4. Condition of the Region
CLEAN AND SAFE

4.1 Water Framework Directive – Classification of transitional and coastal waters

Monitor Inner Firth, Loch Long, Loch Goil and south Bute to east of Arran 'corridor' for continued Good status



Colours are explained in the key at the beginning of the document

KEY SUPPORTING EVIDENCE

SEPA first (2009) and second (2015) River Basin Management Plans

SEPA Water Environment Hub www.sepa.org.uk/data-visualisation/water-environment-hub/

SEPA Water body information sheets http://apps.sepa.org.uk/waterbodydatasheets/

Scotland's Marine Atlas Clyde: no score included

Introduction

The European Union (EU) Water Framework Directive (WFD) was adopted in 2000, for the protection, improvement and sustainable use of rivers, lochs, ground, transitional[58] and coastal waters across Europe. The WFD was transposed into Scottish law as the Water Environment and Water Services (Scotland) Act 2003 (WEWS Act),[59] the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (CAR) and their amendments.[60] CAR applies regulatory controls over activities which may affect Scotland's water environment such as discharges, diffuse pollution, abstractions, impoundments and engineering works on inland waters and they also protect groundwater.

The Scottish Environment Protection Agency (SEPA) is the lead national authority responsible for implementing the WEWS Act, in partnership with other responsible organisations such as Scottish Natural Heritage (SNH), Scottish Water, Forestry Commission Scotland, Scottish Canals, Local Authorities, District Salmon fisheries board and National park authorities. SEPA is also responsible for the enforcements of CAR.[61]

River Basin Management

Water management in the UK is carried out based on the geographical and hydrological unit of river basins. The WFD requires the production of the Scotland river Basin District (all of the CMR's water bodies are within the Scotland River Basin District) and Solway Tweed river basin district River Basin Management Plans (RBMPs). They will identify the current condition of water bodies, where activities are reducing the quality of water bodies, and will describe and carry out actions required to ensure waters meet the necessary standards. The RBMPs set out statutory objectives needed to deliver environmental improvements over a six yearly cycle up until 2027.[62, 63]

Within the Scotland River Basin District, river basin catchment areas are organised into nine Area Advisory Groups (AAGs) which contribute to the development and the delivery of the River Basin Management Plan. These groups provide a platform for disseminating information on the river basin management process and help identify opportunities for joint working. In addition, active engagement and partnership working will be targeted at the appropriate scale; this may involve small delivery groups at a single water body level or at a catchment level. There are two AAGs in the Clyde Marine Region (CMR) – Argyll and Lochaber, and Clyde.[64] The River Basin Management Plan for the Scotland River Basin District identifies priorities for environmental improvements and protection and set objectives for water bodies in these two areas.

The Clyde AAG area includes all of the land that drains into the Rivers Clyde, Ayr, Irvine, Leven, White and Black Cart Waters and Kelvin. The area covers

58. Areas of water found at river mouths and estuaries which are partly saline, but are also affected by freshwater flows from upstream
59. Water Environment and Water Services (Scotland) Act 2003
60. Scottish Environment Protection Agency, g
61. Scottish Environment Protection Agency, d
62. Natural Scotland, 2015
63. Scottish Natural Heritage, 2016b
64. Scottish Environment Protection Agency, a

11,139km^2 and is made up of 28 catchment areas, 17 of which include transitional or coastal water bodies. The south east of the Mull of Kintyre, Loch Fyne, Campbeltown loch and the Kilbrannan Sound water bodies make up the small area of the Argyll and Lochaber advisory area that is part of the CMR. Taking forward lessons learned in the first RBMP phase, SEPA intend to work flexibly with AAGs and other partners during the second RBMP. This means not necessarily implementing the objectives of the plan through the AAGs but working adaptably in each area depending on issues faced and local involvement.

Classification of water body status

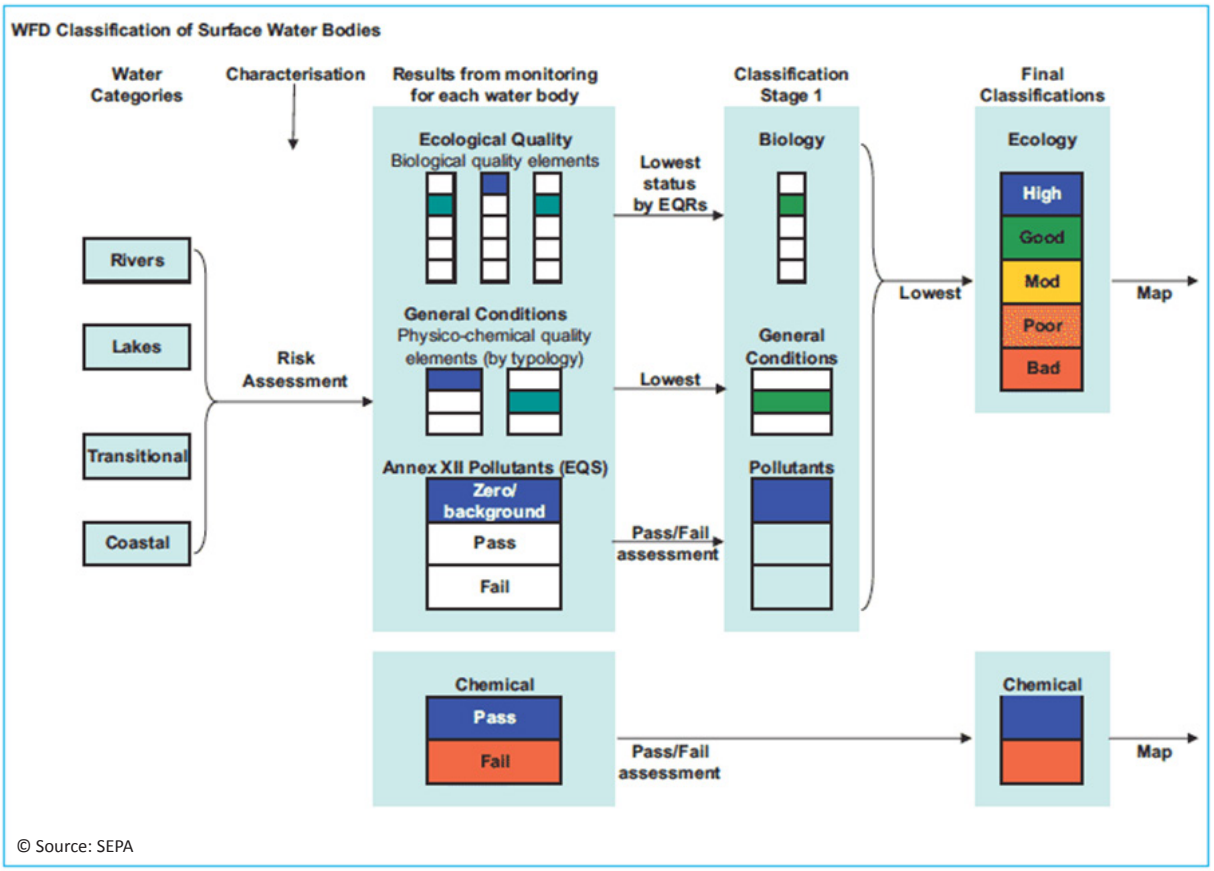
Each water body is classified according to its ecological condition from *Bad* to *High*. The status of a water body is determined by the lowest-classed quality element. Water bodies achieving less than *Moderate* status require action to be taken on the pressures affecting the water body; SEPA's aim is for water bodies to be at *Good* or higher status.

Some of the surface water bodies have been substantially modified over time for social and economic purposes including flood protection, hydropower generation, navigation, drainage and water storage for drinking water supply. Others may be totally man-made such as canals. The former are referred to as Heavily Modified Water Bodies (HMWB); canals are an example of artificial water bodies (AWB). Such water bodies may not be able to achieve *Good* status and are not subject to the conventional classification system. The principal objective in these cases is to achieve *Good Ecological Potential* (GEcP).[65] GEcP can be achieved when all efforts are made to mitigate man-made physical conditions, so they impact as little as possible on ecological or chemical conditions. It is called a 'potential' status as Good Ecological Status cannot be achieved under the conditions created by man–made features.

Water bodies of the Clyde Marine Region and their classification status

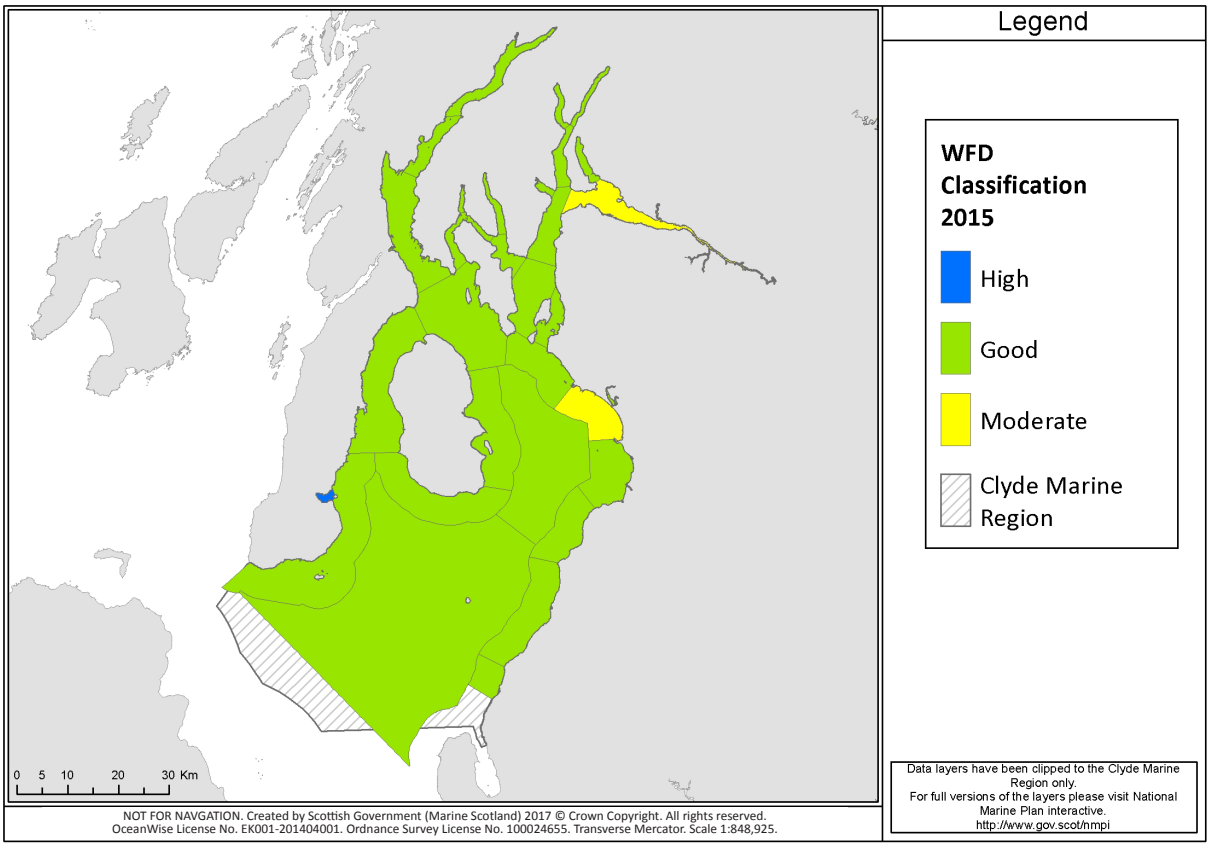
There are nine transitional and 26 coastal water bodies in the CMR. Table 4.1 lists all 37 water bodies, and shows their current and historical classifications. Table 4.2 outlines the pressures affecting water bodies classified as *Moderate* based on the 2014 classification results (at the time of writing, pressures related to the 2015 classification are not available).

Figure 4.1 WFD Decision tree for classification of surface water bodies



65. The Scottish Government, 2014a.

Map 10. WFD classification of water bodies in the Clyde Marine Region, 2015



The information in table 4.1 is taken from SEPAs Water Classification Hub: www.sepa.org.uk/data-visualisation/water-classification-hub – SEPAs Water Environment Hub: www.sepa.org.uk/data-visualisation/water-environment-hub/. This site provides information on water body status. Please check this site for updated information.

From 2014 to 2015 eight water bodies improved condition overall; none deteriorated. Seven water bodies: East Arran, Firth of Clyde Middle (Offshore), Loch Goil, Seamill and Ardrossan, sound of Bute, Loch Long North and Loch Long South improved from *Moderate* to *Good* status. Campbeltown Loch improved from *Good* to *High* Status. Of the remaining three water bodies which are at Moderate status, two, the Clyde Estuary Inner and Outer are HMWBs and the third, Irvine Bay is affected by morphological pressures. SEPA will work with relevant partners to improve the condition of water bodies at less than good status and to maintain the *Good* or *High* condition of the remaining water bodies.

Two of the HMWBs in the Clyde area are those of the Clyde river estuary. The inner and outer Clyde estuary has been changed by dredging to create channelization to improve waterways for traffic and also by the building of weirs and dams. In addition to these physical changes, the inner Estuary is exposed to point source pollution from sewage and industrial waste disposal. The Clyde estuary water bodies have consistently received *Moderate Ecological Potential*.[67] The other two HMWBs are Ayr estuary and Girvan estuary; both of these water bodies have *Good Ecological Potential*.

