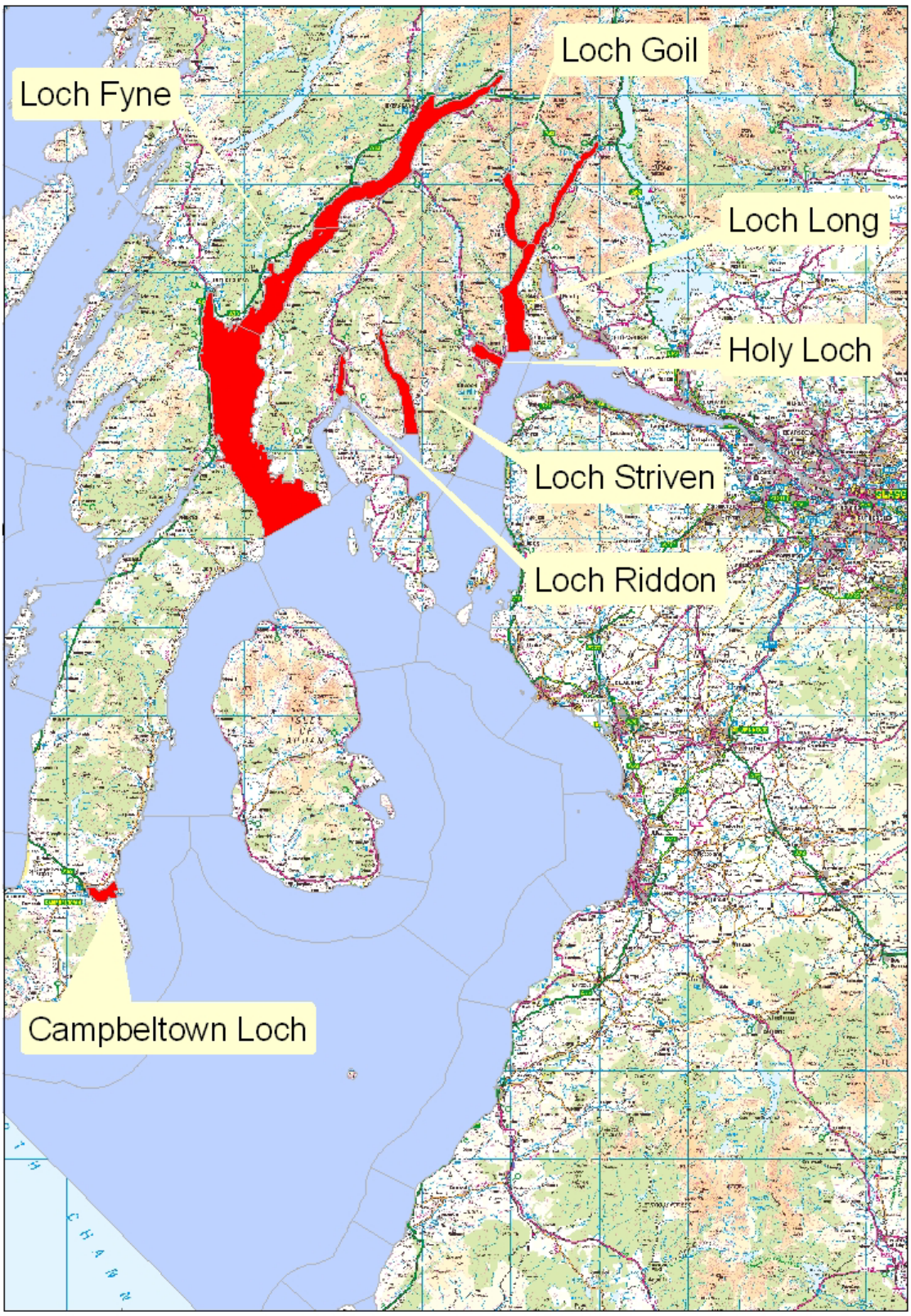


Figure 4: Sealochs in the Firth of Clyde (Crown copyright. Licence number 100020538)

All the lochs, and in particular the deeper northern ones, are generally sheltered throughout their length. The steep sided nature of the Clyde's sealoch landscape is shown in Figure 5.



Figure 5: Dunderave Castle in Upper Loch Fyne

In many cases this steep sided profile continues underwater, with several of the sealochs rapidly reaching depths of over 100m. Tidal currents are generally weak within these glacially deepened lochs, leading to the accumulation of thick sequences of mud across the loch bed. It is usual for these physical characteristics to remain unchanged over time. However, in 1991 the innermost of the two sills in the Gareloch was partially removed by dredging to allow access for submarines using the Naval base at Faslane.

Manganese nodules lying on and just below the surface of the sea floor are found in many of the sealochs of the Firth. These are a result of historic volcanic activity. However, commercial extraction has not proved worthwhile to date.

ISSUES

Partial removal of the inner sill in the Gareloch	Removal of inner sill may increase water circulation through the Gareloch, with the potential to reduce stratification and increase bottom water dissolved oxygen levels.

2.3 The Estuaries

An estuary can be described as 'a partially enclosed area at least partly composed of soft tidal shores, open to saline water from the sea, and receiving fresh water from rivers, land run-off or seepage' (Davidson *et al.* 1991).

In the glacially influenced region of the Firth there are few places shallow and sheltered enough for soft intertidal sediments to accumulate and as a consequence only five estuaries are identified across this area. Their locations are shown in Figure 6.

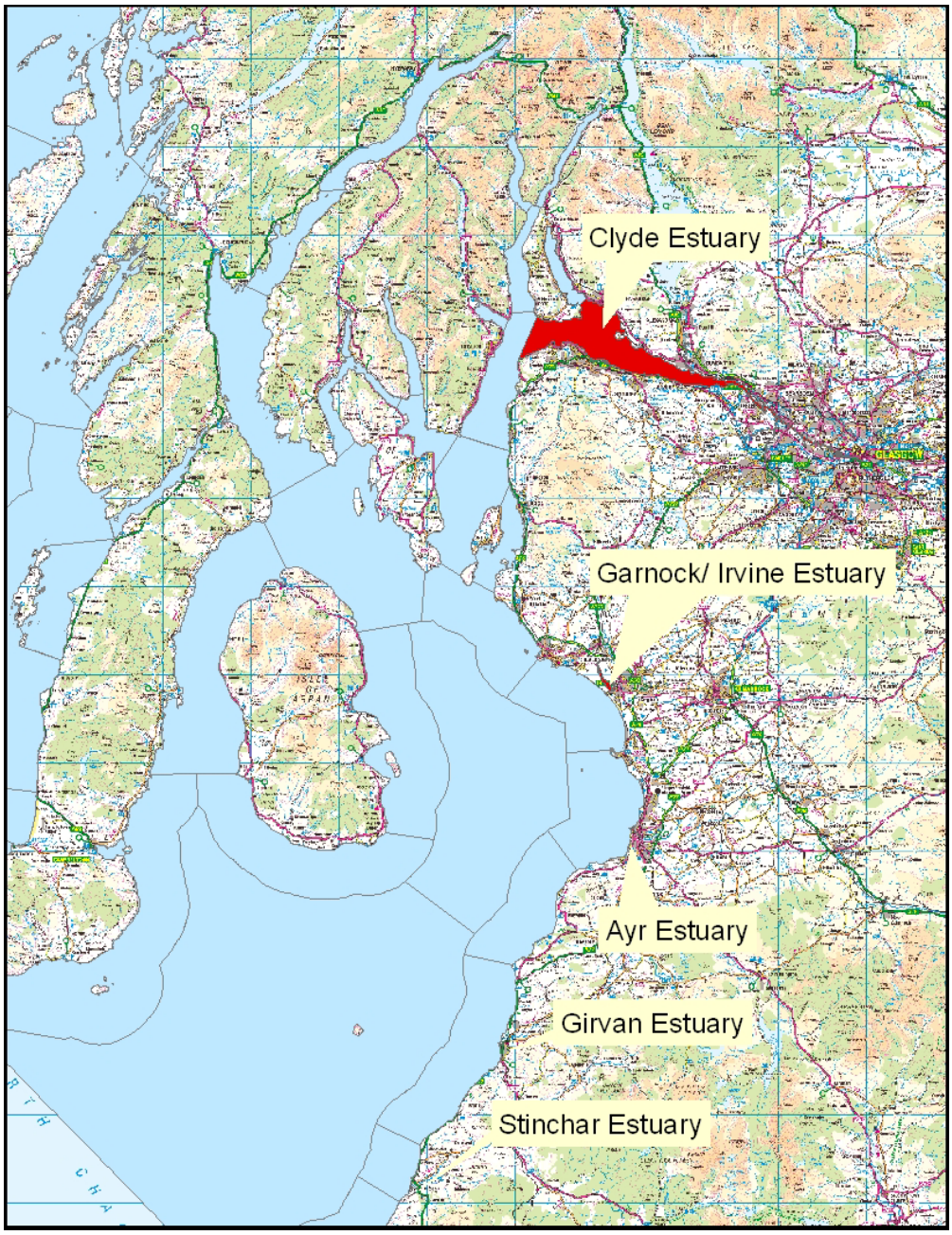


Figure 6: Estuaries in the Firth of Clyde (Crown copyright. Licence number 100020538)

The Clyde is the major estuary of the area and runs through the centre of Glasgow, stretching downstream to Gourock. It is fed by the freshwaters of the River Clyde, White Cart, Black Cart, River Gryfe and River Leven. It has an overall area of approximately 60km^2, of which some 20km^2 are intertidal. From its upper tidal limit at Glasgow Green to Erskine, the Inner Clyde Estuary is bounded by urban and industrial land (Figure 7).



Figure 7: The Inner Clyde Estuary

Below Erskine the Outer Clyde Estuary widens, the salinity becomes more stable, and at low tide banks of mud and sand are obvious on both north and south shores (Figure 8). As detailed in section 3.1.1, the historical modification of the Clyde Estuary's form has profoundly influenced its character.



Figure 8: Exposed intertidal mud of the Outer Clyde Estuary

The small, muddy estuary of the Rivers Irvine and Garnock (the Garnock/ Irvine Estuary) has suffered from severe pollution as a result of historic industrial activity, which discharged untreated chemical waste directly into it until the 1980s. Prior to this the Garnock Estuary was artificially straightened along part of its length, with the likely loss of intertidal habitat.

In spite of these pressures, the intertidal mudflats, saltmarsh and adjoining pasture of the Garnock/ Irvine Estuary remain a locally important feeding and roosting site for migrant and wintering waterfowl (section 4.4).

ISSUES

Land claim	Loss of intertidal habitat and flood plain may increase risk of flooding.
Seabed dredging	Artificially deepened channels may cause reduction in current speed in Clyde Estuary
Flow manipulation	Artificial manipulation of flow at tidal weir may reduce tidal energy through the Clyde Estuary.

2.4 The Inner Firth

Firth is the Scots word used to denote various coastal waters in Scotland. It is usually a large sea bay, which may be part of an estuary, or just an inlet, or even a strait. A firth is generally the result of ice age glaciation and is very often associated with a large river.

The Firth can be split into two broad areas according to exposure to wave action. The first of these, the Inner Firth of Clyde (the Inner Firth), is a sheltered area (Figure 9), which includes the Kyles of Bute and Largs Channel.



Figure 9: The Inner Firth of Clyde (Crown copyright. Licence number 100020538**)**

The Inner Firth is 30km long and up to 6km wide and has several of the characteristics of a fjordic system, since it consists of glaciated valleys now covered

by seawater. The bathymetry of this area is very complex, with some parts being relatively shallow, whilst others are narrow and deep, reaching up to 100m depth.

The tidal range is relatively small at about 1.8m for mean neap tides and 3.1m for mean springs tides (UK Hydrographic Office, 2007). Tidal velocities are also weak, in the range 0.1-0.4 ms^{-1}. This results in small tidal excursions (i.e. the distance water travels during a tide), typically about 3.6 to 3.8 km on a spring tide at Little Cumbrae and Wemyss Bay (Townson and Collar, 1986). The sheltered nature and high scenic quality of much of the Inner Firth makes it a favoured location for recreational sailing.

2.5 The Outer Firth

The Outer Firth of Clyde (the Outer Firth) is shown in Figure 10.

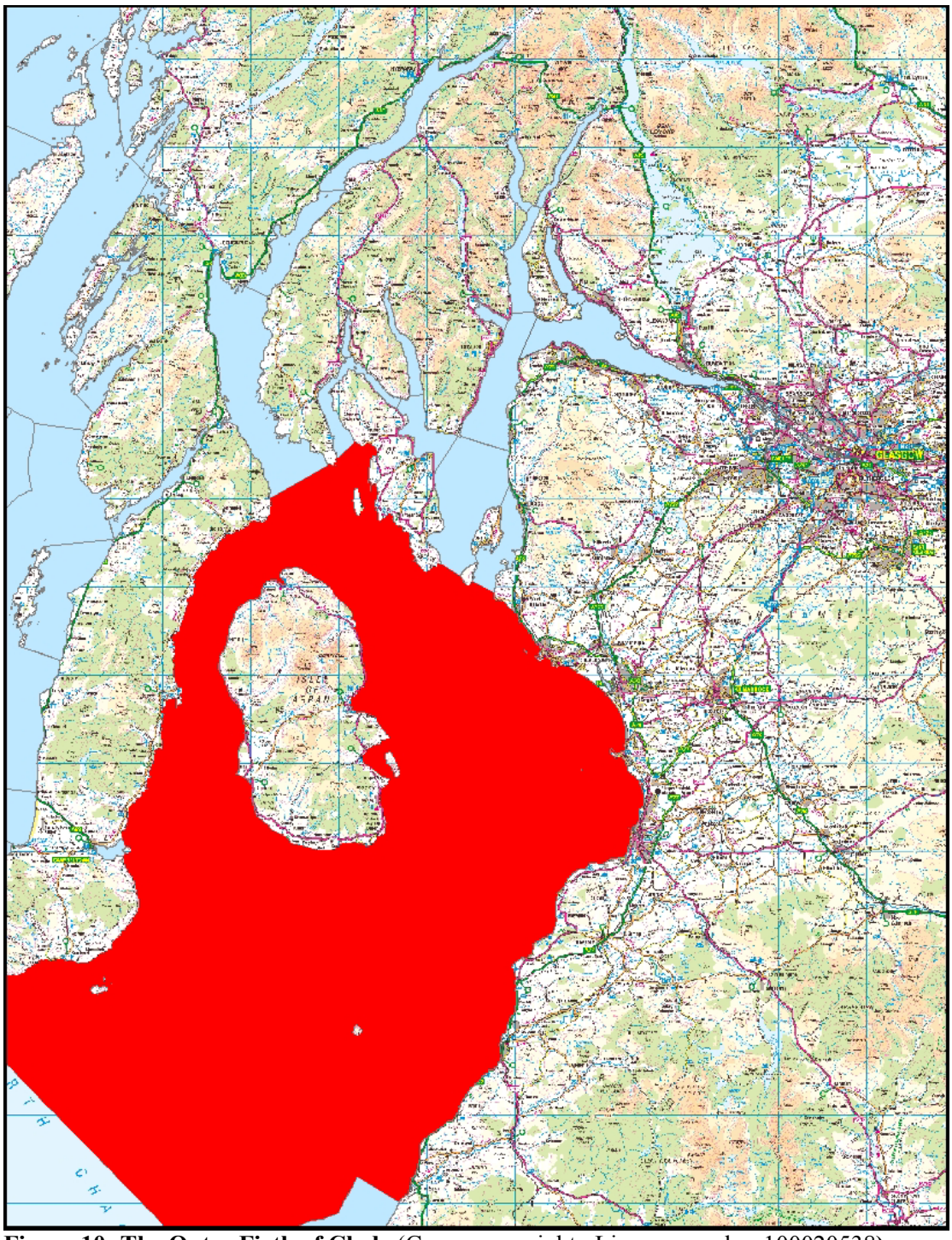


Figure 10: The Outer Firth of Clyde (Crown copyright. Licence number 100020538**)**

Whilst generally more exposed than the Inner Firth, this area remains reasonably sheltered from the prevailing south-westerly winds by Northern Ireland, the Kintyre Peninsula, and the Isle of Arran. The maximum fetch for south-westerly winds is 96km and wave heights rarely exceed 2.5m.

The water circulation across the area is weak, with the direction of movement dictated by the wind when it exceeds 7m/s. Under conditions of gentler winds, the water circulation is a weak northwards movement as part of the general circulation of the Firth.

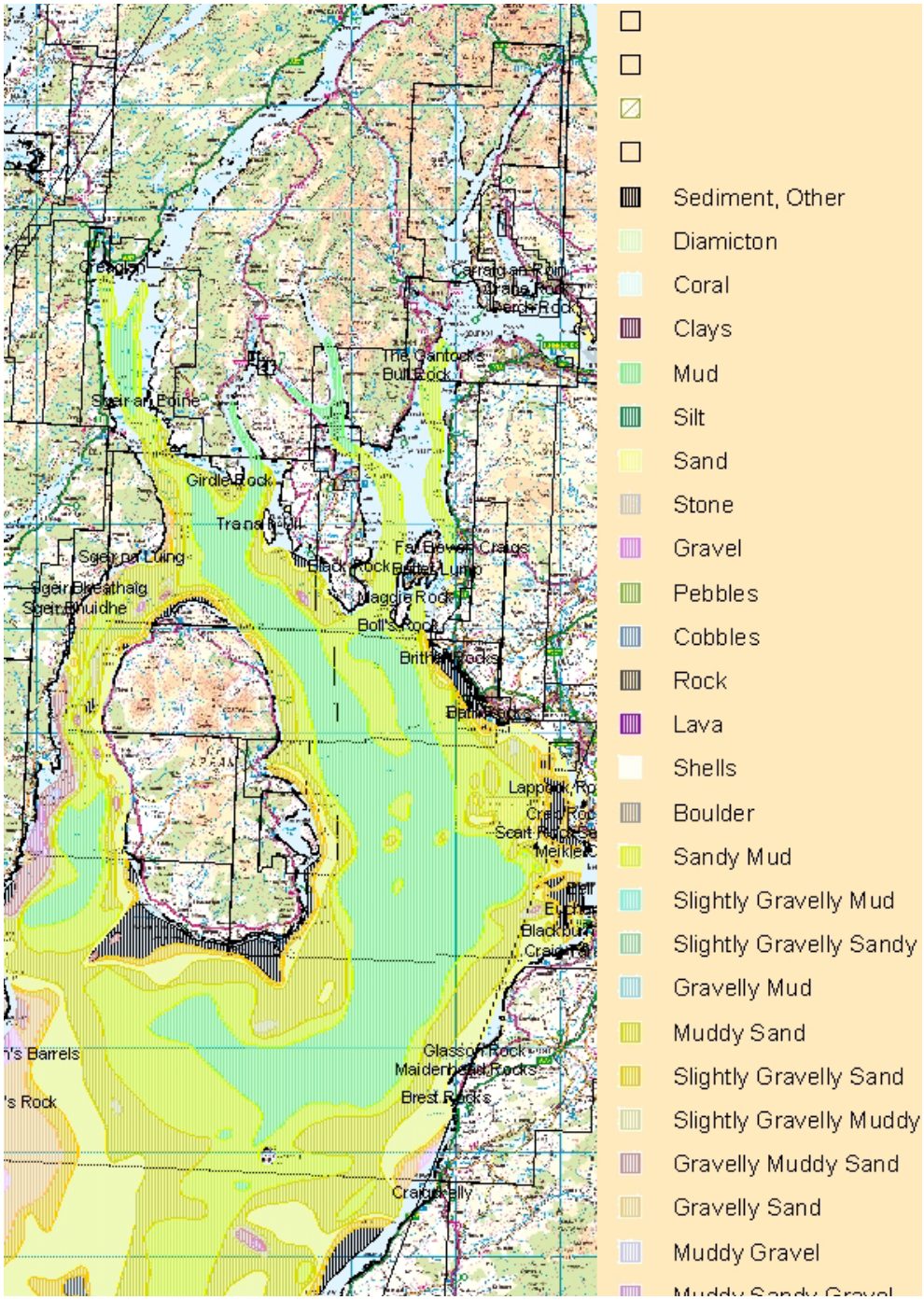


Figure 11: Seabed substrates of the Firth of Clyde

In winter the Great Plateau to the south of Arran marks a well defined temperature boundary, with temperatures to the north being slightly lower than those to the south. In the summer this effect is not so well displayed and the warmest area is east of

Arran (13.2°C), while the more open sea to the south is around 12°C (Ellet & Edwards, 1983).

The wind directions recorded at Prestwick airport show only a moderate bias towards the south-west, as the site is open to winds from the east. The difference in mean wind speed at Prestwick (about 4.7 m/s) and Tiree (about 7.6 m/s) reflects the sheltering effect of Arran and Kintyre, compared with the more windy conditions experienced on exposed westernmost coasts. The gale of 1968 generated winds of 44.6 m/s at Prestwick compared with the normal average annual maximum of 31.7 m/s. Such extreme events are estimated to occur at Prestwick once every 75 years (British Geological Survey, 1997a).

This sheltering, coupled with deep waters (depths of up to 140m off Arran) and a moderate tidal range, leads to a seabed dominated by mud. Figure 11 shows the range of seabed sediments found across the Firth by the British Geological Survey, and highlights the scarcity of rock and gravel substrates.

Sand dunes exist in the low lying bays around Irvine and Ayr, with these and other hindshore dunes having been modified by human activity, including the development of golf courses. There is severe erosion between Troon and Saltcoats in Irvine Bay, which is being defended by a variety of means, including a collapsing seawall as shown in Figure 12.



Figure 12 : Collapsed sea defences at Irvine Bay, Outer Firth of Clyde

Within the Outer Firth there are extensive shingle shores, which include present shores as well as those deposited at the end of the last glaciation, when sea levels were some metres higher, and which are now out of reach of normal tides. At

Ballantrae these shores have been piled up against one another to form shingle structures, which are deemed of national geological importance (Table 1).

ISSUES

Coastal defences	Protecting the coast from erosion may restrict the natural movement of shorelines and shoreline sediments and potentially increase coastal flooding elsewhere

2.6 Coastal Flooding

Coastal flooding is usually associated with a combination of high tide and storm surge. A storm surge is a meteorologically induced change in the water level (generated by atmospheric pressure and wind effects) relative to the predicted astronomic tide. Wave effects during flood events are also important in exposed areas.

Flooding of coastal communities and transport links around the Firth and into the Clyde Estuary from high tides, storm surges and wave impacts cause disruption on an almost annual basis. SEPA has recorded positive surge values in the Clyde Estuary of up to 2m during major storm surge events and the coastal rail and road links in North Ayrshire, the Helensburgh area and parts of Argyll and Bute can be particularly affected by waves and spray.

Flood events can cause major and widespread impacts to coastal communities such as Tarbet, Rothesay, Dumbarton and Saltcoats. The flood which occurred on the 5th January 1991, caused an estimated £7M (1990 prices) worth of damage (Becker, pers.com). More recently, flooding has seriously affected Renfrew and parts of Dumbarton where a large number of properties and businesses are potentially at risk of flooding from high tides and storm surges. Parts of Glasgow adjacent to the River Clyde are also potentially at flood risk from tidal inundation during an extreme flood event.

In 1999 SEPA implemented a coastal flood-warning scheme for the Firth, which provides a forecast of high water levels up to 24 hours in advance of the flood event. The forecasting system utilises forecast data from the Met Office to drive a sophisticated modelling system of the Firth and Clyde Estuary. The warnings are available to the public via the SEPA Floodline (0845 9881188 or at sepa.org.uk/flooding) and are also disseminated to Local Authorities and Strathclyde Police.

Some Local Authorities have also developed flood alleviation schemes for some of the higher risk areas, such as Rothesay and Largs and proposals for other alleviation schemes are being developed for other areas.

SEPA has also recently developed a coastal flood map for the whole of the Scottish coastline, including the Firth, which is available on the SEPA website at www.sepa.org.uk/mapping. This tool is primarily to support planning processes, but is also a useful tool to raise awareness of flood risk.

ISSUES

Periodic coastal flooding around the Firth during storm surges	Potential negative impact on coastal communities and wildlife (e.g. ground nesting birds).

3 Clean and Safe Seas

"Clean and safe seas" is a key element of the vision for Scotland's seas (Scottish Executive, 2005), and is taken as principally relating to the chemical, nutrient, bacteriological and litter status of Scottish seas.

3.1 The Chemical Environment

Almost anything can be found in seawater**,** including dissolved materials from the Earth's crust as well as materials released by man. The most important components of seawater that influence life are salinity, temperature, dissolved gases (mostly oxygen and carbon dioxide), nutrients, and pH.

