The Scottish Government
Riaghaltas na h-Alba

Scottish Marine and Freshwater Science

Volume 4 Number 4

Measurement of Contaminants and their Effects in Environmental Samples- Proposal for the Revision of the Sampling Programme

L. Webster, C. D. Robinson and C. F. Moffat

marinescotland

Scottish Marine and Freshwater Science Vol 04 No 04

Measurement of Contaminants and their Effects in Environmental Samples- Proposal for the Revision of the Sampling Programme

L. Webster, C. D. Robinson and C. F. Moffat

Published by Marine Scotland Science

ISSN: 2043-7722

Marine Scotland is the directorate of the Scottish Government responsible for the integrated management of Scotland's seas. Marine Scotland Science (formerly Fisheries Research Services) provides expert scientific and technical advice on marine and fisheries issues. *Scottish Marine and Freshwater Science* is a series of reports that publish results of research and monitoring carried out by Marine Scotland Science. These reports are not subject to formal external peer-review.

Marine Scotland Science
Marine Laboratory
375 Victoria Road
Aberdeen
AB11 9DB

Copies of this report are available from the Marine Scotland website at
www.scotland.gov.uk/marinescotland

Measurement of Contaminants and their Effects in Environmental Samples- Proposal for the Revision of the Sampling Programme

L. Webster, C. D. Robinson and C. F. Moffat

Marine Scotland Science, Marine Laboratory
375 Victoria Road, Aberdeen, AB11 9DB

Executive Summary

Descriptor 8 (contaminants and their effects) is one of the eleven Marine Strategy Framework Directive (MSFD) qualitative descriptors for determining Good Environmental Status (GES) (Directive 2008/56/EC). To monitor compliance with Good Environmental Status (GES) for Descriptor 8, contaminant concentrations and biological effects should be measured in environmental samples and compared to assessment criteria. The contaminant monitoring currently undertaken in Scotland's seas was reviewed. Monitoring programmes include the UK Clean Seas Environment Monitoring Programme (CSEMP), undertaken by Marine Scotland Science (MSS) and the Scottish Environment Protection Agency (SEPA), and the Water Framework Directive (WFD) monitoring, undertaken mainly by SEPA. The suitability of current monitoring programmes in addressing the requirements of Descriptor 8 was assessed.

Contaminants and effects monitoring is undertaken in Scottish coastal and offshore areas as part of the CSEMP. The main focus of the CSEMP to date has been to meet the temporal trend monitoring requirements of the OSPAR Convention and in respect of compliance with EC Directives such as WFD. Monitoring of the OSPAR Coordinated Environmental Monitoring Programme (CEMP) determinands is undertaken in sediment and biota and may also be used for assessment of GES for Descriptor 8. WFD monitoring in coastal and transitional water bodies is undertaken by SEPA (mainly water and some biota), although monitoring of organic contaminants in water has largely stopped in Scotland as concentrations are well below the WFD Environmental Quality Standards (EQSs) and frequently below the limit of detection of the analyses. As most WFD substances are not an issue in coastal or transitional waters, further monitoring in offshore waters will not be required for MSFD unless there are recognised point source emissions or following a chemical spill.

Currently sediment and fish from a number of Scottish sea areas[1] are monitored annually, whilst other sea areas (e.g. Forties, Hebrides) have not been monitored. The frequency of monitoring contaminant groups and biological effects in each sea area was reviewed. Where concentrations are below Background Assessment Concentrations (BACs) and are stable or declining, monitoring should be every 6 years. Where concentrations are above BACs but below EQSs, Environmental Assessment Criteria (EACs), Effects Range Low (ERL) or EC food levels and concentrations are not increasing monitoring should be every 3 years. Three yearly monitoring should also be undertaken if concentrations are <BACs and showing an upward trend. Annual monitoring will only continue if concentrations are greater than the EQS/EAC/ERL/EC food level or above the BAC and showing an upward trend. Areas not currently monitored but where concentrations are expected to be low should be sampled on a rolling basis every 6 years.

For biological effects it is proposed that Scotland will monitor selected effects measurements (including the end points considered to be OSPAR 'common' and 'candidate' indicators) from the ICES integrated scheme on a rolling basis such that each sea area is sampled at least once per MSFD reporting cycle (every 6 years). At locations where human pressures are highest (Clyde and Forth), or where there is evidence of several effects currently being above the EAC (e.g. in the Integrated Assessment research project), then sampling should be conducted annually; if several effects are above the BAC then monitoring should be every three years; otherwise once per 6-year MSFD cycle.

[1] The Scottish sea areas are defined in Baxter, J.M., Boyd, I.L., Cox, M., Donald, A.E., Malcolm, S.J., Miles, H., Miller, B. and Moffat. C.F. (Editors) 2011. Scotland's Marine Atlas: Information for the national marine plan. Marine Scotland, Edinburgh. pp. 191.

List of acronyms

BAC	Background Assessment Concentration (contaminants) or Background Assessment Criteria (biological effects)
BC	Background Concentration
CEMP	OSPAR Coordinated Environmental Monitoring Programme
CSEMP	UK Clean Seas Environmental Monitoring Programme
EAC	Environmental Assessment Criteria
EQS	Environmental Quality Standard
EQSD	Environmental Quality Standard Directive (2008/105/EC)
EROD	7-ethoxyresorufin *O*-deethylase
FSA	Food Standards Agency
GES	Good Environmental Status
HBCDD	Hexabromocyclododecane
MSFD	Marine Strategy Framework Directive 2008/56/EC)
MSS	Marine Scotland Science
OSPAR	OSPAR Convention for the protection of the north east Atlantic
PAHs	Polycyclic aromatic hydrocarbons
PBDEs	Polybrominated diphenyl ethers
PCBs	Polychlorinated biphenyls
PSD	Priority Substances directive (2013/39/EU)
SEPA	Scottish Environment Protection Agency
TBT	Tributyltin
WFD	Water Framework Directive (2000/60/EC)

Introduction

The Marine Strategy Framework Directive (MSFD) took effect on 17 June 2008 (Directive 2008/56/EC, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019: 0040:EN:PDF) and was transposed into UK law in July 2010 through the Marine Strategy Regulations 2010. The aim of the MSFD is to achieve or maintain Good Environmental Status (GES) in the marine environment by the year 2020 at the latest. The Directive sets out eleven qualitative descriptors against which GES should be assessed. Descriptor 8 states that ***'Concentrations of contaminants are at levels not giving rise to pollution effects'***. The Directive required an Initial Assessment of status by July 2012 and the identification by 2014 of any measures required to achieve GES. The UK State of the Seas report, *Charting Progress 2 – The State of UK Seas*[1] and Scotland's Marine Atlas[2], were used as the basis for the UK Initial Assessment[3]. A public consultation exercise on the UK Initial Assessment and the UK's Targets and Indicators for GES was recently undertaken by Defra; a report on the consultation exercise will be produced by Defra and the Devolved Administrations in due course. Monitoring programmes for the assessment of environmental status should be in place by 2014, while a programme of measures has to be established by 31 December 2015 with notification to the commission by 30 March 2016. The next status assessments are due in 2018.

Task Groups were established by the European Commission's Joint Research Centre (JRC) for 10 of the 11 MSFD Descriptors (not Descriptor 7: Alteration of hydrographical conditions); the International Council for the Exploration of the Sea (ICES) and the JRC produced advice on the scope of Descriptor 8[4]. In that document, contaminants were defined as:

'*substances or groups of substances that are toxic, persistent and liable to bioaccumulate, and other substances or groups of substances which give rise to an equivalent level of concern*'.

Pollution effects were defined as:

'*direct and/or indirect adverse impacts of contaminants on the marine environment such as harm to living resources or marine ecosystems, including loss of biodiversity, hazards to human health, the hindering of marine activities, such as fishing, tourism, recreation and other legitimate uses of the sea, impairment of the quality for use of sea water and reduction of amenities or, in general, impairment of the sustainable use of marine goods and services'*.

Contaminants found in the marine environment can be from either anthropogenic or natural sources. However, most contaminants are produced by anthropogenic activities. Direct or indirect releases to rivers, from industrial discharges and from wastewater treatment work discharges, are a major source of a range of contaminants. Furthermore, run-off from urban areas and atmospheric deposition continue to be diffuse sources of hazardous substances to the marine environment.

MSFD Descriptor 8 Requirements: Targets and Indicators

Details of the criteria and indicators for GES for each of the eleven descriptors are provided in the European Commission Decision of 1 September 2010 (Com Decision 2010/477/EU). Member States must use these when implementing the Directive.

For Descriptor 8, the Commission Decision Document states that:

- The concentration of contaminants in the marine environment and their effects need to be assessed taking into account the impacts and threats to the ecosystem.
- Relevant provisions of Directive 2000/60/EC (WFD) in territorial and/or coastal waters have to be taken into consideration to ensure proper coordination of the implementation of the two legal frameworks, having also regard to the information and knowledge gathered and approaches developed in Regional Sea Conventions.

The indicators listed in Commission Decision 2010/477/EU for Descriptor 8 are:

- 8.1. Concentration of contaminants — Concentration of the contaminants measured in the relevant matrix (such as biota, sediment and water) in a way that ensures comparability with the assessments under Directive 2000/60/EC.
- 8.2.1 Effects of contaminants — Levels of pollution effects on the ecosystem components concerned, having regard to the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored.
- 8.2.2 Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution.

Descriptor 8 covers those substances which are classed as priority substances for the Water Framework Directive (WFD). Commission Decision 2010/477/EU states that for Descriptor 8 *'Member States have to consider the substances or groups of substances, where relevant for the marine environment, that 'are listed as priority substances in Annex X to Directive 2000/60/EC and further regulated in Directive 2008/105/EC* [environmental quality standards in the field of water policy]*, which are discharged into the concerned marine region, sub-region or subdivision'.* The WFD (2000/60/EC) and the EQSD (2008/105/EC) have since been amended by the Priority Substances Directive (PSD; 2013/39/EU) which lists 45 Priority Substances, of which 21 are Priority Hazardous Substances. For each substance, the PSD specifies the Environmental Quality Standards (EQSs) to be used in assessing compliance with the WFD, whether compliance monitoring should be in water or biota, and also whether trend monitoring in biota and/or sediment is required. The Priority Substances, their saltwater and/or biota EQS values and requirements for trend analysis are listed in Appendix 1 to this report; the list includes metals, herbicides, insecticides, fungicides, biocides, volatile organic compounds, alkylphenols, polycyclic aromatic hydrocarbons (PAHs) and phthalates.

The UK Government and Devolved Administrations developed proposals for more detailed targets and indicators of Good Environmental Status for each of the eleven descriptors, through which the UK will measure progress towards achieving or maintaining Good Environmental Status.

For Descriptor 8, three GES target and indicators were proposed by the UK[3]:

- Concentrations of substances identified within relevant legislation and international obligations are below the concentrations at which adverse effects are likely to occur (e.g. are less than Environmental Quality Standards (EQS) applied within the Water Framework Directive and Environmental Assessment Criteria (EAC) applied within the OSPAR Commission).
- The intensity of biological or ecological effects due to contaminants is below the toxicologically-based standards agreed by the OSPAR Commission as appropriate for MSFD purposes, in a statistically significant number of samples at relevant monitoring stations.
- For oil/chemical spills - As a wide range of oils and chemicals may be spilled, targets will be incident-specific and will need to be derived at the time. For spilled chemical compounds relevant assessment criteria (e.g. established EQSs and EACs) will be used to help establish significance of impact and appropriate response.

This report reviews the contaminants monitoring requirements and activities currently undertaken in the Scottish marine environment and the suitability of these activities in addressing the requirements of Descriptor 8.