66. Scottish Environment Protection Agency, F
67. Scottish Environment Protection Agency, F

Table 4.1 Classification status of transitional and coastal water bodies in the Clyde Marine Region, from 2008-2014 and the pressures (2014) affecting these water bodies.[68,69]

WATER BODY TYPE	SUB BASIN	WATER BODY	2008	2009	2010	2011	2012	2013	2014	2015
TRANSITIONAL	CLYDE	Ayr Estuary	Good EcP	Good EcP	Good EcP	Good EcP	Good EcP	Good EcP	Good EcP	Good EcP
		Ballantrae Lagoon North	High	High	High	High	High	High	High	High
		Ballantrae Lagoon South	High	High	High	High	High	High	High	High
		Clyde Estuary – Inner (incl. Cart)	Moderate EcP	Moderate EcP	Moderate EcP	Moderate EcP	Moderate EcP	Moderate EcP	Moderate EcP	Moderate EcP
		Clyde Estuary – Outer	Moderate EcP	Moderate EcP	Moderate EcP	Moderate EcP	Moderate EcP	Moderate EcP	Moderate EcP	Moderate EcP
		Gare Loch	Good	Good	Good	Good	Good	Good	Good	Good
		Girvan Estuary	Good EcP	Good EcP	Good EcP	Good EcP	Good EcP	Good EcP	Good EcP	Good EcP
		Garnock/Irvine Estuary	Good	Good	Good	Good	Good	Good	Good	Good
		Stinchar Estuary	High	High	High	High	High	Good	Good	Good
COASTAL	CLYDE	Ayr Bay	Good	Good	High	High	High	Good	Good	Good
		Ballantrae	Good	Good	High	High	High	Good	Good	Good
		Culzean	Good	Good	Good	Good	Good	Good	Good	Good
		East Arran	Moderate	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Good
		Firth of Clyde inner-Dunoon and Wemyss Bay	Good	Good	Good	Good	Moderate	Moderate	Good	Good
		Firth of Clyde inner Cumbraes	Moderate	Moderate	Moderate	Good	Good	Good	Good	Good
		Firth of Clyde Middle (offshore)	Moderate	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Good
		Firth of Clyde Outer (offshore)	Moderate	Moderate	Moderate	Moderate	Good	Good	Good	Good
		Girvan	Good	Good	High	High	High	Good	Good	Good
		Holy Loch	Good	Good	Good	Good	Good	Good	Good	Good
		Irvine Bay	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
		Kyles of Bute	Moderate	Moderate	Good	Good	Good	Good	Good	Good
		Largs Channel (Fairlie Roads)	Good	Good	Good	Good	Good	Good	Good	Good
		Loch Goil	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Good
		Loch Striven	Good	Good	Good	Good	Good	Good	Good	Good
		Rothesay	Good	Good	Good	Good	Good	Good	Good	Good
		Seamill and Ardrossan	Moderate	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Good
		Sound of Bute	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Good
		South Arran	Moderate	Moderate	Moderate	Moderate	Good	Good	Good	Good
		Loch Long North	Good	Good	Good	Good	Good	Moderate	Moderate	Good
		Loch Long South	Good	Good	Good	Good	Good	Moderate	Moderate	Good
		Loch Riddon	Good	Good	Good	Good	Good	Good	Good	Good
	ARGYLL AND LOCHABER	Campbeltown Loch	Moderate	Moderate	Moderate	Moderate	Moderate	Good	Good	High
		Kilbrannan Sound	Moderate	Moderate	Moderate	Moderate	Good	Good	Good	Good
		Loch Fyne Middle	Good	Good	Good	Good	Good	Good	Good	Good
		Loch Fyne Outer	Good	Good	Good	Good	Good	Good	Good	Good
		Loch Fyne Upper	Good	Good	Good	Good	Good	Good	Good	Good
		Mull of Kintyre – South East	Moderate	Moderate	Moderate	Moderate	Good	Good	Good	Good

68. Scottish Environment Protection Agency, F

69. Due to improvements in data collection and reviews of classification methods, standards for measuring the status of a water body change from year to year. As a result the table may indicate that water bodies have degraded in classification. This may not necessarily be due to failure to prevent deterioration in such water bodies, but as a result of classification standards becoming stricter; this is indicated where it is the case. Pressures also change from year to year based on updated information.

Table 4.2 Pressures on water bodies classified at less than Good status

N.B. Pressures related to the 2014 classification are noted here as the pressures related to the 2015 classifications were not available at time of writing.

WATER BODY	STATUS	PRESSURES (2014)[70]
Clyde Estuary-Inner (incl. Cart)	Moderate EcP	• Point source discharges from waste water (sewage) disposal to be dealt with 2021-2027. • Unknown pressure on water quality to be dealt with 2015-2021
Clyde Estuary-Outer	Moderate EcP	• Modifications to bed, banks and shores as a result of land uses and navigation. This will be addressed from 2021-27 through partnership work by SEPA, other public bodies, voluntary organisations and land managers
Irvine Bay	Moderate	• Modifications to bed, banks and shores as a result of land uses and navigation. SEPA have phased completion of the work to improve the physical condition of the water body for 2021-2027

When a water body shows a downgrade in classification, this could be due to the review of the methodology used in classification, rather than any actual environmental change. This is the case for Stinchar Estuary, when the status of the water body went from *High* in 2012 to Good in 2013 and this was due to the fact that in 2013 the classification assessment started to consider fish in transitional waters. For the classification to achieve *High* status fish fauna has to have ecological elements (such as: species composition, abundance, presence of indicator species, number of taxa and number of estuarine resident taxa) consistent with undisturbed conditions. The tool used to access the fish element (and also other elements) in water bodies shows when there are pressures affecting an element, but it is not known at this time what those pressures may be.

One of the objectives of the WFD is for water bodies to attain GEcS and GEcP. SEPA is responsible for working with partners to set out measures to deal with the pressures affecting water bodies. This is a collaborative process as sometimes improving measures are the responsibility of external authorities, such as Scottish Water, or can only be achieved through partnership work with various stakeholders. Overall, SEPA seeks to make sustainable improvements where possible.

ECOSYSTEM SERVICES[71]		
SERVICE TYPE	BENEFITS PROVIDED	COMMENTARY
Provisioning	Food	Poor water quality could impact on the system's ability to provide food that is safe to eat. Healthy habitats support a functioning ecosystem and stocks of commercially important species through provision of spawning and nursery areas.
Regulating	Waste processing and assimilation	Enhancing the capacity for the ecosystem to provide waste processing and water purification services will ensure that provisioning and cultural services can be provided. Some parts of the CMR are impacted by waste water and pollution. Local contamination can exceed the capacity, in particular of an estuarine ecosystem, to remediate or assimilate it.
Cultural	Recreational activities and sense of place	Clean and safe water is essential for recreational activities such as immersion watersports. Improvement in the condition of water bodies can potentially lead to increased biodiversity and productivity, resulting in a greater sense of place and increasing a place's educational and inspirational capacity.
Supporting services underpin the provision of other services		Supporting services underpin the provision of other services Coastal and transitional water bodies in the CMR support primary production, nutrient cycling and photosynthesis. Nutrient processing in sediments depends on invertebrates disturbing and irrigating the sediment and is fundamental to the survival of other marine organisms. Where supporting ecosystem services are functioning fully, they support stocks of commercially important species. Improving the ecological and chemical classification of these water bodies (including sediments) will optimise these supporting services and help improve overall ecosystem resilience.

70. Scottish Environment Protection Agency, i
71. UK National Ecosystem Assessment, 2011

4.2 Hazardous substances and their biological effects

Clyde estuary and inner Firth



Other Lochs and Outer Firth



Colours are explained in the key at the beginning of the document

KEY SUPPORTING EVIDENCE

Clean Safe Seas Environmental Monitoring Programme (CSEMP) data www.bodc.ac.uk/projects/data_management/uk/merman/assessments_and_data_access/csemp/

Marine Scotland Science Regional Assessment of Hazardous Substances in Coastal and Offshore Marine Environments: 1999-2009 marinedata.scotland.gov.uk/dataset/regional-assessment-hazardous-substances-coastal-and-offshore-marine-environments-1999-2009

Scotland's Marine Atlas Clyde score: 'Generally some concerns but improving, with many local concerns'. Regional scoring is consistent with this.

Introduction

Hazardous substances are toxic substances; metals and chemicals which accumulate in the environment and in organisms and have a negative impact on them. Hazardous substances can bioaccumulate (gradual build-up of substances in an organism over time) and are biomagnified (pollutants become concentrated in organisms as they move up food chains and webs).[72] Specific biological effects are discussed further on in this chapter.

Types of hazardous substances

Polycyclic aromatic hydrocarbons (PAHs) are widespread pollutants which enter the marine environment through atmospheric deposition, road run-off and industrial discharges. Car emissions contribute more than 50% of PAH inputs to the atmosphere and 28% are from residential and industrial fuel combustion. PAHs are known to be mutagenic and carcinogenic.

Polychlorinated biphenyl hydrocarbons (PCBs) were widely used in transformers, capacitors, hydraulic fluids and as plasticisers in paints, plastics and sealants and can cause endocrine disruption, immunosuppression and Vitamin A deficiency. Production in Western Europe ceased in the 1970s, but continued in closed systems in the UK until 1986.

Polybrominated diphenyl ethers (PBDEs) are an organobromine compound and were used in the production of flame retardants. These were historically released into the environment during manufacturing and through atmospheric transportation. They continue to leak from treated materials through everyday use of household products. While effects on humans are not known, animal studies show that they are endocrine disruptors and can affect the central nervous system and the brain.[73] Although heavy metals can be found naturally in the environment at low levels, at elevated levels cadmium, for example, has long term effects on health and mercury is highly toxic.[74]

Tri-Butyl-Tin (TBT) was extensively used in the past to protect hulls from fouling but caused damage to many species in the marine environment; its use was phased out for boats under 25m from 1988 and then for all boats and ships by 2008.

Historic legacy of hazardous substances in the Clyde Marine Region

Hazardous substances are found in high concentrations in the Clyde Marine Region (CMR) due to the Clyde's industrial history and large population. Higher concentrations of contaminants are usually found in estuaries rather than on the open coast. Furthermore, Clyde sites have a greater potential to accumulate contaminants due to the hydrophobic nature of PCBs and PAHs. This means they accumulate in sediment and accumulate more readily in sediment types which have a high organic content and smaller particle size (larger surface: volume ratio), so higher levels can be found in muddy, rather than sandy sediments[75] (See Chapter 5.3 Shallow and Shelf Subtidal Sediments, for a map of sediment types in the CMR).

In terms of historic inputs, there are three areas in the CMR which are known point sources; the sewage sludge dump site at Garroch Head, the dredge spoil dump site at Cloch point and the former naval base at Holy Loch. All are located in the inner Firth. Annually, 1,500,000 tonnes of sewage sludge (industrial and domestic waste) from the greater Glasgow area was dumped at Garroch head from 1904-1998, resulting in a highly concentrated area of contamination. This was stopped as part of the UK's obligation under the EC Urban Waste Water Treatment Directive (see Chapter 6.10 Waste Water Treatment and industrial outfalls).

72. Webster *et al*., 2010
73. Webster *et al*., 2010
74. Webster *et al*., 2010
75. Webster et al., 2005



Creel boat © PETER SANDGROUND

Organic enrichment of the sediment from the sludge has caused levels of heavy metals, PCBs and PAHs to become elevated (due to sediment types with higher organic content having a greater potential to accumulate these pollutants). Concentrations of organic compounds remain high in these areas in both biota and sediment following the cessation of dumping. A study published in 2005, found that PCB concentrations were not found to have decreased significantly since dumping ceased in 1998. However, they were less persistent in plaice liver sampled from Garroch Head after dumping had ceased.[76]

Holy Loch was used as a United States Navy Submarine base from 1961,[77] until closure of this base in 1992.[78] Video surveys of the site following closure showed a large amount of debris on the sea bed – mainly scrap metal, furniture, electrical equipment and small vessels. The Ministry of Defence led a working group and SEPA carried out a study to analyse contaminants in the sediment and in mussels, to examine the potential for bioaccumulation in the loch. Samples of sediment were taken from several sites around the loch and elevated levels of heavy metals and PCBs were found at depths of 5-10cm, suggesting that contamination had been higher in the past. The contamination of PCBs and some some metals was described as 'severe but localised'. Body burdens in mussels for PCBs and heavy metals examined before and after debris were removed (which may have caused the release of sediment-bound contaminants) showed no significant changes in concentrations.[79]

Natural and anthropogenic activities carried out in the marine environment have the potential to remobilise contaminated sediments and release contaminants from sediments into the water column. Desorption rates and times depend on the type of contaminant, size of sediment particles and environmental factors, such as exposure to oxygen.[80]

76. Webster *et al*., 2005
77. Baxter, 2011
78. Miller *et al*., 2000
79. Miller *et al*., 2000
80. Eggleton and Thomas, 2004

Regulating and monitoring hazardous substances

Some contaminants cannot be physically removed once they have entered a system; some can only reduce by degrading or becoming more dispersed over time.[81] Regular monitoring ensures that concentrations do not pose a risk to human health, and where they do, action can be taken. There is potential to use shellfish, macroalgae, seagrass and saltmarsh to bio-remediate environments with excess chemicals.[82]

Most effects felt today are due to historic inputs and the persistent and semi-volatile character of some contaminants, meaning that they are still present in the environment. In the marine environment, many are considered ubiquitous partly due to their wide usage, ability to travel long-ranges through atmospheric transportation and run off from land. It is acknowledged that the marine environment acts as a sink for contaminants. Increasing knowledge and awareness of the harmful effect of such chemicals over time has led to their production being stopped and their use banned.[83]

The Stockholm Convention entered into force in 2004 and is a global treaty designed to protect human health by eliminating 12 of the most harmful persistent organic pollutants (POPs – organic chemicals) from the environment. It also works towards supporting the transition to safer alternatives, targeting additional POPs for action and cleaning up stockpiles.[84]

Descriptors eight and nine of the Marine Strategy Framework Directive (MSFD) seek to ensure that concentrations of contaminants cause no effect and contaminants in seafood are below safe levels in order to achieve Good Environmental Status (GEnvS). OSPAR (the mechanism by which 15 Governments and the EU cooperate to protect the marine environment of the North-East Atlantic, named for the Oslo and Paris conventions) monitors substances which may be of possible concern and has developed a strategy to prevent further pollution of the OSPAR Commission maritime area. This strategy aims to reduce discharges of hazardous substances, with the overall objective of ensuring concentrations are near background values for naturally occurring substances and close to zero for man-made synthetic substances in the marine environment.