In addition, a range of other organic and inorganic compounds may be present in seawater, with these being either natural or manmade. The hazards presented by these chemicals vary and only some are of concern in the environment.

Monitoring Water Quality

In the ten years to 2006, SEPA classified the status of estuarine and coastal waters in Scotland on the basis of a range of assessment criteria including various aesthetic, biological and chemical condition measures. From 2007, in accordance with the requirements of the Water Framework Directive (2000/60/EC), a new system of assessing coastal and estuarine water quality around Scotland, based on ecological and chemical status measures, is being introduced. The first classifications based on this new system will be published in 2009. Bacteriological quality assessments will be continued within designated Shellfish Growing Waters and Bathing Waters.

The water quality assessments reported here are based on the system in place up to 2006.

During the last twenty years significant improvements have been made to the chemical quality of the coastal environment as a result of the cessation of discharge or improvements in the treatment of sewage and industrial wastes. As a consequence, diffuse pollution from farmland and urban areas is now considered the largest source of pollution to Scottish coastal waters (SEPA, 2006).

3.1.1 Dissolved Oxygen

Dissolved oxygen (DO) is vital to sustain aquatic life and hence reduced levels of oxygen in water can stress the plants and animals dependant on it. Microbial degradation of organic waste requires oxygen and hence organic pollution or naturally occurring organic material entering watercourses can give rise to low oxygen levels.

The Clyde Estuary has suffered from severe pollution since the industrial revolution, primarily as a consequence of a densely populated catchment reliant on it for waste disposal. Figure 13 shows the shallow River Clyde at Glasgow in the mid 17th century, with two men watering their horses.



Figure 13: The Auld Brig by William Simpson (1823-1899)

The poor flushing characteristics of the River Clyde between Glasgow and Erskine were exacerbated by physical modifications made between 1750 and 1900, designed to allow greater access to Glasgow for an ever-increasing shipping industry. These modifications included the narrowing and deepening of the River Clyde from Erskine upstream and the installation of a tidal weir at Glasgow, all of which affected tidal movement; essentially moving the original natural tidal limit from Erskine to Glasgow and increasing sedimentation. Figure 14 shows the canalised Inner Clyde Estuary of today.



Figure 14: The Inner Clyde Estuary at Broomielaw, Glasgow

Dissolved oxygen levels have been routinely measured in the Clyde Estuary for nearly 40 years, with summarised results shown in Figure 15. These indicate that the Inner Clyde Estuary was completely devoid of oxygen during the early 1970s. Steady improvements through the 1980s coincided with the return of salmon in 1983, after an absence of over 120 years. This milestone event marked the culmination of over a century of effort to restore to health one of the most polluted river basins in Britain.

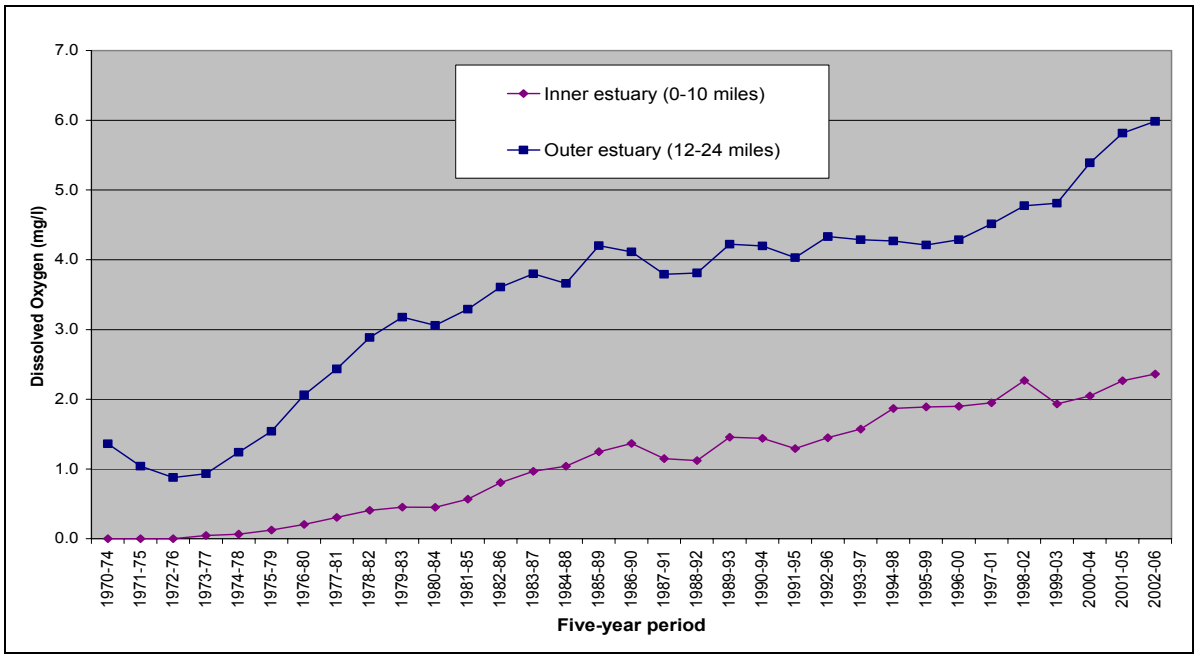


Figure 15: Dissolved oxygen levels in the Clyde Estuary (1970-2006), as five-year depth average mean values

Recent studies indicate that an upper limit of 7mg/l will satisfy most ecological requirements and that a dissolved oxygen level below 2 mg/l will stress the majority of fish species. These limits form part of the Water Framework Directive's regulatory and classification standards, and, when applied to Figure 15, show that current water quality in the Inner Clyde Estuary can be described as 'poor' (>2.0 mg/litre but <3.0 mg/litre), while in the Outer Clyde Estuary it is 'good' (>5.0 mg/litre).

Urban diffuse pollution and overflows from the sewerage system following periods of heavy rain continue to cause poor water quality in the River Clyde, its tributaries and the Inner Clyde Estuary. Consequently, work has started to address these problems, with the Metropolitan Glasgow Strategic Drainage Partnership (MGSDP) providing a strategic solution to drainage within the greater Glasgow area. This will require major investment in new sewers and sustainable urban drainage, but will improve the quality of life for people in Glasgow and support the regeneration of the city.

Deep sealochs may have naturally low dissolved oxygen levels due to isolation of their bottom waters through the natural process of stratification. This can be exacerbated through the oxygen-demanding decay of natural or anthropogenic organic material.

The bottom waters of the Gareloch and Loch Goil are known to have low dissolved oxygen levels, with waters at 40m in Loch Goil regularly falling to less than 2.0 mg/l (Figure 16). This is believed to be an entirely natural occurrence resulting from the silled nature of these lochs and is not associated with any recorded instances of mortalities of seabed species.

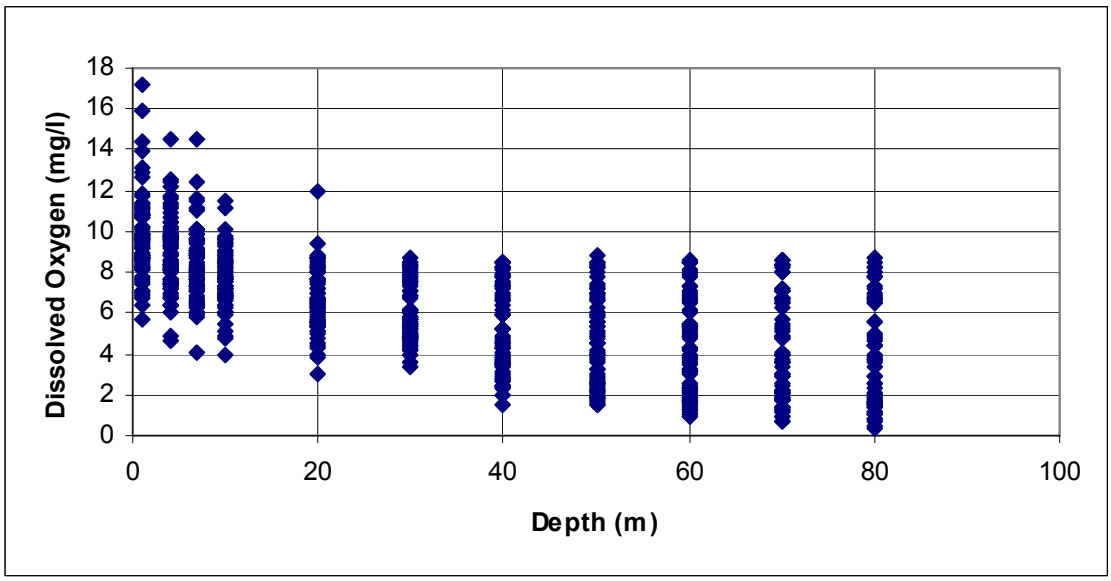


Figure 16: Variation in dissolved oxygen with depth in Loch Goil

ISSUES

Low Dissolved Oxygen	There are threats to the biological and recreational value of the Inner Clyde Estuary due to a combination of poor flushing characteristics and oxygen demand from degrading organic material.

3.1.2 Nutrients

Nutrients such as nitrogen and phosphorus are essential to support life and are naturally 'cycled' within the environment. The balance of these cycles can be disturbed by the addition of extra nutrients through natural events and human activity. The adverse effects of elevated nutrient levels is known as hypernutrification, and this can lead to eutrophication if the excess nutrients lead to excessive plant growth (e.g. plankton blooms). These events can in turn lead to oxygen depletion and impacts on seabed animals, with detrimental effects on fisheries and recreational value. In the sea it is nitrogen, rather than phosphorous, that generally limits plant growth and hence man-made inputs of nitrogen compounds, such as nitrates from household waste and fertilisers, may cause hypernutrification and in turn, eutrophication in estuarine and coastal waters.

Across Scotland the majority of nutrient inputs come from diffuse sources such as agriculture, but this can vary widely according to the size of the river catchment and weather conditions. However, in the Firth the majority of nitrogen inputs come from the Clyde Estuary, due to a combination of point source inputs from sewage

treatment works and diffuse sources from agricultural land, which contribute nutrients to local rivers. Nutrient loadings entering Scottish marine waters are measured from rivers, sewage treatment works, industrial discharges and marine cage fish farms and the most recent data on loadings shows a generally downward trend (SEPA, 2006).

In coastal waters of salinity 30 to 34.5, such as those typically found in the Firth, the Water Framework Directive (WFD) has identified status boundaries for dissolved inorganic nitrogen (DIN) of:

- <12 μM for high status
- >12 and <18 μM for good status

Winter nutrient concentrations in the Firth have been routinely measured since the 1970s, with the concentrations in the Firth and its sealochs consistently achieving good or high status, as shown by Figure 17.

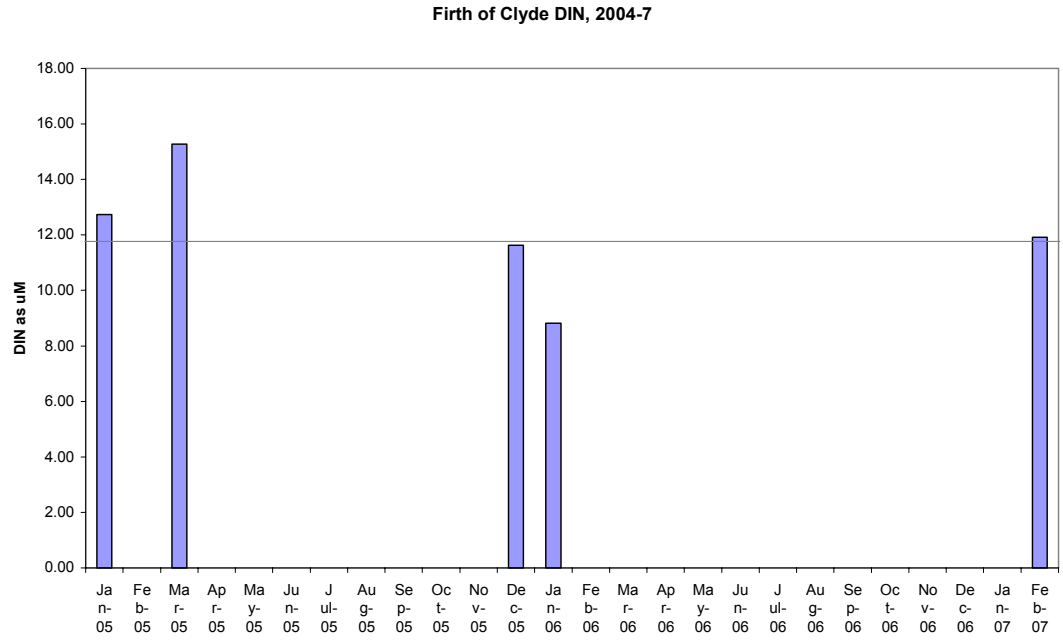


Figure 17: Winter DIN in the Firth of Clyde, 2004 to 2007

Phytoplankton levels in the Firth are generally low to moderate and below the threshold of 15 ug/l as the 90%-ile for the summer months April to September. This shows that the nutrients entering the Firth are not causing observable detrimental effects.

For estuary waters of salinity less than 30, the WFD requires winter DIN concentrations to be normalised to a salinity of 25, then for these normalised concentrations to be compared to threshold values of:

- <20 μM for high status
- >20 and <30 μM for good status

These threshold values only apply to estuaries with “clear” waters (i.e. with total suspended solids levels of less than 10 mg/l).

Figure 18 shows nitrogen concentrations in the Clyde Estuary for the period 1998-2004, which indicate that the nutrient status of the Clyde Estuary is generally good.

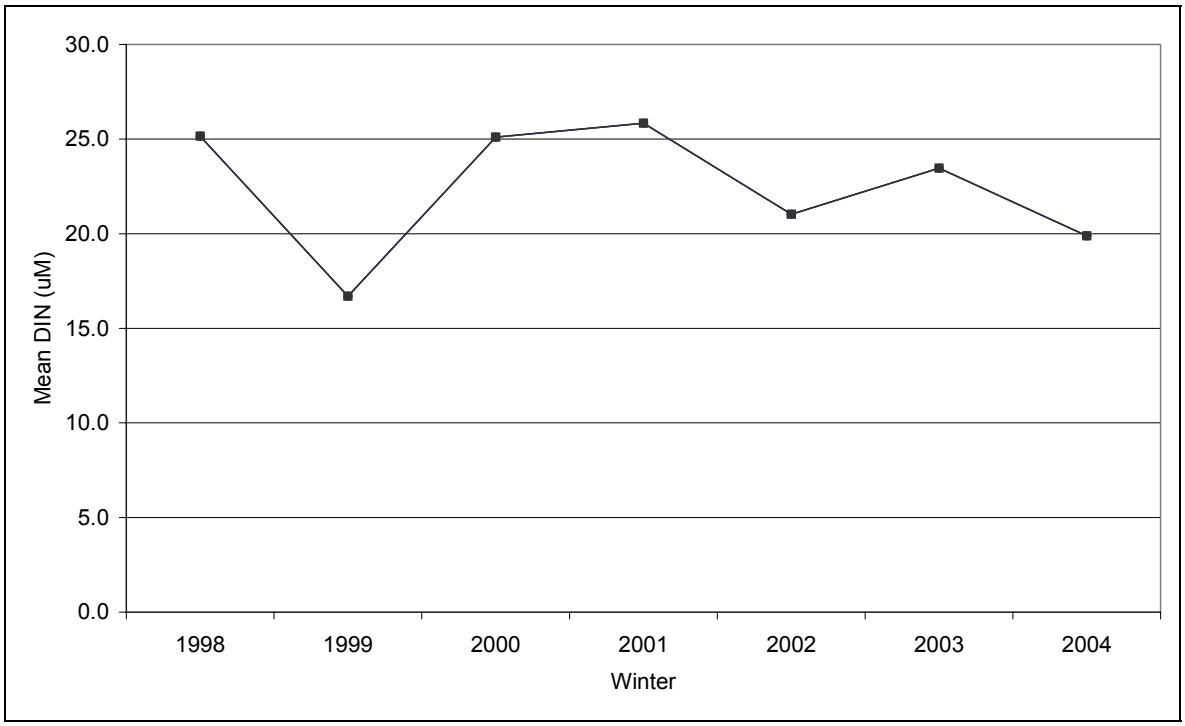


Figure 18: Clyde Estuary mean winter nitrogen, 1998 to 2004

ISSUES

Elevated nutrient levels	Nutrient levels in the Clyde Estuary are elevated due to point source inputs from sewage works, and diffuse sources from rivers draining agricultural land.

3.1.3 Hazardous Substances

A wide assortment of chemicals is used by society every day, including plastics, metals, medicines, fertilisers and paints. Current estimates suggest that there are approximately 30,000 chemicals on the EU market, with approximately 300 new ones added each year. The hazards presented by these chemicals vary and only some are of concern in the environment (SEPA, 2006).

Hazardous chemicals are taken here to represent chemicals that are toxic, persistent, bio-accumulative, hormone disrupting or of an equivalent level of concern.

Such chemicals may be released into the environment in many ways (e.g. disposal down drains and sewers, litter, industrial emissions, releases from cars, fertilisers spread on fields, and waste disposal tips).

There is a long history of chemicals having been used and released into the Scottish environment, with industrial and sewage waste disposed of to river and sea with no treatment until the 1950s. Indeed a government report in the late nineteenth century identified pollution from sewage and lead mining in the Clyde catchment, and over 100 years later the contamination from lead mining is still evident. Pollution from other industries such as steelworks, gasworks and shipbuilding also remain, with significant levels of contaminants in Clyde Estuary sediments, and even elevated levels of chromium in Clyde Estuary waters from leachate from polluted land upstream.

These chemicals can remain locked in sediments for a long time, but may be released by disturbance and translocated elsewhere, from activities such as seabed dredging. There are several licensed disposal sites across the Firth at which dredged sediment can be deposited.

It is not surprising therefore, that there is a noticeable increase in contamination in the area used for dumping dredge spoil in the Inner Firth, close to the mouth of the Holy Loch (Baxter et al, 2008).

Some areas of the Clyde Estuary have been degraded due to elevated levels of persistent substances such as lead, chromium and polychlorinated biphenyls (PCBs). Mussels are used as biomonitors for such chemical contaminants because they bioaccumulate elevated concentrations of these substances over time. Cadmium and lead concentrations in Clyde mussels fell significantly between 1980 and 1997. The downward trend for cadmium may reflect a general decline in heavy industry in the area, whilst the decrease in lead levels may be linked to the introduction of lead-free petrol in the UK in 1983 (SEPA, 2007). Data from SEPA's 2006 estuarine classification scheme show that contaminant concentrations in mussels from the Clyde Estuary continue to decline. In particular chromium concentrations at previous pockets of unsatisfactory waters at Cardross, Woodhall, Port Glasgow, Helensburgh, Portkil Bay, Ardmore and Dunoon East have all fallen, to an extent that water quality at these locations is now classed as good. The 2006 classification results for the Clyde Estuary are shown in Figure 19.

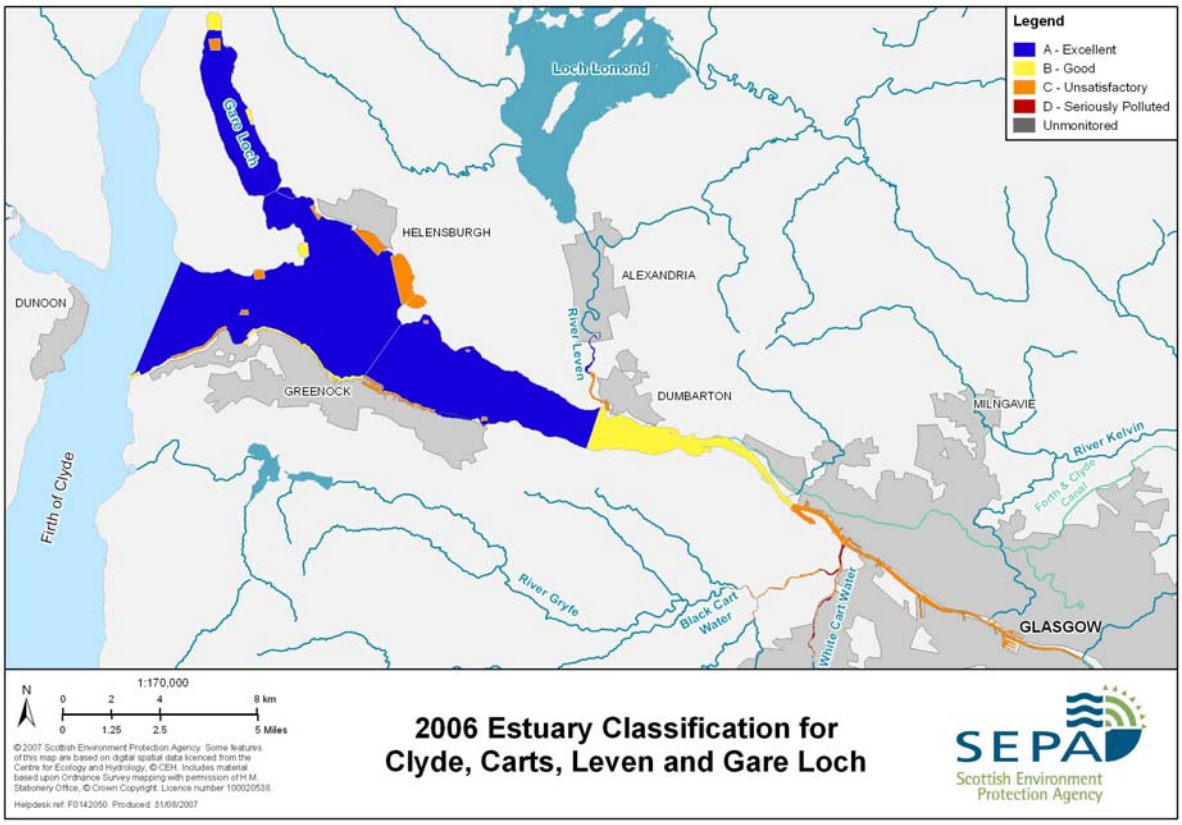


Figure 19: SEPA estuary classifications for Clyde, Carts, Leven and Gareloch

Monitoring of chemical substances is also done in waters and shellfish at locations where naturally occurring shellfish are harvested for human consumption. Monitoring data at these sites over the past 10 years has shown that contaminant levels in waters and shellfish from these sites consistently achieve EU environmental standards (Table 2)

Table 2: Chemical status for designated shellfish growing waters in the Firth of Clyde

Name	Date Designated	Chemical Status
Ayrshire Coast	01/04/1998	Good
Lochs Long and Goil	01/04/1998	Good
Loch Fyne Coastal Strip	01/04/1998	Good
Kyles of Bute	01/04/1998	Good
Fairlie	21/03/2002	Good
Loch Striven	21/03/2002	Good

3.1.4 Radioactive Substances

The sea is also subject to contamination by radioactive substances arising from a range of applications, including power generation, medicine and defence. In Scotland, the handling and disposal of such substances are regulated by SEPA and the agency also undertakes a continual and wide-ranging monitoring programme.

There are several potential sources of radionuclide contamination within or adjacent to the Firth, notably the Sellafield complex in Cumbria, the Hunterston A and B reactors in Ayrshire (of which A is currently being decommissioned), and the Faslane nuclear submarine base and Coulport arms depot (Baxter *et al*, 2008).

Authorised liquid discharges are made to the Firth from Hunterston B via the stations' cooling water outfall. Authorised liquid discharges from Hunterston A are also made via the same outfall. The main part of the aquatic monitoring programme around Hunterston consists of sampling of fish and shellfish and the measurement of gamma dose rates on the foreshore. Samples of sediment, seawater and seaweed are analysed as environmental indicator materials. The results of aquatic monitoring in 2007 around Hunterston are shown in Table 3 and Table 4 (CEFAS, 2008).