Current Scottish Monitoring Requirements

In Scotland a number of the contaminants highlighted to be of concern are monitored routinely in sediment and biota by Marine Scotland Science (MSS) and/or the Scottish Environment Protection Agency (SEPA). Monitoring of contaminants and their biological effects in the Scottish marine environment is undertaken as part of the UK Clean Seas Environment Monitoring Programme (CSEMP). The main focus of the CSEMP has been to meet the temporal trend monitoring requirements of the OSPAR international agreement and in respect of compliance with EC Directives such as the Water Framework Directive (WFD), Dangerous Substances Directive (DSD; 76/464/EEC) and Shellfish Waters Directive (SWD: 79/923/EEC). The DSD and SWD will be repealed from 23 December 2013, from when the WFD will be the primary Directive concerning transitional and coastal water quality; with respect to chemical status, the provisions of the WFD apply to territorial waters (i.e. out to 12 nm).

OSPAR

The OSPAR Coordinated Environmental Monitoring Programme (CEMP) is focussed on monitoring the concentrations of selected contaminants taken from the OSPAR List of Chemicals for Priority Action. In addition some biological effects measurements are included on the CEMP and have been monitored routinely for a number of years. The CEMP determinands are[5]:

- metals (cadmium, mercury and lead) in biota and sediment.
- polycyclic aromatic hydrocarbons (PAHs) (anthracene, benz[*a*]anthracene, benzo[*ghi*]perylene, benzo[*a*]pyrene, chrysene, fluoranthene, ideno[1,2,3-*cd*]pyrene, pyrene and phenanthrene) in biota and sediment.
- polychlorinated biphenyls (PCBs) (ICES7: CB28, 52, 101, 118, 138, 153 and 180) in biota and sediment.
- brominated flame retardants: Hexabromocyclododecane (HBCDD) in biota and sediment and polybrominated diphenyl ethers (PBDEs) (BDE28, 47, 66, 85, 99, 100, 153, 154 and 183 in biota and sediment, and BDE209 in sediment).
- tributyl tin (TBT): TBT-specific biological effects and TBT concentrations in sediment or biota**.** Monitoring of TBT concentrations in the marine

environment in either sediments or biota should be carried out in parallel with monitoring of TBT-specific biological effects.

Further determinands are classed as pre-CEMP. OSPAR Contracting Parties are preparing to monitor these in a co-ordinated manner through the development of monitoring guidance, quality assurance procedures and/or assessment tools. Currently the pre-CEMP includes the following:

- planar PCBs (CB77, 126 and 169) in biota. Monitoring of those congeners in sediment or biota should be undertaken only if levels of marker PCBs are e.g. 100 times higher than the Background Assessment Concentration for these marker PCBs.
- alkylated PAHs: C1-, C2-, and C3-naphthalenes, C1-, C2- and C3-phenanthrenes, and C1-, C2- and C3-dibenzothiophenes and the parent compound dibenzothiophene in biota and sediment.
- perfluorooctane sulphonate (PFOS) in sediment, biota and water.
- dioxins and furans in biota and sediment.
- PAH- and metal-specific biological effects.
- general biological effects.

The strategic objective of the OSPAR Strategy for Hazardous Substances is to '*Move towards the cessation of discharges, emissions and losses of hazardous substances by 2020 with the ultimate aim of achieving concentrations in the marine environment of near background for naturally occurring substances and close to zero for man-made substances*'[6].

Analyses of sediment, fish and shellfish for contaminants and effects included on the OSPAR CEMP, and some pre-CEMP (Tables 1 and 2), is undertaken by MSS and/or SEPA as part of the UK CSEMP. OSPAR Contracting Parties can opt out of monitoring CEMP determinands if no significant anthropogenic inputs to the marine environment have occurred or are likely to occur, or if concentrations in the marine environment are near background values for naturally occurring substances and close to zero for man-made substances. i.e. "concentrations close to zero and at least below the limits of detection of the most advanced analytical techniques in general use"[5].

EC Directives

Water Framework Directive (WFD)

The Water Framework Directive (2000/60/EC) was adopted by the European Parliament and the Council of the European Union on 22 December 2000. The Directive became law in Scotland during 2003 through the Water Environment and Water Services (Scotland) Act 2003 (the WEWS Act) which sets out the new arrangements for the protection of the water environment in Scotland. The monitoring programme became operational in Scotland in 2007. The aim of the WFD is to protect all transitional[2] and coastal waters[3], prevent deterioration and enhance the status of aquatic ecosystems. Three groups of priority substances (Appendix 1) were identified by the WFD: Priority Hazardous Substances (PHS), Priority Substances (PS) and Priority Substances subject to review to Priority Hazardous Substances (PSR). In addition, Member States are required to list, control and monitor Specific Pollutants that are of concern to the river basin. Originally thirty-three substances or groups of substances were classed as PHS and PS (13 PHSs and 20 PSs), including metals, herbicides, insecticides, fungicides, biocides, volatile organic compounds, alkylphenols, PAHs and phthalates. The European Commission is required to review the list of PSs every four years and identify, where appropriate, new PSs or PHSs and any need to revise the Environmental Quality Standards (EQSs) or the status of existing PSs (2000/60/EC, Article 16). The outcome of the first review was reported in 2011 ((COM(2011)876)). As a result of this review the following additional substances were proposed as priority substances: aclonifen, bifenox, cybutryne, cypermethrin, dichlorvos, terbutryn, 17-alpha-ethinylestradiol, 17-beta-estradiol and diclofenac, and the following as priority hazardous substances: dicofol, PFOS and its derivatives, quinoxyfen, dioxins and dioxin-like compounds, HBCDD and heptachlor/heptachlor epoxide. More recently, the new Priority Substances Directive (2013/39/EU) was published with the revised list of PSs/PHSs, together with their EQS values for freshwater, saltwater and, where applicable, biota; the pharmaceutical compounds (17-alpha-ethinylestradiol, 17-beta-estradiol and diclofenac) have not been included as PSs, and are likely to be included within the next review of PSs to be completed

[2] *Transitional waters' are bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows*

[3] *Coastal water' means surface water on the landward side of a line, every point of which is at a distance of three nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters" "*except in respect of chemical status for which it [surface waters] shall also include territorial waters" (WFD Article 2.1)

by 2017. Biological effects measurements are not required for WFD although their role in providing information on substances not known *a priori* to be present in the environment, and on the effects of mixtures of substances has been recognised by the EU. The Scottish River Basin District Directions sets out the environmental standards to be applied by SEPA[7].

The objective for PHSs is for the cessation of discharges, emissions and losses within 20 years of appropriate measures being introduced, with the "ultimate aim of achieving concentrations in the marine environment near background values for naturally occurring substances and close to zero for man-made synthetic substances" (WFD, Article 1); close-to-background/zero concentrations are required in order to achieve "High Ecological Status" (WFD Annex V, 1.2). For PS the objective is for progressive reduction of discharges, emissions and losses. The WFD requires that the chemical status of water bodies to be categorised as 'Good' or 'Failing to achieve good'. Chemical status applies to territorial waters (out to 12 miles), whilst ecological status applies to coastal waters (out to 3 nautical miles for Scotland). The over-all objective of the WFD is to achieve a good chemical status, in addition to a good ecological status, by 2015.

The majority of monitoring for WFD is undertaken in Scotland by SEPA, with contaminant monitoring occurring in transitional and coastal waters at surveillance sites and operational sites. Operational sites are related to identified pressures whereas surveillance sites are not related to pressures and contaminant concentrations found at these sites should be representative of background concentrations. Concentrations of trace organic substances monitored in water samples from transitional and coastal waters in Scotland are well below EQS and frequently below the limit of detection of the analyses; consequently monitoring in water was stopped when there was sufficient evidence to show there was no risk of failing EQS. SEPA has continued monitoring trace metals in waters at selected sites where concentrations are greater than the limit of detection of the analyses.

Dangerous Substances Directive (DSD) and the EC Shellfish Waters Directive (SWD)

SEPA undertakes the analysis of organic compounds and trace metals to meet the requirements of the EC Dangerous Substances Directive (DSD) (76/464/EEC) and the EC Shellfish Waters Directive (SWD) (79/923/EEC, updated in 2006 (2006/113/EC). The DSD requires environmental monitoring wherever there is a consented discharge of a specified dangerous substance to determine if EQSs are exceeded and the analysis of either sediment or biota annually to determine if the

substances are accumulating. The Directive lists 11 metals and 52 organic compounds, however, only those with known discharges are monitored. Concentrations are compared to EQSs set by the DSD. EQSs are concentrations below which a substance is not believed to be detrimental to aquatic life and were derived using acute toxicity testing and have only been established for water. The WFD will take over the provisions of the DSD, which will be repealed 22 December 2013 (13 years after the date of entry into force of the WFD).

The SWD requires the analysis of water and shellfish biannually. The Directive states that the concentration of the substance in the water column or shellfish flesh should not harm the shellfish. The Directive prescribes the minimum quality criteria which must be met by shellfish waters, and guideline values which Member States must endeavour to observe. Analysis for SWD is undertaken by SEPA for Scotland, concentrations in shellfish and water samples are compared to EC Directive Quality Standards for Shellfish Growing Waters. The SWD allows reduced frequency or no monitoring where there is no risk of failing the Directive standards. In practice the concentration of hazardous substances in water samples from shellfish waters are low (below SWD quality standard) and frequently below the limit of detection of the analysis so monitoring in water samples was discontinued. However, contaminants (trace metals, PCBs and PAHs) continue to be monitored in shellfish flesh by SEPA. Only metals and organochlorine pesticide data are required by the SWD, but PCBs and PAHs are also measured by SEPA to provide data for the OSPAR CEMP. The SWD will be repealed in 22 December 2013, after which monitoring for contaminants in shellfish flesh will be covered by the existing WFD requirements.

Contaminant and Biological Effects Monitoring Programmes Currently Undertaken in Scotland

Biota

Biota contaminant monitoring programmes currently undertaken in Scotland are described in the Marine Scotland Science Descriptor 9 (contaminants in food) report[8]. SEPA monitor contaminants (trace metals, PCBs and PAHs) in native mussels collected from the intertidal zone from 56 sites across Scotland between January and March each year[8] (Fig. 1). SEPA also measure PBDEs in mussels from the Firth of Clyde and Firth of Forth. Samples are collected to assess compliance with the standstill clause in the DSD, to assess compliance with the SWD, and for OSPAR CEMP, so as to assess progress in respect of the OSPAR Hazardous Substances Strategy. This data is submitted to the UK Marine Environment Monitoring and Assessment National (MERMAN) database. Contaminants have

also been measured in mussels (2001-2012) as part of MSS's Long Term Hazardous Substances Monitoring Programme and submitted to MERMAN. Farmed, rope grown mussels (Loch Etive and Loch Ewe) and wild mussels (Straad on the west coast, Shell Bay and Aberdeen Breakwater on the east coast)[8] (Fig. 1) have been analysed for PAHs, PCBs and PBDEs, although this programme has now been concluded. MSS sample fish for contaminants as part of their annual CSEMP and Clyde trend monitoring cruises (Fig. 2). The OSPAR CEMP programme requires the determination of lead, cadmium, PCB, and PBDE concentrations in fish liver, and mercury in fish muscle tissue. For CSEMP, MSS monitor contaminants in plaice, dab or flounder from 10 sites annually. The use of modern analytical methodologies means that data for the three specified metals (and several others) are routinely obtained for both liver and muscle of fish. CSEMP contaminant data for fish are submitted to MERMAN and from there to international databases (ICES).

Figure 1 Scottish shellfish sites, including MSS's Long Term Hazardous Substances Monitoring Programme (LTHSMP) 2005 – 2012 sites, MSS integrated assessment sites and SEPA's Shellfish Water and DSD sites. MSS sites include 2 rope grown sites (Loch Etive and Loch Ewe) and 3 wild mussel sites (Straad on the west coast and Shell Bay and Aberdeen Breakwater, this sampling programme has now stopped). SEPA's sites are all wild mussel sites. Grey lines show the Scottish sea areas[2].