The Water Framework Directive (2000) (see Chapter 4.1 for more information on the WFD classification of water bodies in the CMR) sets out strategies against pollution in water, outlining steps to be taken and producing a first list of priority substances which pose a threat to the aquatic environment. This was updated with the WFD daughter directive – the Directive on Environmental Quality Standards (2008), also known as the Priority Substances Directive. This sets environmental quality standards for substances in river, lakes, coastal and transitional waters.

The main monitoring programme in the UK is the UK Clean Seas Environment Monitoring Programme (CSEMP). This programme fulfils the monitoring requirements set by OSPAR and EU directives across the UK, and has been established under advice from the International Council for the Exploration of the Sea (ICES).[85] Monitoring for this programme in Scotland is carried out in cooperation between Marine Scotland and Scottish Environment Protection Agency (SEPA). As the central programme examining contaminants, the CESMP provides spatial and some temporal data when available for monitoring conducted across the CMR.

UK Clean Seas Environment Monitoring Programme results

CSEMP assessment results discussed below are available to view from this website: www.bodc.ac.uk/projects/data_management/uk/merman/assessments_and_data_access/csemp/ where they are mapped and more details are available for specific contaminants across all sites. They are also available to view on NMPi: marinescotland.atkinsgeospatial.com/nmpi/.

Monitoring for hazardous substances is carried out across 34 sites in the Clyde Marine Region for sediments. Additionally, monitoring for hazardous substances and for biological effects (such as imposex) in biota is carried out across 32 sites and in 5 species– European plaice (*Pleuronectes platessa*), European flounder (*Platichthys flesus*), dog whelk (*Nucella lapillus*), blue mussel (*Mytilus edulis*) and common dab (*Limanda limanda*). Depending on how long a site has been monitored, trends can be determined. The following assessment criteria are used:

- Background Assessment Concentration (BAC). Mean concentrations significantly below the BAC are said to be near background concentrations of a contaminant at a pristine or remote sire to be considered of no concern.[86]
- Environmental Assessment Criteria (EAC). Concentrations above EAC can cause adverse effects on marine life.
- Effects Range Low (ERL). Concentrations below the ERL rarely cause adverse effects in marine organisms.
- In assessing hazardous substances in biota, European Commission food standard (EC) is

81. Webster *et al.*, 2010
82. Marine Maritime Organisation
83. Webster *et al.*, 2010
84. Secreteriat of the Stockhold Convention http://chm.pops.int/default.aspx
85. Webster *et al.*, 2010
86. Baxter *et al.*, 2011

also used, when EACs are not available. ECs are the maximum acceptable concentrations in food for the protection of public health.[87]

For alkylated PAHs and organobromines in sediment, and in organibromines in biota, no assessment criteria has been developed, so no indication of contamination levels is given, but where possible a trend is.[88]

Assessment of sediments

Overall the assessment for hazardous substances in sediments in the CMR showed that there is a high proportion of results which are above ERL (could cause adverse effects on marine organisms) at monitoring stations in the inner Firth compared to other sites in the CMR. However, across the CMR, the chlorobiphenys congener CB118 was shown to be above EAC at 23 out of 29 monitoring stations and one particular PAH, Benzo [g,h,i]perylene was above ERL at 33 out of 34 monitoring sites. More details of the assessment are provided below. Of all the monitoring sites, North of Ailsa Craig showed a consistent picture of concentrations decreasing over 10 years; across all hazardous substances measured, 29 of the 46 had a downward trend.[89]

Metals

- All monitoring sites in the CMR have levels of chromium which are above ERL, except for at Pladda (off the south of Arran), which was below ERL. There are no results for monitoring of metals at Garroch head.
- Lead was above ERL at 12 out of 17 monitoring sites.
- Zinc was above ERL at 9 out of 17 sites with an upward trend (concentrations going up in the last 10 years) indicated at 2 sites: off Cloch point and at Lunderston Bay.
- An upward trend (concentrations increasing) was also seen off Cloch point and at Lunderston Bay for arsenic; all sites in the inner Firth were above BAC for arsenic.
- Metals across all inner Firth sites were assessed at above ERL or BAC except for cadmium which was below BAC or ERL at all sites.

PCBs

- Majority of sites were below BAC or EAC for all PCBs, except for CB118 which was above EAC at 23 out of 29 sites.

PAH (parents)

- Results were mixed for PAH (parents) in the inner Firth; a number of monitoring sites across a range of contaminants in this group were above ERL.
- Benzo [g,h,i]perylene, was above ERL at 33 out of 34 monitoring sites.

Assessment of Biota

CSEMP monitoring in biota includes sites in the outer Clyde estuary whereas monitoring in sediment does not. In the outer estuary there are a high number of results above EAC (in PAHs and PCBs) or EC food limits (for metals) and BAC in biota compared to other sites across the CMR.[90]

Metals

- Lead was above the EC food limit in blue mussels at Woodhall and in Flounder at Bowling.
- Cadmium in flounder was above the EC food limit at Bowling. At Ardrossan cadmium was below BAC and decreasing in the last 10 years. At all other sites, cadmium was below the EC food limit.
- Zinc was above BAC in blue mussel at 13 out of 18 monitoring sites throughout the CMR.
- Copper was above BAC in blue mussel at 9 out of 18 monitoring sites, all of which were in the Clyde estuary, inner Firth and Lochs Goil, Riddon and Striven.

PCBs

- A high number of results for PCBs were above EAC or above BAC in the outer Clyde estuary and inner Firth compared to the rest of the CMR.
- CB105 was above BAC all 14 sites monitored across the CMR. All species except dog whelk were tested.
- CB118 was above EAC for all monitoring sites across the CMR (all species except dog whelk were tested across 24 sites), except in blue mussels at Strone Point which were below EAC.

PAH (parents)

- PAH (parents) were measured in blue mussels and were generally below EAC across the majority of sites.
- An exception to this is Chrysene and Ideno[123-cd]pyrene, which were above BAC at every site monitored.
- Benzo[a]anthracene and Pyrene were above EAC in all sites monitored in the inner Firth and outer estuary.
- Fluroanthene was also above EAC at all sites monitored in the outer estuary and inner Firth as well as at Seamill Boydston, Loch Striven, Loch Goil and at the Loch Ryan monitoring site (the latter is outwith the CMR).

For a visual representation of CSEMP monitoring results, please refer to the National Marine Plan interactive[91] or the CSEMP assessment results page https://www.bodc.ac.uk/projects/data_management/uk/merman/assessments_and_data_access/csemp/.

87. British Oceanographic Data Centre, 2014
88. British Oceanographic Data Centre, 2014
89. British Oceanographic Data Centre, 2014
90. British Oceanographic Data Centre, 2014
91. Marine Scotland, 2016a



Starfish © SUE SCOTT, SNH/MNCR

Concentrations of contaminants in the Clyde were described in a 2009 study as *'generally at levels such that there is an unacceptable risk of chronic effects occurring in marine species. This is mainly due to historic industrial inputs. However, downward trends were detected for Pb and PAHs in Clyde sediment indicating that the implementation of relevant regulations is beginning to have a positive environmental impact.'*[92] It is worth noting, that dredging and disposal are regulated activities within the CMR and that disposal in marine waters will only be licensed by Marine Scotland if it can be demonstrated that there is no unacceptable risk to aquatic life.

Biological effects of hazardous substances

Scotland's Marine Atlas highlights several examples of biological effects on living marine organisms. These include imposex (a disorder which causes females to develop male reproductive organs) in dog whelks, which is caused by exposure to the chemical TBT, an anti-fouling paint used on boats and ships since the 1970s. This has shown a significant downward trend, reducing to background levels in some areas since the ban on the use of TBT in paints used on both commercial and recreational vehicles.[93]

Imposex results

- Measurements were below EAC at all sites (15 were sampled). At Ballantrae, results were below BAC. Measurements at Loch Ryan were above EAC.

EROD results

The enzyme 7-Ethoxyresorufin-O-deethylase (EROD) is expressed in fish livers when certain contaminants are metabolised. Measuring this can show whether organisms are being exposed to contaminants through the food they eat.

- EROD was tested for in female flounder, dab and plaice at 6 monitoring sites. There is no assessment criteria available for some species; and for dab at Holy Loch concentrations were below BAC.
- Results in males, across the same species, were all above BAC at all sites; again except for dab at Holy Loch which was below BAC.

Genetic analysis of mussels has revealed the extent of adaptive stress response to contaminants.[94] Food Standards Scotland manages the Official Controls chemical contaminants monitoring programme, whereby shellfish from Classified Shellfish Harvesting Areas (CSHA) are analysed for hazardous substances to ensure they are safe for consumption.[95] For more information on CSHAs see Chapter 4.3 Microbiological contamination – Shellfish water protected areas.

92. Webster *et al.*, 2010
93. Baxter *et al.*, 2011
94. Baxter *et al.*, 2011
95. Food Standards Scotland, 2015b

ECOSYSTEM SERVICES[96]		
SERVICE TYPE	**BENEFITS PROVIDED**	**COMMENTARY**
Provisioning	Food	The presence of hazardous substances in seabed sediment can cause chronic effects on living marine organisms. This can impact negatively on community structures and in turn, impact on food webs and chains. Hazardous substances can also have a genetic effect and disrupt hormones of organisms, affecting their capacity to reproduce. Many hazardous substances in biota are above the EC food limit in the outer Clyde estuary and inner Firth. Where levels of hazardous substances exceed set limits in the CMR, bivalve shellfish are not considered fit for human consumption.
Regulating	Waste processing and detoxification	Hazardous substances can affect the ecosystem's ability to provide water purification services, and can limit the capacity for provisioning and cultural services to be provided.
Supporting services underpin the provision of other services		Marine sediment can act as a sink for hazardous substances where these substances can then detoxify and degrade over time. There are concerns that certain parts of the Clyde estuary and inner Firth have been historically overloaded with contaminants and that this will impact the ability of the sediments to perform this essential ecosystem service.

96. UK National Ecosystem Assessment, 2011

4.3 Microbiological contamination – Shellfish water protected areas



Colours are explained in the key at the beginning of the document

KEY SUPPORTING EVIDENCE

SEPA Water Environment Hub www.sepa.org.uk/data-visualisation/water-environment-hub/

Food Standards Scotland www.foodstandards.gov.scot/food-safety-standards/advice-business-and-industry/shellfish

Scotland's Marine Atlas Clyde score: 'Generally few concerns and no trend, but with some local concerns'. Regional assessment considers more recent SWPA designation and status.

Introduction

Harmful toxins and microorganisms can become concentrated in shellfish flesh and are harmful to humans once consumed. These include: *Escherichia coli* (bacteria related to faecal contamination); phytoplankton and toxins produced by phytoplankton including: paralytic shellfish poisoning toxins, amnesic shellfish poisoning toxins and lipophilic shellfish toxins and chemical contaminants.[97] There are two levels of protection to public health; Shellfish Water Protected Areas (SWPAs) and Classified Shellfish Harvesting Areas (CSHAs).

Shellfish Water Protected Areas

The designation order (The water Environment (Shellfish Water Protected Areas: Designation) (Scotland) Order 2013) identifies the 84 areas around Scotland as Shellfish Water Protected Areas. The shellfish growing water areas are protected and, where necessary improved by a package of measures integrated with the river basin management process.[98]

These areas have been designated by Scottish Government based on the existing Shellfish Growing Waters (which were created under the Shellfish Waters Directive which was managed by SEPA and repealed in 2013) and attempted to overlap with the existing CSHAs (which are managed by Food Standards Scotland, formerly Food Standards Agency Scotland), while also taking into consideration potential growth of the industry. These areas are reviewed every six years. There are six SWPAs within the Clyde Marine Region (CMR), accounting for 7% of all the SWPAs in Scotland, and they include: Fairlie, Kyles of Bute, Lamlash, Loch Long, Loch Striven and Loch Fyne.[99] These are shown in Map 11. This legislation does not prevent sites being developed in zones outside of the designated areas.

SWPAs are classified as 'good', 'fair' or 'insufficient' according to the amount of *E. Coli* present in shellfish samples taken from SWPAs.[100] The objective under the SWPA Designation is for the SWPA's to reach 'good'; results highlighted on SEPAs Water Environment Hub show that none of the SWPAs in the CMR have reached target objective. All were classified as 'fair' from 2011-2014 except Loch Long which was classified as 'insufficient' for that period.

SEPA has set a timeline for the SWPAs to reach target objective or 'good' by 2027, except for Fairlie SWPA where the target is 2021. SEPA gives the reason for the failures to meet the objective as diffuse pollution from a rural source affecting water quality. The target objective at Fairlie SWPA will be met through priority catchment action. Loch Fyne, Loch Long, Lamlash and Loch Striven protected areas will be addressed by focussed area action by public bodies and land managers working together. It is still to be determined how to address the status of the protected area at Kyles of Bute.[101] As this information becomes known it will be added to SEPA's Water Environment Hub www.sepa.org.uk/data-visualisation/water-environment-hub/?riverbasindistrict=Scotland.