Table 3: Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2007

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{54}Mn	^{58}Co	^{60}Co	^{90}Sr	^{99}Tc	^{110m}Ag
Marine samples									
Cod	Millport	2		<0.10	<0.15	<0.10			<0.10
Hake	Millport	2		<0.16	<0.33	<0.15			<0.19
Crabs	Millport	2		<0.17	<0.31	<0.17		8.5	<0.18
Nephrops	Millport	2		<0.10	<0.13	<0.10			<0.10
Lobsters	Largs	1		<0.10	<0.10	<0.10		57	<0.10
Squat lobsters	Largs	3		<0.10	<0.13	<0.10	<0.10	2.9	<0.10
Winkles	Pipeline	2		0.45	<0.23	<0.28			0.31
Scallops	Largs	4		<0.11	<0.15	<0.12			<0.11
Oysters	Hunterston	1		<0.10	<0.16	<0.10			<0.10
Fucus vesiculosus	N of pipeline	2		0.71	<0.12	0.19			<0.10
Fucus vesiculosus	S of pipeline	2		1.4	<0.13	<0.31			<0.10
Sediment	Fairlie	1		<0.10	<0.15	<0.10			<0.11
Sediment	Millport	1		<0.10	<0.10	<0.10			<0.10
Sediment	Gull's Walk	1		<0.10	<0.10	0.81			<0.10
Sediment	Ardneil Bay	1		<0.10	<0.10	<0.10			<0.10
Seawater	Pipeline	2	2.2						

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{125}Sb	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Marine samples									
Cod	Millport	2	<0.16	1.7	<0.40	<0.19			<0.17
Hake	Millport	2	<0.29	2.3	<0.73	<0.27			<0.19
Crabs	Millport	2	<0.32	0.41	<0.77	<0.33	<0.0040	0.0075	0.0070
Nephrops	Millport	2	<0.34	0.62	<0.27	<0.14			<0.15
Lobsters	Largs	1	<0.10	0.32	<0.21	<0.10			<0.10
Squat lobsters	Largs	3	<0.16	0.35	<0.33	<0.16	0.0045	0.022	0.0091
Winkles	Pipeline	2	<0.36	0.42	<0.78	<0.33	0.023	0.11	0.025
Scallops	Largs	4	<0.21	0.44	<0.47	<0.22	<0.00084	0.011	0.0064
Oysters	Hunterston	1	<0.20	0.29	<0.44	<0.19			<0.11
Fucus vesiculosus	N of pipeline	2	<0.10	0.94	<0.28	<0.13			<0.10
Fucus vesiculosus	S of pipeline	2	<0.15	0.61	<0.31	<0.14			<0.11
Sediment	Fairlie	1	<0.33	8.1	<0.60	<0.30			<0.28
Sediment	Millport	1	<0.10	3.8	<0.29	<0.15			0.21
Sediment	Gull's Walk	1	0.39	6.3	<0.39	<0.12			0.61
Sediment	Ardneil Bay	1	<0.10	2.8	<0.28	0.39			0.13

Table 4: Monitoring of radiation dose rates near Hunterston nuclear power station, 2007

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Largs Bay	Stones	2	0.055
Kilchatten Bay	Sand	2	0.051
Millport	Sand	2	<0.047
Gulls Walk	Mud	2	0.056
0.5 km north of pipeline	Sand	2	0.055
0.5 km south of pipeline	Sand and stones	2	0.068
Ardneil Bay	NA	2	<0.047
Ardrossan Bay	NA	2	0.051
Beta dose rates			µSv h^{-1}
Millport	Sand	1	<1.0
Fairlie	Sand	1	<1.0

NA *Not available*

The concentrations of artificial radionuclides in the Firth are predominantly due to Sellafield discharges, the general values being consistent with those to be expected at this distance from Sellafield. The reported concentrations of technetium-99 from Sellafield in crabs around Hunterston were similar to those in 2006. Technetium-99 concentrations in the common lobster continued to decrease in 2007. Small concentrations of activation products such as manganese-54 that are likely to have originated from the site were also detected, but were of negligible radiological significance (CEFAS, 2007).

Caesium-137 concentrations in marine sediments near nuclear power stations, from 1998 to 2007 are shown in Figure 20.

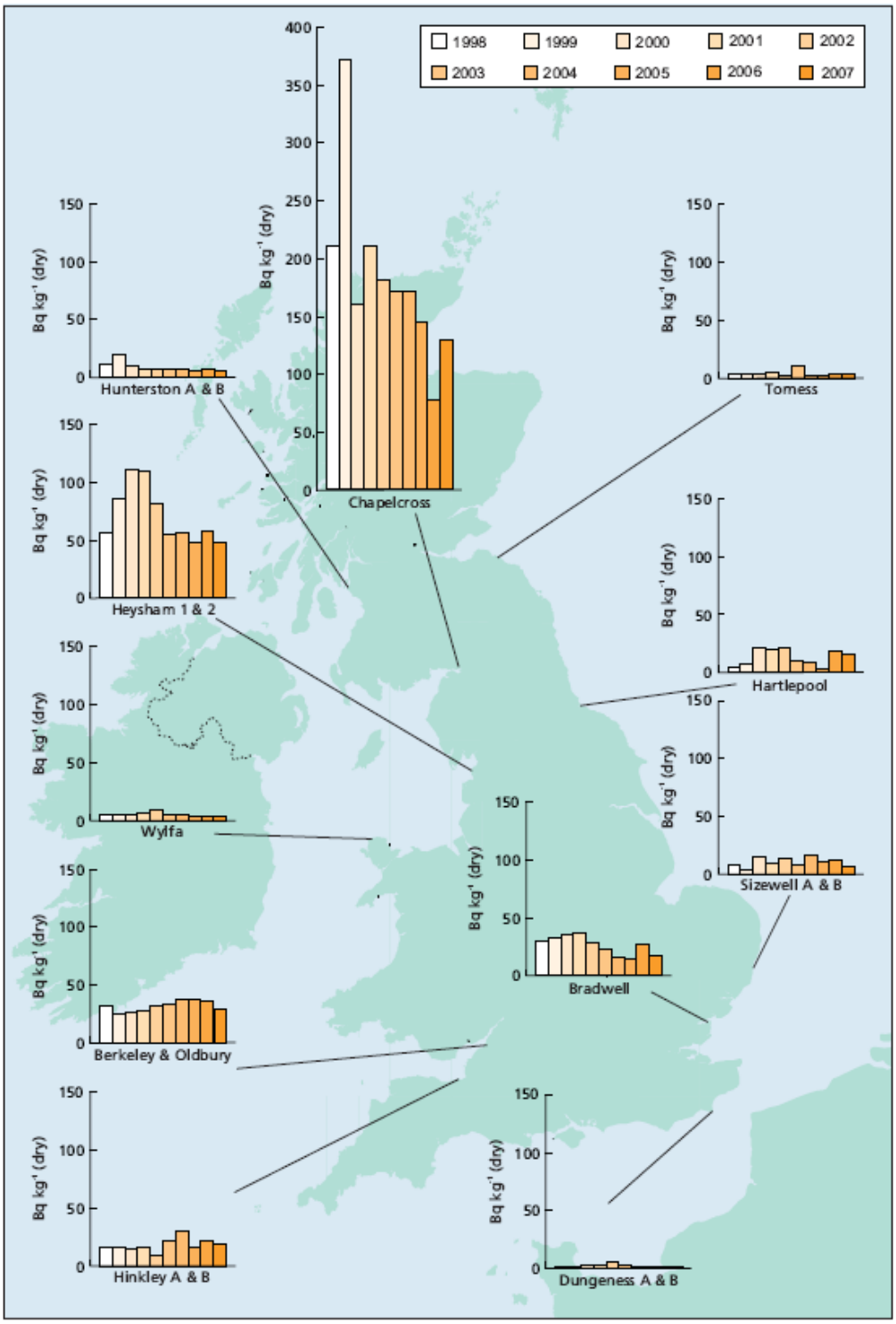


Figure 20: Caesium-137 concentration in marine sediments near nuclear power stations 1998-2007

Discharges of liquid radioactive waste into Gare Loch from Faslane and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from Coulport are made under letters of agreement between SEPA and the MoD.

In 2007, the monitoring programme consisted of the analysis of seawater and seaweed samples, and gamma dose rate measurements. Samples of non-migratory fish species were not available. In addition SEPA collected samples of mussels and had the shell and flesh analysed separately to assess the impact of utilising the mussel shell as a fertiliser. A small programme of monitoring at Holy Loch continued in order to determine the effects of past discharges from the US submarine support facilities which closed in March 1992. The results of aquatic monitoring around Faslane and Holy Loch are shown in Table 5. These indicate that radioactivity concentrations were low, and in most part due to the combined effects of Sellafield, weapons testing and Chernobyl (CEFAS, 2007).

Table 5: Concentrations of radionuclides in food and the environment near defence establishments, 2007

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}										
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{58}Co	^{60}Co	^{65}Zn	^{95}Zr	^{106}Ru	^{110m}Ag	^{125}Sb
Faslane													
Mussels (flesh)		1				<0.11	0.68	<0.05			<0.94	0.21	<0.26
Mussels (shell)						<0.02	0.04	0.09		<0.03	<0.19	0.05	<0.06
Fucus vesiculosus	Rhu	1				<0.10	<0.10	<0.10	<0.10	<0.14	<0.26	<0.10	<0.10
Seawater	Carnban boatyard	2		<14		<0.10	<0.10	<0.10	<0.11	<0.13	<0.30	<0.10	<0.12
Holy Loch													
Sediment	Mid Loch	1				<0.10	<0.10	<0.10	<0.22	<0.15	<0.49	<0.10	<0.16

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}										
			^{131}I	^{134}Cs	^{137}Cs	^{155}Eu	Total U	^{234}U	^{235}U	^{238}U	^{241}Am	Gross alpha	Gross beta
Faslane													
Mussels (flesh)		1		0.46	0.34	<0.09					<0.06		
Mussels (shell)				<0.02	<0.02	<0.04					<0.03		
Fucus vesiculosus	Rhu	1		<0.10	0.58	<0.10					<0.10		
Seawater	Carnban boatyard	2		<0.10	<0.10	<0.13					<0.10		
Holy Loch													
Sediment	Mid Loch	1		<0.10	3.1	0.73					0.52		

Establishment	Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate				
Faslane	Gareloch Head	Mud, sand and stones	2	0.052
Faslane	Gulley Bridge Pier	Sand and stones	2	0.057
Faslane	Rhu	Gravel	2	0.062
Faslane	Helensburgh	Sand	2	0.051
Faslane	Carnban boatyard	Gravel	2	0.075
Holy Loch	North Sandbank	Mud and sand	1	0.062
Holy Loch	Kilmun Pier	Sand and stones	1	0.067
Holy Loch	Mid-Loch	Sand	1	0.049

Note: data in tables 3, 4 and 5 is taken from Radioactivity in Food and the Environment Report, 2007 (Cefas, 2008)

ISSUES

Historic contamination of seabed sediment	There are threats to the biological and commercial value of the Clyde Estuary and the Inner Firth due to potentially elevated chemical levels resulting from historic seabed contamination.
Historic contamination of industrial land	There are threats to the biological and commercial value of the Clyde Estuary and the Inner Firth due to potentially elevated chemical levels resulting from historic land contamination.

3.2 Bacteria

A key indicator of water quality is the number of faecal indicator organisms present such as total and faecal coliforms and faecal streptococci. If swallowed in sufficient quantities by people swimming or bathing, faecal coliforms can cause illnesses such as stomach upsets and ear infections.

These bacteria exist in human sewage and in traces of animal faeces washed from farmland during periods of wet weather. Runoff 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.

3.2.1 Designated Bathing Waters

High quality bathing waters are important for a wide variety of interests and help to promote the important and valuable tourism industry within Scotland. One of the Clyde's designated bathing beaches, Ettrick Bay on the Isle of Bute, can be seen in Figure 21 .



Figure 21: Ettrick Bay bathing beach, Firth of Clyde

Figure 22 shows the ongoing overall decline in the average counts of faecal coliforms across 60 continuously monitored designated bathing waters in Scotland (SEPA, 2007). The elevated faecal coliform levels recorded in Scottish bathing waters in 2007 reflected unusually heavy summer rainfall. Recent results and previous reports can be referenced at (www.sepa.org.uk/data/bathingwaters).

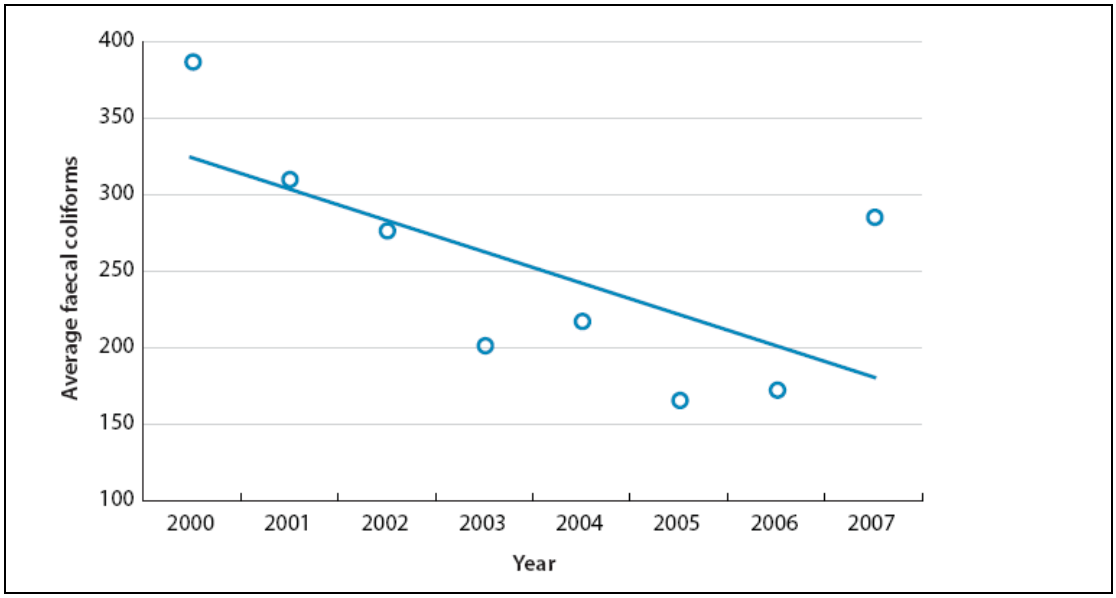


Figure 22: Average faecal coliform counts at designated bathing beaches

In 2008 additional bathing waters were designated by Scottish Government so there are now 80 official designated bathing water beaches in Scotland. Fourteen of these are in the Firth, with the majority along the Ayrshire coast (Figure 23).

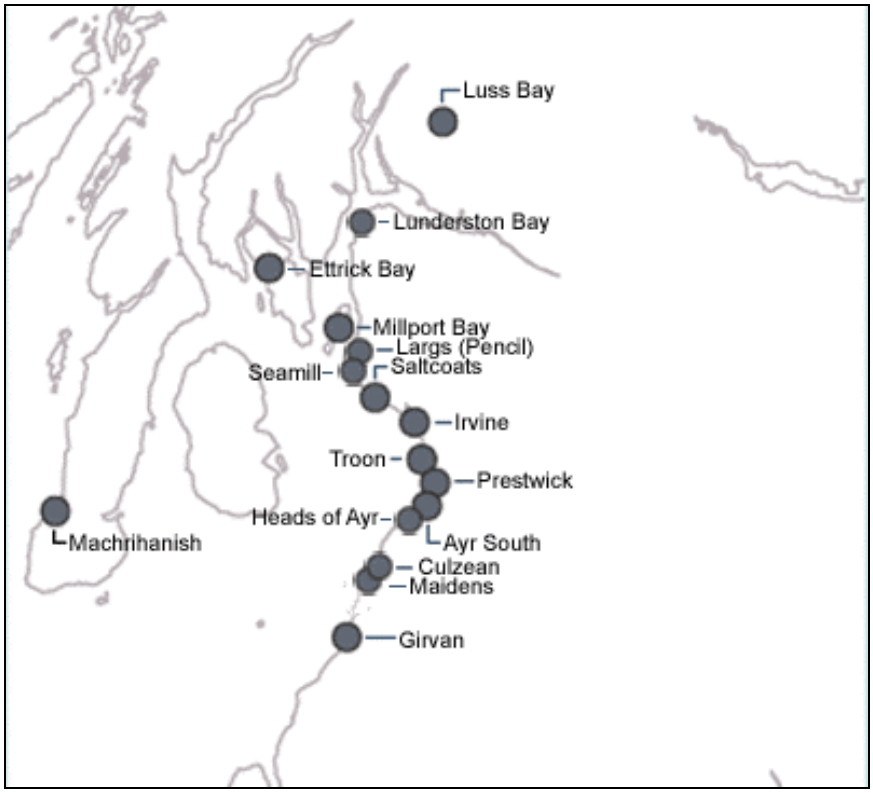


Figure 23: EU designated bathing beaches in or adjacent to the Firth of Clyde

Table 6 summarises bacterial water quality results for designated bathing beaches in the Firth for the period 2005 to 2007.

Table 6: Bacteria results for the designated bathing beaches in the Firth of Clyde 2005 to 2007

Bathing Beach	2005	2006	2007	2008
Lunderston Bay	-	-	-	Good
Ettrick Bay	Good	Good	Poor	Poor
Millport Bay	Good	Good	Excellent	Poor
Largs	-	Good	Good	Good
Seamill	-	-	-	Poor
Saltcoats	Good	Good	Good	Poor
Irvine	Good	Good	Poor	Good
Troon	Excellent	Good	Excellent	Good
Prestwick	Good	Good	Poor	Poor
Ayr South	Good	Good	Poor	Good
Heads of Ayr	-	-	-	Poor
Culzean	-	-	-	Good
Maidens	-	-	-	Good
Girvan	Good	Good	Poor	Good

3.2.2 Designated Shellfish Waters

The European Community Shellfish Waters Directive was adopted in 1979 to protect and, where necessary, improve the quality of waters where shellfish grow and to contribute to the high quality of directly edible shellfish products. It prescribes the minimum quality criteria which must be met by shellfish waters, and guideline values which Member States must endeavour to observe. Compliance with the Shellfish Waters Directive in itself will not ensure protection of public health. This is the objective of the Shellfish Hygiene Directive 1991.

The Shellfish Waters Directive only specifies a guideline value for faecal coliforms (FC) of not more than 300 FC per 100ml of shellfish flesh and intervalvular fluid. Approximately 80% of designated shellfish waters sites across Scotland regularly fail the Directive's bacterial standard. No clear relationship has been established between FC levels in shellfish tissue and the microbiological quality of the ambient waters, excepting those waters which are polluted.

Figure 24 shows the locations of shellfish growing waters areas and shellfish production areas within the Firth. Monitoring results for the shellfish waters areas from 2005 to 2007 are in Table 7.

Table 7: Bacteria results for the designated shellfish growing areas in the Firth of Clyde 2005 to 2007

Site	OS Grid Ref.	2005 P=Pass, F= Fail	2006 P=Pass, F= Fail	2007 P=Pass, F= Fail
Loch Fyne Inner, Head of Loch	NN 18699 12499	F	F	F
Loch Fyne Middle, Loch Gair	NR 92548 90420	P	F	F
Loch Fyne, Inverneill	NR 84983 80190	P	F	F
Loch Fyne Outer, Whitehouse Bay	NR 85111 81114	P	F	F

Kyles Of Bute, Colintraive	NS 02991 74718	F	F	F
Loch Riddon at Ardachuple	NS 01014 79688	F	F	F
Loch Striven	NS 09400 72400	F	F	P
Loch Goil, Cuilimuich	NS 19308 95290	F	P	F
Loch Long, Ardgarten	NN 27733 02754	F	P	F
Loch Long, Ardentinny	NS 19041 88170	F	F	F
Ayrshire Coast, Boydston	NS 21800 44300	F	F	F
Ayrshire Coast, Bellstane	NS 19276 47587	F	F	F
Fairlie	NS 20610 54674	P	F	F

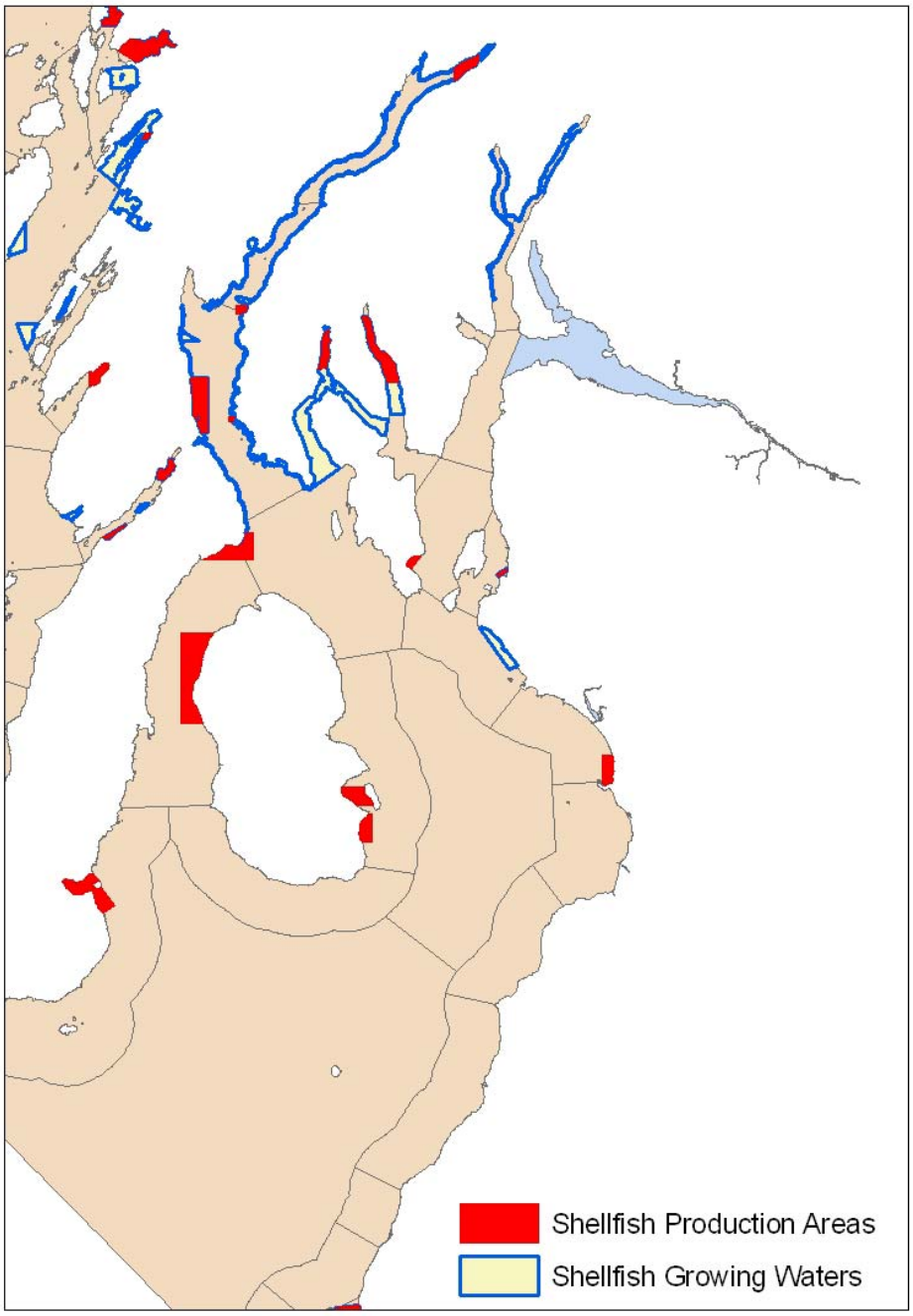


Figure 24: EU designated shellfish waters in the Firth of Clyde

Table 7 shows that all the shellfish growing waters across the Firth routinely fail the guideline bacterial standard of the Directive. Faecal coliform (FC) levels in waters and shellfish flesh are influenced by rainfall, diffuse pollution from agriculture as well as by direct/indirect sewage discharges. Human sewage, animal husbandry and wildlife may all contribute to the overall levels of faecal coliforms observed across the Firth, and it is not always possible to apportion the relative importance of each source.

Despite this uncertainty, SEPA works closely with Scottish Water and the Scottish Government to ensure that the upgrading of wastewater treatment infrastructure results in maximal improvement to the environment.

SEPA is coordinating a research program to determine how environmental, anthropogenic and natural factors impact on the faecal coliform concentrations measured in mussels. This will help to identify appropriate improvement action where it is deemed necessary. SEPA works with farmers in the catchment area to encourage best practice and the minimisation of diffuse pollution from cattle and sheep farming. All farms in appropriate catchment areas will be inspected according to the Scottish Executive's 4 Point Plan to reduce point source farm discharges into inland and coastal waters.

ISSUES

Failure of EU bathing beach standards	Upstream diffuse bacterial pollution causing failure of mandatory EU bathing beach standards.
Failure of EU shellfish growing waters standards	Diffuse bacterial pollution causing failure of guideline EU shellfish growing waters standards.

3.3 Litter

The Marine Conservation Society (MCS) defines marine and coastal litter as being "any item that appears on beaches or at sea as a result of man's activity" (MCS, 2008).