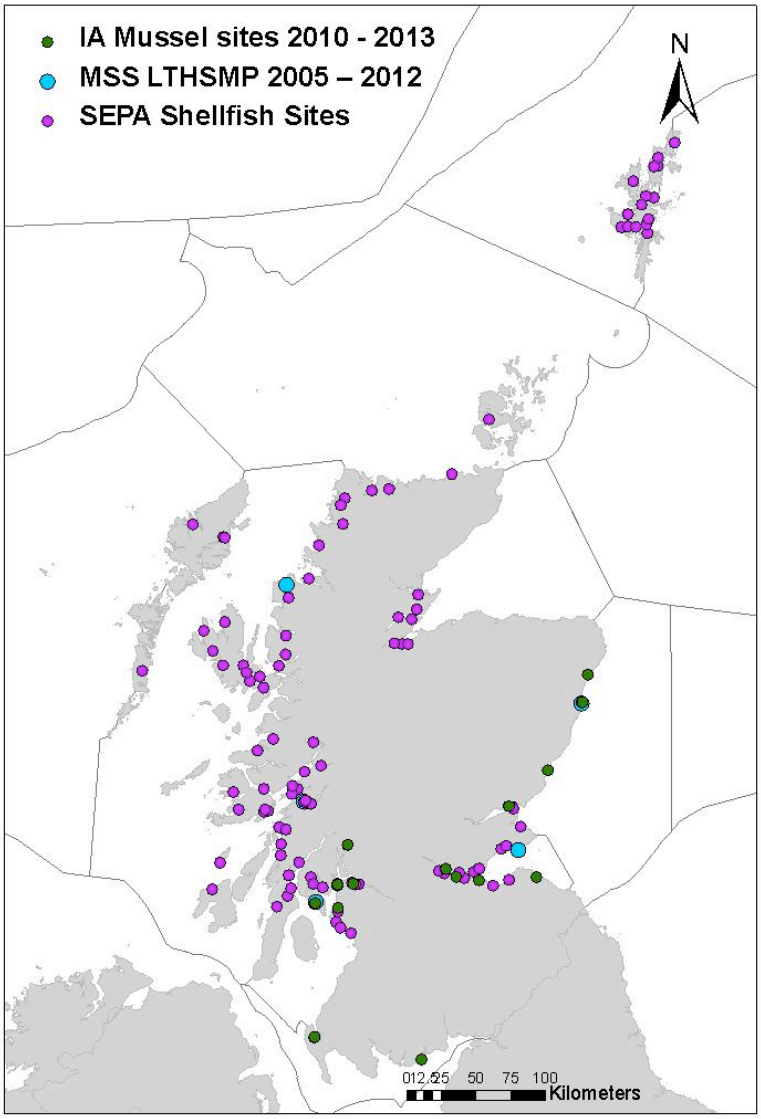
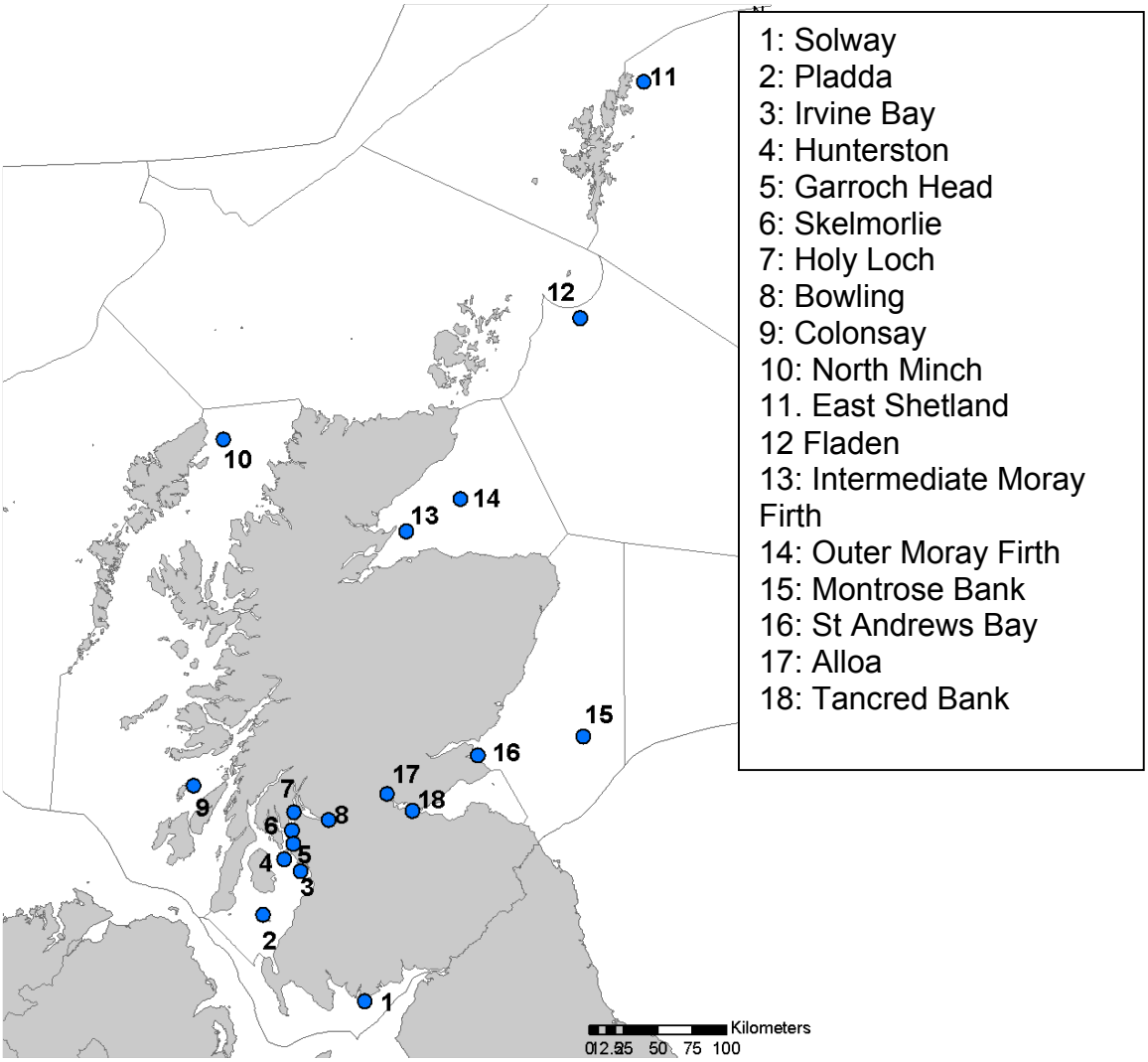


Figure 2 Scottish fish monitoring sites sampled annually for contaminant analysis by MSS. The grey lines show the Scottish sea areas[2].



In addition, a range of biological effects are or have been measured for CSEMP and other monitoring and research programmes. MSS conduct annual determinations of hepatic CYP1A enzyme activity (EROD) in flatfish collected from specific CSEMP locations and from some Clyde trend monitoring sites. Since 2007, biliary PAH metabolites have also been measured in flatfish from these programmes. Additionally, annual fish disease surveys of dab were undertaken from North Sea sites between 2002 and 2008 (reported to MERMAN for 2004-2008) and EROD samples were analysed from these surveys between 2002 and 2008.

MSS began a 3 year research programme in 2009/10 intended to align MSS biological effects monitoring with the scheme for integrated assessment of contaminants and their effects[9,10], although several of the effects measurements are

not currently required for the OSPAR CEMP. This scheme is designed to address the MSFD requirement for determining whether the presence of contaminants causes environmental harm. During this project, MSS has developed expertise in internationally recognised biological effects techniques and obtained data on the concentrations and effects of contaminants in offshore fish (dab; 6 sites annually), inshore fish (flounder; 5 sites annually), and inshore mussels (4 sites in the Clyde in 2010; 4 sites in the Forth in 2011; and four sites on the Scottish east coast in 2012). The mussels monitoring programme continued to include sampling at 4 sites in the Clyde and one in the Solway in 2013.

As part of CSEMP, SEPA and MSS have undertaken a triennial monitoring programme for imposex in dogwhelks from around the Scottish coastline. The most recent survey was in 2010. Whilst a UK survey was due in 2013, it has been deferred to 2014 when it will fall within the MSFD monitoring cycle. In addition, MSS monitor imposex in Sullom Voe every two years on behalf of the Shetland Oil Terminal Environmental Advisory Group, most recently in 2013 (data not yet available).

Table 1 Mandatory and Voluntary CEMP determinands (contaminants and biological effects) monitored in biota annually by SEPA and MSS
Y, currently monitored annually; N, not currently monitored

	SEPA (mussels)	**MSS (fish and mussels)**
Mandatory (CEMP)		
Cadmium	Y (1999 – Present)	Y (1999 – Present)
Mercury	Y (1999 – Present)	Y (1999 – Present)
Lead	Y (1999 – Present)	Y (1999 – Present)
CB28, 52, 101, 118,138, 153, and 180.	Y (1999 – Present)	Y (1999 – Present)
PAHs: anthracene, benz[*a*]anthracene, benzo[*ghi*]perylene, benzo[*a*]pyrene, chrysene, fluoranthene, ideno[1,2,3-cd]pyrene, pyrene and phenanthrene	Y (1999 – Present)	Y (1999 – Present, mussels only)
BDE28, 47, 66, 85, 99, 100, 153, 154, 183 and 209	Y (2011- Present, Clyde and Forth only)	Y (2005 – Present)
Hexabromocyclododecane (HBCDD)	N	N (Limited fish data, mainly from Clyde)
Imposex in dogwhelks	N UK triennial monitoring programme, 1998-2010; no longer have the capability to determine imposex.	Y UK triennial monitoring programme, 1992-present Biennial monitoring on behalf of Sullom Voe Oil Terminal Environmental Advisory Group from 1987 to 2013
Voluntary (pre-CEMP)		
alkylated PAHs: C1-, C2-, and C3-naphthalenes, C1-, C2- and C3-phenanthrenes, and C1-, C2- and C3-dibenzothiophenes and the parent compound dibenzothiophene	Y (2010 – Present)	Y (1999 – Present, mussels only)
PFOS	N	N (Method under development)
Polychlorinated	N, (One off survey in	N

dibenzodioxins and furans	Clyde and Forth in 2009.	
TBT in biota	N	N
CYP1A enzyme activity (EROD) in flatfish	N	Y (1999-present)
Biliary PAH metabolites in flatfish	N	Y (2007-present)
Liver histopathology in flatfish	N	Y (2002-2008, 2010-present)
Liver macroscopic neoplasms in flatfish	N	Y (2002-2008, 2010-present)
Non-CEMP, recommended as part of ICES integrated assessment scheme		
Copper	Y (1999-present)	Y (1999-present)
Zinc	Y (1999-present)	Y (1999-present)
External disease in flatfish	N	Y (2002-2008, 2010-present)
Plasma vitellogenin in flatfish	N	N (Outsourced in 2010)
DNA damage in flatfish haemocytes (micronucleus)	N	N (Outsourced in 2010-2011)
Lysosomal Membrane Stability (LMS) in flatfish liver	N	Y (2010-present)
Lysosomal Membrane Stability (LMS) in mussel haemocytes	N	Y (2009-present)
DNA damage in mussel haemocytes (Comet assay)	N	Y (2009-present)
Mussel histopathology	N	Y (2009-present)
Stress-on-stress in mussels	N	Y (2009-present)