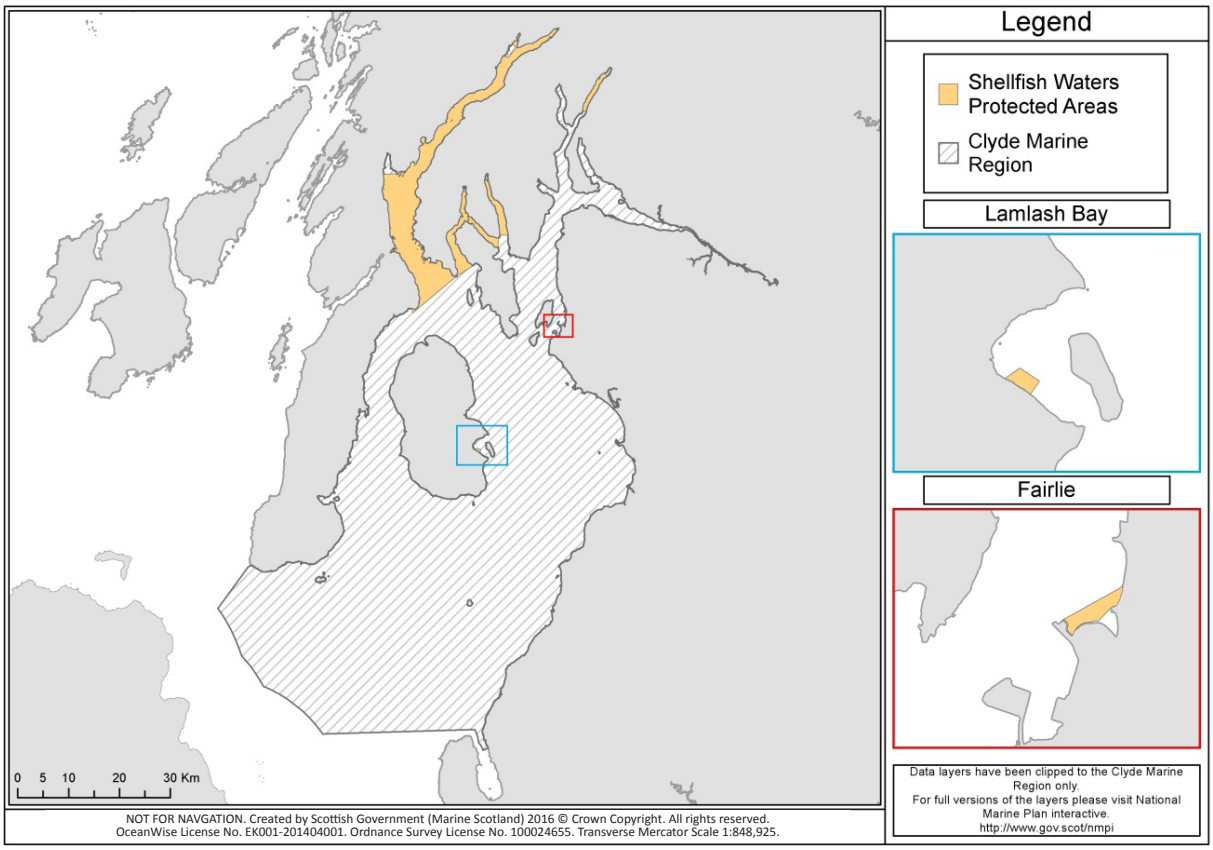
Figure 4.6 Oyster farming



© JOHN CHARITY, SNH

97. Food Standards Scotland, 2015b
98. The Scottish Government, 2016d
99. The Scottish Government, 2016e
100. The Scotland River Basin District (Quality of Shellfish Water Protected Areas) (Scotland) Directions 2015
101. Diffuse pollution priority catchments have been identified by SEPA as catchments failing to meet environmental standards. Fourteen priority catchments, containing some of Scotland's most important waters (for conservation, drinking water, bathing and fishing), have been selected using a risk based approach for action in the first basin planning cycle. Work will also include the mitigation of other water environment impacts, such as morphological change, abstractions, flooding and alien species, where these are also causing waterbody downgrades. The first RBMP identified the River Ayr, River Irvine, River Garnock and North Ayrshire Coast as catchments in or near the CMR for priority action.

Map 11. Shellfish Water Protected Areas in the Clyde Marine Region



Classified Shellfish Harvesting Areas

Food Standards Scotland (FSS) classifies and monitors Classified Shellfish Harvesting Areas (CSHAs) as a food hygiene control measure to protect public health. In this process, shellfish harvesters apply to their Local Authority to have a site classified for harvesting. However, CSHAs do not always lie within designated SWPAs. Samples from CSHAs are monitored for biotoxins and *E. coli*, presence of either would result in an intervention to ensure that a safe product reaches the consumer market. Depending on the amount of *E. coli* found, the FSS provides a number of different options to a harvester – either submitting shellfish product to purification or heat treatment/cooking of shellfish product by an approved method. When levels reach over 46,000 *E. coli*/100g of flesh, harvesting is not permitted.[102] Table 4.4 shows the action taken, depending on the level of *E. coli* found in samples. Discovery of biotoxins in harvesting areas is more reactive, and results in a temporary closure of sites until biotoxin levels return to normal.[103] More information on biotoxin monitoring is available in Scotland's Marine Atlas.[104]

The FSS classification for 2015-2016 identifies 20 shellfish harvesting areas within the CMR. All were given a classification rating of A, or B apart from the Campbeltown Loch production area which was given a classification rating of C for the period June-October. Two sites: Stevenson Sands Razors

Table 4.4: Shellfish Harvesting Area classification (Food Standards Scotland) categories and permitted levels of E.coli/100g flesh, and required treatments.

CATEGORY	RESULT	ACTION
A	Less than or equal to 230 E. coli/100g of the flesh	May go directly for human consumption if end product standard met
B	Not exceeding 4600 E. coli/100g of the flesh	Must be subject to purification, relaying in Class A area (to meet Category A requirements) or cooked by an approved method.
C	Not exceeding 46,000 E. coli/100g of the flesh	Must be subject to relaying for a period of at least 2 months or cooked by an approved method.
Above 46,000 E. coli/100g of the flesh		Harvesting not permitted.

102. Food Standards Scotland, 2015b
103. Food Standards Scotland, 2015b
104. Baxter *et al.*, 2011

North and South were declassified in 2015.[105] Sites can become declassified due to failure to produce samples of analysis, or cessation of harvesting from a site and so trends in declassification are not a reflection in the trend of the environment. Two areas were declassified in 2014-15, to be later reclassified in 2015-16. These were Arran: Pirnmill and Carradale Bay.[106] FSS works with Local Authorities and harvesters to maintain closely monitored standards. These partners also have an effective communication network with information of sudden or emergency closures, indicating that this is a well regulated sector, with little or no concerns for public health.[107]

Active aquaculture production sites in the Clyde Marine Region

There are over 70 active aquaculture production sites in the CMR, details of these including their locations and production is discussed in Chapter 6.3 Aquaculture.

ECOSYSTEM SERVICES[108]		
SERVICE TYPE	**BENEFITS PROVIDED**	**COMMENTARY**
Provisioning	Food	Some shellfish harvesting areas in the CMR are not in a suitable condition to carry out shellfish farming and harvesting without purification. Purification enables the supply of food, socio-economic activity and income generation despite the fact that the ecosystem service is not functioning.
Regulating	Clean water	Whilst *E. coli*, phytoplankton and biotoxins are naturally present in the marine environment, there is potential in some parts of the CMR that nutrient enrichment and insufficiently treated waste water exceeds the capacity of plants and micro-organisms to assimilate, buffer or process contaminants. This can prevent effective waste processing and water purification services, resulting in higher than safe levels of E. coli, phytoplankton and biotoxins.

105. Food Standards Scotland, 2015c
106. Food Standards Scotland, 2015a
107. Food Standards Scotland, 2015b
108. UK National Ecosystem Assessment, 2011

4.4 Microbiological contamination – Bathing waters



Colours are explained in the key at the beginning of the document

KEY SUPPORTING EVIDENCE

SEPA bathing water profiles
http://apps.sepa.org.uk/bathingwaters/Profiles.aspx

SEPA Bathing waters report 2014/15 and 2016
http://apps.sepa.org.uk/bathingwaters/

Scotland's Marine Atlas Clyde score: 'Some concerns but improving'. Regional assessment is consistent with this.

Introduction

Bathing waters are monitored and protected to safeguard the public health of users. SEPA carries out regular monitoring of faecal indicator organisms, which can cause gastrointestinal illness and ear infections. These are: *Escherichia coli* and intestinal enterococci, cyanobacterial blooms, macroalgae and marine phytoplankton.[109] The monitoring results are published to ensure protection of public health for beach users.

Monitoring and results

Monitoring is carried out by analysing over 1,500 water samples taken throughout the bathing season (1 July – 15 September) from all 84 designated bathing waters around Scotland. Sampling results are published within a few days of being taken, online or via electronic boards at some sites. Daily water predictions are also available at some sites.[110] These sites are also important for recreational activities such as immersion water sports including: dinghy sailing, kayaking and windsurfing. To guide efficiency in monitoring and protecting, sites which are visited by, on average, 150 or more people in a single day (during summer) are designated bathing sites under the Bathing Waters Directive,[111] though of course there will be many other waters which are not monitored which are suitable for recreation and are safe to use as well as those which will be in poor or unsafe condition.

Of the 84 bathing water sites designated in Scotland, 14 are in the Clyde Marine Region (CMR). They are listed in table 4.5.[112] From 2005-2014 monitored bathing waters were classified against European Standards to give an overall rating of (from highest to lowest) 'guideline' pass, 'mandatory' pass or 'fail'.

In 2016 the revised 2006 Bathing Water Directive came into operation and a new assessment system based on updated science was implemented for the 2015 results. In this new system, bathing waters fall under one of four classification types, based on a dataset gathered over four years giving an indication of 'normal' water quality condition in each location. Bathing waters are classified as protected areas under Annex IV of the WFD and continue to be protected under the Bathing Waters Directive. Currently 80% of Scottish bathing waters meet sufficient or better classification and in the CMR 79% of bathing waters also meet this standard. SEPA aims to bring all waters up to at least sufficient by 2020, as any bathing water which has five successive poor classifications will have permanent advice against bathing to be displayed.[113] Water quality of each of the CMR bathing waters is shown in table 4.5.

The new classification is driven by developments in understanding health risks posed by microbial contaminants and is considerably more stringent, resulting in some water bodies falling in classification. The new classification gives a more consistent picture, as it will take into consideration short term deterioration, how often this occurs and how severe this is. There is quite a high risk associated with failure under the new assessment system; this is not only for local communities who might lose the amenity and security of safe bathing waters, but also the associated impact on tourism and recreational activities and financial penalties which can imposed if bathing water standards are not met and maintained.

Diffuse pollution, surface runoff from rain and sewage from combined sewer overflows are the biggest risks to the cleanliness of coastal bathing waters.[114] The condition of bathing waters is affected by the quality of nearby water bodies and their catchments which drain into the bathing waters. Quality of bathing waters depends on how land and pollution pathways are managed. SEPA notes that integrating land and water pollution control is essential for effective protection and improvement of bathing waters. SEPA work in partnership with Scottish Water, the agricultural community, local authorities, Keep Scotland Beautiful and the Marine Conservation Society to deliver integrated land and water pollution control, with the aim of achieving high quality bathing waters.[115]

109. Scottish Environment Protection Agency, 2016b
110. Scottish Environment Protection Agency, 2016e
111. The Scottish Government, 2012b
112. Scottish Environment Protection Agency, c
113. Scottish Environment Protection Agency, 2016b
114. Scotland's Environment, 2014
115. Scottish Environment Protection Agency, 2016b

Table 4.5 Protected bathing designated areas in the Clyde Marine Region and their historic and current classification[116]

2005–2014 classification: White – site not designated as a bathing site in the year show, blue – guideline pass, green – mandatory pass and red – fail.
2015 classification: blue – excellent, purple – good, green – sufficient and red – poor

BATHING WATER COMPLIANCE RESULTS											
BEACH	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Ayr (South Beach)											
Culzean											
Ettrick Bay											
Girvan											
Heads of Ayr											
Irvine											
Largs (Pencil beach)											
Lunderston bay											
Maidens											
Millport bay											
Prestwick											
Saltcoats and Ardrossan											
Seamill											
Troon (South beach)											

SEPA, in partnership with other organisations uses a number of different methods to determine the source of pollutants entering bathing waters. This includes tools such as:

- Microbial source tracking analysis where analysing microbial DNA allows identification of the generic origin of pollution to determine if human, ruminant or other derived faecal indicator organisms are either present or present at a significant level.
- Scottish Water Quality and standards programme whereby Scottish Water identifies capital investment to be made in water and drainage infrastructure. The main bathing water focus in recent periods has been an investment programme to identify and reduce the effects of unsatisfactory intermittent discharges in Ayrshire and 41 other bathing water studies. Scottish Water estimates it will spend £35m during 2015-2021 on further water pollution improvement to the benefit of Scotland's currently impacted bathing waters.
- Working directly with rural land managers in the 14 priority catchment areas across Scotland to increase understanding of diffuse pollution sources in rural areas. This resulted in over 80% of non-compliant land managers changing their behaviour and becoming compliant with environmental regulations. Priority catchment areas in the CMR include: River Ayr, River Doon, River Irvine, River Garnock and the North Ayrshire Coast.[117] The lowest classified bathing waters in the CMR: Girvan, Heads of Aye, Prestwick are all drained into by at least one of these catchments.