This includes items deposited directly by beach users, items deposited on beaches from adjacent land or waterways, and items washed up on beaches after entering the marine environment at another location (e.g. from marine vessels, offshore installations or sewage outfalls).

Litter in the marine environment gives rise to a range of adverse ecological impacts, including: entanglement of or ingestion by wildlife; habitats smothering; transport of invasive species; and poisoning by breakdown products. Marine litter also causes direct damage to commercial and leisure vessels (e.g. through fouling of propellers or blockage of engine coolant water inflows). It contaminates fish catches and causes damage to fishing gear.

Accumulations of litter are also an aesthetic issue, that may adversely impact local communities and tourist-based economic activity, and beach cleansing operations are both costly and potentially damaging to intertidal habitats (MCS, 2008).

The major sources of marine and coastal litter include:

- Sewage treatment works
- Combined sewer overflows
- Other industrial discharges
- Urban runoff
- Shipping
- Oil rigs
- Ministry of Defence munitions
- Dereliction (piers, wrecks, etc)
- Agricultural waste
- The fishing industry
- Fly tipping
- Aquaculture
- Municipal waste
- Recreational and leisure usage

Litter from these and other sources is composed of various materials, of which plastics (including items such as food containers and other packaging, bags, fragments of fishing nets and buoys, polystyrene cups and packaging) are the most predominant, on beaches, on the sea surface and on the seabed, at both global and UK levels (Fanshawe, 2002; MCS, 2008). Plastics are of especial concern given their persistence in the environment. Microscopic plastic fibres, formed by the slow degradation of larger items, are now commonly found in beach and subtidal sediments and are increasingly common in the water column (MCS, 2008).

Potentially toxic chemicals within these materials or accumulated on their surfaces may potentially enter the marine food chain. Other types of litter commonly found in the marine environment include:

- Rubber (gloves, boots, tyres)
- Wood (construction timbers, pallets, fragments of both)
- Metals (drink cans, oil drums, aerosol containers, scrap)

- Paper and cardboard
- Cloth (clothing, furnishings, shoes)
- Glass (bottles, light bulbs)
- Pottery / Ceramic
- Munitions (phosphorous flares)

Marine litter circulates through a range of pathways, operating at various geographic scales, and accumulates at various locations known as litter sinks. Several coastal locations in the Firth, including Helensburgh (Figure 25) and the head of Loch Long at Arrochar (Baxter *et al* 2008; MCS, 2008) are noted litter sinks.

Since 1993, the Marine Conservation Society has undertaken an annual survey and clean-up of beach litter in the UK. The survey relies on volunteers coming forward to survey beaches of their choice and the results cannot be taken as representative of beaches across Scotland or the UK as a whole. However, the MCS survey does highlight a growing beach litter problem in the UK and some particular concerns for Scotland (MCS, 2008). A number of beaches in the Clyde Estuary are noted for their abnormally large accumulations of sewage related debris, such as cotton buds (MCS, 2008).



Figure 25: Beach litter at Helensburgh

Given the wide range of sources and types of marine and beach litter, effective solutions to this growing problem will require diverse and co-ordinated action at many levels (MCS, 2008; Fanshawe, 2002).

ISSUES

Accumulation of litter at local 'sinks'	Reduced amenity value of beaches where litter collects.

4 The Biological Environment

Scotland's seas, positioned between subpolar and subtropical influences, are among the most biologically productive in the world. They support an abundance of marine habitats and species, and provide a wealth of important natural resources upon which people and communities depend (Saunders, 2004). This variety of life is encompassed by the term biodiversity, which includes the variety of individual species, their genetic diversity and the range of ecosystems that support them. The vision for Scotland's seas (Scottish Executive, 2005) includes healthy, productive and biologically diverse seas.

There are more than 6,500 species of animals and plants living in Scotland's seas (Baxter *et al* 2008). Beneath the waves some of the finest marine habitats in Europe can be found, including rugged rocky reefs carpeted in soft corals, sea fans and sponges; shallow beds of pink maerl - a delicate coralline seaweed; beds of seagrass; and saline lagoons.[1]

An example of Scottish marine life is shown in Figure 26, which shows *Alcyonium digitatum,* encrusting coralline algae, anemones and kelp *Laminaria hyperborea* with epiphytes on stipes, growing on exposed bedrock. Species such as these, and seabed and intertidal habitats in turn support a high diversity of marine fish, mammals and birds.



Figure 26: Exposed bedrock on St Kilda

[1] http://www.snh.org.uk/calendar/nov.asp accessed 11 November 2008

The key pressures affecting biological quality globally are pollution, habitat loss, introduced species, fragmentation of the environment and over-harvesting (www.bbc.co.uk state of the planet[2]). In the Firth there are examples of all these pressures. Several of the 24 marine non-native species recorded in Scottish waters are known to occur in the Firth, including the large brown seaweed known as wireweed and the skeleton shrimp (Baxter *et al*, 2008). Along with accidental introductions associated with mariculture, the most common mode of introduction of such species is via ships' ballast or fouling on ships' hulls.

4.1 Intertidal Habitat and Communities

The intertidal or littoral zone is the area of the foreshore and seabed that is exposed to the air at low tide and submerged at high tide. Organisms in the intertidal zone are adapted to an environment of harsh extremes, where water is available regularly with the tides, but varies from fresh with rain to highly saline and dry salt between tidal inundations.

Common habitats of the intertidal zone are outlined in Table 8, following the European Environment Agency's coastal habitats hierarchy, as detailed in the European Nature Information System (EUNIS).

Table 8: Intertidal habitat types of relevance to the Firth of Clyde
(source:*eunis.eea.europa.eu)*

EUNIS Code	EUNIS Habitat Type
A1	Littoral rock and other hard substrata
A2	Littoral sediment
B1	Coastal sand dunes and sandy shores
B2	Coastal shingle
B3	Rock cliffs, ledges and shores, including supralittoral

Figure 27 shows a typical sandy shore (i.e. type A2) in the Firth.

[2] http://www.bbc.co.uk/nature/programmes/tv/state_planet/ accessed 11 November 2008



Figure 27: Intertidal zone at Ardnacross Bay, Isle of Arran

4.1.1 Intertidal Designations

A number of international and national designations exist for the protection of important intertidal communities. These include Sites of Special Scientific Interest (SSSIs), Ramsar Sites and Special Protection Areas (SPAs).

There are three intertidal SPA designations and fifteen biological SSSIs with a maritime connection in the Firth (Figure 28).

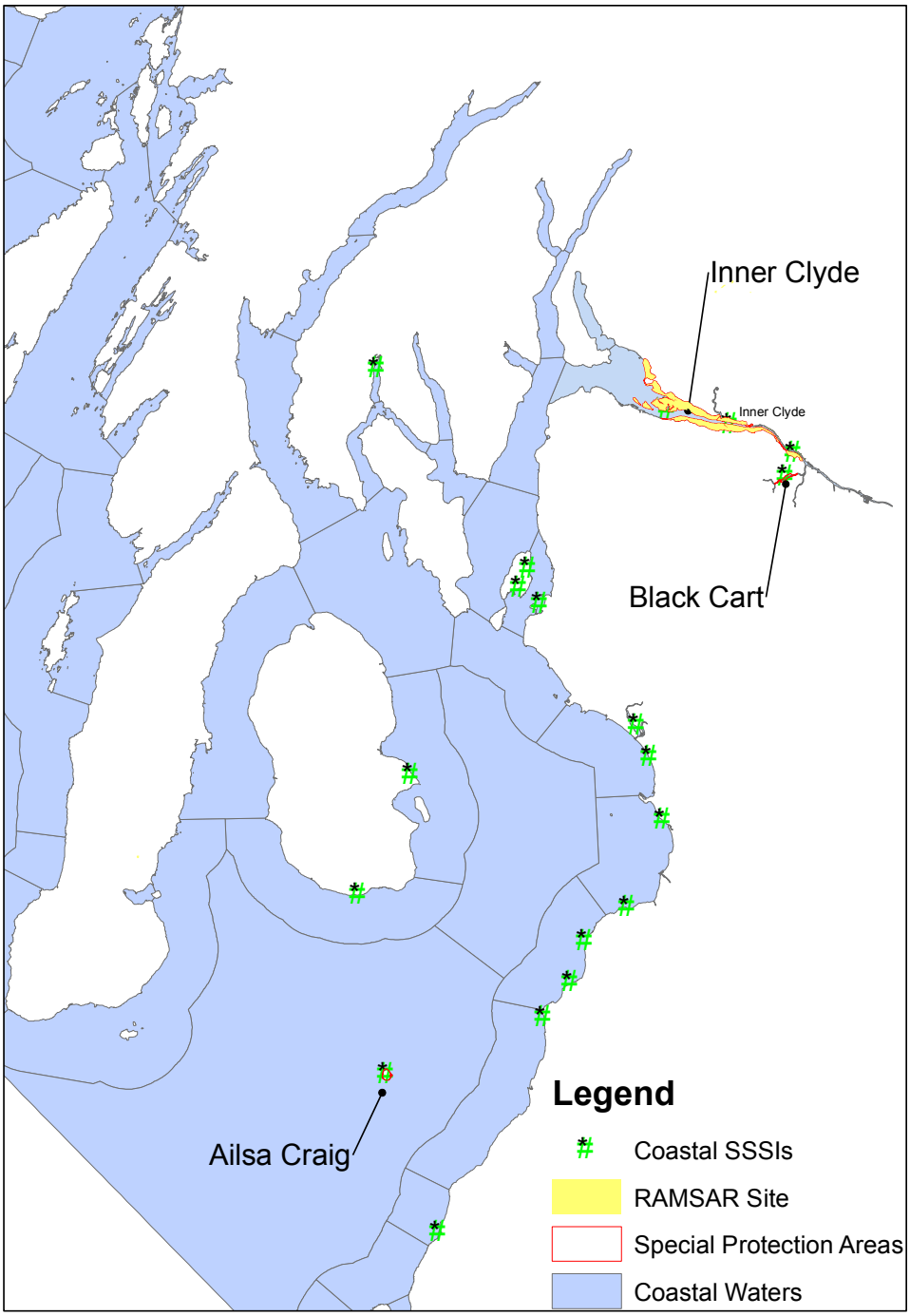


Figure 28: Coastal protected areas for biological features in the Firth of Clyde

Sites of Special Scientific Interest in the Clyde

Sites of Special Scientific Interest represent the best examples of our natural heritage. Scottish Natural Heritage selects them for their plants, animals or habitats; their rocks or landforms; or a combination of such natural features. Together they form a network of the best examples of natural features throughout Scotland, and support a wider network across Great Britain and the European Union.

SSSIs can include sea water down to the mean low water mark of spring tides, as well as land and freshwater. Their designation ensures that the nature conservation interest is taken fully into account before development, or a change in management practice which would cause damage, is permitted.

Scottish Natural Heritage has a programme of monitoring, known as site condition monitoring, which determines if designated sites are meeting their objectives.

The biological SSSIs in the Firth with a maritime connection are detailed in Table 9.

Table 9: Coastal SSSIs for maritime biological features in the Firth of Clyde

Name	Feature	Site Condition[1]
Portencross Coastal	Birds	Info not available
Ballochmartin Bay	Intertidal flora and fauna	Info not available
Kames Bay	Intertidal flora and fauna	Info not available
Inner Clyde	Birds, Intertidal flora and fauna	Unfavourable (declining) for Oystercatcher and Cormorant. Favourable (maintained) for Saltmarsh, Redshank, Goldeneye, Red-breasted merganser, Eider and Scaup.
Ruel Estuary	Grassland/ Wetland transition	Unfavourable (declining) for saltmarsh.
Black Cart	Whooper swan aggregations	Favourable (maintained)
Bogside Flats	Saltmarsh and mudflat	Favourable (maintained)
Western Gailes	Sanddune habitat and fauna	Unfavourable (declining) for sand dune. Unfavourable (no change) for flies. Favourable (maintained) for beetles.
Maidens to Doonfoot	Coastal woodland and intertidal habitat	Unfavourable (no change) for sand dune.
Turnberry Dunes	Sanddune habitat and fauna	Favourable (maintained)
Ballantrae Shingle Beach	Saltmarsh, shingle and bird aggregations	Unfavourable (declining) for little tern and shingle. Favourable (maintained) for saltmarsh.
Troon Golf Links and Foreshore	Sanddune habitat	Unfavourable (no change) for sand dune.
South Coast of Arran	Sanddune, saltmarsh, shingle habitats and butterflies	Unfavourable (no change) for sand dune. Favourable (maintained) for saltmarsh and shingle.

Clauchlands Point	Saltmarsh and maritime cliff habitats	Unfavourable (no change) for maritime cliff. Favourable (maintained) for saltmarsh.
Ailsa Craig	Breeding birds and invertebrates	Favourable (maintained)

1: as listed at URL, June 2008

Ramsar Sites, Special Protection Areas and Special Areas

Ramsar sites are statutory areas designated by the UK government under the Ramsar convention. Contracting parties are required to designate wetlands of international importance and to promote their conservation and 'wise use'. There is one marine Ramsar site in the Clyde at the Clyde Estuary.

The 1979 Conservation of Wild Birds Directive requires member states to take conservation measures for certain rare or vulnerable species and for regularly occurring migratory species of birds. In part this is achieved through the designation of statutory Special Protection Areas (SPAs) by the UK government on the advice of the conservation agencies. This designation is implemented through the Wildlife and Countryside Act 1981. There are three SPA's in the Clyde at Ailsa Craig, Inner Clyde and Black Cart, which are designated for internationally important numbers of birds. These sites are discussed further in Section 4.4.

Special areas of conservation (SACs) are areas identified as outstanding examples of selected habitat types or areas important for the continued well-being or survival of selected non-bird species. They are one of the main mechanisms for delivering 1992 the habitats and species directive. There are no marine SACs in the Clyde.

Areas of special protection (AoSPs) aim to prevent the disturbance and destruction of the birds for which an area is identified; by making it unlawful to damage or destroy either the birds or their nests, and in some cases by prohibiting or restricting access to the site and their nests. There are two AoSPs in the Firth, Lady Isle and Horse Isle.

ISSUES

Unfavourable condition of some designated biological features	Unfavourable (declining) or unfavourable (no change) condition of some bird species and sand dune habitats.

4.2 Seabed Habitat and Communities

The subtidal or sublittoral zone is that area of the sea, which lies below the low water mark, and is permanently covered by seawater. Common habitats of the subtidal seabed are outlined in Table 10 following the European Environment Agency's marine and coastal habitats hierarchy, as detailed in the European Nature Information System (EUNIS).

Table 10: Subtidal habitat types of relevance to the Firth of Clyde (source: eunis.eea.europa.eu)

EUNIS Code	EUNIS Habitat Type
A3	Infralittoral rock and other hard substrata
A4	Circalittoral rock and other hard substrata
A5	Sublittoral sediment
A7	Pelagic water column

The infralittoral is the shallowest part of the subtidal, extending to approximately 10m depth, whilst the circalittoral is that part of the subtidal which extends from approximately 10m to 200m (www.jncc.gov.uk).

A typical subtidal rock community (i.e. type A3) can be seen in Figure 29.



Figure 29: Subtidal rock community at Cape Wrath

The subtidal is an area that is out of sight to the majority of people, and indeed practices such as the dumping of sewage sludge in the Firth continued into the 1990s. Data on subtidal resources and general seabed condition is highly limited and perhaps as a consequence, whilst there are numerous protected area designations for intertidal features across the Firth, there are none for subtidal features. As a result the SSMEI Clyde Pilot commissioned projects to produce an indicative seabed habitat map for the Firth (Tresadern, 2008) and to collate and analyse biodiversity data (Langmead *et al*, 2008).

4.2.1 Seabed Mapping

Traditional terrestrial habitat mapping techniques, such as direct field observations, are more costly and difficult in the marine environment. Hence, current knowledge of the distribution of seabed habitats is relatively poor. An alternative approach for producing a habitat map, which was applied to the Firth (Tresadern, 2008) is to create a model of the environment based on observed correlations between habitats and various data that have been collected, for example depth or current speed. The modelled results from the two subtidal substrate datasets for the Firth are shown in Figure 30 and Figure 31 with habitat descriptions given in Table 11.

As a management tool these modelled results deliver more accurate habitat maps than was previously available, both in spatial terms and the level to which the output has been resolved under the EUNIS classification.

The successful application of cartographic modelling demonstrated by this, and similar work, underlines the effectiveness of the potential of the tool in the marine environment. However, it is clear that there exists a gap between the current position and realising that potential fully that can only be filled by the capturing of good quality data on the physical and biological variables that are currently missing. Once this gap is filled there is no reason that the technique cannot confidently inform decision making at all levels, as it does in the terrestrial environment (Tresadern, 2008).

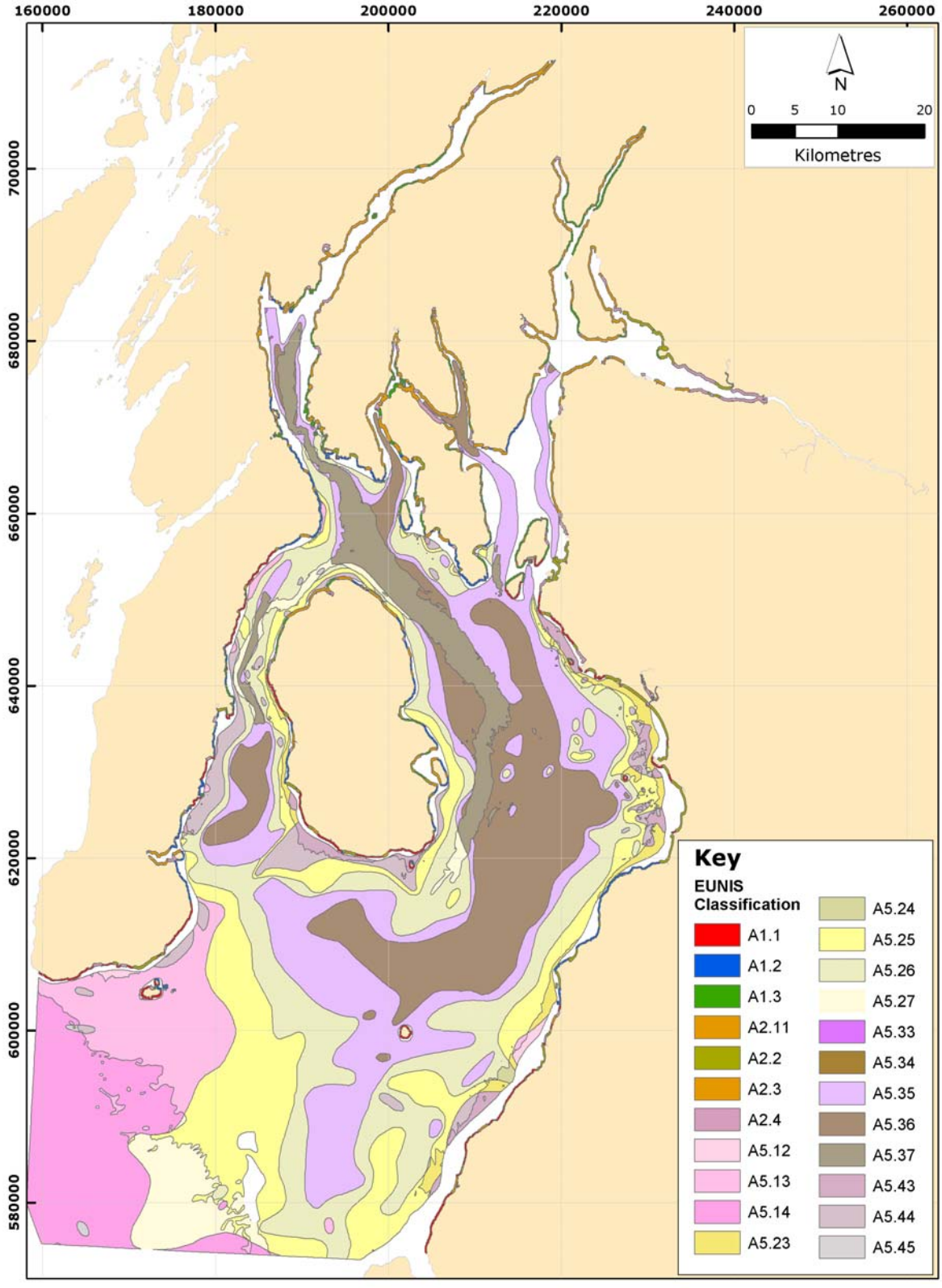


Figure 30: Results of cartographic modelling using BGS DigSBS250 sediment dataset (Tresadern, 2008)

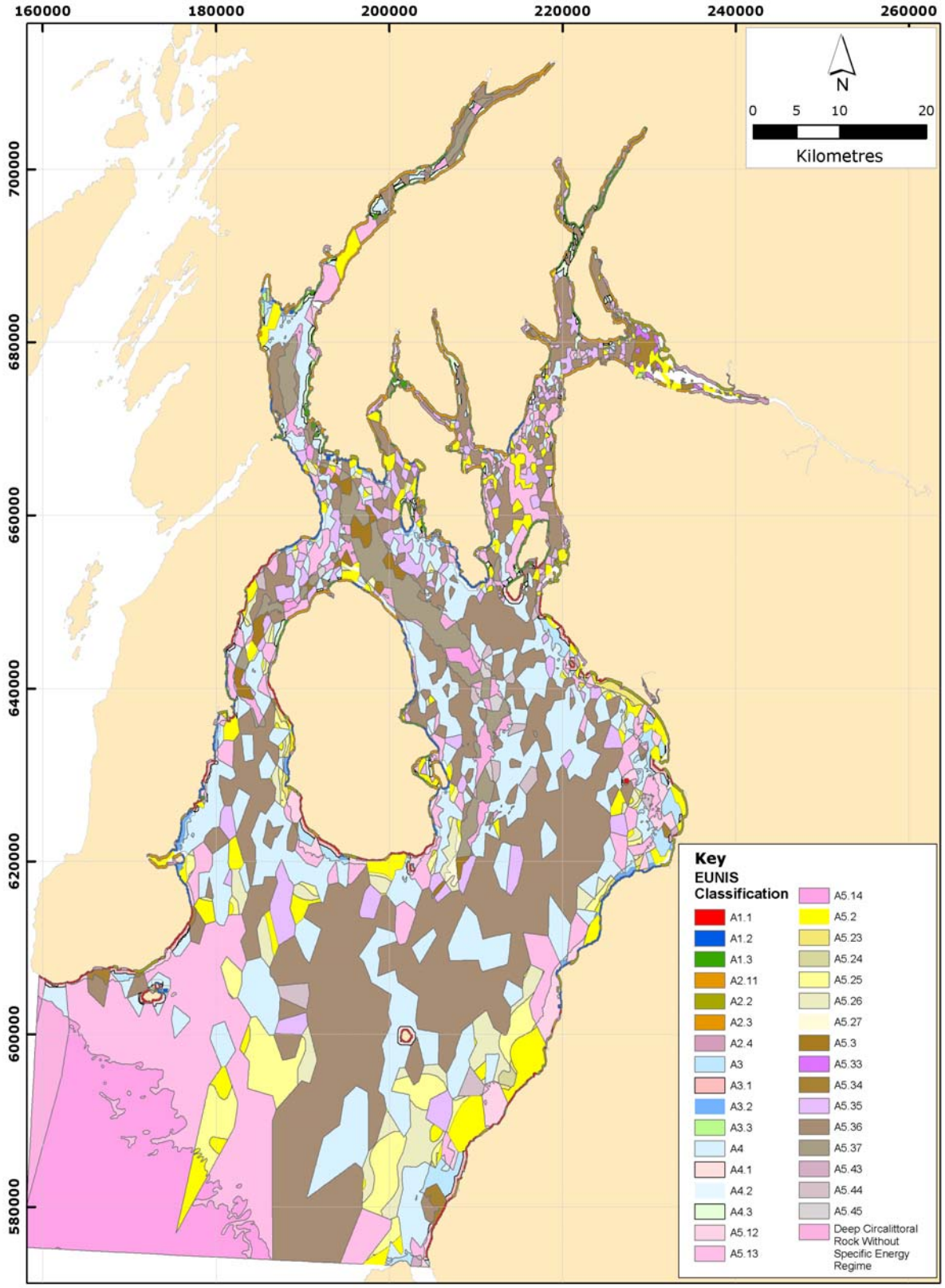


Figure 31: Results of cartographic modelling using Admiralty Chart geology point sediment dataset (Tresadern, 2008)

Table 11: Habitat model values and their associated EUNIS Code and text habitat description

Model Value	EUNIS Code	Habitat Description
1	Infralittoral Sand And Muddy Sand	Infralittoral Sand And Muddy Sand
2	A3	Infralittoral rock and other hard substrata
3	Circalittoral Rock Deep No Specific Energy Regime	Circalittoral Rock Deep No Specific Energy Regime
4	A4	Circalittoral rock and other hard substrata
5	A4.1	Atlantic and Mediterranean high energy circalittoral rock
6	A4.3	Atlantic and Mediterranean low energy circalittoral rock
7	A4.2	Atlantic and Mediterranean moderate energy circalittoral rock
8	A3.1	Atlantic and Mediterranean high energy infralittoral rock
9	A3.3	Atlantic and Mediterranean low energy infralittoral rock
10	A3.2	Atlantic and Mediterranean moderate energy infralittoral rock
11	A1.1	High energy littoral rock
12	A1.3	Low energy littoral rock
13	A1.2	Moderate energy littoral rock
14	A2.11	Shingle (pebble) and gravel shores
15	A2.3	Littoral mud
16	A2.4	Littoral mixed sediments
17	A2.2	Littoral sand and muddy sand
18	A5.13	Circalittoral coarse sediment
19	A5.12	Infralittoral coarse sediment
20	A5.14	Deep circalittoral coarse sediment
21	A5.3	Sublittoral mud
22	A5.36	Circalittoral fine mud
23	A5.35	Circalittoral sandy mud
24	A5.34	Infralittoral fine mud
25	A5.33	Infralittoral sandy mud
26	A5.37	Deep circalittoral mud
27	A5.4	Sublittoral mixed sediments
28	A5.44	Circalittoral mixed sediments
29	A5.43	Infralittoral mixed sediments
30	A5.45	Deep mixed sediments
31	A5.2	Sublittoral sand
32	A5.25	Circalittoral fine sand
33	A5.26	Circalittoral muddy sand
34	A5.23	Infralittoral fine sand
35	A5.24	Infralittoral muddy sand
36	A5.27	Deep circalittoral sand

4.2.2 Biodiversity Review

The review of biodiversity (Langmead *et al*, 2008) identified and collated c. 133,000 species and habitat data records for the Firth. Patterns of distribution of species and habitats of conservation concern were analysed. The analysis of patterns of biodiversity included an examination of the distribution of hotspots, defined as "areas of high species and habitat richness that include representative, rare and threatened features" (Hiscock & Breckels, 2007). The identification of biodiversity hotspots is one possible approach to inform the targeting of conservation effort and identification of sites for protection under existing or future legislation.