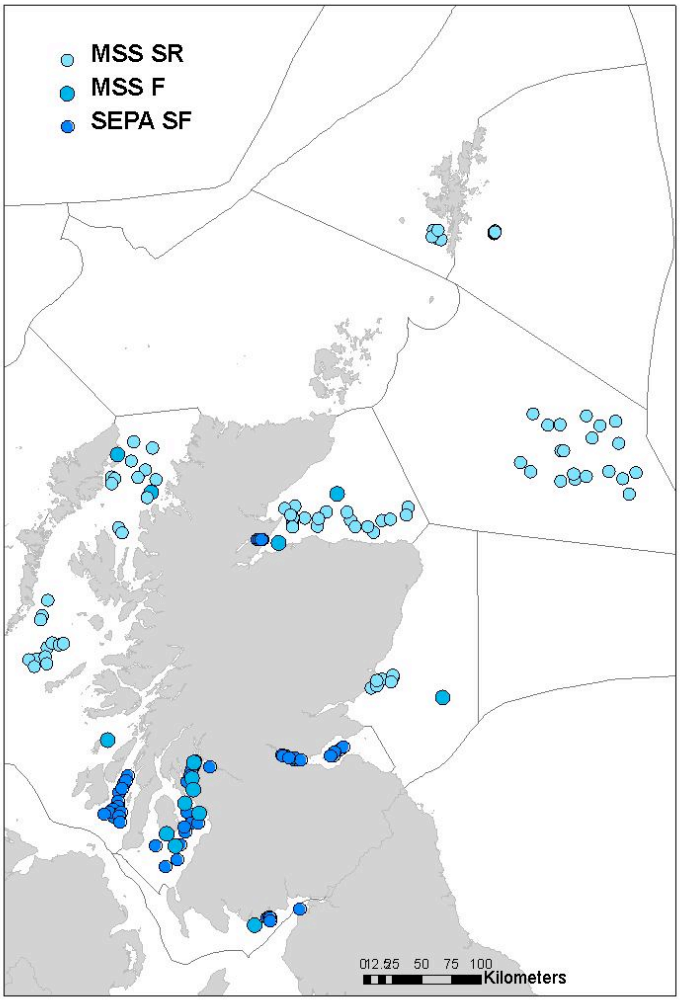
Sediments

Sediment samples are collected and analysed for contaminants and benthic invertebrates [4]as part of UK CSEMP. This sediment sampling programme was modified for Scotland in 2005 following a review of the statistical power of the programme to detect a trend. Previously, five replicate samples were collected from each fixed CSEMP site and the results used to determine trends in contaminants and the benthic community. Sediments are not homogeneous so this approach provided low within-year variability but large between-year variability, which limited the power of the programme to detect a trend. It also led to data from a small area

[4] This report does not cover benthic invertebrate but this data may be useful for Descriptors 1 & 6

being used to represent a wide sea area. For these reasons, collecting five replicate samples at a fixed site was replaced by collecting 3-10 (depending on the size of the geographical area, or strata) more widely dispersed samples from within the same strata (based on WFD water bodies, if present), with sediment samples being collected in areas of fine sediment only. British Geological Survey maps showing sediment type were used to identify suitable areas. Most of the east coast consists of shell and gravel and, therefore, was unsuitable for contaminant analysis. Dispersing the sampling over a wider area increased within-year variability but reduce between-year variability so increasing the power of the programme to detect trends. Furthermore, the sampling programme will also be more representative of the wider sea area. This approach is similar to the approach recommended by the ICES Working Group on Marine Sediments (WGMS) in 2013. WGMS were asked by OSPAR to produce a sampling strategy for spatial monitoring of sediments on a sub-regional scale. It recommended that for a sub-region (e.g. southern North Sea), the areas of fine sediment be identified and, depending upon local hydrography and sediment transport patterns, grouped to form a number of coherent strata (which may transcend national boundaries). A statistically defined number of samples would then be randomly collected from each of the strata; the number of samples collected in each stratum is defined in order to provide sufficient power to determine whether a concentration exceeds the EAC/EQS and depends upon the variability of any data already available for that strata.

Figure 3 Locations of SEPA and MSS sediment sites sampled as part of the UK CSEMP. An example of MSS stratified random (SR) sampling sites from 2009 are shown along with the MSS fixed (F) locations, sampled annually since 1999. SEPA use a stratified fixed (SF) sampling protocol and these sites have been sampled annually since 2005.



For CSEMP sites, MSS adopted a random stratified approach to sediment sampling whereby samples are collected from 5-10 random sites in a strata (based on WFD water bodies, where present) every year, although samples are only collected from fine sediments (Fig. 3). Sampling at the six fixed sites sampled since 1999 is also undertaken annually (Fig. 3), however, since 2005 only one sample is collected (1999 – 2005 five replicate samples were collected). Sediment samples are collected for both hazardous substances and benthic invertebrate analysis.

In 2005, SEPA adopted a stratified fixed sampling approach where five fixed locations in each selected water body (eight water bodies, 40 samples) are sampled (Fig. 3). SEPA made further modifications to the sediment programme in 2010 when

a new 3 yearly monitoring programme was introduced for benthic invertebrates[11]. The 3 yearly monitoring programme is based on 3 regions, west, east and north. For contaminants annual sampling has been retained in the Forth (3 strata) and Clyde (2 strata) with triennial sampling in Minches and Malin Sea (1 stratum) and Moray Firth (1 stratum).

Table 2 Mandatory and voluntary OSPAR CEMP determinands monitored in sediments by SEPA and MSS.
Y, currently monitored annually; N, not currently monitored

	SEPA*	**MSS**
Mandatory (CEMP)		
Cadmium	Y (1999 – Present)	Y (1999 – Present)
Mercury	Y (1999 – Present)	Y (1999 – Present)
Lead	Y (1999 – Present)	Y (1999 – Present)
Tributyltin	N	N (Monitored historically, but stopped as below detection limits)
CB28, 52, 101, 118, 138, 153 and 180.	Y (1999 – Present)	Y (1999 – Present)
PAHs: anthracene, benz[*a*]anthracene, benzo[*ghi*]perylene, benzo[*a*]pyrene, chrysene, fluoranthene, ideno[1,2,3-*cd*]pyrene, pyrene and phenanthrene	Y (1999 – Present)	Y (1999 – Present)
BDE 28, 47, 66, 85, 99, 100, 153, 154, 183 and 209	N	Y (2005 – Present)
HBCDD	N	N (Limited monitoring, in the Clyde in 2009
Cofactors (particle size, organic carbon, lithium and aluminium)	Y	Y
Voluntary (pre-CEMP)		
alkylated PAHs C1-, C2-, and C3-naphthalenes, C1-, C2- and C3-phenanthrenes, and C1-, C2- and C3-dibenzothiophenes and the parent compound dibenzothiophene	Y (2010 – Present)	Y (1999 – Present)
PFOS	N	N (Method under

		development)
Polychlorinated dibenzodioxins and furans	N	N
General biological effects	N (Sediment bioassays discontinued in 2011 due to resourcing)	N

*Since 2010 sediment sites are generally visited on a three yearly cycle. The exception is the Forth and Clyde.

Data Assessment

Contaminant and biological effects (EROD, bile metabolites, fish disease) data collected for the above sediment and biota monitoring programmes are submitted annually (by 1st June) to the UK MERMAN database; this data is subsequently submitted to ICES (September of the same year). The MERMAN and ICES databases are being updated to allow data to be submitted for effects in mussels (e.g. LMS, stress-on-stress, comet assay) and for additional effects in fish (e.g. LMS, micronucleus). Currently the majority of contaminant and effects data collected in Scotland is held in the MERMAN database and is readily available for Descriptor 8 data assessments. Data collected as part of one-off surveys/research projects and some of SEPA's WFD data is not submitted to MERMAN, but are held on other databases (e.g. MSS contaminants database). Station dictionary names will be obtained for any new sites proposed for Descriptor 8 monitoring and this data will be submitted to MERMAN. Contaminant data from the Food Standards Agency in Scotland (FSAS) that may be useful for D8 assessments (e.g. dioxins in shellfish) are not currently submitted to MERMAN, although FSAS have agreed to try and do this. However, there may be resourcing issues for the addition of new contaminants/effects to MERMAN, as this will require changes to the database structure.

Contaminants and effects data have been assessed for the OSPAR Quality Status report (1998 - 2008)[12], UK Charting Progress 2 (1999 - 2007)[1] and Scotland's Marine Atlas (1999 - 2009)[2]. Charting Progress 2 and Scotland's Marine Atlas were used for the UK's initial assessment for the MSFD. MSS have also assessed data on persistent organic pollutants from 1999 up to 2010; PCB, PBDE and PAH concentrations in sediment and biota from Scottish sea areas were assessed[13]. Temporal and spatial trends were investigated and the concentrations assessed against internationally agreed assessment criteria. Rules were developed for the aggregation of the contaminant data across each sea area. An overall assessment for each sea area was then assigned, looking at the frequency of sites or strata within each sea area that were above or below the relevant assessment criteria.

MSS have also been influential in the development of guidelines by ICES for the integrated monitoring and assessment of contaminants and their effects[14]. These guidelines have been accepted by OSPAR for a three-year trial (2012-2015) and rely upon a coherent approach to sample collection, sample analysis, data handling, and data assessment for both contaminants and biological effects, and associated supporting data.

Suitability of the Existing Scottish Monitoring Programmes to Meet MSFD Descriptor 8 Requirements

Current contaminant and biological effects monitoring undertaken as part of Scottish monitoring programmes, including UK CSEMP, will help fulfil the requirement of MSFD Descriptor 8. However, there are limitations, particularly in the spatial coverage of the datasets and the range of contaminants monitored.

Spatial Coverage for MSFD

The MSFD (Article 4) lists 10 sub-regions for monitoring purposes, the relevant sub-regions for the UK are:

- The Greater North Sea, including the Kattegat and the English Channel (OSPAR Region II)
- The Celtic Seas (OSPAR Region III)

Scottish waters fall within OSPAR Region II (includes the Scottish sea areas east Shetland, Fladen, Moray Firth, east Scotland coast, Forties, and Forth) and OSPAR Region III (includes the Scottish sea areas Solway Firth and North Channel, Clyde, Minches and Malin Sea, Hebrides, Rockall, Bailey, north Scotland coast, Faroe-Shetland, west Shetland).

Under the UK CSEMP, SEPA sample annually shellfish (mussels) from all Scottish sea areas with a coastline and SEPA/MSS sample dogwhelks from around Scotland on a triennial basis. Sediment samples are collected annually in the Solway Firth and North Channel, Clyde, Minches and Malin Sea, east Shetland and west Shetland, Fladen, Moray Firth, east Scotland and Forth, which covers both OSPAR Region II and III. Samples are not collected in all Scottish sea areas e.g. Forties and Hebrides.

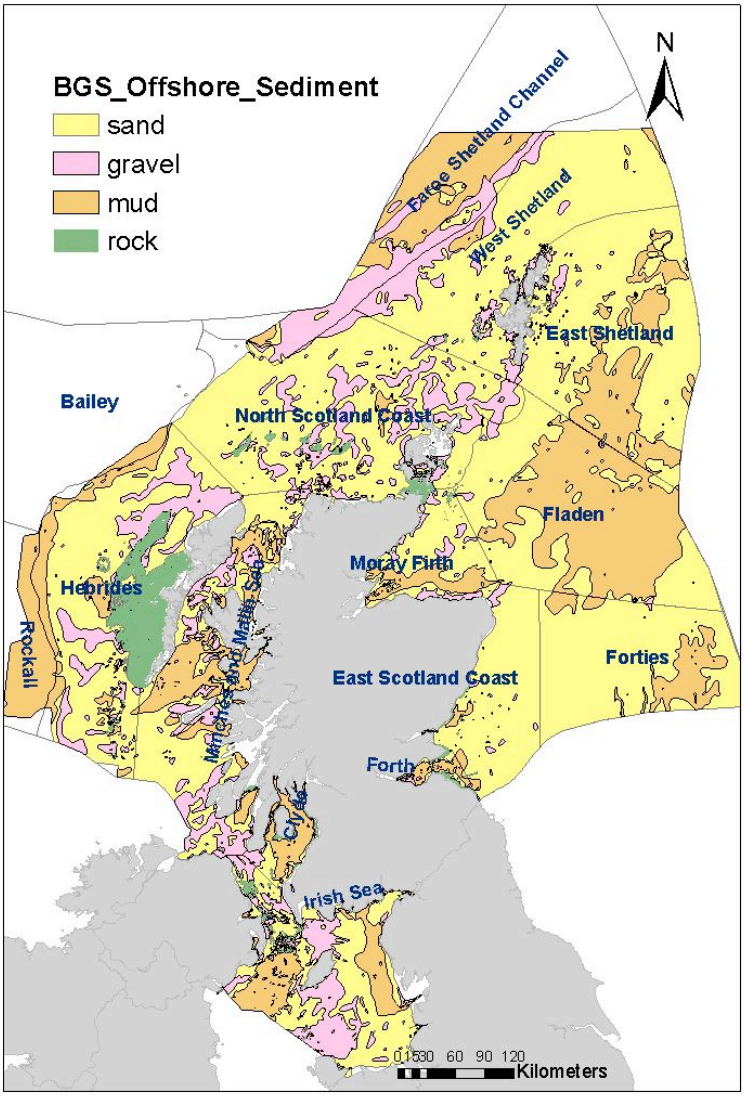
For CSEMP, fish samples are collected annually in the same sea areas as sediments (but not West Shetland), although the sites in the Forth sea area are

within the estuary and therefore not suitable for use under the MSFD which is not applicable to transitional waters. The Hebrides, Rockall, Bailey, north Scotland coast, Faroe-Shetland and Forties sea areas are not routinely sampled for contaminants or effects monitoring for either biota or sediment, although fish were sampled from Rockall, Bailey and Hebrides (2006-2012) and the north Scotland coast (2012) as part of research projects on deep sea fish or MSFD Descriptor 9.