Clyde Marine Region bathing waters classification

The failure to meet standards at Heads of Ayr in 2014 may be as a result of wet weather in this period which increased run-off from agricultural land and surface water urban drainage. The catchment draining into Heads of Ayr bathing water is 90% agricultural land used for dairy farming. Average summer rainfall for the region is 392mm compared to 331mm across Scotland. There is also a sewage effluent discharge south of the bathing area, which may affect results.[118] In 2015, the classification was as a result of diffuse pollution from rural sources and

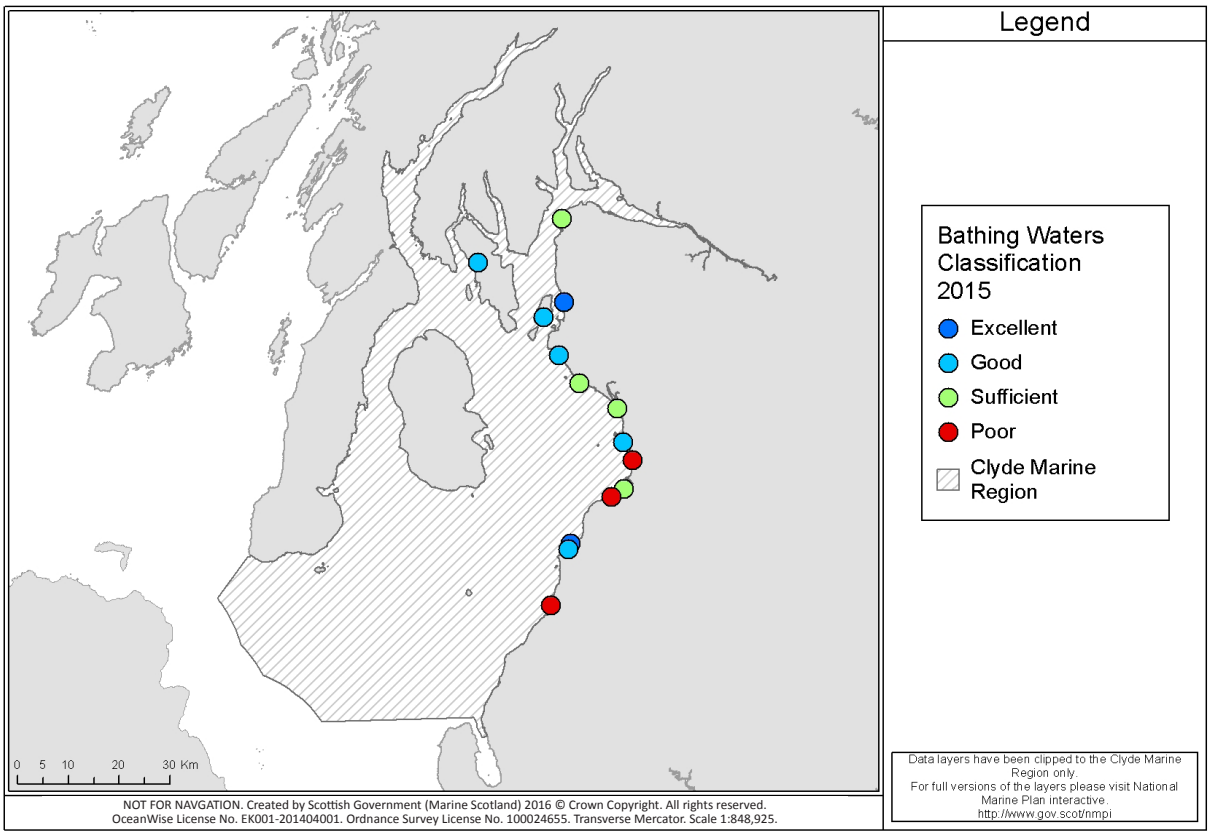
116. Scotland's Environment
117. Scottish Environment Protection Agency, 2016b
118. Scottish Environment Protection Agency, 2016a

point source discharges from waste water disposal. These issues will be addressed by priority catchment action[119] and partnership work between SEPA and Scottish Water from 2015-2021.[120]

Whilst Ettrick Bay is similarly surrounded by agricultural land and experiences higher than average rainfall, the bathing waters here experienced an improvement from guideline to mandatory from 2013 to 2014 and increased to 'good' under the new classification in 2015. This may be due to the fact that the population in the catchment is very low and that there are no sewage treatment works or sewerage overflows in the vicinity. Ongoing efforts by SEPA to reduce diffuse pollution and substantial investment in sewerage systems are also contributing to this improvement.[121]

In 2015 Prestwick has been classified as 'poor' as a result of diffuse pollution from rural sources; this will be addressed through priority catchment action. Additionally, the site is subject to point source pollution (work on this is underway, continuing to 2021) as a result of waste water disposal. This will be addressed through partnership work between SEPA and Scottish Water from 2015-2021. Also in 2015, Girvan's classification has been attributed to diffuse source pollution from rural sources. SEPA will address this through priority catchment action from 2015-2021.[122]

Map 12. 2015 classification of bathing waters in the Clyde Marine Region



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119. Diffuse pollution priority catchments have been identified by SEPA as catchments failing to meet environmental standards. Fourteen priority catchments, containing some of Scotland's most important waters (for conservation, drinking water, bathing and fishing), have been selected using a risk based approach for action in the first basin planning cycle. Work will also include the mitigation of other water environment impacts, such as morphological change, abstractions, flooding and alien species, where these are also causing waterbody downgrades. The first RBMP identified the River Ayr, River Irvine, River Garnock and North Ayrshire Coast as catchments in or near the CMR for priority action.
120. Scottish Environment Protection Agency, i
121. Scottish Environment Protection Agency, 2015a
122. Scottish Environment Protection Agency, i



Windsurfing © PETER SANDGROUND

ECOSYSTEM SERVICES		
SERVICE TYPE	**BENEFITS PROVIDED**	**COMMENTARY**
Regulating	Waste processing and water purification	Diffuse pollution and combined sewer overflows at certain points in Ayrshire exceed the capacity of plants and micro-organisms to assimilate, buffer or process faecal contaminants, thereby preventing effective regulating services and leading to poor bathing water quality. Increasing sea temperatures will exacerbate this issue (see Chapter 3.1 Climate change – impacts on marine life and processes).
Cultural	Sense of place and cultural heritage	Maintaining clean and safe bathing waters contributes to people's sense of place and interaction with the marine environment and maintains the cultural heritage of seaside bathing sites.
	Health benefits	Having clean and safe bathing waters enables people to utilise the marine environment for exercise and sport.
	Recreation and tourism	The general improvement in the condition of bathing waters in the CMR over the last five years can support increased sport, tourism and recreation.
Supporting services underpin the provision of other services		Elevated levels of *E.Coli* in the marine environment can impact on effective storage, cycling and maintenance of nutrients essential for marine living organisms and for the support of all other marine ecosystem services.

4.5 Eutrophication



Monitor Loch Long and Loch Goil for continued Good status

Colours are explained in the key at the beginning of the document

KEY SUPPORTING EVIDENCE

SEPA bathing water profiles
apps.sepa.org.uk/bathingwaters/Profiles.aspx

SEPA Bathing waters report 2014/15 and 2016
apps.sepa.org.uk/bathingwaters/

Scotland's Marine Atlas Clyde score: 'Some concerns but improving'. Regional assessment is consistent with this.

Introduction

Nutrients in the correct amount are essential for supporting primary production in aquatic environments. Eutrophication is the addition of extra nutrients (nitrogen and phosphorus) to water bodies which results in the hypernutrification of the environment. Too much nitrogen and phosphorus can lead to excessive plant growth and plankton blooms. This can in turn cause oxygen depletion and have a damaging effect on marine organisms as well as making water unsafe for recreational or aquaculture purposes.[123]

Excess Nutrients

Excess nutrients enter the water system through agricultural run-off and diffuse pollution via river catchments and point source pollution from sewage treatment works and industrial discharges. Aquaculture activities can cause eutrophication when waste produced by farmed fish and any waste feed released fall to the seabed. However, all these activities are licensed and controlled by SEPA through the Controlled Activities Regulations (CAR), which minimises excess nutrients entering the system.

Treatment requirements for waste water are based on population size within the plant catchment and the state of the water receiving discharges (this topic is discussed in Chapter 6.10 Waste water treatment and industrial outfalls). In addition, SEPA works with the agricultural sector to prevent the amount of nitrates polluting water systems through promoting good farming practises. The Nitrates Directive (1991) is now a key part of the Water Framework Directive (WFD), and is focussed on reducing agricultural pressures including diffuse pollution on water quality. As well as establishing codes of good agricultural practise, the Nitrates Directive requires member states to report on eutrophication, nitrate concentrations and estimations of future trends in water quality.[124] Although there are no Nitrate Vulnerable Zones in the CMR, suggesting that agriculture is not a major emitter of nitrate, it may still contribute to eutrophication of aquatic environments in some areas.



Agriculture in the Clyde © LORNE GILL, SNH

123. Baxter et al., 2011
124. European Commission, 2016c

Monitoring and assessment of water bodies

SEPA collects data for the assessment of water bodies under the WFD. This process is fully explained in Chapter 4.1 Water Framework Directive and classification of water bodies. These data are also used for OSPAR monitoring for eutrophication, as discussed in Scotland's Marine Atlas.[125] The relevant biological and chemical parameters which give an indication as to whether or not a water body is at risk of eutrophication are: dissolved oxygen, dissolved inorganic nitrogen, macroalgae and phytoplankton.

Phytoplankton blooms have been known to cause loss of stock in fish farms at Loch Striven and Loch Fyne. Both these lochs have little freshwater input, a low rate of tidal exchange and undergo periods of deepwater stagnation.[126] A study published in 2001, indicated that historically phytoplankton chlorophyll in Loch Striven regularly exceeded 10mgm^{-3} during summer and this qualified it as eutrophic.[127] However, WFD classification from 2008-2015 now assesses this water body to be in Good condition.

Three *Moderate* water bodies (Loch Long North, Loch Long South and Loch Goil) which were subject to unknown pressures affecting phytoplankton in 2013 and 2014 have subsequently improved to *Good* status in the 2015 classification results. Water body classifications can be examined in more detail using SEPA's interactive tool 'Water Environment Hub' www.sepa.org.uk/data-visualisation/water-environment-hub/. The data on this site are also updated as water body assessments are carried out and more information becomes available and will reflect any changes in condition or when pressures and sources of pollution become known for Loch Long North, Loch Long South and Loch Goil.

ECOSYSTEM SERVICES[128]		
SERVICE TYPE	**BENEFITS PROVIDED**	**COMMENTARY**
Provisioning	Food	Eutrophication can deplete the system of oxygen by facilitating excess plant growth. This can have a negative impact on other biodiversity, for example, resulting in a reduction in fish species. Harmful algal blooms can make shellfish unfit for human consumption although this has not been a major issue in the CMR.
Regulating	Clean and safe water	Overwhelming the marine environment with excess nutrients results in pollution and reduces the ecosystem's capacity to degrade and process nutrients in the water.
Cultural	Health benefits and recreation and tourism	Algal blooms, resulting from eutrophication can be harmful to humans and restrict recreational and cultural activities and enjoyment of the marine environment. They have not been an issue in the CMR in recent years; however warmer sea temperatures may lead to an increase in the tendency for stratification of the water column and could influence the developments of harmful algal blooms (see Chapter 3.1 Climate change – Impacts on marine life and processes).
Supporting services underpin the provision of other services		Effective storage, cycling and maintenance of nutrients are essential for marine living organisms and support all other marine ecosystem services. Nutrient cycling encourages productivity and makes nutrients available to all other levels of food chains and webs. Draining through soil on land can dilute pollutants to safe levels by processing or assimilating them. If the ability of this system is compromised, pollutants can be transferred from the land via river catchments to the sea. This can impact the ability of the system to carry out nutrient cycling. There were concerns over the condition of phytoplankton in Loch Long and Loch Goil in the 2013 & 2014 WFD classification results, but these improved in 2015 (see Chapter 4.1 Water Framework Directive – Classification of transitional and coastal waters).

125. Baxter *et al.*, 2011
126. Tett *et al.*, 1986
127. Tett *et al.*, 2001
128. UK National Ecosystem Assessment, 2011

4.6 Oil and chemical spills and accidents



Colours are explained in the key at the beginning of the document

KEY SUPPORTING EVIDENCE

ACOPS annual survey reports www.acops.org.uk/acops-reports/

Scotland's Marine Atlas Clyde score: : 'Few concerns and no discernible trend'. Regional assessment includes a detailed look at oil spills which shows an improving trend.

Introduction

It is important to monitor oil and chemical spills as these may result in contamination of the Clyde Marine Region (CMR) with resulting harm to birds or other marine animals. Marine accidents are also monitored to help improve safety at sea.

Oil and chemical spills

The Maritime and Coastguard Agency (MCA) has statutory responsibility for taking action when oil or hazardous and noxious substances emanating from any at-sea activity threatens the United Kingdom or its surrounding waters. As part of its commitment to provide cleaner seas around the United Kingdom, the MCA publishes, via the Advisory Committee on Protection of the Sea (ACOPS), an annual survey of reported discharges and releases attributed to vessels and offshore oil and gas installations operating in the United Kingdom Pollution Control Zone (UKPCZ). Survey results, in co-ordination with historical data and records, enable MCA's Counter Pollution and Response (CPR) team to monitor trends in the number of incidents, the amount of oil and chemicals spilled, the geographical distribution of spills, the sources of pollution and the nature of the pollution.[129]

Analysis of ACOPS annual surveys for incidents in the CMR reveals that the number of incidents and the total amount of litres of oil spilled can vary

Table 4.6 Coastal oil spills in the Clyde Marine Region 2002–2013

YEAR	NUMBER OF INCIDENTS	TOTAL LITRES
2013	1	0*
2012	3	30*
2011	3	102*
2010	1	0*
2009	2	980
2008	7	560*
2007	6	1539*
2006	2	159
2005	2	345
2004	5	122*
2003	8	821.5
2002	4	315*

*figure includes at least 1 incident where the quantity involved was not known.