Six measures of diversity were analysed in the hotspots study to provide information about diversity at two levels of ecological organisation: a) the species composition of communities and b) the diversity of biotopes (which includes aspects of the physical environment). The measures were species richness, average taxonomic distinctness, number of priority species, biotope richness, average biotope distinctness and number of priority biotopes[3] .

Ninety of the 435 spatial units (5km hexagons) adopted for this study contained sufficient to inform the measures of species hotpots. The five key areas identified as species hotpots (Figure 32), are in:

- Northern Loch Fyne (HS2) and Loch Shira (HS1);
- Irvine Bay (HS8-11);
- East of Dunoon in the Inner Firth of Clyde (HS4);
- East of Rothesay, Bute (HS7); and
- The Kyles of Bute (HS6) and Loch Striven (HS3 and 5)

Of these Irvine Bay, East of Dunoon and East of Rothesay score highly in terms of species richness and taxonomic distinctness, but do not have high numbers of priority species. The hotspots in Northern Loch Fyne and Loch Shira, and in Irvine Bay showed high numbers of priority species and species richness was high, but the taxonomic distinctness of the six benthic phyla measured was low.

Although not classed as hotspots within the scoring scheme, species richness was high for some areas including Glenan Bay, East of Loch Tarbet (Loch Fyne), West of Skipness (Tarbet), Kilcousland Bay (near Campbeltown) and North of Brodick Bay on Arran.

Eleven areas were identified as species "cold spots" in the analysis, scoring low for all of the measures (e.g. north of Ardmore point, Turnberry Bay, Troon point and the deeper parts of Irvine Bay and Lunderston Bay in the Inner Firth).

However, for cold spots around Sanda Island, Holy island and an area off Port Ann, Loch Fyne, whilst species richness and taxonomic distinctness were low the number of priority species was high.

[3] A biotope is the smallest geographical unit of the biosphere or of a habitat that can be delimited by convenient boundaries and is characterized by its biota (Lincoln *et al.*, 1998).

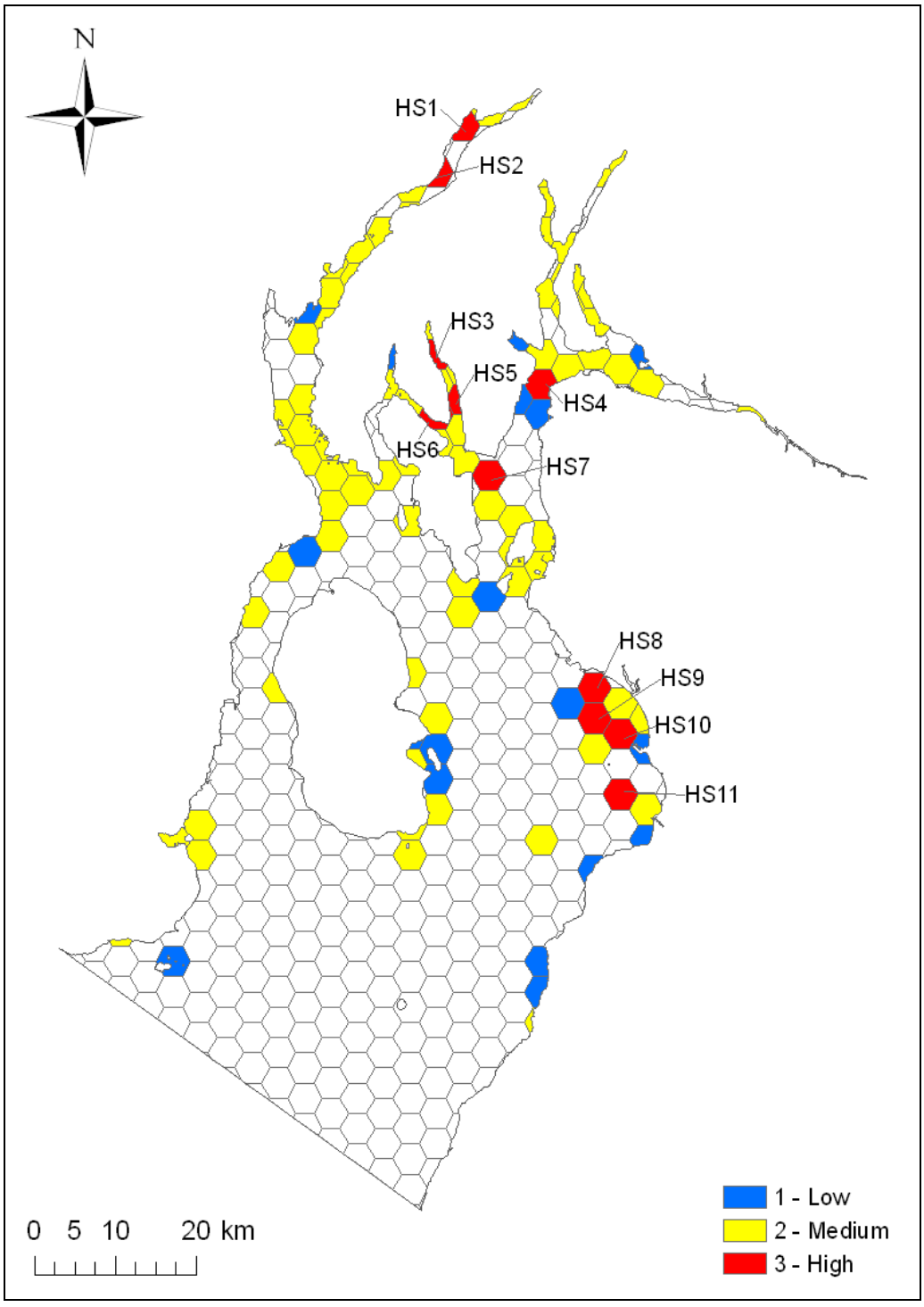


Figure 32: Species hotspot scores for the Firth of Clyde (Langmead *et al* 2008)

Biotope information is mostly confined to the sea lochs apart from a few areas in the south east of the Firth (areas off Irvine, Turnberry Bay, Ballantrae Bay). On the basis of the available data, ten biotope hotspots were identified (Figure 33) including an area in the northern part of Loch Fyne (HS14), Loch Goil (HS13), in the mouth of Holy Loch (HS17) and Ardlamont Point (HS20).

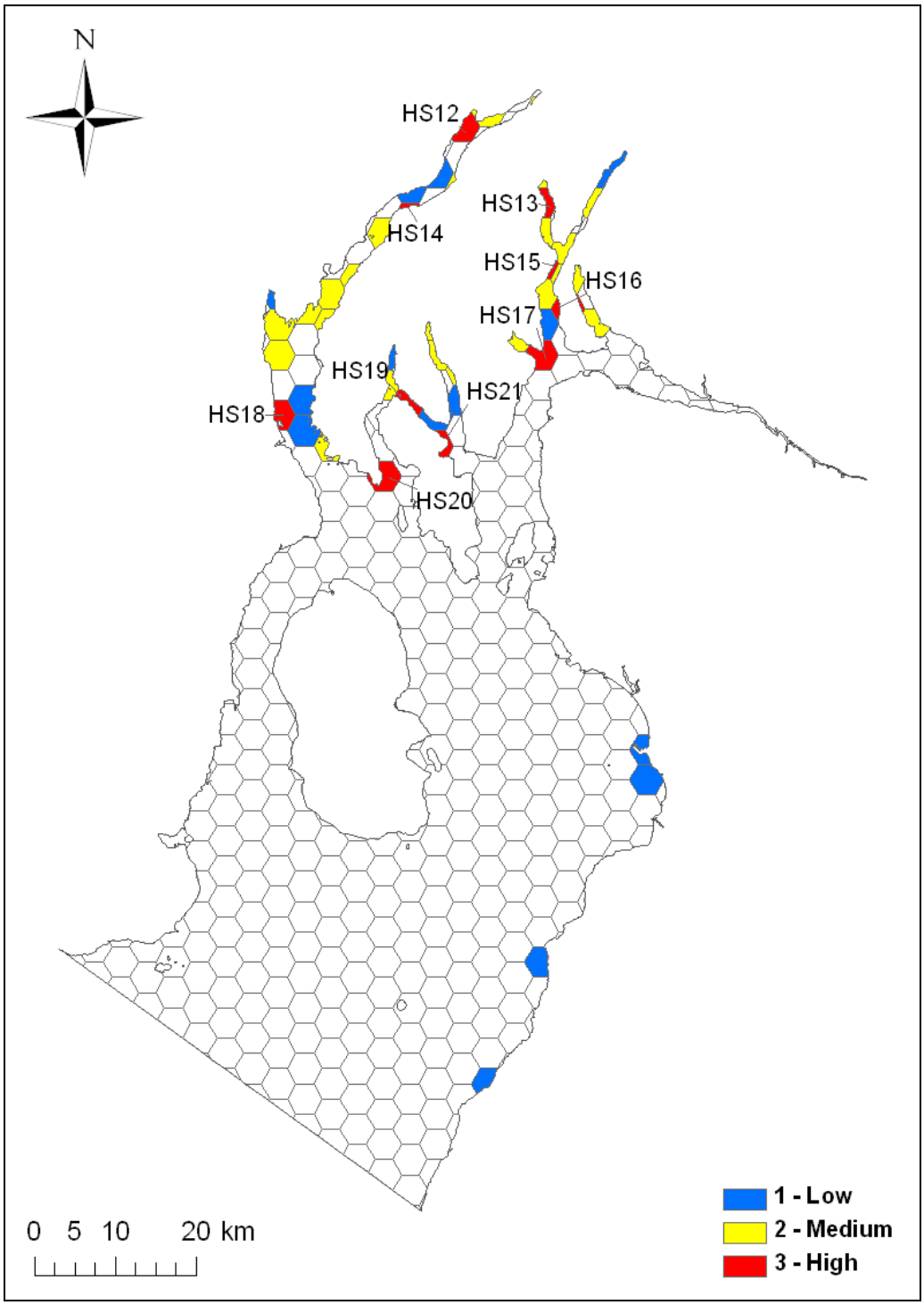


Figure 33: Biotope hotspot scores for the Firth of Clyde (Langmead *et al* 2008)

Biotope richness was particularly high in Loch Fyne, around Ardlamont Point, the mouth of Holy Loch, and on the eastern side of Kyles of Bute. Biotope distinctness was particularly high in Loch Goil and in Holy Loch, while all areas outside of the seas lochs scored low. All hotspots had underlying high numbers of priority biotopes driving the final score.

One site (HS1 in Figure 32, HS12 in Figure 33), at the mouth of Loch Shira in Loch Fyne was categorised as a hotspot for both species and biotopes. This area currently has restrictions in place for fishing and dredging due to military activities. Nine further locations scored highly, including: Loch Goil, the mouth of Holy Loch, the north of Loch Striven, Kyles of Bute, Ardlamont Point and Loch Fyne, near Tarbert.

Consultation with local stakeholders provided anecdotal evidence of additional potential biodiversity hotspots and highlighted the issue of limited formal survey data coverage within the Firth. The hotspot approach has the advantage of combining different biodiversity measures into one, but necessarily excludes much available data and may not provide a definitive representation of regional patterns of biodiversity. The study concluded that no one measure provides a complete representation of biodiversity, and that a range of approaches needs to be used for marine planning purposes (Langmead *et al*, 2008).

4.2.3 Seabed Status

The WFD has introduced a requirement to classify seabed status using invertebrates which live in or on the seabed. This has increased the amount of monitoring done on subtidal habitats across Scotland. Sampling at the majority of WFD surveillance stations started in 2007, and data on water body status is not yet available. However, historical data exists for a site off Cloch Point and a site North of Cumbrae in the Inner Firth (Figure 34).

The long term trend data for the northerly station shown (CMT7), off Cloch Point, is shown in Figure 35, and reveals that by taking the cumulative mean Infaunal Quality Index (IQI) value, for the total number of grabs collected across the years, this site consistently classifies at good ecological status. The IQI is the WFD classification tool for seabed invertebrates, developed and agreed across the United Kingdom and Republic of Ireland, and used as part of the assessment of ecological status for WFD.

The invertebrate fauna of estuarine sediments also provide a useful indicator of status, although their fauna is naturally impoverished due to the low salinities encountered. Figure 36 shows the long-term trend in the number of invertebrate species found in the sediments of the Clyde Estuary between 1967 and 2003. It shows a general increase in numbers of species on moving seawards from Glasgow city centre to Erskine, 10 miles downstream. In addition to this natural gradient, the graph shows a gradual increase in species numbers throughout the Clyde Estuary over a period of years as water quality has improved and sensitive species have returned.



Figure 34: Long term invertebrate sampling locations in the Firth of Clyde (Crown copyright. Licence number 100020538)

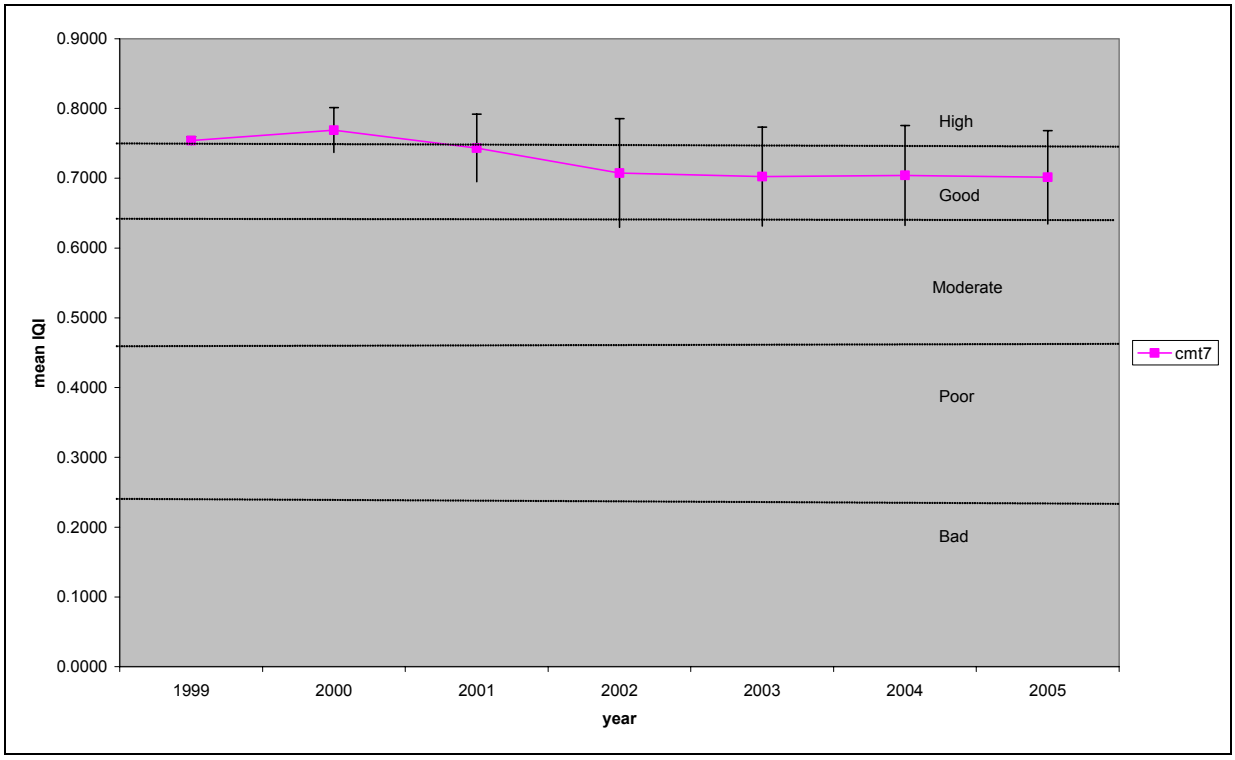


Figure 35: Mean cumulative Infaunal Quality Index for station CMT7 in the Inner Firth of Clyde

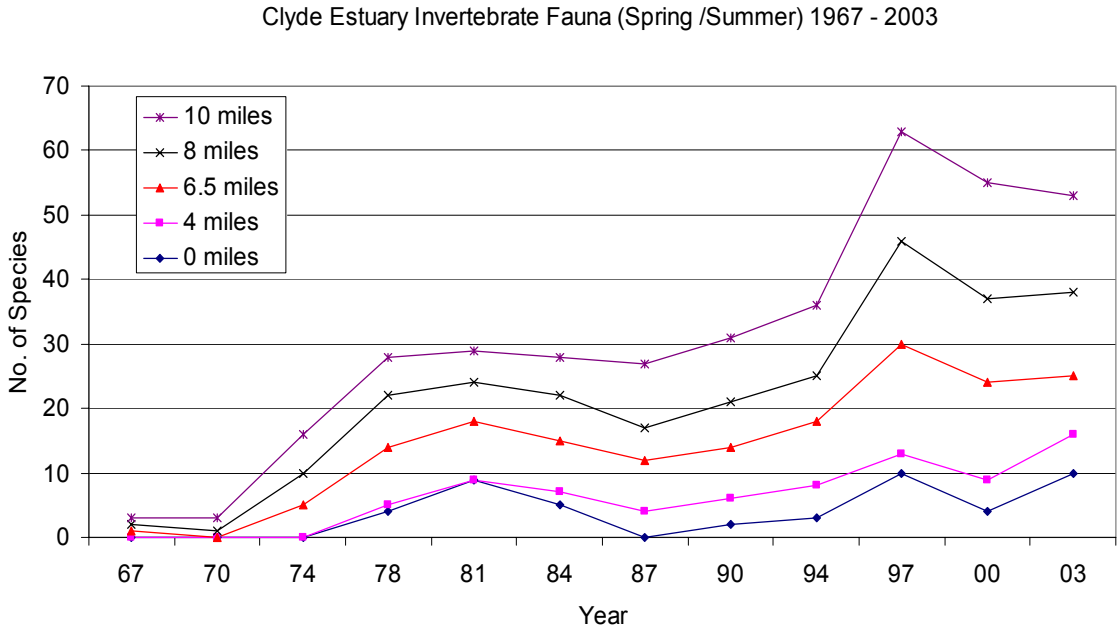


Figure 36: Number of benthic invertebrate species in the Inner Clyde Estuary from 1967-2003

ISSUES

Lack of data on subtidal habitats	Lack of data on seabed habitats limits the ability to plan marine activities effectively and ensure protection of important species and habitats.

4.2.4 Seabed Fisheries

The *Nephrops* fishery is currently the most important fishery resource in the Firth. *Nephrops* are also known as Dublin bay prawns, scampi (usually reserved for the tail portion), langoustines, Norway lobsters, or more colloquially in Scotland, as 'prawns' (Combes and Lart, 2007).

Nephrops distribution is limited by the extent of suitable muddy sediment in which they construct burrows up to 30cm deep. Populations exist in depths as shallow as a few metres in sheltered sea lochs, down to over 500 metres on the shelf edge, west of the Hebrides, and to over 800m in some parts of its range within the NE Atlantic and Mediterranean (Chapman, 1980).

In the Firth *Nephrops* occur at high density in the southern part, with animals having a smaller mean size at age than those in the north (Combes and Lart, 2007). There is evidence that the more southerly animals are food limited and that the high density of animals in this area inhibits growth because of lack of nutritional resources (Parslow-Williams *et al*., 2001, 2002).

Nephrops spend most of their time in burrows, coming out only to feed and, at appropriate times of year, for reproduction. Since *Nephrops* are protected from trawls when in burrows, these emergence patterns determine the pattern of catch. The timing of emergence to feed appears to be related to light conditions, and greatest catches are often taken at dawn and dusk, although this varies with water depth and clarity. In deeper waters peak catches are during the daytime, in shallow waters at night (Chapman, 1980).

The *Nephrops* fishery in the Firth started as a seasonal fishery in the 1950s, when demersal and pelagic fishing were the main activity, but by 1983 was worth more than the combined values of cod, haddock, hake and herring (Bailey *et al.* 1986). Using conservative estimates the Clyde Sea stock of *Nephrops* was estimated to be 25,000t, with a high intensity of exploitation of 2,600t in 2001. These figures should be compared with the larger Fladen ground stock with a stock biomass of 100,000t and only 6% exploitation rate in 2001 (Marrs *et al*., 2002). In 2006 Nephrops landings from the Firth reached approximately 4200t.

The work of Marrs *et al* (2002) shows favoured *Nephrops* grounds to the east and north of Arran, Kilbrannan Sound, Loch Fyne near Tarbert and the channels between Cumbrae, Bute and Fairlie.

A valuable component of the *Nephrops* population is collected in some areas using baited traps known as creels. Creels tend to select the larger animals in the population, but may tempt berried females from their burrows (Adey *et al*, 2006).

The fishery for scallops in Scottish waters started in the early 1930s and is now the second most valuable shellfish species landed in Scotland (£17.3 million in 2001). Clyde landings of king and queen scallops remained low at approximately 110t pa, until the 1950s, when the fishery was targeted during the off-season for other fisheries. By 1961 the advent of shore based processing capacity and access to export markets led to a steady increase in scallop landings until a peak of 690t pa in 1980 (Combes and Lart, 2007).

Queen scallops had been used for long line bait, but it wasn't until 1967 that targeted fishing activity, rather than bycatch, developed.

Scallops normally lie in shallow recesses excavated into seabed sediments consisting of sand, gravel and mud which can occur in patches between rocks or stones. The distribution of preferred seabed type generally restricts Clyde populations to a narrow strip at 10-40m depth.

Scallops are generally caught by 10 to 30 metre vessels towing between four and 20 specialised scallop dredges from each side. Clyde vessels are limited to 8 dredges each side. In 2005 there were 10 fishing vessels in the Firth using mechanical dredge assumed to be scallop gear (Scottish Fishery Statistics*). Scallops are also collected by divers and landed.

Poor scallop recruitment in the late 1960's recovered in the 1970's and remained good until the mid-1980s (Mason and Fraser 1986). However, the industry's perception now (2006) is that 1986 was a downward turning point for queen scallop stocks that have not recovered since (Combes and Lart, 2007).

There are small fisheries in the Firth for crabs, lobsters and shrimps usually as a mixed creel fishery and/ or on a part time basis.