The main source of contaminants in the offshore areas will be from diffuse impacts (although there may be some licensed inputs as a result of petroleum-related activities in some of these areas) from atmospheric deposition or shipping and contaminant concentrations are likely to be low, such as seen in the Fladen for PBDEs and PCBs. It will not be necessary to monitor every Scottish sea area on an annual basis, particularly if concentrations are below the EQS/EAC (or equivalent assessment criteria) (See Section - “Proposed MSFD Descriptor 8 Monitoring for Scotland”).

The available sediment type may not be suitable for contaminant monitoring in all Scottish sea areas. Furthermore, obtaining undisturbed sediment samples in deep water sea areas (Rockall and Bailey) can be difficult; although information is not currently available on the sediment type in these sea areas, there are likely to be areas of fine sediment. Sediment in the east Scotland coast, north Scotland coast, west Shetland and Hebrides sea areas are mainly sand, gravel or rock, with limited areas of fine sediment, and therefore, it may be difficult to find suitable sediment for contaminant monitoring in these areas (Fig. 4). Small areas are currently monitored in the east Scotland coast and west Shetland regions, however, collecting a suitable sample for contaminant monitoring in these area can be difficult due to a lack of suitable sediment. Sampling in the east of Shetland is also undertaken in a small area of fine sediment close to Shetland, sampling here should change to focus on the larger area of fine sediment in the east Shetland area (Fig. 3), using stratified random sampling. Previous sediment sampling in this area has been undertaken with samples being analysed for PAHs[15]; similar to the Fladen area concentrations were found to be close to background and therefore monitoring every 6 years in this area may be sufficient.

Figure 4 Map showing the Sediment type of offshore sediment around Scotland from the British Geological Survey (BGS)



Although fish are sampled from most of the Scottish sea areas with a coastline (not Hebrides or west Shetland), existing fish sampling is focussed on the Clyde and Forth sea areas (Fig. 2), with 3 CSEMP sites (2 estuarine and one coastal), five Clyde trend monitoring stations and one estuarine research site. This is because the Clyde and the Forth are subject to the greatest inputs.

The MSFD covers the UK Exclusive Economic Zone, including coastal waters, but not transitional waters (i.e. estuaries). WFD also includes coastal waters, which for chemical status includes territorial waters to 12 nautical miles. The MSFD applies in coastal waters only in so far as particular aspects of the environmental status of the marine environment are not already addressed through the WFD or other Community legislation. Hence, contaminant monitoring in coastal waters for WFD purposes may also be used for Descriptor 8 assessments. However, WFD has a

requirement for sediment and biota trend monitoring of some Priority Substances (see Appendix 1), this is covered by CSEMP for those contaminants considered to be an issue in Scottish waters[16]. The majority of WFD monitoring in water samples from transitional and coastal waters has shown concentrations are below limits of detection and EQS. Therefore, monitoring of organic contaminants in water samples for WFD has stopped and only trace metals are monitored at sites where concentrations are above the limit of detection. MSFD also has additional requirements not covered by WFD, such as biological effects measurements. Therefore, effects measurement are required in coastal waters for Descriptor 8 monitoring. Monitoring of contaminants and effects measurements in offshore, coastal and transitional waters is undertaken as part of UK CSEMP for OSPAR purposes and will be used for Descriptor 8 assessments; following the integrated assessment research project, an additional shellfish biological effects monitoring has been established.

Shellfish are monitored from around the Scottish coastline (Fig. 1); this is done primarily by SEPA, although MSS undertakes a limited biological effects monitoring programme. Monitoring uses mussels for contaminants and effects, with dogwhelks used for assessing the impacts of TBT (imposex). The mussel contaminants and imposex programmes are sufficient for MSFD purposes; the mussels biological effects programme covers each of the coastal Scottish sea areas on a rolling basis; as with the fish sampling, the numbers of sites in each varies depending upon the perceived environmental hazards, thus there are more sites in the Forth and Clyde than on the northwest coast. The Moray Firth, north and southwest coasts have few sites where mussels can be obtained.

Determinands Required for MSFD

Descriptor 8 covers those substances which are classed as priority substances for WFD (Appendix 1). This list covers a much wider range of contaminants than are currently monitored in marine waters as part of the OSPAR CEMP. Many of these substances will not be relevant for marine waters as they are from land-based sources and concentrations are low (< EQS) in water samples collected from coastal and transitional waters. In 2012 the OSPAR Working Group on Monitoring and on Trends and Effects of Substances in the Marine Environment (MIME) reviewed the contaminants and effects that member states were planning on monitoring for Descriptor 8 and developed a list of common indicators for use in the next JAMP and in assessment of GES for Descriptor 8. This list was reviewed and amended by OSPAR in June 2013 (OSPAR 13/21/1, Annex 4), to produce a minimum set of determinands that should be monitored in all north east Atlantic MSFD sub-regions

(for the UK, OSPAR regions II and III, see previous section) in order to allow comparisons to be made across regions (from Directive 2008/56/EC these are north east Atlantic). For contaminants, the list of common indicators includes the OSPAR CEMP determinands: Hg, Cd, Pb, PCBs and PBDEs in sediments and biota, and PAHs and organotins in sediments. Imposex/intersex in gastropod molluscs was the only biological effect agreed as an OSPAR common indicator.

Currently, as part of the UK CSEMP, sediment and biota from some Scottish sea areas are monitored for all the MIME common indicators, except TBT in sediment. TBT is no longer monitored in sediment for CSEMP as TBT concentrations are low and usually below detection limits, although TBT concentrations continue to be monitored at dredged spoil disposal sites as part of post-disposal monitoring undertaken by MS Licensing Operations Team. Of these, almost all disposal site sediments were assessed as being unlikely to have acute exposure risks and TBT was undetectable in many[17]. Female gastropod molluscs exposed to TBT develop male sexual characteristics, a condition known as imposex and monitoring for imposex is mandatory under the CEMP; within the UK this has taken place on a triennial basis (the last survey was in 2010). The occurrence and severity of imposex in gastropods collected from the Scottish coastline has decreased markedly since the ban on the use of TBT as an antifoulant was introduced. The most recent available imposex data (2009-2011) indicate 11 Scottish sites where the EAC is exceeded. Five of these sites are from Sullom Voe and are being sampled in 2013. Defra are proposing that a UK-wide imposex survey take place in 2014 of any sites which were not classified as consistent with GES in both 2007 and 2010. In Scotland this will require 7 sites to be sampled, six sites that exceed the EAC in 2010 and one which was borderline. SEPA no longer have the capability to determine imposex, hence they will collect the samples and MSS will analyse them.

OSPAR also produced a list of “candidate indicators”, that require further development before being considered for adoption as “common indicators”. This list included four contaminants and five biological effects, although none of these were prioritised for urgent development and inclusion in the OSPAR 2017 Intermediate Assessment. The contaminant candidate indicators are PAHs and TBT in biota and hexachlorobenzene (HCB) and hexachlorobutadiene (HCBD) in sediment and biota. The biological effects candidate indicators are externally visible fish diseases, EROD activity, biliary PAH metabolites, lysosomal stability and micronuclei.

Of the OSPAR contaminant candidate indicators, PAHs in biota are already monitored in Scotland through SEPA’s mussel monitoring, whereas TBT, HCB and HCBD in biota and, HCB and HCBD in sediment are no longer monitored. HCB and

HCBD are classed as WFD PHSs, but are not included on the OSPAR CEMP or pre-CEMP. Hazardous substances included on the OSPAR CEMP and/or classed as priority substances for WFD were reviewed and prioritised in 2010 for Scotland[16]. This report concluded that the occurrence of HCB and HCBD in the Scottish marine environment was low with concentrations generally below detection limits, therefore, monitoring of these contaminants was a low priority and is not required under WFD. Ni and its compounds is a WFD PS, but not listed under the OSPAR CEMP/pre-CEMP and was not suggested as a common or candidate indicator, whilst trend analysis is not required (it is not hydrophobic), both MSS and SEPA routinely report Ni as part of their CEMP trace metals analyses in sediments and biota.

Of the biological effects measurements listed as OSPAR candidate indicators, externally visible fish disease, EROD and bile metabolites are routinely monitored in fish samples by MSS as part of UK CSEMP and reported to national (MERMAN) and international (ICES) databases. Lysosomal stability and micronuclei have also been measured in Scottish waters as part of a MSS integrated contaminants and biological effects research project. MSS have now established the lysosomal stability techniques, however, the micronuclei analyses were out-sourced and there may be a need to develop this expertise in Scotland; MERMAN and ICES databases are being adapted to accept these data.

Assessment Criteria Currently Available for Contaminants and Biological Effects

Criteria have been developed for the assessment of data collected for WFD and OSPAR purposes and which will be used for Descriptor 8 assessments. For WFD, Environmental Quality Standards (EQS) are required to enable assessments of the chemical status of a water body to be made. For consistency between Directives, EQSs are also to be used in assessments for the MSFD, although EQSs have not been developed for sediments. The recently published Priority Substances Directive (2013/39/EU) specifies freshwater and saltwater EQS values for 25 priority substances (PSs) and 9 priority hazardous substances (PHSs) and for 6, non-priority, substances, together with biota EQS values for 1 PS and 10 PHSs (see Appendix 1). EQSs are the boundary between “Good” and “Failing to achieve good” status. Concentrations of each contaminant must be below EQS before the water body is classified as having “Good” chemical status. The EU Technical Guidance Document on how to define EQS values specifies that Quality Standards are produced for several different matrices (freshwater, saltwater, biota, sediment, human health, etc.) and that it is the most protective of these that is chosen as the EQS value. For each PS/PHS, the EC produced a dossier including additional

Quality Standards for each different matrix; for hydrophobic contaminants these could be converted to provide sediment or biota assessment criteria by the use of equilibrium partitioning theory.