Container shipping © PETER SANDGROUND

129. Dixon, 2014

substantially from one year to another (see table 4.6). Overall, however, there has been a decreasing trend for both of these indicators since 2010. There have been no chemical spills reported in the area since 2002; these are usually associated with offshore oil and gas installations and vessels which are not present in the CMR.

All of the above incidents involved crude, fuel, lubrication or hydraulic oil. Many oil spills are minor and can be dispersed by natural means; up to 50% may evaporate, a small amount may dissolve, microbes can degrade the oil and some can attach to particles and fall to the sea floor. The rate at which this occurs depends on the oil type and the sea state. In some cases a water-in-oil emulsion may form what is known as 'chocolate mousse'. In inshore waters, depending on the size and type of spill, there are a number of options should the oil need to be removed; the movement of oil can be restricted through the use of booms and barriers, the oil can then be recovered through the use of skimmers, oil mops or vacuum pumps, or a dispersant can be used if conditions are appropriate. If the oil has reached the shore, then a shoreline clean-up operation will be needed to reduce the pollution to a tolerable level and to restore the coastline with the least impact on the environment.[130] For more information on response to marine pollution incidents, see www.gov.uk/guidance/how-we-respond-to-marine-pollution-incidents. Consult National Marine Plan interactive to view shoreline types around the CMR as contained within the Oil Spill Contingency Planning.

It should be noted that oil can also enter the marine environment through terrestrial drainage systems. It is a requirement for new developments with surface water drainage discharging to the water environment that such discharges will pass through sustainable urban drainage systems (SUDS).[131] Regulatory controls on the storage of oil also exist.[132]

Accidents

The Maritime Coastguard Agency is responsible for responding to maritime emergencies. For further information on the Search and Rescue framework for the UK and Northern Ireland, see www.gov.uk/government/publications/search-and-rescue-framework-uksar. There is a potential for up to five strategic decision-making cells to be established for specific aspects of an incident. The Maritime & Coastguard Agency (MCA) leads the at sea response from a Maritime Rescue Co-ordination Centre (MRCC), Salvage Control Unit (SCU), and Marine Response Centre. The Secretary of State's

Table 4.7 MAIB investigated accidents in the Clyde Marine Region since 2000

OCCURRED	DESCCRIPTION	LOCATION	VESSEL TYPE
26 Nov 2011	Series of accidents including windlass damage, grounding and 1 person injured on RO-RO cargo ferry *Norcape*	Operating in and around Troon Harbour	Merchant >100 tonnes
5 Dec 2010	Fire in engine room on tug SD Dexterous	0.5nm north of Rhu Narrows, Gareloch	Merchant >100 tonnes
27 Jan 2010	Collision between general cargo vessel *Leeswig* and trawler *Spes Bona V*	3.5' north-east of Pladda lighthouse	Merchant > 100 tonnes
3 Nov 2009	Contact made by bulk carrier *Mornes* with concrete dolphin	Hunterston Jetty	Merchant >100 tonnes
2 Nov 2009	Capsize and sinking of twin-rig prawn trawler *Jubilee Star*	Near Cowal buoy off Dunoon	Fishing
23 May 2008	Grounding of prawn trawler *Bountiful*	Scart Rock off Lady Isle near Troon	Fishing
19 Dec 2007	Girting (when the line of a tug becomes taught and the tug is pulled over and capsized) of the tug Flying *Phantom* while towing bulk carrier Red *Jasmine* with 1 person injured and loss of 3 lives	River Clyde	Merchant >100 tonnes
1 Sep 2004	Grounding of general cargo vessel *Jackie Moon*	Off Dunoon Breakwater	Merchant >100 tonnes
27 Dec 2000	Collision between feeder container vessel Nordsee and passenger vessel *Poole Scene*	River Clyde	Merchant >100 tonnes

Source: Marine Accident Investigation Branch

130. Department of Transport, Marine Pollution Control Unit, 1994
131. Scottish Environment Protections Agency, k
132. Scottish Environment Protections Agency, l

Representative has overall responsibility for salvage and will determine if a SCU is required. Where there are significant onshore consequences, a Strategic Co-ordinating Group and/or a Shoreline Response Centre may be required, with the lead being provided by the police or the local authority. For further details see www.gov.uk/government/publications/emergency-response-and-recovery. The Port Marine Safety Code applies to all harbour authorities in the UK that have statutory powers and duties. It is also strongly recommended that facilities outside of harbour areas such as berths, terminals and marinas should seek to have safety management systems in place which comply with the Code. See www.gov.uk/government/publications/port-marine-safety-code.

There are no Emergency Towing Vehicles funded by central Government for the CMR. Ships in need of assistance meet the full cost of towage through the commercial market, but must notify the relevant port authority.

The Marine Accidents Investigation Branch (MAIB)[133] investigates marine accidents involving UK vessels worldwide and all vessels in UK territorial waters in order to prevent further avoidable accidents from occurring and reports directly to the Secretary of State for Transport.

The following table shows the accidents in the CMR that have been investigated by the MAIB since the year 2000. For further information about action taken and recommendations, visit MAIB reports.[134]

ECOSYSTEM SERVICES		
SERVICE TYPE	**BENEFITS PROVIDED**	**COMMENTARY**
General comment – whilst minor oil spills can be dispersed by natural means, a major incident could have severe implications for services provided by those habitats and species that are affected.		
Cultural	Recreation and tourism	Clean and safe seas are essential for marine sport, recreation and tourism activities.

133. Marine Accident Investigation Branch, a
134. Marine Accident Investigation Branch, b

4.7 Dissolved oxygen

Inner Clyde Estuary



Rest of CMR



Colours are explained in the key at the beginning of the document

KEY SUPPORTING EVIDENCE

SEPA monitoring
River Clyde oxygenation project www.georgeleslie.co.uk/what-we-do/case-study/river-clyde-oxygenation-project/
Scotland's Marine Atlas Clyde score: no score included

Introduction

Oxygen is supplied to the water of an estuary by rivers, through the surface of the water and by plant photosynthesis. The many organisms living within the estuary will, however, rapidly consume the oxygen. Where there is excessive organic enrichment, for example through input of untreated sewage, the sediments can become anoxic and microorganisms which degrade the sewage can consume all the oxygen within the water body itself.[135]

The situation in the Clyde Marine Region

In addition to organic enrichment, the narrowing and deepening of the River Clyde from Erskine upstream has resulted in the past in significant stratification, limited natural mixing between layers, and pockets of very low Dissolved Oxygen occurring at depth.[136] Studies indicate that an upper limit of 7mg/l of oxygen will support most ecological processes whilst a level below 2mg/l will stress the majority of fish species.[137]

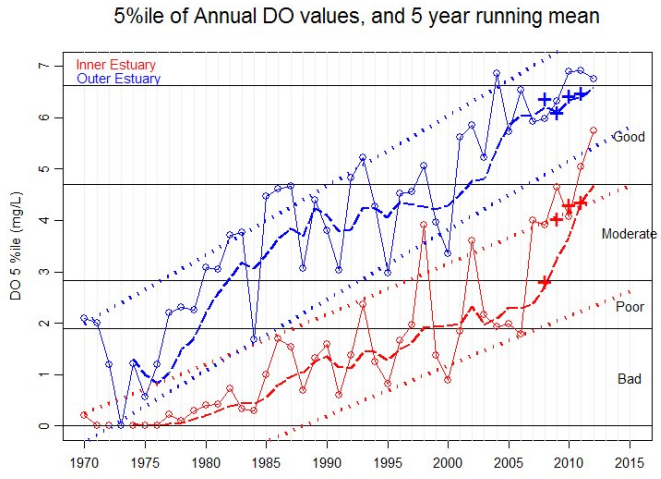
Dissolved Oxygen levels have been routinely monitored in the Clyde Estuary since the 1970s. Results indicate that the Inner Clyde Estuary was completely devoid of oxygen when monitoring began and this had resulted in the lack of any migratory fish such as salmon and sea trout using the estuary. Since that time, there have been steady improvements, such that the Outer Clyde Estuary is currently at 'Good' status in terms of Dissolved Oxygen. Migratory fish returned to the River Clyde during the 1980s

Oxygenation option

Under the Water Framework Directive, the Clyde Estuary is required to reach the status of 'Good Ecological Potential' by 2027. In 2011 oxygenation tests were carried out on the Inner Clyde Estuary. Two oxygenation units were suspended from an unpowered barge moored off the river bank at the Shieldhall waste water treatment works. The units drew water in, oxygenated it and discharged it back into the river. This test allowed Scottish Water and other project partners (SEPA, Glasgow City Council and Peel Ports Clydeport) to assess the feasibility and costs of oxygenation as part of a wider body of work looking to improve water quality, reduce flood risk, and support economic development objectives for the area.

In 2013 Scottish Water finalised their Glasgow Strategic Study Wastewater Strategy which concluded that whilst discharges from Shieldhall

Figure 4.3 Annual Dissolved Oxygen values with 5 year running average



This SEPA graph shows:
a. 5%ile DO concentrations in individual years (circles connected by solid lines);
b. 5 year running average of these values (dashed lines)
c. prediction intervals (dotted lines);
d. values used for WFD classification (+ signs).

SOURCE: SEPA

135. McLusky and Elliott, 2004
136. Scottish Environment Protection Agency, 2013a
137. Ross *et al.*, 2009



The River Clyde in Glasgow © PETER SANDGROUND

and Dalmuir Waste water Treatment Works and intermittent discharges from the sewer network contribute to the problem, removal of these discharges will not, in themselves, achieve Good Ecological Potential as required under the Water Framework Directive by 2027. Target Dissolved Oxygen levels will only be achieved at this time through oxygenation. A Disproportionate Cost Assessment undertaken by SEPA under the Water Framework Directive has confirmed that whilst oxygenation is the most cost-effective solution, there is uncertainty about both the Dissolved Oxygen trend and the ecological impacts. This leads SEPA to conclude that it would be disproportionate to implement oxygenation at this stage; however, this will be reviewed in the future. In the meantime, Scottish Water are evaluating the option of making operational changes to the Shieldhall Waste water Treatment works so that the final effluent discharges into the upper layer of the estuary. This takes advantage of the seaward velocities that exist in both the ebb and flood tides.

Metropolitan Glasgow Strategic Drainage Partnership (MGSDP)

The MGSDP is a partnership formed by organisations involved with the operation of the sewerage and drainage network within the area -Scottish Water, Glasgow City Council, Scottish Canals, South Lanarkshire Council, Clyde Gateway, Scottish Enterprise, Renfrewshire Council, East Dunbartonshire Council and the Scottish Environment Protection Agency (SEPA).

The Partnership's objectives are:

1. Flood risk reduction
2. River water quality improvement
3. Enabling economic development
4. Habitat improvement.
5. Integrated investment planning

Various projects are being undertaken to deliver the above objectives. Details of these are available on the MGSDP website at www.mgsdp.org/.

ECOSYSTEM SERVICES		
SERVICE TYPE	**BENEFITS PROVIDED**	**COMMENTARY**
Supporting services underpin the provision of other services		An adequate level of dissolved oxygen within marine waters is essential to support marine life. Levels of dissolved oxygen in the Clyde estuary are now returning to levels which will support most ecological processes.

4.8 Marine litter



Colours are explained in the key at the beginning of the document

KEY SUPPORTING EVIDENCE

MCS beach clean data
Marine Litter Strategy for Scotland
www.gov.scot/Publications/2014/09/4891

Scotland's Marine Atlas Clyde score:
beach litter – some concerns and no discernible trend. Regional assessment is for marine litter including a worsening situation in particular for microplastics and a general perceived deterioration in marine litter from groups around the Clyde.

Introduction

Marine litter is found in all seas and ocean regions of the world and represents the effects of the wider problem of inefficient waste management and people's attitudes and behaviours towards litter. Marine litter is defined as: '*any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment*'.[138] Marine Litter is a trans-boundary issue which affects a range of sectors across different scales, with no clear solution to resolve it and which requires policy reform across a range of areas and investment in long-term social change.[139]

Sources and types of marine litter

About 80% of marine litter in Scotland is identified as coming from land based sources.[140] This includes sewage related debris (SRD) such as cotton buds, nappies, wet wipes and sanitary products. Activities carried out at sea contribute the remaining 20% of marine litter. In UK waters around 70% of marine litter is plastic[141] which will persist in the environment for thousands of years. Additionally, all plastics progressively fragment into microplastics (any plastic which is <5mm) through mechanical action and photo-degradation. Microplastics are also used as industrial 'scrubbers' and in personal hygiene products, so they also enter the environment ready formed. The UK Government plans to introduce legislation to ban the use of microplastics in cosmetic products from the end of 2018.