Carradale fishermen are said to fish round the Arran coast, including in Lamlash Bay, for razor fish. Fishing for razors with electricity is reported to be highly effective since there is perceived to be no physical disturbance to the seabed. Razors emerge from the substrate to be hand picked by divers that follow the track of the electrodes. The undersized razors are then able to re-burrow. There is, to date, no knowledge of what effect the electric field may have upon other species. There are issues of legality associated with fishing using electricity (Combes and Lart, 2007).

The periwinkle fishery was second only to scallops for value in 1986 (Mason and Fraser, 1986), with most being hand picked. No updates on the current extent of this fishery have been sourced.

Whelks, *Buccinum undatum,* are caught with pots specifically designed for the fishery. The pot typically consists of a 25 litre plastic drum with the top cut off. The rim is edged with netting to create the entrance, the bottom of the drum filled with concrete to weight it down and secure a bait holding system. Whelks are often sold to Asian markets cooked or live whole. Whelks are common on Clyde *Nephrops* grounds but potting for them would be problematic due to interaction with trawl gear.

Mussels, *Mytilus edulis*, are produced in the Firth by aquaculture rather than commercial wild harvest. There was a fishery 1883-1897 of 12,000t pa for bait for line fishing (Mason and Fraser 1986).

*http://www.scotland.gov.uk/Topics/Statistics/Browse/Agriculture-Fisheries/PubFisheries

4.3 Mobile and Migratory Species

These important species include fish, turtles, sharks, seals, whales, dolphins and porpoises, all of which occur as either residents or visitors to the Firth.

4.3.1 Fish

Fish include jawless fish, sharks and rays, and bony fish. It is estimated that Scotland has a total of 250 fish species, with the bony fish (species such as herring and cod) comprising the majority, with 207 species recorded (Baxter *et al*., 2008).

The sharks, skates and rays make up the group of cartilaginous fish (jawed fish with a skeleton composed primarily of cartilage) known as the elasmobranchs. Scottish coastal waters hold at least 18 species of shark, eight species of ray and three species of skate (Saunders, 2004).

Sharks recorded in Scottish waters, vary in size from the small dogfish to the second largest fish in the world, the basking shark (Figure 37). Basking sharks are frequent seasonal visitors to the Firth, observed mainly in summer, with sightings peaking around August. Movements are thought to be migratory and in response to the sharks' zooplankton food source (Saunders, 2004).

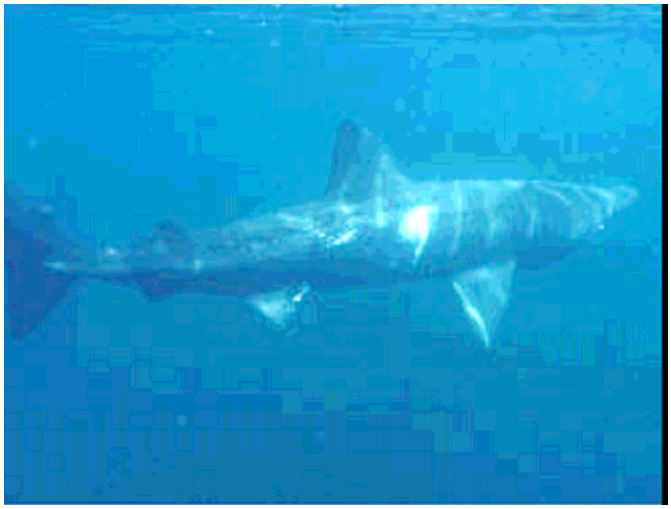


Figure 37: Basking shark

Historically the basking shark was exploited for the high oil content of its liver, which was used in the steel, medical, cosmetic and tanning industries, as well as a fuel for lighting. A fishery remained in the Clyde until the 1980s, when declining numbers and reduced public support meant the fishery was no longer viable.

Accurate and reliable quantitative data on basking shark populations in Scottish waters are not available (Saunders, 2004) as there are no regular, scientifically supported surveys of basking shark abundance across UK waters. Consequently little is known of basking shark life history, feeding or migration habits.

However, in 1987 the Marine Conservation Society (MCS) initiated a reporting scheme for public participation and in 2005 reported the west of Scotland as the new UK hotspot for basking sharks, with particular concentrations in the Firth.

Historically the Clyde was renowned for the quality and quantity of its herring fishery. Landings of herring from the Firth fluctuated about a long-term average of 14,200t in the period 1893-1960, with a maximum of 42,000t in 1932 and a minimum of 4,100t in 1914. Since 1960 the average landings were 8,300t per annum up to 1978 and only 2,400t in the six years 1979-1984 when landings were regulated by total allowable catch (TAC). Since the total allowable catch regulations have been in force, the fishery has been restricted, opening in May or June and closing sometime during the period August to October when the TAC is taken (Bailey *et al*, 1986).

The fishery was prosecuted by anchored drift net and ring netting until pair trawling arrived in 1968, this becoming the predominant method by 1973. In 1986 ICES allowed for a TAC of 4,650t pa, but expected discards of 1,580t pa had to be subtracted from this TAC. By 1986 the resident stock of herring, spawning in spring on the Ballantrae Bank, were greatly diminished leaving a fishery dependent on the non-resident autumn spawning stock with a TAC of 300t pa. By 2001 the catch had dropped to 157t pa (Combes and Lart, 2007).

Mass mortalities of herring embryos and egg mats were observed to occur over two consecutive years, 1990 and 1991. Anoxic conditions prevailed on the spawning grounds to the south of Arran, when cells of the phytoplankton *Skeletonema costatum* fell out of the water column and obstructed the gaps between eggs. The egg mat on the Ballantrae Banks suffered extensive wave damage in 1990 and a mass mortality for unknown reasons in 1991 (Napier, 1992).

The Clyde fishery for sprats began with a short-lived ring-net fishery in the early 1960s, and led to a pair-trawl fishery beginning in the winter of 1980-81. The most important fishing grounds for sprats are in the lower reaches of Loch Fyne and in the northern part of Kilbrannan Sound. The total catches for the winters 1980-85 ranged from 664 to 1505t (Bailey *et al*, 1986).

Annual Clyde mackerel landings fluctuated between 200 and 2,400t during the last century, and are insignificant in comparison with those in the Minch and to the north of Scotland (Bailey *et al*, 1986). Mackerel are not currently exploited commercially from Clyde waters (Combes and Lart, 2007).

During the early 1960s saithe landings in the Firth were approximately 100t per annum, but increased to a maximum of 6,700t per annum in 1973, equating to 50% of Clyde demersal landings and 24% of saithe landed in Scotland. Thereafter landings reduced to 500-1500t *p.a.,* until 1986 (Hislop 1986).

Between 18-57% of Scottish landings for hake were caught from the Clyde area between 1976 and 1986.

The Clyde fishery for demersal species; cod, whiting, saithe, haddock, hake (the Clyde catch represented 50% of the Scottish TAC in 1986), dogfish, plaice (Ayr and Irvine Bays), skates, rays and monkfish were already described as minor compared

to the *Nephrops* landings of 4500t worth £4.5m from the Clyde ports in 1983 (Hislop 1986).

Nationally, estuaries are used by up to 180 fish species for migration, spawning, feeding and as nursery grounds (Potts and Swaby, 1993). SEPA and its predecessors have monitored Clyde Estuary fish populations since the 1970s. The number of species recorded from year to year is quite variable and may include vagrants from freshwater (e.g. pike or roach) or from offshore water (e.g. garfish). Migratory salmon and sea trout returned in the mid-1980s and are still present, though they have only rarely been captured in routine sampling.

Figure 37 shows the cumulative number of species recorded in the Clyde Estuary since 1979 and shows a continuous upward trend, with the return of salmon observed in 1983. In addition to the salmonids, species which appear to have been absent in earlier years, but which are now regularly observed include sole, dragonets, and Nilssons pipefish (a relative of the seahorse).

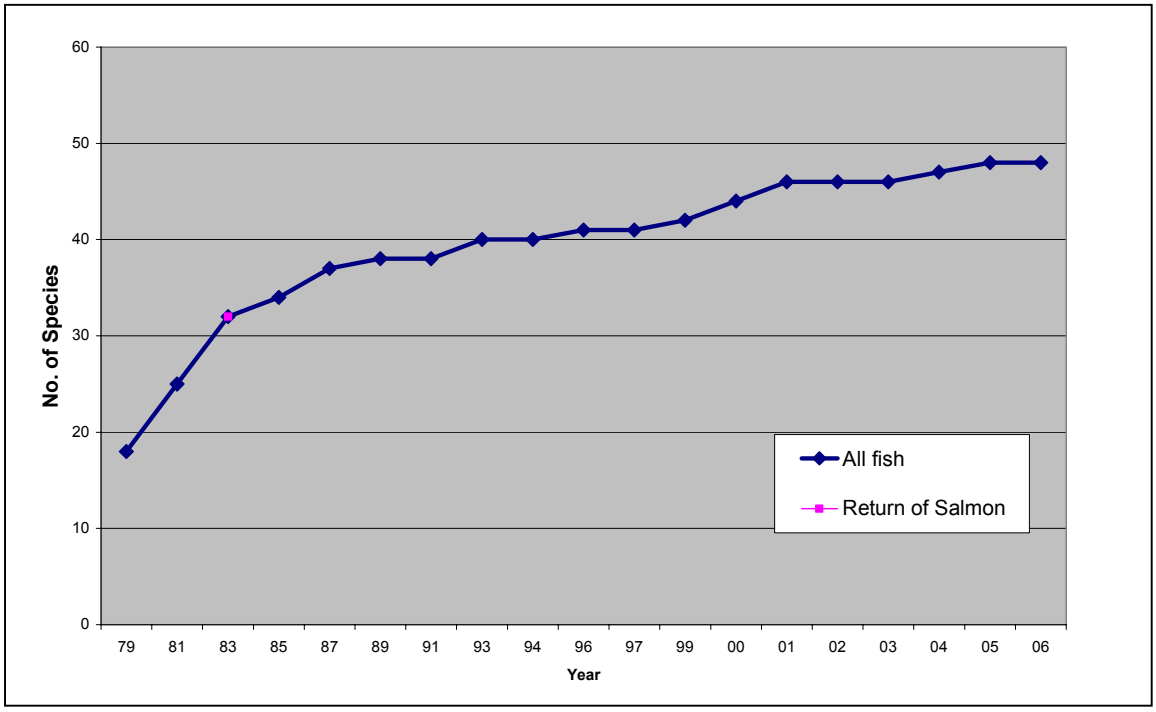


Figure 38: Cumulative number of fish species recorded in the Clyde Estuary 1979-2006

Of conservation interest is the discovery of migrating river lampreys recovered in traps at the tidal weir in Glasgow in 2000. These threatened fish spend their early years in freshwater, but migrate to marine waters to feed and grow before returning once again to rivers as adults to spawn.

ISSUES

Decline in pelagic fish stocks	Reduced commercial and recreational value of the Clyde's natural fish resources.

Lack of available, up to date, information on Clyde fish stocks	Lack of data detailing the composition and abundance of the Clyde's fish stocks limits the ability to plan marine activities effectively, whilst ensuring protection of the Clyde's biodiversity.
Lack of available data on Clyde fishing grounds	Lack of data on traditional fishing grounds limits the ability to plan marine activities effectively, whilst ensuring protection of the Clyde's biodiversity.
Lack of available data on Clyde fish spawning and nursery areas	Lack of data on fish spawning and nursery areas limits the ability to plan marine activities effectively, whilst ensuring protection of the Clyde's biodiversity.

4.3.2 Seals

Two species of seal, the grey seal and the harbour or common seal (Figure 39), are present around the coast of Scotland in internationally important numbers (SCOS, 2007).

Grey seals feed predominantly on bottom dwelling fish while common seals are opportunistic feeders taking a variety of species that are locally abundant, including fish and invertebrates such as cephalopods, gastropods and crustaceans. Historically in the UK, especially in Shetland and around the Wash, harbour seal pups were hunted for their skins until the early 1970s. While the Firth was not one of major seal hunting areas, pups continued to be hunted for their skin in north and west Scotland until the passing of the conservation of seals act in 1970.



Common seal numbers in Scotland are monitored through aerial surveys during the August moult and grey seal numbers primarily through pup counts at major colonies during their autumn breeding season. However, grey seals are also counted opportunistically in the August common seal surveys. The Sea Mammal Research Unit (SMRU) have completed four August surveys of the Firth since the current survey programme started in 1988 (Table 12).

Figure 39: Common seal

Table 12: Total numbers of seals recorded at haul out sites in the Firth of Clyde during August surveys of common (harbour) seals

Year	Harbour seals	Grey s
1989	381	117
1996	991	0
2005	581	132
2007	811	272

Data supplied by C. Duck, SMRU. These figures do not include the unknown proportions of seals in the water during the surveys and so represent minimum estimates of actual numbers present

Some 23,400 common seals were recorded in Scotland in 2005/6 (SCOS, 2007), of which fewer than 1,000 occur in the Firth (Table 12). The biggest concentrations in the Firth are on Sanda at the southern end of the Mull of Kintyre, the west and south coasts of Arran, around Bute and on Lady Isle off Troon. The remaining animals are scattered around the rest of the Firth, although their density is considerably lower than elsewhere along Scotland's west coast. In recent years, there have been marked declines in common seal numbers in the Northern Isles and along the Scottish east coast, but no such trend has been detected at west coast colonies (SCOS, 2007).

There are no major grey seal breeding colonies in the Firth. Very small numbers of pups are born on Lady Isle, off Troon in most years and some pups may be born at various other locations in the Firth. The nearest breeding colonies of any substance are on Nave Island, off north-west Islay, and on islands off the coast of Oronsay. Numbers of grey seals across Scotland are stable or slowly increasing with an estimated 40,600 pups born in 2006 (SCOS, 2007)

A UK-wide annual grey seal cull was maintained from 1962 until 1979, when it was abandoned in the face of sustained public protest (Saunders, 2004). In 1988, populations in some areas, notably the Wash, were severely reduced following an outbreak of the phocine distemper virus. Large numbers of seals were also found dead in the Firth but it is unknown if these were local seals or if they had drifted in from Northern Ireland, where the population was known to have declined substantially. Elsewhere in Scotland there was some mortality but at quite a low level.

Seals are often perceived as having a great impact on fisheries, particularly those using set nets and cages, although their actual impact on fish populations is estimated to be very low (Saunders, 2004). The extent of seal bycatch in commercial fisheries and of illegal shooting is unknown (SCOS, 2007).

ISSUES

Disturbance	Various studies have found that hauled out seals are sensitive to disturbance from leisure craft, and especially kayaks[4] At breeding beaches, this can result in injury to pups as adults flee into the water.

[4] http://montereybay.noaa.gov/sitechar/soci2.html#2a accessed 11 November 2008

4.3.3 Whales, Dolphins and Porpoises

Whales, dolphins and porpoises are warm-blooded marine mammals known as cetaceans. They range in size from the smallest dolphins and porpoises at a metre or so in length to the enormous blue whale (the largest animal on earth), which can grow to more than 30m in length.

Twenty-five species of cetacean have been recorded in British and Irish waters within the last 100 years, and 23 within the last 25 years (Evans, 1992). In the nearshore waters of the Clyde and Argyll seas fifteen species have been recorded since 1980 (Evans, 1996). However, the precise population status of most cetaceans occurring in Scottish waters, and indeed those around the whole of the UK, is largely unknown, with reliable scientific data restricted to observations on distribution rather than numerical abundance.

In the past, commercial whaling activities reduced populations of target species throughout the northeast Atlantic and northern North Sea. The International Whaling Commission imposed a global moratorium on commercial whaling in 1986.

The harbour porpoise is now the most abundant of the Scottish cetaceans, with the highest reported concentrations around the western and north-eastern coasts (Evans, 1992). In the Firth they are not reported as regularly or consistently as whales and dolphins (Gore, 2006).

The number of minke whales in the Firth appeared to have increased in 2006, but a pod of 27 bottlenose dolphins that visited in 2004 and 2005 did not return in 2006 (Gore, 2006).

In 1996 an immature humpback whale remained in the Firth from January to March, where it was observed feeding on sprat and herring. A humpback whale, a rare visitor to the Firth, appeared in Loch Long in October 2006 and remained for 4 days (Gore, 2006).

Data on sightings can be accessed through the joint cetacean database, a repository of sightings data recently created by merging three databases previously held separately by the Sea Watch Foundation, the JNCC and the Sea Mammal Research Unit. This database is not a publicly accessible facility.

ISSUES

Lack of easily available, up to date, information on Clyde cetacean population	Lack of available data detailing the cetacean movements within the Firth limits the ability to plan marine activities effectively, whilst ensuring protection of the Firth's biodiversity

4.4 Breeding and Wintering Birds

The marine and intertidal areas of the Firth provide important seasonal feeding grounds for a wide range of seabirds, seaducks, divers, grebes and waders, some of which also nest on the Firth's islands and along its shores. The Firth is of particular importance to gannets, redshank, eider and whooper swan and it holds three Special Protection Areas (SPAs) (see Figure 28), designated under the European Birds Directive, at Ailsa Craig (Figure 40), the Inner Clyde Estuary, and the tidal reaches of the Black Cart River.



Figure 40: Ailsa Craig

4.4.1 Seabirds

Scotland as a whole is home to three quarters of the UK's breeding seabirds (Baxter et al, 2008). Table 13 shows the numbers of breeding seabirds recorded in the Firth during the Seabird 2000 survey of UK and Ireland. The Firth holds nationally important populations of European shags, cormorants, great black-backed gulls, guillemots and razorbills; internationally important populations of lesser black-backed and herring gulls; and a globally significant site for breeding gannets at Ailsa Craig. Other important seabird breeding sites include the Sanda island group, off the south coast of Kintyre, the south Ayrshire coast (south of Downan Point), Lady Isle and Horse Isle, and Little Cumbrae.

Historically, gannets, especially young, were extensively hunted for food and fishing bait, but following their protection there has been a steady population expansion over the past century averaging approximately 2% per annum. Numbers on Ailsa Craig increased steadily in line with the national trend, from 13,000 apparently occupied

sites (AOS) in 1970, to 23,000 AOS in 1985. By 1995 the colony was the third largest in Britain and Ireland, with 32,500 breeding pairs, 16.5% of the UK total (Mitchell *et al*, 2004).

The latest aerial census in 2004 suggested that overall numbers of breeding gannets on Ailsa Craig had declined to 27,130 AOS (Murray *et al*, 2006). However, this is believed to be a result of the survey being completed too early in the season. Ground based observations suggest that the colony is still expanding beyond the 1995 total and another aerial survey is being considered for 2009 (Z. Clelland, RSPB pers. comm.).

Breeding success between 1991 and 2006 averaged 0.71 chicks fledged per nesting pair, slightly above the UK average for this species, and was particularly high in the five years to 2006, averaging 0.78 (data supplied by JNCC Seabird Monitoring Programme). Gannets are generally more resilient to depletion of fish stocks, for example in response to climate change or oceanic fluctuations, than some other seabirds as they will take a range of prey species and can forage over distances of several hundred kilometers and down to depths of over 20m. However, recent studies at the Bass Rock indicate that breeding gannets are having to forage further afield than in the past to feed young (Hamer *et al,* 2007), while at Ailsa Craig the 2004 and 2005 breeding seasons were much later than usual (Mavor *et al*, 2006). These findings are suggestive of changes in feeding conditions around colonies, while recoveries of ringed gannets suggest an increase in adult mortality rates over the past decade (Murray *et al*, 2006). Hence, there is evidence that gannets, in common with a number of other seabirds, are facing increasing threats and pressures. Data from JNCC's Seabird Monitoring programme (see box) indicate a 30% decline in the abundance of 13 seabird species across Scotland between 1986 and 2004 (Baxter *et al*, 2008).

Monitoring Breeding Seabirds

Slightly fewer than 8 million seabirds, from 25 species, breed in Britain and Ireland. Seabirds are potentially valuable monitors of their marine environment and since 1986 breeding seabirds in Britain and Ireland have been systematically monitored through the Seabird Monitoring Programme, coordinated by JNCC in collaboration with other statutory agencies and voluntary groups including RSPB and BirdWatch Ireland. Numbers and productivity of seabirds are monitored annually by staff and volunteers at tens of sample colonies, including Ailsa Craig and Sanda in the Firth of Clyde. More intensive studies are carried out at several key sites, including Canna, Skomer, Fair Isle and the Isle of May. Further details can be found at: http://www.jncc.gov.uk/page-1550

Annual monitoring studies are underpinned by regular censuses of all breeding seabirds in Britain and Ireland. The third full census, Seabird 2000, was completed in 1998-2002. Further details can be found at: http://www.jncc.gov.uk/page-1548

Table 13: Numbers of seabirds breeding at key sites in the Firth of Clyde in 2000 and trends at Ailsa Craig since 1987
(Figures in brackets are believed to be substantial underestimates)

Species	Count Unit	Total for Firth of Clyde[1,4,5]	1% Threshold[2]		Ailsa Craig	Sanda Island group	Other sites holding 10% or more of Firth of Clyde population
			GB	Inter-national			
Northern Fulmar *Fulmarus glacialis*	Pairs	1182	5390	75,400	197 (=)	510	-
Manx Shearwater *Puffinus puffinus*	Pairs	204	2,200	2650	3	200	-
Storm Petrel *Hydrobates pelagicus*	Pairs	200	850	2570	0 (=)	200	-
Northern Gannet[3] *Morus bassanus*	Pairs	(27,130)	2010	2630	(27,130)(▼)	0	-
Great Cormorant *Phalacrocorax carbo*	Pairs	428	70	410	0	28	Finnarts Point to Downan Point (83); Lady Isle (198); Horse Isle (51)
European Shag *Phalacrocorax aristotelis*	Pairs	1089	375	1250	28 (▲)	500	Finnarts Point to Downan Point (179); Lady Isle (178)
Lesser Black-backed Gull[4] *Larus fuscus*	Pairs	8059	830	1240	400 (▼)	59	Little Cumbrae (1200); Lady Isle (1000); Horse Isle (2677)
Herring Gull[4] *Larus argentatus*	Pairs	11,074	1600	9400	1450 (▼)	700	Inchmarnock Island, Bute (1550); Lady Isle (1500); Little Cumbrae (2000); Loch Fyne – various sites (1470);
Great Black-Backed Gull *Larus marinus*	Pairs	661	190	955	85 (▲)	38	Little Cumbrae (120); Lady Isle (200); Loch Fyne – various sites (168)
Common Gull[5] *Larus canus*	Pairs	612	680	1240	0	38	Holy Island, Arran (96); Great Cumbrae (144); Cowal Peninsula - various sites (84)
Black-headed Gull[5] Larus ridibundus	Pairs	61	1670	16,500	0	0	Hunterston (50)
Black-legged Kittiwake *Rissa tridactyla*	Pairs	1677	4900	31,700	1675 (▼)	0	-
Common Tern *Sterna hirundo*	Pairs	73	123	1950	0 (=)	0	Bowling (16); Hunterston (12); MoD pier, Campbeltown (12); Duncairn, Loch Fyne (34)
Arctic Tern *Sterna paradisaea*	Pairs	11 (▼)	440	9000	0 (=)	0	Bowling (2); Ballantrae (2); Pladda, Arran |(4); Dougarie, Arran (3)
Little Tern *Sterna albifrons*	Pairs	0 (▼)	24	205	0 (=)	0	Formerly bred at Ballantrae – 4 pairs in 1986/87
Common Guillemot *Uria aalge*	Pairs	8512[6]	7035	22,500	6308[6] (▲)	2204[6]	-
Razorbill *Alca torda*	Pairs	2955[6]	991	5,750	986[6] (▲)	1950[6]	-
Black Guillemot *Cepphus grylle*	Birds	949	None set	None set	24 (▲)	442	Finnarts Point to Downan Point (163)
Atlanitc Puffin *Fratercula arctica*	Pairs	284	4490	9010	20 (▲)	264	-

Notes: 1 Seabird 2000 Counts supplied by JNCC, Seabirds and Cetaceans branch, Aberdeen
2 JNCC (see http://www.jncc.gov.uk/page-1419; accessed 20 December 2007)
3 Gannet counts are from 2004 for Ailsa Craig. This figure is believed to be a substantial underestimate; the true population may be as high as 40,000 pairs (Z. Clelland, RSPB pers. comm.)
4 Larger gull totals are for coastal breeding populations, including roof-nesting birds, as defined in JNCC database (less than 5km from MHWM) only.
5 Totals for common and black-headed gulls also exclude birds on reservoirs and other freshwater bodies
6 Estimated numbers of pairs based on multiplying raw counts of individuals by 0.67 (Walsh *et al.* 1995)

Numbers of lesser black-backed gulls have declined at Ailsa Craig. There were 1800 pairs in 1987, representing at least 1.5% of the breeding Western Europe/ Mediterranean/ Western Africa population, but by 2000 numbers had declined by 78%, to just 400 pairs. This unexplained decline contrasted with an overall increase of 42% in numbers of this species breeding in coastal colonies in Britain and Ireland over the same period. However, a decline of 38% in numbers of breeding herring gulls on Ailsa Craig over the same period, to 1,450 pairs in 2000, is in line with the trend throughout Britain and Ireland over the same period. This national decline has been attributed to various factors, including predation by foxes and mink and outbreaks of bacterial botulism, an often fatal disease. However, within the Firth the most likely causes may be reduced food availability arising from improved sewage and waste management and changes in fishing practices.