Within OSPAR, assessment criteria have been developed for contaminants in sediment and biota so as to permit environmental status assessments to be made. Background Concentrations and Background Assessment Concentrations (BACs) have been developed for OSPAR CEMP determinands in biota and sediment to allow assessment of whether concentrations are at the OSPAR target of close-to-background; Background Concentrations (BCs) determined as freely dissolved concentrations (C_{free}) in saltwater by passive sampling are available for some CEMP substances (e.g. PCBs, PAHs). Environmental Assessment Criteria (EACs) are concentration thresholds designed to be protective of the most sensitive species and have been developed for most CEMP determinands. Where it has not been possible to develop EACs, other assessment criteria were used in the OSPAR Quality Status report 2010, including EC Food Regulation limits and the Effects Range-Low (ERL)[12] of the United States National Oceanic and Atmospheric Administration were used (NOAA, 1999). However, it is recognised that there is a need to further develop assessment criteria for both existing CEMP determinands and the pre-CEMP determinands. OSPAR also have a number of Ecological Quality Objectives (EcoQOs) which are environmental indicators stating aspirations for a healthy North Sea as part of the ecosystem approach; one of these is for imposex in gastropod molluscs. Assessment criteria have been developed for a suite of effects measurements, though currently not approved for use. The ICES/OSPAR Study Group on Integrated Monitoring of Contaminants and Biological Effects (SGIMC) developed assessment criteria analogous to contaminant BACs and EACs for biological effects determinants. Background Assessment Criteria are available for all biological effects common and candidate indicators and Environmental Assessment Criteria are available for four (imposex, fish disease, LMS and PAH metabolites)[18].

The Assessment Criteria to be used for MSFD assessments are WFD EQSs or, where these are not available (e.g. for sediments), OSPAR EACs. The EC WFD Working Group E (Chemicals) is expected to develop additional EQSs, nonetheless, if EQSs/EACs do not become available, sediment ERLs will be used. For OSPAR assessments, BACs are additionally available for sediments, biota and (for some hydrophobic compounds) freely-dissolved water concentrations (determined by passive sampling). Currently available assessment criteria for CEMP determinands and the OSPAR common and candidate indicators are listed below.

Metals (Hg, Cd, Pb, Ni): An EQS is available for Hg in biota (whole fish), but not for sediments or mussels. For sediment, OSPAR BACs are available, but there are no EACs; ERLs were used to assess sediments for the OSPAR Quality Status Report (QSR) 2010. OSPAR BACs are available for mussels and fish, but there are no EACs; EC food regulations were used for the OSPAR QSR 2010. Although not required for MSFD, ERLs are available for Ni in sediment, but no assessment criteria are available for Ni in biota. Saltwater EQSs exist for dissolved Ni, Cd and Pb and are used by SEPA for assessing transitional waters.

PCBs: OSPAR BACs and EACs are available for the ICES7 PCBs (ortho-PCBs, non dioxin-like) for use in sediment, but no EQSs are available. For fish liver and mussels BACs are available; BCs are available for saltwater C_{free}. For the OSPAR QSR 2010, an EAC was calculated using biota sediment accumulation factor ($EAC^{passive}$). For dioxin-like PCBs there is a WFD EQS for whole fish.

PAHs: BACs are available for parent PAHs in sediment but there are no EACs or EQSs available and ERLs were used for the OSPAR QSR 2010. For PAHs in mussels (candidate indicator), BACs and EACs are available for parent PAHs and EQSs exist for fluoranthene and benzo[*a*]pyrene. EQSs exist for naphthalene and anthracene in total water and PAH BCs exist for saltwater C_{free}. Alkylated PAHs are also on the pre-CEMP; there are no BACs or EACs available, but sediment BCs and ERLs are available for some e.g. 2-methyl naphthalene.

PBDEs: BACs and EACs are not available for sediment or biota. There is an EQS for biota (whole fish) however, this value, 0.0085 µg kg^{-1} wet weight, is several orders of magnitude below current achievable detection limits.

TBT: OSPAR BAC and EAC are not available for sediment (common indicator) and the EQS is for water. BAC and EAC are available for shellfish. The Priority Substance Directive (PSD) dossier on TBT includes quality standards for sediments and biota, although these are several orders of magnitude below the detection limits currently achievable by Competent Monitoring Authorities. Within OSPAR, the significance of TBT is assessed using its biological effect (imposex) on gastropods; this will also be used for MSFD.

HCB: OSPAR BACs are available for HCB in mussels and fish, but there are no EACs and no BACs or EACs for sediment. There is a BC for saltwater C_{free} and a WFD EQS for whole fish and ERLs for sediment.

HCBD: There are no BACs or EACs for sediment or biota. However, there is an EQS for whole fish.

Imposex in gastropods: Common indicator. OSPAR have a six class assessment scheme from which an OSPAR EcoQO and ICES biological effect BAC/EACs have been developed.

Externally visible fish diseases: Candidate indicator. ICES BACs and EACs are available for dab, cod and flounder.

Liver macroscopic neoplasms: Included on the OSPAR pre-CEMP, but not a candidate indicator. ICES BAC and EAC values are available for dab.

Liver histopathology (contaminant specific): Included on the pre-CEMP, but not a candidate indicator. ICES BAC and EAC values are available for dab.

Bile metabolites of PAH: Included on the pre-CEMP and a candidate indicator. ICES BAC and EAC values are available for dab.

Lysosomal stability: Included on the pre-CEMP and a candidate indicator. ICES BAC and EAC values are available for fish and mussels.

Micronuclei: Biomarker of genotoxicity, included on the pre-CEMP and as a candidate indicator. ICES BAC values are available for dab, flounder, cod, viviparous blenny and mussels.

EROD: Biomarker of exposure to planar organic compounds (e.g. PAH, dioxins). Included on the pre-CEMP and as a candidate indicator. ICES BAC values are available for dab, flounder, plaice, and cod.

DNA Adducts: Biomarker of effects due to PAHs. Included on the pre-CEMP, but not a candidate indicator. ICES BAC and EAC values available for dab, flounder, haddock and cod.

Sediment Bioassays: Included on the pre-CEMP, but not a candidate indicator. ICES BAC and EAC values available for *Corophium* and *Arenicola* bioassays.

Water bioassays: Included on the pre-CEMP, but not a candidate indicator. ICES BAC and EAC values available for copepod, sea urchin embryo, oyster embryo and mussel embryo bioassays.

Proposed MSFD Descriptor 8 Monitoring for Scotland

MSFD will require the monitoring of contaminants and effects in coastal (≤12 nm) and offshore (>12 nm) waters. Table 3 summarises the gaps identified above in the monitoring programme on a Scottish sea area basis. Monitoring programmes (UK CSEMP) are already in place in coastal and offshore waters for OSPAR CEMP determinands (PAHs, PCBs, PBDEs, Hg, Cd, Pb and imposex) in sediment and/or biota. Selected WFD priority substances are also monitored by SEPA in WFD water bodies, which include transitional and coastal waters. SEPA reviewed results for contaminants in water samples collected from transitional and coastal waters and stopped monitoring where all results were below the limit of detection of the analysis and there was no risk of failing the EQS. However, SEPA continues to monitor CEMP contaminants in biota and sediments to assess trends in contaminants and their status with respect to WFD EQS in biota and OSPAR assessment criteria. Most of the WFD priority substances enter the marine environment from land-based sources and therefore if concentrations are low and below EQSs in coastal and transitional waters, it is very unlikely that there will be an issue for offshore waters unless there are recognised offshore sources e.g. PAHs from flaring and exhausts from ships. Therefore, monitoring of WFD priority substances (that are not on the OSPAR CEMP) should not be required in offshore waters, unless a specific offshore input is identified (from oil and gas installations for example).

Table 3: Summary of gaps in the current monitoring of Scottish sea areas, compared to MSFD and OSPAR requirements.

Sea Area	Gap	Response
Solway and North Channel	None	Monitor as per Table 4
Clyde	None	Monitor as per Table 4
Minches and Malin Sea	None	Monitor as per Table 4
Hebrides	Contaminants in sediment	Investigate if suitable sediment can be found
	Effects in fish	Availability of suitable species to be investigated
	Effects in mussels	Aim to include Loch Roag in 2014 survey
Rockall	Contaminants in sediment	Investigate ability to obtain a suitable sample
	Effects in fish	Availability of suitable species to be investigated

Bailey	Contaminants in sediment	Investigate ability to obtain a suitable sample
	Effects in fish	Availability of suitable species to be investigated
North Scotland Coast	Contaminants in fish	Seek a new fishing area
	Effects in fish	
	Effects in mussels	Aim to include 1 Orkney site in 2014 survey
Faroe-Shetland	Contaminants in sediment	Investigate ability to obtain a suitable sample
	Contaminants in fish	Aim to find a suitable fishing site
	Effects in fish	Availability of suitable species to be investigated
West Shetland	Contaminants in fish	Aim to find a suitable fishing site
	Effects in fish	
	Effects in mussels	Aim to include Clift or Vaila Sound in 2014 survey
East Shetland	Contaminants in sediment	Extend area of Stratified Random sampling
	Effects in mussels	Aim to include Ness of Sound Shore in 2014 survey
Forties	Contaminants in sediment	Begin Stratified Random sampling
	Contaminants in fish	Aim to establish a suitable fishing site
	Effects in fish	
Fladen	None	Monitor as per Table 4
Moray Firth	None	Monitor as per Table 4
East Scotland Coast	None	Monitor as per Table 4
Forth	Contaminants in fish	Establish a fishing site in MSFD waters
	Effects in fish	

The frequency of monitoring for MSFD Descriptor 8 should be based on whether concentrations in sediment and biota exceed the relevant assessment criteria, and if there are trends or concentrations are stable.

- Where concentrations are below the BACs (OSPAR CEMP determinands only) and are stable or declining, monitoring will be required less frequently, and only to confirm there has been no change. Monitoring should be undertaken once per MSFD reporting cycle (every 6 years).
- Where concentrations are acceptable (less than relevant assessment criteria, EQS, ERL or EAC) but greater than the BAC, and concentrations are stable or declining, it may be appropriate to reduce the frequency of monitoring to one in every three years. If concentrations are below BACs, but if there is an upward trend monitoring should also be done every 3 years.
- Annual monitoring will continue at sites where contaminant concentrations are elevated (greater than relevant assessment criteria, EQS, ERL or EAC). Annual monitoring should also be undertaken if concentrations are above BACs, but below EACs/EQS, but there is an upward trend.

This is similar to the approach adopted in England and Wales. SEPA have already reduced their sediment monitoring (contaminants and benthic invertebrates) to one-year-in-three at some locations, although annual monitoring continues at locations where concentrations are elevated (Clyde and Forth). This above approach should be taken for sediment and biota in all Scottish sea areas. Proposed monitoring frequency for each contaminant groups is shown in Table 4. Concentrations of PAHs, PCBs, PBDEs and trace metals in a number of Scottish sea areas are low, however, no area is below BACs for all contaminant groups. PAHs and most PCBs are less than BACs in sediment from east Shetland, west Shetland and Fladen. Some metals (Pb in Fladen) and CB118 exceed BACs, however, concentrations are below EACs for all contaminant groups in sediment from these areas, and are stable or showing downwards trends. Therefore, monitoring should be undertaken every 6 years for PAHs (Fladen and east Shetland[5]) and trace metals (east Shetland) and every 3 years for PCBs (Fladen and east Shetland) and for trace metals (Fladen). Sediment from Moray Firth, Solway Firth and North Channel, Minches and Malin Sea and east Scotland coast are below ERLs for PAHs, but exceed EACs/ERLs for some metals and CB118. Concentrations are either stable or declining and therefore monitoring should be every 3 years for PAHs and annually for PCBs and trace metals. Fish data (PCBs and trace metals) is also available for these areas, and concentrations are below assessment criteria (EACs or EC food safety levels) and are not increasing for all contaminant groups, except for trace metals (Cd) in the east Scotland coast. Therefore, fish monitoring should be every 3 years, except for trace metals in east Scotland coast where annual monitoring should continue. PBDE concentrations in sediment from Scottish sea areas are generally below LoDs

[5] Monitoring of sediment in West Shetland will stop as sediment is sandy and in East Shetland sampling will move to focus on a larger area of fine sediment

(except in Clyde and Forth). There are currently no OSPAR assessment criteria (BACs or EAC). There is an EQS proposed, but this is below detection limits using the best available techniques. However, if concentrations are close to zero and at least below the limits of detection of the most advanced analytical techniques in general use then monitoring can be reduced[5]. Monitoring for PBDEs in sediment should therefore be reduced to once per reporting cycle (6 years) in all areas except the Clyde and Forth, where annual monitoring should continue. In the Clyde assessment criteria (EACs/ERLs/EC values) are generally exceeded for all contaminant groups in fish and sediment therefore annual monitoring of sediment and biota should continue.