Shallow coastal areas of depths less than 40m have a much greater abundance of marine litter

Figure 4.4 Marine Litter in Kintyre following a storm event



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138. United Nations Environment Programme, 2005
139. Hastings and Potts, 2013
140. McIntyre *et al.*, 2012
141. HM government, 2012

than deeper waters. Greater abundances have been found in bays, which are more sheltered. This is reflected in the Clyde Marine Region (CMR) where, due to the prevailing south westerly winds, litter congregation areas or 'sinks' are found in sheltered areas at the top of the Clyde sea lochs and also northern shores, especially at Helensburgh.[142]

Impact of marine litter on species, ecosystems and society

The negative impacts of marine litter are well documented and wide ranging. Marine wildlife can ingest or become entangled in marine litter, causing death or false satiation effects, leading to increased mortality. The OSPAR Ecological Quality Objectives project has found that in Scotland 91% of dead northern fulmars (*Fulmarus glacialis*) surveyed have plastics in their stomach.[143] In the CMR, there is evidence of *Nephrops* (*Nephrops norvegicus*) ingesting microplastics.[144]

SRD and other marine litter accumulating on beaches and any accessible coastline present a public health issue, as well as a deterrent to recreation and tourism on Scottish beaches. MCS beach cleans carried out in the CMR from 2010-2015, were carried out over a total of 2,695.98 volunteer hours. If calculated at an approximate council worker hourly rate,[145] the labour costs for voluntary beach cleans would total between £22,969.75- £26,258.85 (based on a 35 or 40 hour week), not including other expenses such as transport or equipment. This figure and the number of volunteer hours given above does not take into account other beach cleans organised outwith the MCS.

Marine litter presents a threat to the fishing industry, as gear can snag on large objects on the seabed, damaging gear and increasing the risk of capsizing. Objects caught in nets cost time to remove, resulting in fishing time lost and potentially damaged gear. The estimated cost to the Scottish fishing fleet is approximately £11.5m each year in damages to vessels, equating to approximately £10,000 per vessel and 41 hours of lost fishing time, a significant portion of their time allocated at sea.[146] Floating marine litter presents a significant hazard to recreational craft, both through collision and through entanglement of ropes and other floating debris in propellers.

The accumulation of seaweed and other organic debris at the high water mark is known as the strandline. The strandline is a habitat for invertebrates and is an important part of the coastal ecosystem. Marine litter often becomes entangled in the strandline, to the degree that manual litter picking presents an onerous task. This can lead to the use of tractors and mechanical methods of seaweed removal, resulting in the loss or degrading of this important feature on the shore.[147, 148]

Microplastics in the marine environment

Research from the University of Plymouth was the first to identify the widespread occurrence of microplastics in the marine environment which have been accumulating since the 1960s.[149] This research has shown that microplastics are present on the shore and in the water column throughout the North East Atlantic. Moreover, microplastics have been shown to have persistent organic pollutants (POPs) concentrations of up to a million times the ambient level of sea water.[150]

A positive correlation between the presence of toxins in the fat tissue of great shearwaters (*Puffinus gravis*) and the ingestion of plastic suggest that consuming plastic facilitates the assimilation of toxins and POPs in marine organisms (see Chapter 4.2 on Hazardous substances for more information on this).[151] The United Nations Environment Programme (UNEP) recommends a precautionary approach to microplastic use and an eventual ban on their production and use.[152] Marine litter can also be used as a vector for the transport of invasive and non-native species, most commonly by bryozoans, barnacles and polychaete worms.[153]

A study of microplastics in the West Coast of Scotland showed filaments were the most commonly recovered plastics, followed by fragments, recovered from 34.4% of samples. Analysis of the samples showed variation is not due to a single contamination source or re-dispersal event and the amount of plastics in the sediment was not significantly related to the amount of plastics in the water column.[154] Additionally, the study examined a sample of the CMR *Nephrops* population for the presence of plastics. In the CMR, 84.1% of *Nephrops* sampled were found to have plastic in their gut. Larger individuals have a larger gastric mill and larger gaps between teeth, making them more capable of digesting plastics. As the gut lining is shed during moulting, individuals which are newly moulted have a lower weight of plastic in their gut,

142. Ross *et al*., 2009
143. OSPAR Commission, 2009b
144. Murray and Cowie, 2011
145. This figure is estimated based on the Annual Survey of Hours and Earnings: 2015 Provisional Results median full-time gross weekly earnings by elementary occupations from the Office for National Statistics.
146. Fishing for Litter, 2004
147. Mills, 2012a
148. Dyson, 2011
149. University of Plymouth
150. European Commission, 2016d
151. Galgani, 2010
152. United National environment Programme, 2015
153. Potts and Hastings, 2011
154. Welden, 2015

suggesting that langoustines are capable of reducing their plastic load. The large amount of microplastic fibers in the CMR indicate that *Nephrops* are at increased risk of the biological impacts of plastic ingestion; this can include false satiation which may affect body condition.[155, 156]

National and local action on reducing marine litter and marine litter data in the Clyde Marine Region

No agency in Scotland has overall responsibility for coordinating efforts to reduce marine litter. Just as a range of regional and national policies create a framework to advise and guide activity on the reduction of marine litter, a network of local, regional and national statutory bodies, charities, NGOs and organisations have a role in litter reduction activities. Some of these bodies deal with litter where it enters water sources or when it ends up on coastal habitats. This includes Scottish Water, which has responsibility for maintaining sewerage systems. To support the implementation of the Marine Litter Strategy for Scotland, Marine Scotland has formed the Marine Litter Strategy Steering Group. There is a general perceived deterioration in marine litter, especially amongst communities directly affected by it, with growing concern over increasing microplastics.

SRD ends up in the marine and coastal environment when combined sewers overflow during heavy rain or flooding events, resulting in SRD being washed out to sea. Scottish Water undertakes education initiatives, such as the 'Bag it don't bin it' campaign. The Scottish Environmental Protection Agency (SEPA) has a role in regulating and maintaining rivers and waterways.

Duty bodies have responsibility for keeping public beaches clean. Data collated in 2011 in the Firth of Clyde Forum's *'Marine Litter Strategy for the Firth of Clyde Step 1: Defining the Status Quo'* report found that in terms of Local Authority activity, the frequency of beach cleans amongst the seven Local Authorities with a coastline in the CMR region varies between each authority and it is thought that effort in beach cleaning is higher during the summer season and is dependent on the economic importance of the beach to the area.[157]

Much work on cleaning up marine litter is carried out by volunteers, community groups and charities. In the CMR there are:

- the Group for Recycling in Argyll and Bute (GRAB) Trust runs the Beaches & Marine Litter Project across the Argyll and Bute area (excluding Helensburgh and Lomond) and manages the Argyll and Bute Beach Forum.
- The Helensburgh East Esplanade Protection Group (longest running beach clean in the UK, operating since 1995).
- Arran Coastal Way.
- Community of Arran Seabed Trust (COAST).
- Field Studies Council, Millport, Isle of Cumbrae.
- Beachwatch Bute, removes 10 tonnes of litter from the island's beaches every year.[158]
- Loch Lomond and The Trossachs National Park at Arrochar and Lochgoilhead.
- Girvan, Alloway, Ayr, Prestwick and Troon Rotary Clubs.
- Clyde Muirshiel Regional Park rangers at Lunderston Bay.
- The MCS operates a national citizen science programme of beach cleans called 'Beachwatch'.[159, 160]
- The Great Nurdle Hunt – Clyde Nurdle Quest.

Whilst not all beach cleans in the CMR collect data for inclusion in the MCS figures, between 2010- 2015 a total of 90 MCS beach cleans were carried out over a total 2,695.98 hours.[161] The most time was spent and most litter collected was in Argyll and Bute. No beach cleaning through the MCS programme was carried out in West Dunbartonshire and so no data are available for any beach cleans that may have been carried out in this Local Authority. Table 7 provides a yearly breakdown of beach cleaning data by effort according to Local Authority areas.

The data from MCS beach cleans, 2010-2015 (figure 4.6), shows that overall plastic is the most prevalent type of litter collected throughout all Local Authorities (does not include the Local Authorities own beach cleaning activities). Following this, were levels of sanitary waste, in Argyll and Bute and Inverclyde and polystyrene in Renfrewshire and South Ayrshire. The data for North Ayrshire showed equal proportions of polystyrene and sanitary waste was collected. A high level of cotton buds were collected,

155. Welden, 2015
156. Welden and Cowie, 2016
157. Dyson, 2011
158. Bute Community Links
159. Marine conservation Society, 2014
160. MCS has been collecting data on marine litter through the citizen science program Beachwatch since 1994 and has thus amassed a large bank of data detailing both type and source of litter to be found in the UK. The protocols and methodology used are compatible with other systems on a European and worldwide basis. The data is analysed by MCS to identify the quantities, types and sources of litter affecting the UK coastline and the impacts of litter on marine life, human health and local economies, providing evidence that can be used to target specific polluters and pollutants at local, national and international levels. Beachwatch data is fed into the OSPAR project on Marine Litter. MCS also designed and hosts the current OSPAR marine litter database. Beachwatch data formed the evidence for the Government's two reports, Charting Progress 1 and Charting Progress 2 on the state of the UK seas Defra acknowledged that Beachwatch "provides the only long-term dataset" for beach litter in the UK. MCS were the lead author for the beach litter section in Charting Progress 2. MCS is a member of the EU Technical working group on Marine Litter which is devising guidelines for the monitoring of marine litter, to ensure consistency throughout the EU for the MSFD.
161. Data provided by MCS, 2015. It is not possible to calculate the number of volunteers involved, as it is likely that the same people carried out more than one beach clean per year in the MCS surveys.

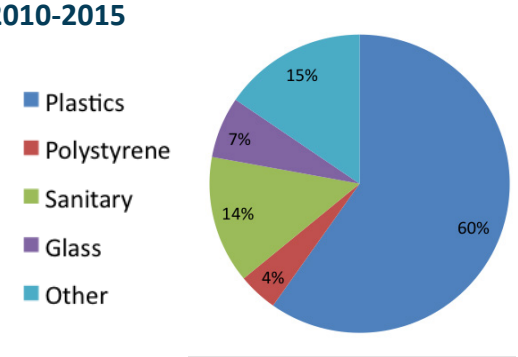
Table 4.8 Data from MCS Clyde beach clean 2010-2015 showing beach clean effort according to local authority area[162]

		LOCAL AUTHORITY				
		Argyll and Bute	North Ayrshire	South Ayrshire	Inverclyde	Renfrewshire
Total number of beach cleans 2010-2015		51	7	13	15	4
Average beach litter density per metre of beach (total no. of items/total length of beach cleaned)		2.52	3.05	1.79	7.75	2.30
Total weight collected (kg)		2042.15	250.25	456.5	393.6	58
Total no. of volunteer hours		1587.24	47.92	303	732.42	25.4
2010	No. of beaches cleaned	13	4	3	1	1
	Ave. beach litter density	1.76	2.91	1.57	7.28	4.58
	Total weight collected	414	208.25	171	25	No data
	Total no. volunteer hours	288.3	21.25	90	26	18
2011	No. of beaches cleaned	6	1	4	2	No data
	Ave. beach litter density	1.6	0.35	5.92	8.05	
	Total weight collected	200.5	2	99	58.5	
	Total no. volunteer hours	229.25	4	115.5	52.75	
2012	No. of beaches cleaned	10	1	2	5	No data
	Ave. beach litter density	1.35	0.94	10.63	10.08	
	Total weight collected	195	20	131	109.5	
	Total no. volunteer hours	219.3	6.67	50.5	499.17	
2013	No. of beaches cleaned	5	No data	2	3	No data
	Ave. beach litter density	3.14		0.25	6.87	
	Total weight collected	87.3		55.5	39.4	
	Total no. volunteer hours	221.5		29.5	25.5	
2014	No. of beaches cleaned	8	No data	1	4	1
	Ave. beach litter density	7.58		0.14	6.52	0.38
	Total weight collected	9.35		No data	161.2	22.4
	Total no. volunteer hours	416.42		17.5	129	6
2015	No. of beaches cleaned	9	1	No data	No data	2
	Ave. beach litter density	3.24	0.18			1.31
	Total weight collected	1136	20			3
	Total no. volunteer hours	212.47	16			34

which overall account for 77% of all sanitary items collected. It is also interesting to note that high proportions of cotton buds and other sanitary items were collected repeatedly in Lunderston bay in Inverclyde and Helensburgh in Argyll and Bute, supporting information that these areas are known litter sinks.

The results above are largely typical for each Local Authority; however, Renfrewshire recorded the highest amount polystyrene collected in the CMR, recording 18%, North Ayrshire had the highest percentage of plastics, recording 67%, and Inverclyde reported that sanitary products made up 20% of all litter collected; also the highest amount

Figure 4.6 Proportions by weight of types of marine litter collected as part of MCS beach cleans in the Clyde Marine Region 2010-2015



162. Data provided by MCS, 2015

for litter of this type. As part of their requirements under the Marine Strategy Framework Directive, DEFRA has contracted the MCS to supply data four times a year on beach litter levels at 19 beaches across the UK, four of which are in Scotland. One of these beaches is Lunderston Bay due to the long and robust data set available for the beach here. The Fishing for Litter (FFL) initiative is a UK-wide project and has been in action since 2005. FFL works with fishermen and harbour staff, providing collection facilities for fishermen to dispose of any marine litter they catch while at sea. The scheme currently operates in four harbours in the CMR: Tarbert, Campbeltown, Rothesay and Troon, and there is potential for the project to expand into other harbours within the CMR. The scheme has recently begun in Troon. Tarbert has five vessels registered, Campbeltown also has five and Rothesay currently has two registered vessels. From 2008-2011, four tonnes were collected at Rothesay and from 2008-2014 approximately 60 tonnes of litter have been collected from Tarbert. This equates to one 11yd^3 skip filled every six weeks, or enough to fill 2.5 local swimming pools.[163]

Glasgow City Council operates a workboat 'water witch' called *St Mungo*, which scoops or dredges rubbish and debris out of the River Clyde. The water witch was employed as part of a major clean-up of the Clyde and it collects both naturally produced debris such as tree branches and weeds and man-made created litter, such as large items dumped in the river, including shopping trolleys and gas bottles.