In line with national trends, kittiwakes have also declined in the Firth over the past decade. Kittiwakes may potentially be a useful indicator of local conditions as they feed on small fish near the surface. Breeding success has been monitored annually since 1986 at some forty colonies in Britain and Ireland and this has revealed regional differences as well as temporal shifts. Average success at Ailsa Craig from 1986 to 2004 was 0.49 chicks fledged per breeding pair, but exceeded 0.6 in 2004 and 2005 (Mavor *et al*, 2006).

Numbers of auks such as guillemots and razorbill have increased in the Firth as they have generally in the UK. The related black guillemot and Atlantic puffin, which nest in crevices and burrows, are gradually increasing on Ailsa Craig, following the eradication in 1991 of brown rats which were accidentally introduced in the 1880s. Ailsa Craig historically held a very large puffin colony. The removal of rats may also enable colonisation by Manx shearwaters, with a small colony already present on Sanda Island.

Numbers of breeding terns in the Firth have historically declined, from hundreds of breeding pairs of five species in the 1960s (Zonfrillo, 2001) to just 84 of two species, common and Arctic, in 2000. Several former breeding colonies, such as Lady Isle and Horse Isle are no longer used by terns and little terns no longer breed at Ballantrae. This decline may in part be related to changes in food availability, especially presence of juvenile herring (Monaghan and Zonfrillo, 1986) but disturbance or predation is a probable contributory factor at some sites (e.g. Ballantrae, which was formerly wardened to protect breeding terns). These factors may in part also explain the colonisation of new artificial sites such as Hunterston since the mid 1980s.

In addition to being an important breeding location for cormorants and shags, the Firth also holds nationally important populations of both these species, outwith the breeding season. Peak autumn (August-October) numbers of cormorants in standard WeBS core count sites across the Firth averaged 837 birds between 2002 and 2006, equivalent to 3.6% of the UK total. The Inner Clyde (including the SPA) accounted for some 500 of these and parts of the Ayrshire coast are also important for this species. The mean autumn peak count for shags over the same five-year period was 448. Three areas, the

Inner Clyde SPA, Arran, and the coast between Girvan and Turnberry each held around 100 birds.

ISSUES

Large scale oceanographic fluctuations or climatic trends	Increasing sea temperatures may affect distribution of key prey species for seabirds, while more direct effects may include reductions in the amount of breeding habitat available for shoreline nesting species, such as terns.
Increasingly stormy weather	May adversely affect colonies in summer and lead to increased incidence of mass mortality events, or 'wrecks', in winter
Fishing practices	Direct impacts on fish stocks or through availability of discarded bycatch or offal
Ground predators	Predators such as brown rats and foxes can significantly reduce breeding success of vulnerable ground-nesting species and should be prevented from (re)colonising island seabird nesting sites
Disturbance on land	Disturbance of ground nesting species such as terns on accessible beaches
Disturbance at sea	May be an issue at particular times of year (e.g. when flightless young guillemots or razorbills join their parents at sea)

4.4.2 Waders

The Firth is an important feeding area for a number of species of wintering or passage (i.e. on migration between breeding and wintering areas) wader. Table 14 summarises recent high tide peak count data, collected by the Wetland Bird Survey (WeBS) for those species that occur in nationally or internationally important numbers. These figures are not estimates of the total numbers, as WeBS coverage across the Firth is incomplete, particularly along the Kintyre coast and in the sealochs, and there may also be considerable turnover in bird populations using Intertidal areas for feeding outwith the breeding season. However, they indicate the overall importance of the Firth for wintering and passage waders and also highlight sites of particular interest within the Firth.

The most important area for overwintering and passage waders is the Clyde Estuary. Parts of the Inner Clyde Estuary, encompassing some 1,800 hectares of mudflats and fringing semi-natural coastal vegetation, were designated as an SSSI in 1999 in recognition of their national importance to a range of waterbirds, including redshank, oystercatcher and curlew (see also section 4.4.3). The site was further designated as the Inner Clyde Estuary SPA and Ramsar Site (Figure 28) in March 2000 on the basis of its international importance to redshank (see Table 14).

In the mid 1970s up to 10,800 redshank, together with similar numbers of dunlin, were recorded wintering on the Clyde Estuary (Halliday *et al*., 1982; Furness et al., 1986). However, as illustrated for redshank in Figure 41, numbers of these two species declined very substantially between the mid-1970s and mid-1980s. Subsequently, peak winter numbers of redshank

Monitoring Waterbird Numbers

Numbers of wading birds, such as redshank, and other waterbirds (including divers, grebes, swans, geese, ducks and herons) are monitored annually through the Wetland Bird Survey (WeBS). This is run jointly by the British Trust for Ornithology (BTO), the Wildfowl & Wetlands Trust (WWT), Royal Society for the Protection of Birds (RSPB), and Joint Nature Conservation Committee (JNCC). The principal aims of the scheme are to identify population sizes, to determine trends in numbers and distribution, and to identify important sites for waterbirds. In estuaries, the main monitoring data are collected through nationally synchronised monthly high tide counts, principally between September and March.

Under the Ramsar Convention, a wetland is deemed to be of international importance, if it regularly supports 1% of the individuals in a population of a (sub)species of waterbird and/or more than 20,000 waterbirds in total. Similarly, a site is regarded as of national importance if it regularly supports 1% of the British population of a (sub)species of waterbird. International population estimates and associated 1% thresholds are subject to regular review.

recorded in the Clyde Estuary have generally fluctuated around 2000, although within the past five years (to 2006/07), peak numbers have been consistently below this level. It is as yet unclear whether this is a temporary fluctuation or a longer lasting decline; the GB population index for this species declined in the three seasons to 2006/07 following a period of relative stability over the preceding twenty years (Musgrove *et al*, 2007; Austin *et al* 2008).

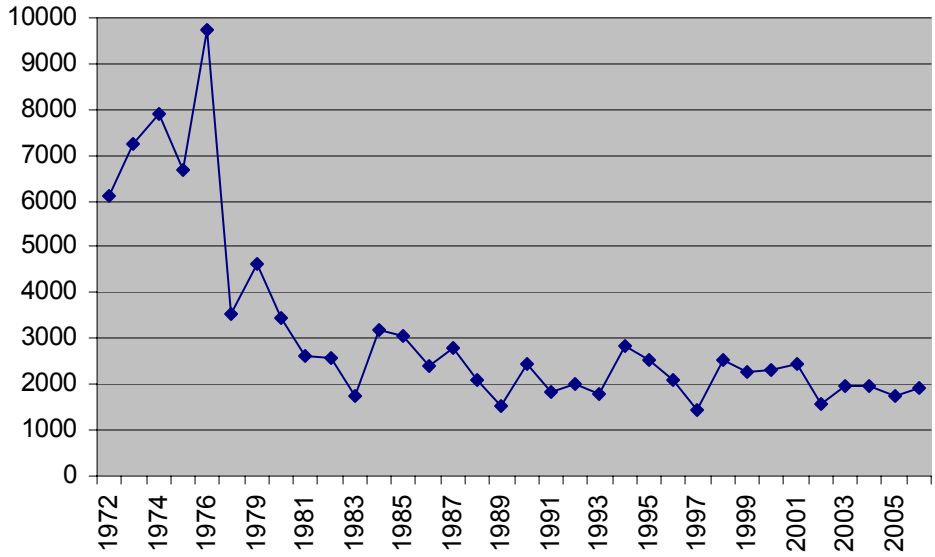


Figure 41: Peak winter (November to February) numbers of redshank counted in the Inner Firth of Clyde (*see notes to Table 11a for location details*).
Figure derived from data supplied by the BTO.

Within the Inner Clyde SPA, the decline in numbers of redshank from the mid-1970s to the mid-1990s was sufficiently high, as compared to the Scotland-wide trend, to trigger a long-term, medium WeBS alert for redshank at this site (Maclean and Austin, 2008). Since the mid-1980s, there has been a tendency for wintering waders in Britain to move eastwards, in response to climate change, but the earlier dramatic decline in redshank numbers may have been in response to changes in food availability associated with reductions in inputs of organic pollutants (Furness *et al*., 1986).

Analysis of 2007/08 low tide counts of redshank within the Inner Clyde Estuary SPA found little change in overall distribution from 1999/2000, with the exception of the narrow section of mudflats between Erskine Bridge and West Ferry, where both the absolute numbers and the proportion of birds recorded had declined substantially; from 1578 to 592 birds and from 48% to 28% (Harding, 2008a). The observed decline in numbers of redshank feeding in this area is coincident with the creation of a new public footpath, popular with dog walkers (Figure 42), along part of the shoreline, but it is currently unknown whether human disturbance is a factor affecting numbers of redshank and other waterbirds utilising the Clyde Estuary.



Figure 42: Dog being exercised on tidal mudflats near Erskine

The Inner Clyde Estuary SPA also holds small, but nationally significant, numbers of greenshank, with smaller numbers recorded at several other locations (Table 14). Oystercatcher are a notified feature of the Inner Clyde SSSI and, together with autumn passage curlew, occur in nationally important numbers within the site. Both of these species are found throughout the Firth in suitable habitats, as are ringed plover. Other species of wader found in substantial, although not nationally significant, numbers within the Firth include golden plover, lapwing, dunlin and turnstone. Areas of particular local

note for wintering waders include the Garnock/ Irvine Estuary and Bogside Flats at Irvine Bay, the coast between Girvan and Turnberry, Hunterston Sands and parts of the Arran coastline.

ISSUES

Water quality improvements	Declines in the population densities of non-breeding waterfowl and waders, particularly dunlin, redshank and lapwing, utilising the Clyde Estuary and of their principal invertebrate prey species
Disturbance associated with shore-based recreational activities	The relatively narrow intertidal zone within substantial areas of the Clyde Estuary may tend to exacerbate disturbance impacts on feeding birds
Loss of intertidal mudflat habitat	A programme of land claim was implemented at Hunterston in the 1970s to allow development of a steel works. There was a loss of intertidal habitat as a result.

Table 14: Summary WeBS counts of wader species for which the mean of peak counts across the Firth of Clyde between 2002/03 and 2006/07 exceed or approach 1% (inter)national population thresholds (*data supplied by BTO*)

Species	1%GB[a]	1% Inter-national[a]	Season	Composite counts	Inner Firth of Clyde[b]	Inner Clyde SPA[c]	Notes
Redshank *Tringa totanus*	1200	2800 (revised up from 1,300)	Autumn Winter Spring	2484 2677 (2040)	1620 1895 890	1471 1804 873	In autumn and winter peak counts of several hundred birds at Irvine/ Garnock Estuary, Girvan to Turnberry and Ayr to N. Troon
Oystercatcher *Haematopus ostralegus*	3200	10,200	Autumn Winter	7407 7226	5021 4896	3293 3408	Widely distributed throughout suitable habitats across the Firth, including Arran
Ringed Plover *Charadrius hiaticula*	330	730	Autumn Winter	586 731*	123 104	57 33	*based on one complete count in 2002/03. Widely distributed throughout suitable habitats, including Arran
Curlew *Numenius arquata*	1500	8,500 (revised up from 4,200	Autumn Winter	2354 2208	1693 1362	1610 1196	Mean peak winter count of 749 birds in Girvan to Turnberry section; otherwise widely distributed in suitable habitats
Greenshank *Tringa nebularia*	6[d]	2,300	Autumn Winter	15 19	11 11	11 11	Rare in Britain. Sites within Clyde outwith Inner Clyde SPA are Hunterston Sands, Doon Estuary, Irvine/ Garnock Estuary and Ardrossan to W. Kilbride

Notes to Tables 13 and 14 (1 of 2)
With the exception of whole-firth counts of eider (see note e), the figures shown are 5 year means of summed peak monthly WeBS high tide counts of individual birds within the autumn (July to October), winter (November to February) or spring (March to June) periods. Means are normally calculated using only complete counts, but incomplete counts are included if they raise the value of the mean. Where all peak counts within the 5 year period are incomplete (i.e. coverage was such that areas normally holding 25% or more of a given species were excluded) the 5 year peak mean is taken to be the highest of these counts and is shown in brackets (Banks *et al*, 2006).

Note that these figures do not equate to population totals as WeBS counts do not cover the full coastline of the firth and not all count sections are counted in all years. In addition, numbers of species such as seaduck which also utilise subtidal areas are underestimated by land based counts. The count sections included in the totals shown were: Maidens Harbour, Girvan Harbour, Irvine/Garnock Estuary, Ardrossan to West Kilbride, Hunterston Sands, Inner Firth of Clyde (see note b, below), Girvan to Turnberry, Ayr to North Troon, Wemyss Bay to Fairlie and Isle of Arran. Full details of these sites can be found at http://blx1.bto.org/websonline/public/public-list-region.jsp?REG=7&ORIENT=1. For sections of coastline counted on Arran see http://blx1.bto.org/websonline/public/gpub-boundary.jsp?loclabel=72470_Arran~NR955355
For key to superscripts see Table 15

4.4.3 Seaducks, Divers and Grebes

Table 15 summarises recent counts for those species of ducks, divers and grebes that are found in the Firth in nationally or internationally important numbers.

The Firth is of particular importance to eider, a large seaduck (Figure 43) that feeds primarily on mussels. Eider colonised the Firth and Outer Clyde Estuary from the Inner Hebrides during the 20th Century and by 1999 it was estimated that there were some 3,500 breeding females (Waltho, 2001).

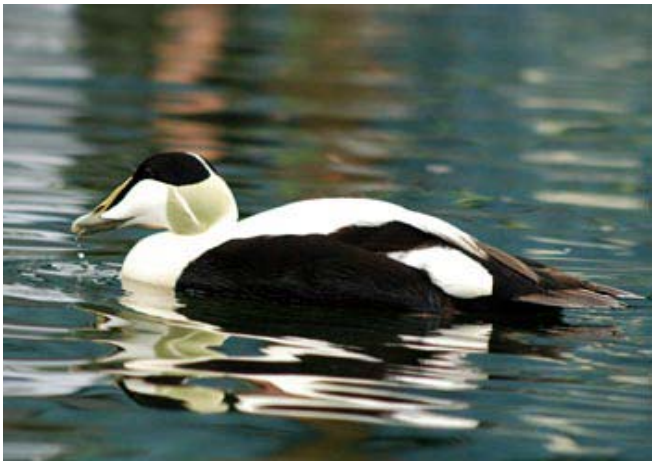


Figure 43: Male eider

The colonies on Burnt Islands (Kyles of Bute) and Horse Island (Ayrshire) each hold around 500 nests and are the largest known breeding sites on the Scottish west coast. Other important breeding sites within the Firth are Inchmarnock and Bute (Waltho, 2007). In recent years, there has been evidence of mink depredation at the Burnt islands colony (R.W. Furness, pers. comm.).

The Firth is the most important site in Britain for eider outwith their breeding season. From first colonisation until the late 1990s, numbers of eider in the Firth grew steadily at 8.5% per annum, reaching a peak of over 19,200 birds (excluding Loch Ryan) by 1997, as revealed by co-ordinated annual counts (Waltho, 2001). This figure was in excess of the 1% international threshold for this species (Table 15). However, by 2004 numbers recorded had declined by c. 25%, apparently due to the displacement, to unidentified alternative location(s), of some 5,000 birds from the Ayrshire coast. This decline in the Firth contrasted with a period of stability throughout Great Britain as a whole (Austin *et al*, 2008). An additional co-ordinated late summer count of (temporarily flightless) moulting eiders in 2004 found 12,419 birds (excluding Loch Ryan) in twelve flocks, of which those at Gareloch (2230), Hunters Quayto Toward Point (2225), Irvine Bay (1547), Turnberry to Girvan (1500), Lower Loch Long (914), Gourock to Wemys Bay (845) and the Clyde Estuary (803) contained over 1%of the GB population (Table 12). The other sites, at Ayr Bay, Hunterston to Fairlie, Ardrossan to Seamill, Otter Ferry, and Campbeltown Loch, together held some 2350 birds (Waltho, 2004).

Error! Reference source not found. shows areas within the SSMEI Clyde Pilot area that contained eider populations of national importance up to 2004.

There have not been complete September counts since 2004, but partial counts in September 2005 (7794 birds) and 2006 (9414) indicate that numbers have continued to fall. As detailed in Table 15, the mean of available complete counts for the period 2002//03 to 2006/07 is just over 13,000 birds, close to the species' (recently revised) 1% international threshold (12,850 birds). If it were assumed that 10,000 birds were present in each of 2005 and 2006, the 5-year mean would be below this threshold.

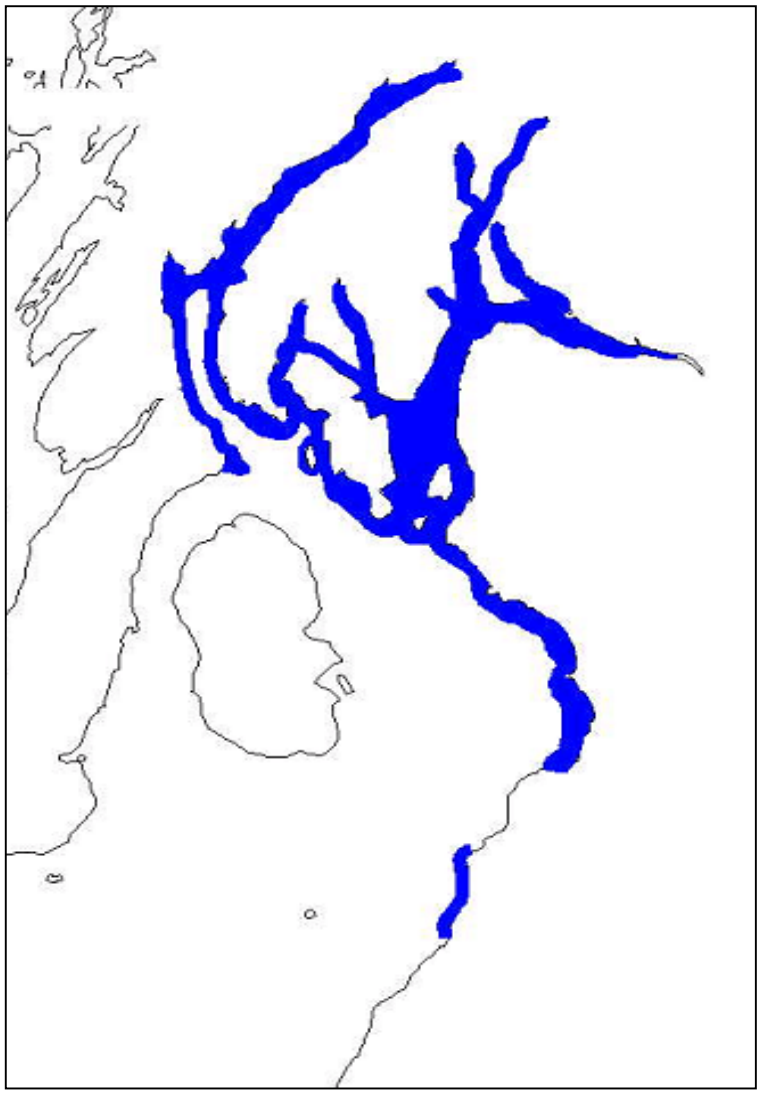


Figure 44: Areas of importance to eider in the Firth of Clyde

Other species which are recorded across the Firth in nationally important numbers are shown in Table 15. In addition to eider, the Inner Clyde SPA is a nationally important site for goldeneye and red-breasted merganser, while the coast between Ayr and North Troon is nationally important for scaup. Other species of seaduck found in substantial, although not nationally significant,

numbers within the Firth include shelduck, wigeon, and teal (BTO WeBS data).

The Inner Clyde SPA is of national importance for red-throated diver. The local importance of Ayr Bay to wintering red-throated divers was confirmed by aerial surveys in January 2007 (Lewis *et al*, 2008) while shore-based surveys in March 2007 and January/ February 2008 found up to 50 birds around Rhu (JNCC, unpublished data). Carradale Bay is a notable feeding site in the breeding season (K. Thompson, pers. obs.). The Inner Clyde SPA also holds nationally important numbers of Slavonian grebes, while peak numbers of great-crested grebe in late summer have slightly exceeded the 1% national threshold of 159 birds for this species in four of the past five years (BTO WeBS data).

Two shore-based surveys in March 2007 and 2008 covering parts of the Firth not routinely covered by WeBS counts, notably the east coast of Kintyre, parts of Loch Fyne and the Kyles of Bute, did not identify any major aggregations of seaduck, divers or grebes in these areas (JNCC, unpublished data).

ISSUES

Ground predators	Predators such as mink can significantly reduce breeding success of vulnerable ground-nesting species, such as eider, and should be prevented from colonising island nesting sites
Possible conflict with commercial shellfish farmers	Eider are attracted to commercial mussel farms and may eat commercially significant amounts of stock. Underwater acoustic deterrents, reinforced by boat chasing, may be effective in reducing levels of damage (Ross *et al*, 2001)
Disturbance at sea	Moulting (flightless) flocks of eider are potentially vulnerable to disturbance in late summer

Table 15: Summary WeBS counts of seaduck, grebes, divers and other waterbirds for which mean of peak counts across the Firth of (*data supplied by BTO and Chris Waltho*)

	1%GB[a]	1% International[a]	Season	Composite counts	Inner Firth of Clyde[b]	Inner Clyde SPA[c]	Notes
Eider[e] *Somateria mollissima*	730	12,850 (down from 15,500)	Autumn	13,125[e]	4759	1346	See main text for details of key locations for this species
Goldeneye *Bucephala clangula*	249	11,500	Winter Spring	(743) (289)	662 105	471 105	Other Important sites are Ayr to N. Troon (mean peak winter count 242) and possibly Irvine to Saltcoats (up to 340 birds in mid-90s)
Red-breasted merganser *Mergus serrator*	98	1,700	Autumn Winter Spring	(360) 249 (239)	154 147 132	146 105 108	Fairly widely distributed. Mean peak autumn count of 111 around Arran. Up to 150 birds between Irvine and Saltcoats in mid-90s
Scaup *Aythya marila*	76	3,100	Winter Spring	93 (56)	32 43	32 43	Numbers recorded are very variable; peak 120 in Jan 2003 in Ayr to N. Troon section. Irvine to Saltcoats held up to 160 birds in mid-90s)
Red-throated diver *Gavia stellata*	49[d]	3,000	Autumn Winter Spring	114 135 108	54 105 108	47 103 90	Numbers very variable ranging from under 30 to nearly 200. Other locally important sites are Girvan to Turnberry (winter and spring mean 31), Ayr to N. Troon (up to 36 in autumn) and possibly Irvine to Saltcoats (up to 60 birds in mid-90s)
Great-crested grebe *Podiceps cristatus*	159	3,600	Autumn Winter	150 118	150 118	150 105	Numbers fairly consistent across years
Slavonian grebe *Podiceps auritus*	7[d]	55 (up from 35)	Winter	31	31	31	Numbers very variable; peak 45 in March 2003

Notes to Tables 14 and 15 (2 of 2)

Key to superscripts

a: Musgrove *et al* (2007). For species where recent revisions to thresholds could affect perceived importance of Firth of Clyde the previous thresholds are also shown.

b: Figures for the WeBS core count unit named "Inner Firth of Clyde". This extends from the estuary of the Black Cart along the south shore of the Clyde Estuary out to Wemyss Bay and from Clydebank along the north shore past Helensburgh to Kilcreggan, including the Gare Loch. Thus it includes, but covers a substantially larger area than, the Inner Clyde Estuary SPA (see note c).

c: Figures for the Inner Clyde SPA are approximate as WeBS core count subsections do not exactly coincide with site boundaries (see Harding 2008a for full details). It should be noted that redshank are the only qualifying interest of the Inner Clyde SPA and Ramsar site. The coincident SSSI holds nationally important populations of a range of waterfowl, as detailed in the tables and text.

d: Where 1% of the British wintering population is less than 50 birds, 50 is normally set as the minimum threshold for determining national importance

e: Figure for whole Firth eider numbers (excluding Loch Ryan) is mean of dedicated September surveys co-ordinated by Chris Waltho for years 2002, 2003 and 2004. Counts in 2005 and 2006 were incomplete. The estimates for the Inner Firth and Inner Clyde SPA are WeBS core counts as for other species

4.4.4 Swans

The Black Cart SPA comprises a 3km tidal stretch of the River Cart and its associated floodplain, encompassing a total area of 56 hectares directly north of Glasgow Airport in Renfrewshire. The site was designated in 2000 in recognition of its importance to wintering whooper swans (*Cygnus cygnus*) of the Icelandic breeding population. The five year peak mean count from 1993 to 1997 was 207 birds, equivalent to 4% of the GB wintering population and to 1% of total Icelandic population. The population forages over the entire Black Cart SPA, roosts on the open water and uses the area as a severe winter refuge. The main mid- and late-winter foraging areas are on agriculturally improved land outside the SPA

More recent counts, from various sources as reported in Banks *et al* (2006) and Austin *et al* (2008), suggest a recent decline in this wintering population (2000/01:299; 2001/02: 238; 2002/03: 176; 2003/04: 151; 2004/05 and 2005/06: 112). Further monitoring, including study of field and roost usage, carried out in the winter of 2007/08 on behalf of SNH indicates a continuing decline in numbers with a peak population estimate of 99 birds (Harding, 2008b). This study also identified a roost in a tidal pool adjoining Newshort Island outwith the Black Cart SPA.