Table 4 Frequency contaminant groups should be monitored in sediment and fish from Scottish sea areas. A number of areas are not currently monitored routinely (*). These areas should be sampled on a 6 yearly rolling programme for all contaminant groups and biological effects (if possible though sampling in some areas may be difficult). North Scotland coast and west Shetland does not have suitable sediment type for sediment monitoring and therefore, should only be sampled for fish (if possible)

Scottish Sea Area	PCBs (ICES 7)	PAHs (OSPAR Set)	PBDEs (OSPAR Set)	Trace Metals	Biological effects (OSPAR MIME common and candidate indicators)
Solway and North Channel	Sediment: annual Fish: 3 years	3 years	Sediment: 6 years Fish: 3 years	Sediment: annual Fish: 3 years	Fish: 3 years Mussels: 3-4 years
Clyde	annual	annual	annual	annual	Fish: annual Mussels: 3-4 years Gastropods: 2014
Minches and Malin Sea	Sediment: annual Fish: 3 years	3 years	Sediment: 6 years Fish: 3 years	Sediment: annual Fish: 3 years	Fish: 6 years Mussels: 6 years Gastropods: 2014

Hebrides*	6 years	6 years	6 years	6 years	Fish: 6 years Mussels: 6 years
Rockall*	6 years	6 years	6 years	6 years	N/A
Bailey*	6 years	6 years	6 years	6 years	N/A
North Scotland Coast*	6 years	6 years	6 years	6 years	Fish: 6 years Mussels: 6 years Gastropods: 2014
Faroe-Shetland*	6 years	6 years	6 years	6 years	N/A
West Shetland	6 years	6 years	6 years	6 years	Fish: 6 years Mussels: 6 years Gastropods: 2 years
East Shetland	3 years	6 years	6 years	6 years	*Fish:* 6 years Mussels: 6 years Gastropods: 2014
Forties*	6 years	6 years	6 years	6 years	Fish: 6 years
Fladen	3 years	6 years	6 years	3 years	Fish: 6 years
Moray Firth	Sediment: annual Fish: annual	3 years	Sediment: 6 years Fish: annual	Sediment: annual Fish: annual	Fish: annual Mussels: 6 years Gastropods: 2014
East Scotland Coast	Sediment: annual Fish: annual	3 years	Sediment: 6 years Fish: 3 years	annual	Fish: annual Mussels: 3 years
Forth	annual	annual	annual	annual	Fish: annual Mussels: 3 years Gastropods: 2014

Biological effects are not required for the WFD, although their role in providing information on substances not known *a priori* to be present in the environment, and on the effects of mixtures of substances has been recognised by the EU commissioning the Chemical Monitoring and Emerging Pollutants expert group of its Working Group E (Chemicals) to produce a technical report on aquatic effect-based monitoring tools. However, some OSPAR pre-CEMP determinands (including the PAH-specific effects measurements of EROD and bile metabolites) are currently monitored in fish in offshore waters as part of CSEMP, or have been measured during research programmes. Some of these were noted by OSPAR MIME as being candidate indicators likely to be used by a number of Member States, allowing regional comparisons.

Scotland will monitor selected biological effects measurements (including the common and candidate indicators) from the ICES integrated scheme on a rolling basis such that we sample from each Scottish sea area at least once per MSFD reporting cycle. The scheme allows for monitoring for mixture effects, which chemical analyses alone cannot do, and provides a view of the health of monitored wildlife, in addition to explicitly informing on contaminants and their direct (and additive) effects.

At locations where pressures are highest (Clyde and Forth), or where there is evidence of several effects currently being above EAC (e.g. in the Integrated Assessment research project), then sampling should be conducted annually; if several effects are above BAC then monitoring should be every three years; otherwise once per 6-year MSFD cycle.

In fish we would use the ICES integrated approach annually in the Clyde and Forth, with samples analysed for: EROD, bile metabolites, lysosomal stability, micronucleus, liver histopathology, liver neoplasms, and external disease. The east Scotland coast and the Moray Firth should also be sampled annually for biological effects measurements. The Solway and North Channel should be sampled every three years, whereas the Minches and Malin Sea, Fladen and Shetland should be sampled every 6 years. New fish sampling sites should be established in the offshore part of the Forth sea area, the north Scotland coast and in the Forties sea area, with possibly (if a suitable site can be found) additional ones in the oil production areas of the east Shetland and Fladen sea areas, although in the latter two areas the sentinel species would need to be cod, and not dab. The frequency of sampling at the new sites will be established in light of the data generated.

With further regard to the spatial distribution of fishing sites, it is proposed to reduce the number of sites visited annually in the Clyde sea area from 7 to 5, maintaining the Bowling (Clyde estuary), Holy Loch (inner Firth), Garroch Head (middle Firth), Hunterston (Largs Channel) and Pladda (outer Firth) sites; the inner four sites to be sampled annually and the Pladda site every 3 years. In the Forth sea area, the Alloa site will no longer be sampled and will be replaced with a coastal water site in the outer Firth, the frequency of sampling to depend upon the data obtained. In the east Scotland coast sea area, the St Andrews Bay site will be moved, if a suitable site can be found, to the Tay estuary and sampled annually, with annual sampling continuing at the Montrose Bank site. Currently there are two fishing sites in each of the Moray Firth and the Minch/Malin sea areas. The Moray Firth sites should be visited every 3 years. In The Minches and Malin Sea, the current North Minch site will be visited one year in six, and sampling at Colonsay will be stopped.

Working with SEPA, contaminants and effects were determined in mussels as part of the MSS research project on the integrated assessment of contaminants and effects. Samples were analysed from the Forth, the Clyde and east Scotland coast sea areas. It is intended to continue using this monitoring using a rolling sampling design to cover each of the Scottish coastal sea areas at least once per OSPAR/MSFD reporting cycle.

Monitoring Responsibilities / Practicalities

The division of marine monitoring work between SEPA and MSS is regularly reviewed and organised through the Scottish Clean and Safe Seas Coordination Group, which meet biannually.

Monitoring for the WFD is the responsibility of SEPA, and under MSFD this responsibility extends to the limit of territorial waters (12 nm) for chemical status. Current monitoring activity by SEPA and MSS was reviewed above. Briefly, SEPA monitor contaminants in mussels and inshore sediments; MSS monitor effects and contaminants in fish, effects in mussels, contaminants in offshore sediments, and contaminants in some inshore sediments from the Clyde. Both organisations have historically monitored coastal imposex.

Under the monitoring programme proposed here, SEPA would continue to undertake coastal mussels monitoring, and MSS will co-ordinate with this in order to undertake biological effects monitoring in mussels on a rolling basis. Imposex monitoring (except for SOTEAG) will probably cease after the small 2014 survey. SEPA will be responsible for sediment monitoring within 12 nm, whilst MSS will be responsible for

sediment monitoring beyond 12 nm. The current stratified random/fixed sediment sampling programme undertaken by SEPA and MSS for CSEMP will also fulfil the sediment monitoring requirements of MSFD. However, to ensure a greater coverage of all Scottish sea areas, areas not currently monitored will be sampled using a stratified random/fixed sampling design, with the frequency being dependent on the concentrations found (annual to 6 yearly).

MSS will be responsible for monitoring of contaminants and biological effects in fish from Scottish waters and will coordinate this with SEPA's WFD monitoring of fish ecology in transitional waters. Co-ordination of research vessels for efficiency in sample collection will be through the Scottish Clean and Safe Seas Coordination Group and the MSS/SEPA ships officers.

Conclusions

1. The Marine Strategy Framework Directive's Descriptor 8 states that ***'Concentrations of contaminants are at levels not giving rise to pollution effects'***. Therefore, for Descriptor 8 assessment, contaminant concentrations and effects measurements must be assessed against the relevant assessment criteria. For common indicator contaminants this will be the WFD EQS (biota), or OSPAR EAC, and for effects measurements the ICES EAC.

2. Currently EQSs and EACs are not available for all common indicators. However, the EC WFD Working Group E (Chemicals) is expected to develop additional EQSs. Where suitable EQSs/EACs are not available, alternative criteria (e.g. Effects Range-Low) will be used for assessment purposes, but not for compliance purposes. However, if EQSs/EACs do not become available, sediment ERLs will be used.

3. The ultimate aim of the WFD (Article 1; and by extension the MSFD), and of the OSPAR Hazardous Substances Strategy, is for contaminant concentrations to be close-to-background; this will be assessed by comparison with OSPAR BACs.

4. Descriptor 8 covers those substances which are classed as priority substances for WFD. However, many of these substances will not be relevant for marine waters. OSPAR MIME recently reviewed the contaminants and effects that Member States were intending to monitor for Descriptor 8 and developed a list of common indicators: concentrations of Hg, Cd, Pb, PCBs and PBDEs in sediment and biota, PAHs and TBT in sediment, and presence

or otherwise of imposex/intersex. All are OSPAR CEMP determinands. In addition, PAHs and TBT in biota and HCB and HCBD in sediment and biota were classed as candidate indicators. Five biological effects measurements were proposed as candidate indicators: externally visible fish disease, EROD, bile metabolites, lysosomal stability and micronuclei. This is a minimum list of what should be measured to allow comparisons across regions to be made.

5. TBT in sediment is the only common indicator not routinely monitored, since the impact of TBT is assessed by its effects on gastropods. TBT in biota is also a candidate indictor and monitoring in sediment or biota is required for the CEMP. Sediment monitoring in Scotland stopped in 2006, as concentrations were found to be below detection limits. In most areas the biological effects of TBT (imposex) are also low and declining. No additional monitoring of TBT in sediments will be undertaken for MSFD.

6. Of the contaminant candidate indicators, HCB and HCBD are not routinely monitored in sediment or biota in Scotland. Due to the low concentrations of both these contaminants in water, sediment and biota they are not considered to be an issue in Scotland and monitoring of HCB and HCBD will not be undertaken for MSFD. PAHs in biota are also a candidate indicator, and are already monitored in Scotland through SEPA's mussel monitoring; no additional monitoring is required for MSFD.

7. WFD contaminants monitoring data will be used for Descriptor 8 assessments of coastal waters. Due to the very low concentrations of most WFD priority substances in water samples (less than LoDs and EQSs for organic contaminants) collected from Scottish transitional and coastal waters, monitoring of most has been stopped. Therefore, there is no requirement to undertake any additional analysis in offshore waters other than where there may be a recognised source e.g. from oil and gas installations.

8. UK CSEMP monitoring of OSPAR CEMP determinands, including biological effects measurements, can be used for MSFD assessments.

9. No areas are below BACs for all contaminant groups in sediment and biota. For contaminant groups that have reached background (and there are no upwards trends) monitoring should be reduced to once every reporting cycle. For areas where concentrations are greater than BACs, but less than EQSs/EACs/ERL/EC levels and showing no upward trends (or <BACs but increasing trend) monitoring should be reduced to every 3 years. Annual

monitoring of contaminants should only continue if concentrations exceed EACs/ERLs/EC levels, or if >BACs and there is also an upward trend. Stratified random/fixed sampling of fine sediments will be applied to all sea areas, including the sea areas not previously monitored.

10. OSPAR CEMP determinands (PAHs, PCBs and PBDEs) have previously been assessed in fish and sediment from Scottish sea areas. Contaminant concentrations in some areas (Fladen and east Shetland) are <EACs (and often below BACs) and concentrations are either stable or decreasing. Monitoring in these areas should be reduced to every 3 or 6 years (depending on contaminant group and area).

11. PBDEs in sediment are mainly below LoDs and generally only found in the Clyde and Forth sediment. Monitoring of PBDEs in all areas except the Clyde and Forth should be reduced to every 6 years.