It is probable that there are many more unpublicised community actions being carried out by numerous groups and individuals. The need for such groups signifies a major issue with marine litter; it often falls to people and authorities who are not responsible for its creation to deal with cleaning it up. A large part of reducing marine litter will fall to achieving long term social change in regard to people's behaviours and attitudes towards waste.

ECOSYSTEM SERVICES[164]		
SERVICE TYPE	**BENEFITS PROVIDED**	**COMMENTARY**
Provisioning	Food	Plastic ingestion by fish and shellfish could have an effect on productivity and food chain dynamics, due to impacts such as false satiation effects, loss of body condition and death. Concerns exist over the impact of microplastics on *Nephrops* in the CMR (and other areas). Research into the implications for human health is at an early stage.
Regulating	Clean and safe water	Presence of SRD on beaches and in the sea from combined overflows may indicate contamination and poor water quality. This has been an issue noted in particular around Helensburgh and the heads of the sea lochs in the past.
	Protection against coastal erosion and storm defence	Mechanical removal of the strandline to remove litter can affect resilience of the beach to physical processes and extreme weather and making them more vulnerable to erosion.
	Life cycle maintenance and biological regulation	Plastic ingestion or entrapment by marine organisms can result in changes in life cycle maintenance and population dynamics.[165]
Cultural	Aesthetic benefits of the seascape/ landscape and sense of place	Marine litter in the environment inhibits people's sense of place, cultural heritage and appreciation of aesthetic and inspirational qualities of beaches. It can detrimentally impact tourism and recreational activities. This is particularly true of litter sinks in the CMR at the heads of lochs and the north side of the Clyde estuary.
Supporting services underpin the provision of other services		Marine litter can contribute to creating anoxic conditions on seabed sediments which can affect nutrient cycling occurring in this zone. Entanglement of litter in strandline seaweed can also prevent its effective degradation and therefore nutrient cycling, whilst removal of the strandline takes important nutrient supply and habitat away from the coastal ecosystem.[166, 167] Accumulations of litter in the strandline have been reported in particular at the heads of lochs in the CMR and in many locations following a storm event.

163. 20 mx8 m with 1.35 m average depth
164. Galgani *et al*., 2010
165. Dyson, 2011
166 Mills, 2012a
167. Dyson, 2011

4.9 Noise

Very little Clyde specific data exists



Colours are explained in the key at the beginning of the document

KEY SUPPORTING EVIDENCE

Scotland's Marine Atlas Clyde score: not included.

Introduction

Underwater noise is increasingly being recognised as an important stressor to marine life. Prior to the mid-19th century Industrial Revolution, low-frequency noise in the ocean was due to spray and bubbles associated with breaking waves, sounds generated by marine life, seismic noise, and other natural sounds. The Industrial Revolution marked the beginning of the use of powered (rather than sailing) vessels to transport goods and provide services. Increases in commercial shipping since that time have caused low-frequency noise levels to increase in many oceanic locations and impulse noises assocated with acoustic deterrants or piling type activities have also increased.[168]

Current status of underwater noise in the Clyde Marine Region

It is unknown how underwater noise has changed in the Clyde since the industrial revolution, however, there is a correlation between increasing background underwater noise and the increase in the world fleet gross tonnage.[169] Also there has been a general increase in human activities in coastal areas around the Clyde (for example- harbour construction and recreational boating) but again the effect this may have on marine life is currently not well understood. In the Clyde significant underwater noise is likely to come from a variety of sources, including shipping but also development (e.g. piling and cable laying), fishing (dredge) and defence (submarine movements and other facility testing) – see table 4.9 for further analysis.

Legislation and regulation of underwater noise

UK regulations mean licensable activities must be licensed or notified and conducted under strict conditions. Marine licences are issued by a range of bodies including Marine Scotland. As part of the licensing process, details of noise-generating activities are recorded in the noise registry. Where noise-generating activities are not licensable, noise information will be collected via a voluntary reporting scheme, further information on this scheme is included later in this chapter. For example, military activity is not licensed but the Ministry of Defence (MoD) is voluntarily co-operating with the system and may submit data as operationally appropriate, during activities such as controlled explosions of historic ordnance and when using active sonar.[170]

A licence may include mitigation measures and may include: timing restrictions on noisy activities during periods when marine organisms are at their most vulnerable to disturbance (e.g. fish spawning seasons or marine mammal breeding seasons); use of noise dampening technologies to reduce source levels or the use of alternative designs.[171]

Issues related to underwater noise

Underwater noise can have significant negative effects on the marine life which inhabit the CMR. Highly susceptible species, such as porpoises and dolphins as well as other fish and even invertebrates, may be impacted by excessive noise. Although the extent of the impact is not well known, there is evidence of the detrimental effects of noise



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168. Discovery of sound in the sea, 2016
169. Tyack *et al*., 2015
170. Frequency band 10 Hz to 10 kHz, exceeding the energy source level 186 dB re 1 $\mu Pa^2 m^2 s$; or the zero to peak source level of 224 dB re 1 $\mu Pa^2 m^2$
171. Marine licensing, as introduced by part 4 of the Marine and Coastal Access Act 2009 (MCAA) and part 4 of the Marine (Scotland) Act 2010

on cetaceans (whales, dolphins and porpoises) and pinnipeds (seals). There is also some evidence available for fish but very little for invertebrates. Cetaceans are particularly sensitive to disturbance and injury due to exposure to excessive noise. Short term changes in behaviour can lead to isolation of animals through fragmentation of groups, reduced feeding and breeding success and changes to swimming, diving and communication behaviours. Longer term effects are less well understood but can include abandonment of preferred feeding and breeding areas, abandonment of calves and increased mortality and injury, including from strandings.[172, 173] This has the potential to affect the biological fitness of these animals, but how this then extrapolates to population effects is not well understood.

Many studies have shown that cetaceans, like humans, are very individual in their behaviour – thresholds for one individual may not be the same for the rest of the species and signs of disturbance can vary.[174]

Sound tends to be the primary sensory modality underwater because of the excellent transmission of sound through water. In comparison, the transmission of light is very limited. The various animal species that live underwater, like fish and marine mammals, each have their own specific hearing sensitivity and frequency range. The difference in hearing abilities will mean that the same sound source may not have the same effect over all exposed species.

What is generally accepted, is that marine life is now inhabiting a world that is increasingly more noisy than that for which it is naturally adapted to. There is increasing evidence that animals are responding to and behaviourally compensating for influences from anthropogenic sounds.

Underwater noise is categorised as 'impulsive' or 'continuous'. Impulsive noise is characterised

Table 4.9 Sources of noise in the underwater environment

Aspects which may be of particular relevance to the CMR are highlighted in **bold**

NATURAL NOISE SOURCES	ANTHROPOGENIC NOISE SOURCES
IMPULSIVE NOISE	
• Lightening • Geological noise	• **Acoustic deterrent devices** • **Coastal industry including construction (e.g. pile driving etc.)** • Explosives: mine and bomb clearance • Offshore industry Platform construction (pile driving, alternative methods) • Ship shock trial • **Acoustic transponders** • **Doppler current profiler** • **Fish-finding sonar** • **Military search sonar** • **Minesweeping equipment** • **Multibeam echo sounder** • **Normal-incidence echo sounder** • **Obstacle avoidance sonar** • **Research sonar** • **Seismic explorations Sidescan sonar** • **Sub-bottom profiler**
CONTINUOUS NOISE	
• Biota other than mammals, fish and crustaceans • Breaking gravity (surf) waves • Crustaceans • Fish • Flow noise • Gravel noise • Mammals • Precipitation other than rain • Rain • Thermal noise* • Wave-wave interactions • Wind	• **Acoustic cameras** • **Acoustic communications equipment** • **Dredging, pipe laying, cable laying** • **Fishing vessels** • Flow noise (pipelines) • **Industrial/harbour noise** • Oil & gas platforms: pumping, drilling, associated supply and maintenance) • **Platform maintenance (supply, tugs)** • **Platform operation (e.g. tidal turbines)** • **Shipping: commercial vessels, leisure craft** • Wind farm decommissioning

*Thermal noise is not sound; it contributes to the background noise of any measurement system based on the detection of pressure fluctuations.

172. Weilgart, L. S., 2007
173. Marine Scotland, 2014a
174. Scottish Marine Wildlife Watching Code, 2017

as a sound with a short rise time (e.g. impulse piling) whereas engine noise, for example, would be classified as continuous. The differences in the characteristics of the noise source may have implications for marine life in either acute or chronic exposures and the effect of either type is likely to be different depending on the exposure.

Underwater noise in the UK

There are data available over the last 70 years or so relating to the underwater noise characteristics of ambient/ background noise. There is a relatively good understanding on the major underwater noise contributors in terms of their acoustic characteristics. Most of these studies are in deep water and historically connected to the military's use of sonar for submarine detections. However, there is an increasing amount of evidence relating to underwater noise in coastal regions including a recent study using 12 sites around the UK.[175] This stems from an increased awareness as to the potential impacts of noisy activities, such as marine construction. However shallow sea evidence is still relatively limited.

The UK initial assessment for the Marine Strategy Framework Directive (MSFD) indicated that it was not possible to provide an assessment of underwater noise and its impacts, or to provide a relevant baseline.[176] It concluded that there was currently insufficient evidence to provide a quantitative assessment of underwater noise.

One study of natural and anthropogenic sound sources and acoustic propagation in the North Sea concluded that there is insufficient information on the physiology and behaviour of the marine fauna of the North Sea to make reasonable predictions of impact and proposals for management. There is also a lack of knowledge on the effects of the various anthropogenic sources of sound on the ecosystem of the North Sea, both individually and cumulatively.[177]

This lack of data are reflected in the CMR, where no primary research has been published on underwater noise. The MOD, whilst having no relevant CMR specific data sets available, has expressed an interest in working in partnership with potential underwater noise researchers.

In areas outside of the CMR where sound records exist, anthropogenic noise in the ocean has been increasing across much of the frequency spectrum[178,179] and especially at lower frequencies (< 500 Hz).[180]

Filling the data gaps

Data on underwater noise in the CMR is extremely limited so any fresh sources of information would be a positive step. Under the MSFD, work towards establishing a marine noise registry to record, assess, and manage the distribution and timing of impulsive anthropogenic sound sources has begun but the data are limited.[181, 182, 183] The work is managed by the Joint Nature Conservation Committee and the registry was launched in the summer of 2016. These data will then be used in future research to assess levels and patterns of impulsive and low frequency continuous noise in order to determine whether or not these could potentially compromise the achievement of GEnvS.

The overarching aim stated by DEFRA in the Marine Strategy Framework Directive is that human activities potentially introducing loud, low and mid frequency impulsive sounds into the marine environment are managed to the extent that no significant long-term adverse effects are incurred at the population level or specifically to vulnerable/ threatened species and key functional groups.[184] We are not yet at the stage where we are able to define where the threshold may sit.

Good practice guidance has been published to try to ensure a standardised measuring and recording of underwater noise. Differing techniques and metrics currently and historically used for measuring underwater noise can lead to misunderstandings and misinterpretation of results.[185] The International Organiastion for Standardisation is also progressing work which will enable improved standardisation.

Research carrie dout in the Moray Firth has revealed that noise differs greatly between sites and throughout the day, effects which are likely to be magnified in the Clyde where the complex underwater profile coupled with the highly urbanised inner Clyde and industrial and transport uses will make for a complexity which will require detailed study to create a useful underwater noise profile for the plan area.[186]

Marine Scotland has produced guidance on European Protected Species legislation[187] and JNCC has produced statutory nature conservation agency guidelines for minimising the risk of injury to marine mammals from seismic activities, piling and explosive use. The application of these guidelines is frequently set as a licence condition. In addition the International Maritime Organization has produced non-mandatory technical 'Guidelines for the

175. Merchant *et al*., 2016
176. HM Government, 2012
177. Ainslie *et al*., 2009
178. Andrew *et al*., 2002
179. McDonald *et al*., 2008
180. Frisk, 2012
181. Joint Nature Conservation Committee, 2016c
182. International Council for the Exploration of the Sea
183. Joint Nature Conservation Committee, 2016c
184. Department for the Environment and Rural Affairs, 2015
185. Robinson, 2014
186. Merchant *et al*., 2012
187. Marine Scotland, 2014a

reduction of underwater noise from commercial shipping to address adverse impacts on marine life' which promote ship quietening technologies for both propellers and equipment.[188, 189, 190, 191, 192]

Our understanding of the effect on the marine environment from anthropogenic noise is still young and further targeted work is required to start filling the gaps in knowledge.

ECOSYSTEM SERVICES		
SERVICE TYPE	**BENEFITS PROVIDED**	**COMMENTARY**
Provisioning	Food (fish and shellfish)	Excessive noise can limit the system's provisioning ability by negatively affecting breeding, hunting and feeding success in a wide range of species.
Cultural	Wellbeing Recreation	Many people reflect on the meditative quality of the marine and coastal environment; listening to the waves is an important part of a trip to the beach for many people. This is also true for diving enthusiasts. Marine noise pollution can negatively affect cultural services.
Supporting services underpin the provision of other services		The absence of noise is as important as noise itself. An absence of noise allows communication between individuals of a species, within groups and it facilitates hunting. Too much underwater noise will limit individual and group communication, potentially physically damaging or disturbing species and the ecosystem services they provide.

188. Joint Nature Conservation Committee, 2015
189. Joint Nature Conservation Committee, 2010b
190. Joint Nature Conservation Committee, 2010a
191. Joint Nature Conservation Committee, 2010a
192. International Maritime Organisation, 2014