Mute swans (*Cygnus olor*) congregate in the Garnock/ Irvine Estuary (mean peak autumn count 102 birds between 2002/03 and 2006/07; WeBs, unpublished data) and parts of the Inner Firth (outwith the Clyde Estuary) in autumn and winter, but overall average numbers are not of national significance for this species.

ISSUES

Development pressure on roosts and feed areas	There is development pressure on whooper swan feeding areas and alternative roost sites lying outwith the Black Cart SPA boundary. With the exception of the Newshot Island roost, these areas are above mean high water mark.
Agricultural practices	Changing land management of feeding areas is affecting the Black Cart SPA whooper swan population. This is outwith the marine environment.

5 Climate Change

In 2007, the Intergovernmental Panel on Climate Change (IPCC) published their fourth assessment report, presenting strong evidence that anthropogenic inputs of greenhouse gases to the atmosphere are the most likely cause of the observed average increase in global temperatures over the last 100 years. Global atmosphere and oceans have warmed at a rate of 0.07°C per decade over the past 100 years and the warming has been observed to have accelerated over the last decade, a trend which is particularly apparent in sea-surface temperatures (Baxter et al, 2008).

The changes already observed have had, and continue to have, impacts on many aspects of society, including health, agriculture, water resources and energy demand. In order to make appropriate plans for the future it is vital to investigate observed changes in climate. In doing so, models of past and present climate can be validated and scenarios of future climate put into the context of any change already recorded. Of the national climate trends studies conducted to date most have made use of data from a small number of stations with long historical records (e.g. Begert *et al*., 2005).

These studies show that the Scottish mainland warmed by 0.69°C over the period 1861 to 2000 (Barnett *et al*, 2006), and that over a similar period precipitation patterns over Scotland have altered (Osborn *et al*., 2000), with summers becoming drier and winters wetter. There has also been an increased frequency of heavy rain events (Mayes, 1996; Smith, 1995).

5.1 Changes in Temperature

Regional effects mean that changes observed at a local level, which includes scales equivalent to Scottish waters, are likely to be different to the global average. In fact, the observed warming in Scottish waters since the early 1990s has been more rapid than the global and northern hemisphere averages (Baxter *et al*., 2008).

Fisheries Research Services maintains a network of coastal temperature monitoring stations around the coast of Scotland, and at three of these sites (including at Millport on the Isle of Cumbrae) data has been collected for more than 25 years. Since the end of the 1980s, the temperature of oceanic water flowing past Scotland has increased at a rate of between 0.22-0.40°C per decade. For all offshore sites monitored, temperatures observed in 2003-2004 were the warmest on record, with 2006 being the second warmest on record (Baxter *et al*., 2008). The variability in coastal waters is higher than that observed in oceanic waters and more closely coupled to atmospheric effects, and the warming trend is generally higher than observed further offshore.

It has been suggested by Hiscock *et al* (2001) that climate change, as a warming of air and seawater temperatures, will result in increased diversity of seabed marine life in Scotland, with adverse effects limited mainly to declines in abundance or loss of a small number of northern species. It has also been suggested that climate change may affect the spread of non-native species (Baxter *et al*, 2008).

5.2 Changes in Sea Level

Global sea level fell to about 120m below the current level some 18,000 years ago, owing to the abstraction of water into ice sheets. With the melting of the ice sheets, sea level rose to its present level about 5,000 years BP (British Geological Survey, 1997b).

The removal of the weight of ice allowed the earth's crust to rise to its original level, but more slowly than sea level. The results of this initial flooding and subsequent uplift have been the formation of raised beaches around the coast. Apparent sea level change is therefore the combined effect of local crustal movements and global rises in sea level.

Sea level rise, as a result of global climate change, is thought to be due to both the thermal expansion of water and the melting of land glaciers. Global sea levels have risen by between 10 and 20cm during the 20th century, and like sea temperature, appear to have accelerated since the late 1990s (Baxter *et al*., 2008).

All Scottish mainland tide gauges have recorded a sea-level rise over the last 100 years, with Aberdeen showing a trend of 0.7mm rise per year across the last 100 years. Such increases in sea level are offset, in some areas, by the rise in the Scottish land mass which has continued since the melting of the overlaying ice sheets at the end of the last ice age.

Estimates of current sea level change for Scotland, adjusted to take account of uplift movements, are shown in Figure 45. This indicates that at present relative sea level rises within the Firth are continuing to fall. Evaluation of tide gauge data across the Firth by Emery & Aubrey (1985) showed a fall in sea level ranging from 2mm/ year across the Mull of Galloway to 6mm/ year across the mouth of the River Clyde.

However, predicted increased rates of sea level rise associated with global warming predict that by 2080[5], sea levels within the Firth may rise by around 20cm. This would lead to increased risk of damage associated with storm surges (see section 2.6)

[5] http://news.bbc.co.uk/1/hi/scotland/tayside_and_central/7632210.stm accessed 1 December 2008

ISSUES

Rising sea level	Greater incidence of coastal flooding in at risk areas, leading to greater degree of 'coastal squeeze'. Evidence for the Firth indicates that while relative sea level is currently still falling there may be significant increases by 2080.
Increasing sea temperature	Potential increase in marine biodiversity
Increasing sea temperature	Potential loss of certain northern species
Increasing sea temperature	Potential increased rate of spread of non-native species
Increasing sea temperature	Potential for earlier phytoplankton blooms and changes in the food web
Increased storm events	Greater incidence of coastal flooding and storm surges in at risk areas, with associated negative impacts on breeding birds.

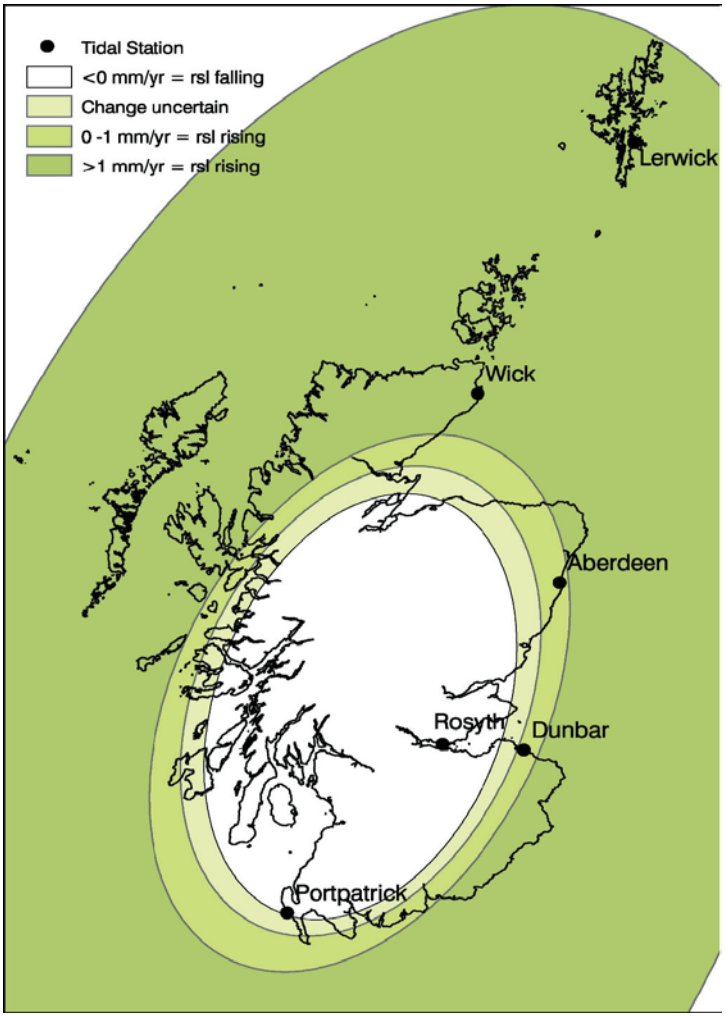


Figure 45: Present rates of relative sea-level change in Scotland (Baxter *et al.*, 2008)

6 The Visual Environment

Much of the Firth is noted for its high quality scenery and there are three nationally important designated areas of landscape interest that include sections of the Firth's coastline. These are the Kyles of Bute and North Arran National Scenic Areas (NSA) and the Loch Lomond and Trossachs National Park. Development in these areas is only likely to be permitted where it does not compromise the quality and character of the landscape. There are also a number of coastal local landscape designations.

Broad scale landscape and seascape characteristics are summarised in a SSMEI Clyde Pilot commissioned report (Grant, 2008). This identifies ten strategic landscape/ seascape character zones within the Firth: Expansive Coast; Wide Settled Bay; Developed Inner Firth; Extensive Estuary; Outer Sea Lochs; Inner Sea Lochs; Enclosed Narrows; Extensive Indented Coast; Steep Coastal Slopes; and, Sloping Coastal Fringe.

These character zones, illustrated in Figure 46 and Figure 47, combine an understanding of coastal landscape character with a brief assessment of seascape qualities, including attributes such as scale, sense of exposure, type and shape of coastline, coastal development and viewpoints.

ISSUES

The report also identified four main landscape/ seascape issues, as summarised below. However, as detailed in Grant (2008) the specifics of these issues, and possible responses to them, vary according to which landscape/seascape character zone is being considered.

Settlement expansion along coast	Pressure on accessible areas where terrain is steep and in some areas any large scale development likely to impact on rural/scenic quality. Avoid siting new developments between roads and the sea to maintain views. Maintain identity of existing settlements, where appropriate maintaining characteristic relationships between settlements and river mouths/bays.
Expansion of marine recreation/ harbour developments	Marinas and harbour developments are not appropriate for narrow lochs where development could quickly dominate small scale space Elsewhere developments should be contained within inlets and bays within or at the edges of settlements. Less developed and more open coastlines and extensive tidal reaches are likely to be more sensitive as are fine views suddenly revealed at the crest of hills or when exiting from passes.
Rising sea levels/ coastal flooding	Expansion of hard coastal defences may alter urban/rural character or townscapes and reduce areas of soft shoreline.
Off shore developments, (e.g. aquaculture, renewable energy)	Where viewpoints are low level and panoramic, structures may be absorbed in vast scale and foreshortened views. Medium scale seascapes and more complex coastlines may limit potential development sites, although horizontal structures might complement the low relief and regular skylines. More remote stretches of coastline, and high level viewpoints are potentially sensitive and ins some areas scenic quality likely to limit sites for development. Views from sea based craft are also important.

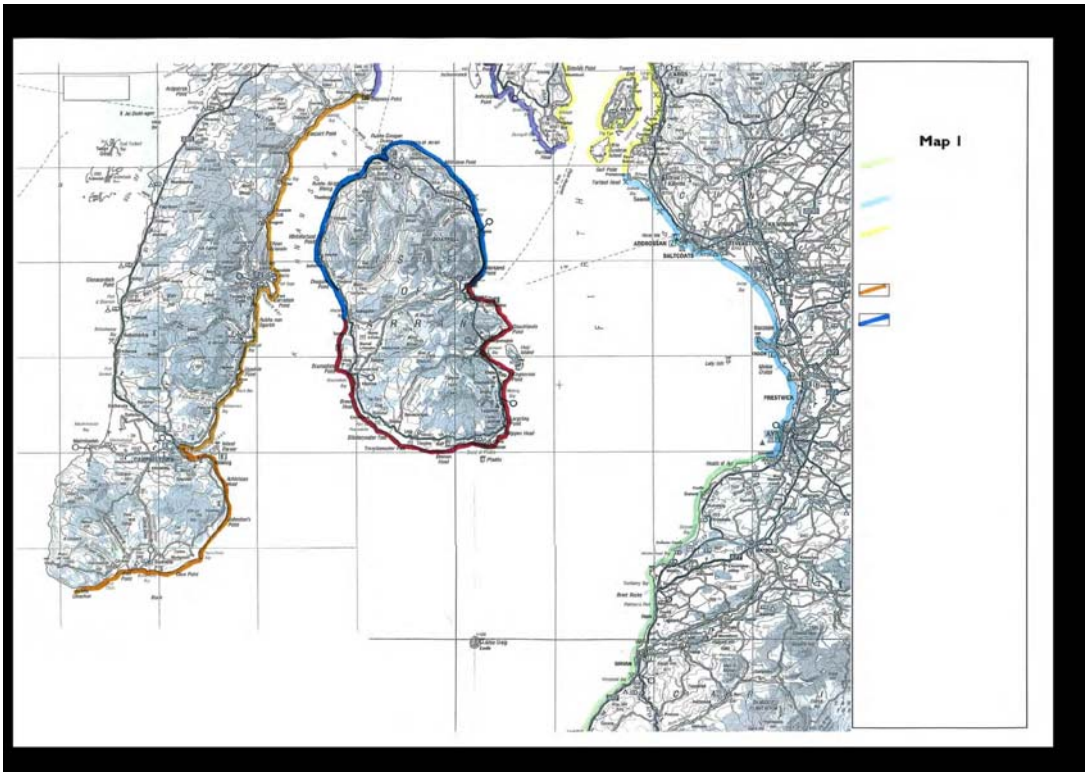


Figure 46: Firth of Clyde Landscape/Seascape Character Zones: Map 1 (Grant, 2008).

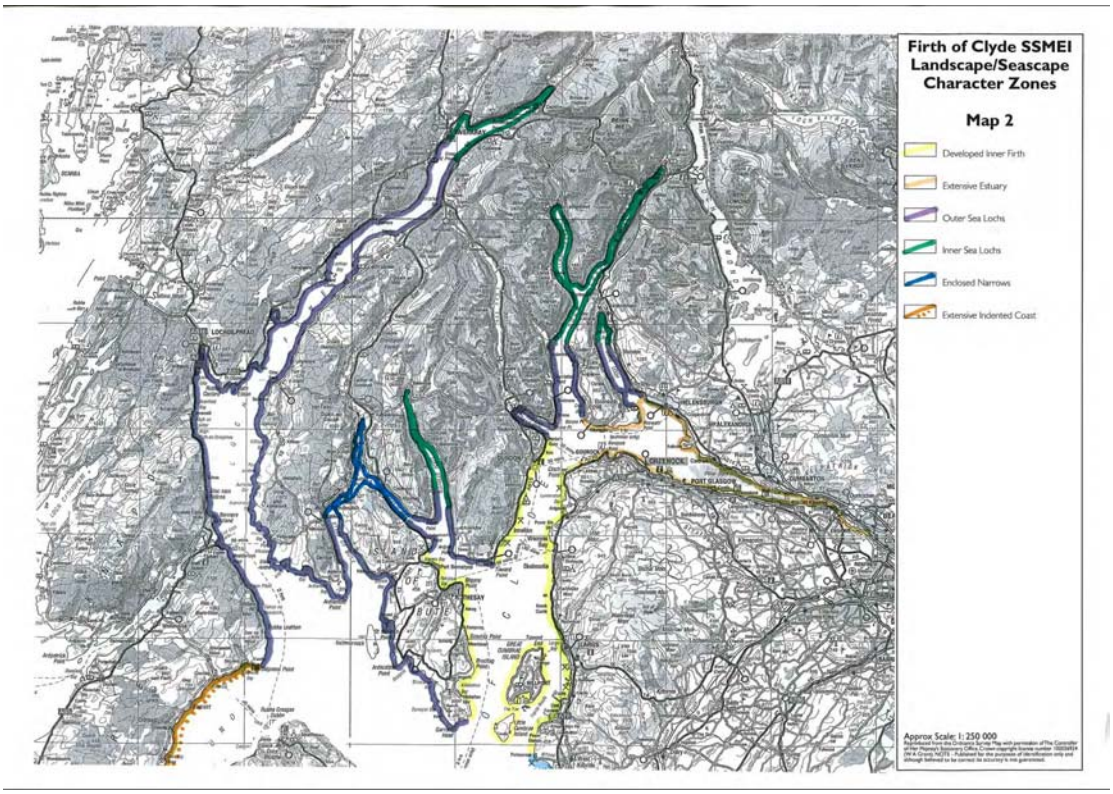


Figure 47: Firth of Clyde Landscape/Seascape Character Zones: Map 2 (Grant, 2008)

Acknowledgements and Sources

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Any errors in analysis or presentation of data are the responsibility of the authors.

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GLOSSARY

Alien Species: a species that has been transported by human activity, intentionally or accidentally, into a region where it does not occur naturally.
Anthropogenic: an effect or object resulting from human activity
Apparently Occupied Sites: a site with a bird sitting tightly on a reasonably horizontal area judged large enough to hold an egg
Aquaculture: the farming of freshwater and saltwater organisms including fish, molluscs (e.g. scallops), crustaceans (e.g. crabs) and aquatic plants.
Ballast Water: water carried in unladen ships to provide stability.
Bathymetry: the measurement of depth of bodies of water
Before Present: a time scale used to specify when events in the past occurred. Standard practice is to use 1 January 1950 as the arbitrary origin of the scale.
Bioaccumulate: the accumulation of substances, such as pesticides, or other organic chemicals in an organism
Biodiversity: the variety (within and between species) of living things from all sources (terrestrial, marine, aquatic).
Biomonitor: an organism that provides quantitative information on the quality of the environment around it
Biotope: a geographical area that has a uniform biological environment and a uniform distribution of plants and animals
Carrying Capacity: the capacity of a location or system to cope with a particular use, activity or species population without being fundamentally altered.
Cetaceans: an animal belonging to the order Cetacea, including dolphins, porpoises, and whales
Circalittoral: the region of the sea below the algal zone
Demersal: refers to fish such as cod, haddock and plaice which live primarily on or near the seabed
Diffuse Pollution: comprises contamination and pollution arising from many dispersed sources
Elasmobranchs: a group of fishes with cartilaginous skeletons and external gill slits, which includes all the sharks, skates and rays
Estuary: a semi-enclosed coastal body of water with one or more rivers or streams flowing into it, and with a free connection to the open sea
Eutrophication: enrichment of water by nutrients, especially compounds of nitrogen and phosphorus, that will accelerate the growth of algae
Faecal Coliform: the portion of the coliform bacteria group which is present in the intestinal tracts and faeces of warm-blooded animals
Fauna and Flora: animals and plants
Fetch: a term for the length of water over which a given wind has blown
Firth: the Lowland Scots word used to denote various coastal waters in Scotland. It is usually a large sea bay, which may be part of an estuary
Flood Plain: Land that may be submerged by flood waters, but is not normally submerged
Geomorphology: the study of landforms (in this case the coastline), including their origin and evolution, and the processes that shape them.
Habitat: the environment in which a species lives at any stage in its life cycle.
Hormone Disrupting Chemical: theory that low-dose exposure to chemicals that interact with hormone receptors can interfere with reproduction, development, and other hormonally mediated processes. Hormone or endocrine disrupting compounds encompass a variety of chemical classes, including hormones, plant constituents, pesticides, compounds used in the plastics industry and in consumer products, and other

industrial by-products and pollutants.
Hypernutrification: situation where excess nutrients, primarily nitrogen, are introduced into the aquatic environment resulting in eutrophication
Infralittoral: the algal dominated zone below the low water mark
Intertidal: the area of coast between the mean high water level and the mean low water level.
Land Claim: the process of creating dry land for agriculture or development from marine, usually intertidal areas.
Littoral: the area at a coast between the highest and lowest tides
Mariculture: aquaculture practised in marine environments.
Natura Site: sites that represent areas of the highest value for natural habitats and species of plants and animals that are rare, endangered or vulnerable in the European Community
Nephrops: the Norway lobster, *Nephrops norvegicus*, (also called Dublin Bay prawn, langoustine or scampi)
Non-native Species: see Alien Species
Pelagic: the upper layers of the ocean where food is plentiful. Pelagic fish include herring, sardine and pilchard.
Persistent Chemical: Organic substance that does not break down quickly in the environment and is readily taken in by living organisms
Phocine Distemper Virus: a virus that is pathogenic to pinniped species (fin footed mammals), particularly seals. Clinical signs include laboured breathing, fever and nervous symptoms
Radionuclide: an isotope of artificial or natural origin that exhibits radioactivity
Ramsar Site: area identified under the internationally agreed Convention on Wetlands of International Importance
Saltmarsh: an intertidal habitat comprising salt tolerant vegetation
Seabed: the bottom of a sea or ocean
Seabed Morphology: the form of the seabed, which is determined by underlying geomorphology and the nature and depth of overlying sediments.
Seascape: the coastal landscape and adjoining areas of open water, including views from land to sea, from sea to land and along the coastline
Site of Special Scientific Interest: areas of special interest by reason of their flora, fauna, geological or physiographical features which have been notified under the Wildlife and Countryside Act, 1981.
Special Protection Area: a designation under the European Union directive on the Conservation of Wild Birds
Storm Surge: a rise in coastal water level caused by a regional low pressure area and water pushed toward coastal shores by prolonged wind forces. A storm surge can significantly raise the mean water level if combined with astronomical high tides.
Stratification: when water of high and low salinity (halocline), as well as cold and warm water (thermocline), forms layers that act as barriers to mixing
Sublittoral: see subtidal
Subtidal: seabed area from the low tide line to the seaward edge of the continental slope.
Supralittoral: the region of low-lying land closest to the shore, but subject to seasonal or occasional flooding
Tidal Range: the vertical distance between low and high water
Toxic Chemical: a substance that can cause severe illness, poisoning, birth defects, disease, or death when ingested, inhaled, or absorbed by living organisms.
Translocate: move from one place to another, especially of wild animals
Waterfowl: birds that swim and live near water, including ducks, geese, and swans
Water Framework Directive: EC Directive which requires member states to achieve good ecological status of surface waters, including transitional and coastal water bodies.
Wireweed: fast growing seaweed (*Sargassum muticum*) that competes with native species such as seagrasses and is considered a nuisance in harbours, beaches and shallow waters.

ABBREVIATIONS AND ACRONYMS

AOS	Apparently Occupied Site
AoSP	Area of Special Protection
BP	Before Present
BTO	British Trust for Ornithology
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
DEFRA	Department for Environment, Food and Rural Affairs
DIN	Dissolved Inorganic Nitrogen
DO	Dissolved Oxygen
EC	European Council
EU	European Union
FC	Faecal Coliform
FoC	Firth of Clyde
FRS	Fisheries Research Services
IFG	Inshore Fisheries Group
IPCC	Intergovernmental Panel on Climate Change
IQI	Infaunal Quality Index
JNCC	Joint Nature Conservation Committee
MarLIN	Marine Life Information Network for Britain and Ireland
MBA	Marine Biological Association of the UK
MCS	Marine Conservation Society
MHWM	Mean High Water Mark
MNCR	Marine Nature Conservation Review
MSP	Marine Spatial Plan(ning)
NSA	National Scenic Area
OSPAR	Oslo & Paris Commission for the Protection of the Marine Environment of the North East Atlantic Problem Area (in respect of OSPAR Comprehensive Procedure)
PCB	Polychlorinated Biphenyl
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SEPA	Scottish Environment Protection Agency
SNH	Scottish Natural Heritage
SMRU	Sea Mammal Research Unit
SPA	Special Protection Area
SSMEI	Scottish Sustainable Marine Environment Initiative
SSSI	Site of Special Scientific Interest
WeBS	Wetlands Bird Survey
WFD	Water Framework Directive (2000/60/EC)
WWT	Wildfowl and Wetlands Trust