12. Contaminant concentrations in the Solway and North Channel, Minches and Malin Sea, Moray Firth and east Scotland coast are mainly below EQS/EACs/ERLs/EC levels and therefore, monitoring should be reduced to 3 yearly (PAHs in sediment and PCBs and trace metals in fish). Annual monitoring should continue for PCBs and trace metals in sediment as EACs/ERLs/EC levels are exceeded

13. Some areas have not been routinely monitored to date for contaminants, such as Forties and Hebrides. Concentrations are likely to be low. These areas should be sampled on a rolling basis (every 6 years, unless concentrations are found to be higher than expected). The sediment type in a number of areas is not suitable for contaminant monitoring, being mainly sand, gravel or rock, (west Shetland, north Scotland coast), therefore, sediment monitoring in these areas is not required.

14. Whilst land-based inputs of contaminants to the Forties, Fladen, east Shetland and west Shetland sea areas are very limited, there are potential inputs from the oil and gas industry, and a potential for cumulative impacts due to the number of installations. A review should be conducted of what substances are discharged, whether any are PSs, and whether any of the discharged substances may require consideration as Specific Pollutants.

15. WFD monitoring does not include biological effects. The only biological effect in the OSPAR CEMP is imposex, which is monitored every 3 years. The

levels of this have declined such that it should only be monitored at sites where it has not reached a classification consistent with GES in two consecutive surveys.

16. In fish, effects monitoring (including the OSPAR pre-CSEMP and candidate indicators) should be undertaken annually in the Forth, Clyde, Moray Firth and at Montrose Bank, every 3 years at the Solway Firth and North Channel and every 6 years elsewhere. Currently SEPA and MSS undertake effects monitoring in mussels as part of a research project and propose to continue with this programme. These data can be used for Descriptor 8 assessments.

17. Most Scottish contaminants and effects data are currently held in MERMAN and are readily available for Descriptor 8 assessments. Station Dictionary Names will be obtained for any additional sites proposed for Descriptor 8 monitoring and this data will be submitted to MERMAN. However, there may be resourcing issues for the addition of any new contaminants/effects to MERMAN, as this will require changes to the database structure.

Acknowledgements

The authors would like to thank Judy Dobson and Clemens Engelke for providing information from SEPA's sampling programme.

References

1. UK Marine Monitoring and Assessment Strategy Community (UKMMAS) (2010). Charting Progress 2 Feeder report: Clean and Safe Seas. (Eds. Law, R. and Maes, T.). Published by Department for Environment Food and Rural Affairs on behalf of UKMMAS. 366pp.
2. Baxter, J. M., Boyd, I. L., Cox, M., Donald, A. E., Malcolm, S. J., Miles, H., Miller, B., Moffat, C.F., (Editors), 2011. Scotland's Marine Atlas: Information for the national marine plan. Marine Scotland, Edinburgh. pp. 191.
3. UK Initial Assessment and Proposals for Good Environmental Status, 2012. http://www.defra.gov.uk/consult/files/20120327-msfd-consult-document.pdf
4. ICES and JRC, 2010. Task Group 8 Report: Contaminants and Pollution Effects.
5. OSPAR Commission, 2010. OSPAR Coordinated Environmental Monitoring Programme (CEMP), OSPAR Agreement 2010-1.

6. OSPAR Commission, 2010. The North-East Atlantic Environment Strategy: Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2010–2020. OSPAR Agreement 2010-3.
7. The Scotland River Basin District (Surface Water Typology, Environmental Standards, Condition Limits and Groundwater Threshold Values) Directions, 2009. http://www.scotland.gov.uk/Resource/Doc/298071/0092869.pdf
8. L. Webster, C. D. Robinson and R. Fryer, 2013. Design of a Sampling Programme and Measurement of Contaminants in Food for Marine Strategy Framework Directive Descriptor 9, Scottish Marine and Freshwater Science (*DRAFT*).
9. Gubbins, M.J., Strand, J., Thain, J. and Davies, I.M. 2012. Assessment criteria for imposex in marine gastropods affected by exposure to organotin compounds. In Davies, I.M., and Vethaak, D. (ed.s), 2012. *Integrated marine environmental monitoring of chemicals and their effects.* ICES Cooperative Research Report number 315. International Council for the Exploration of the Sea, Copenhagen, Denmark. 277pp.
10. OSPAR 2012. *JAMP Guidelines for the Integrated Monitoring and Assessment of Contaminants and their effects.* OSPAR Commission (Agreement 2012-09), London, UK. 22pp.
11. Ross, D, 2012. A geographic to monitoring in Scotland's transitional and coastal waters, http://www.sepa.org.uk/science_and_research/data_and_reports/water.aspx
12. OSPAR, 2010, Quality status report 2010. OSPAR Commission, London 176pp.
13. L. Webster, M. Russell, P. Walsham, L. A. Phillips, I. Hussy, G. Packer, E. J. Dalgarno and C. F. Moffat, 2011 An assessment of persistent organic pollutants in Scottish coastal and offshore marine environments. *J. Environ. Monit*, **13**, 1288-1307
14. Davies, I.M., and Vethaak, D. (ed.s), 2012. *Integrated marine environmental monitoring of chemicals and their effects.* ICES Cooperative Research Report number 315. International Council for the Exploration of the Sea, Copenhagen, Denmark. 277pp.
15. Russell, M., Webster, L., Walsham, P., Packer G., Dalgarno, E. J., McIntosh, A. D., Fryer R. J. and Moffat C. F., 2008. Composition and concentration of hydrocarbons in sediment samples from the oil producing area of the east Shetland basin, Scotland**,** *J. Environ. Monit.*, **10**, 559 – 569.
16. L. Webster, C. D. Robinson, M. J. Gubbins, I. M. Davies and C. F. Moffat, 2004. A review of hazardous substances in the Scottish marine environment. FRS Internal Report No. 01/04.

17. Devalla, S., Robinson, C.D., Megginson, C. and Webster, L. 2013. *Analysis and assessment of organotins in sediments from Scottish harbours and sea disposal sites.* Poster presentation at SETAC Europe 23rd Annual Meeting in Glasgow, Scotland. 12-16 May, 2013.
18. Davies, I.M., Gubbins, G., Hylland, K., Thain, J., Maes, T., Martinez-Gomez, C., Giltrap, M., Burgeot, T., Wosniok, W., Lang, T. and Vethaak, A.D. 2012. Technical Annex: assessment criteria for biological effects measurements. In Davies, I.M., and Vethaak, D. (ed.s), 2012. *Integrated marine environmental monitoring of chemicals and their effects.* ICES Cooperative Research Report number 315. International Council for the Exploration of the Sea, Copenhagen, Denmark. 277ppOSPAR Commission 2008. Draft agreement on CEMP assessment criteria for the QSR 2010, MON 09/8/1/6 Add.1.
19. Robinson, C.D., MacNeish, K., Webster, L., Baršienė, J., Butrimavičienė, L., Bignell, J., Katsiadaki, I., Sabire, M., and Gubbins, M., 2013. *An assessment of contaminants and their biological effects in Scottish flatfish.* Poster presentation to the 23rd Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC Europe), 12-15th May 2013, Glasgow, UK.
20. EU 2013. *Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy.* Official Journal of the European Union, L226, 1-17.

APPENDIX 1

Priority Substances (2013/39/EU) and OSPAR Chemicals for Priority Action

PSD substance number	Name	Priority Hazardous Substance?	AA-EQS$_{sw}$ (ug/L)[6]	EQS$_{biota}$ (ug/kg w.wt)[ii]	Trends in biota/sediment required?	Common or Candidate Indicator?	OSPAR Priority List?	Sediment BAC / EAC	Biota BAC / EAC
1	Alachlor		0.3						
2	Anthracene	Y	0.1		Y	Common	CEMP	Y / ERL	Y / Y
3	Atrazine		0.6						
4	Benzene		8						
5	Brominated diphenyl ethers (PBDEs; n=4)	Y		0.0085	Y	Common	CEMP	N / N	N / N
6	Cadmium and its compounds	Y	0.2		Y	Common	CEMP	Y / ERL	Y / food
7	C10-13 chloroalkanes	Y	0.4		Y				
8	Chlorfenvinphos		0.1						
9	Chlorpyriphos		0.03						
10	1,2-dichloroethane		10						
11	Dichloromethane		20						
12	Di(2-ethylhexyl)phthalate (DEHP)	Y	1.3		Y		Y	N / N	N / N
13	Diuron		0.2						
14	Endosulfan	Y	0.0005				Y	N / N	N / N
15	Fluoranthene		*0.0063*[iii]	30[iv]	Y	Common	CEMP	Y / ERL	Y / Y
16	Hexachlorobenzene (HCB)	Y		10	Y	Candidate			
17	Hexachlorobutadiene (HCBD)	Y		55	Y	Candidate			
18	Hexachlorocyclohexane	Y	0.002		Y		Y	Y / N	Y / Y
19	Isoproturon		0.3						
20	Lead and its compounds		1.3		Y	Common	CEMP	Y / ERL	Y / food
21	Mercury and its compounds	Y		20	Y	Common	CEMP	Y / ERL	Y / food
22	Naphthalene		2			Common	CEMP	Y / ERL	Y / Y
23	Nickle and its compounds		8.6						
24	Nonylphenols	Y	0.3				Y	N / N	N / N

[6] Environmental Quality Standard for salt waters as an annual average

[ii] EQS in biota (refers to whole fish unless otherwise indicated)

[iii] Biota monitoring is recommended

[iv] EQS$_{biota}$ refers to molluscs and crustacea

25	Ocytlphenols		0.01				Y	N / N	N / N
26	Pentachlorobenzene	Y	0.0007		Y				
27	Pentachlorophenol		0.4				Y	N / N	N / N
28	Polycyclic aromatic hydrocarbons (n=5, EQS refers to benzo[*a*]pyrene)	Y	*0.00017*[ii7]	5[iv]	Y	Common	CEMP	Y / ERL	Y / Y
29	Simazine		1						
30	Tributyltin compounds (TBT cation)	Y	0.0002		Y	Common	CEMP	N / N	Y / Y
31	Trichlorobenzenes		0.4				Y	N / N	N / N
32	Trichloromethane (chloroform)		2.5						
33	Trifluoralin	Y	0.03				Y	N / N	N / N
34	Dicofol	Y	*0.000032*[iii]	33	Y		Y	N / N	N / N
35	Perfluorooctane sulphonic acid and its derivatives (PFOS)	Y	*0.00013*	9.1	Y		pre-CEMP	N / N	N / N
36	Quinoxyfen	Y	0.015		Y				
37	Dioxins and dioxin-like compounds (n=29)	Y		0.0065[v]	Y		pre-CEMP	N / N	N / N
38	Aclonifen		0.012						
39	Bifonex		0.0012						
40	Cybutryne (Irgarol)		0.0025						
41	Cypermethrin (n=4 isomers)		0.000008						
42	Dichlorvos		0.00006						
43	Hexabromocyclododecanes (HCBDD; n=5)	Y	*0.0008*[iii]	167	Y		CEMP	N / N	N / N
44	Heptachlor and heptachlor epoxide	Y	*0.00000001*[iii]	0.0067	Y				
45	Terbutryn		0.0065						
-	Polychlorinated biphenyls					Common	CEMP	Y / Y	Y / Y
-	Tetrabromobisphenol A (TBBP-A)						Y	N / N	N / N
-	2,4,6-tri-*tert* butylphenol						Y	N / N	N / N
-	Dibutyl phthalate						Y	N / N	N / N
-	Methoxychlor						Y	N / N	N / N

[7ii] *Biota monitoring is recommended*

[iv] *EQS biota is for molluscs and crustacean*

[v] *EQS biota is for fish, molluscs and crustacea*

ISSN: 2043-7722 ISBN: 978-1-78256-984-8 (web only)

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

Produced for the Scottish Government by APS Group Scotland
DPPAS194963 (10/13)

Published by the Scottish Government, October 2013

w w w . s c o t l a n d . g o v . u k