CLEAN AND SAFE : HAZARDOUS SUBSTANCES AND THEIR EFFECTS

Concentration of mercury (Hg), cadmium (Cd) and lead (Pb) in biota and sediment

Scottish Government
Riaghaltas na h-Alba
gov.scot

Key message

Mercury concentrations in sediment showed significant decreases in all three regions, but in the Irish Sea (Clyde and Solway) they are still at levels where adverse effects occur. Lead concentrations were of concern in Irish Sea (Clyde and Solway) sediment. Mercury, cadmium and lead concentrations in biota (fish and shellfish) were above background but below European Commission food limit.

Sample of mud collected from the seabed for the analysis of Hg, Cd and Pd. The sample was collected using a Day grab.

Background

Heavy metals are ubiquitous in the marine environment being from both natural and anthropogenic sources. Mercury (Hg), cadmium (Cd) and lead (Pb) are three of the most toxic heavy metals commonly found in the marine environment. Natural sources of Cd and Hg include volcanic activity. Principal anthropogenic inputs of mercury to the environment are from fossil fuel combustion, metal and cement production. Inputs of Cd include non-ferrous metal mining and smelting, batteries and the use of phosphate fertilizers. Sources of Pb include non-ferrous metal mining and smelting, batteries, spent ammunition and lost fishing tackle.

Heavy metals often end up in marine sediment, where they may be trapped in lower layers unless the sediments are disturbed. Hg and Cd can bioaccumulate in marine food chains.

Due to their persistence, potential to accumulate and toxicity, analyses (Figure 1) of Hg, Cd and Pb in sediment and biota (fish and shellfish) are required for the OSPAR Coordinated Environmental Monitoring Programme (CEMP), the Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD) (Hg in biota only). Heavy metals have the potential to impact on an organisms activity, growth, metabolism, reproduction and overall

Figure 1: Inductively coupled plasma mass spectrometry (ICP-MS) inlet and autosampler, with standard bottles alongside. Heavy metals were analysed in fish, shellfish and sediment by ICP-MS.

chance of survival. To fulfill these monitoring commitments, heavy metals are monitored in sediment and biota as part of the UK Clean Seas Environmental Monitoring Programme (CSEMP) for 4 biogeographic regions (Figure 2): Irish Sea (Clyde and Solway), Minches and Western Scotland, Scottish Continental Shelf and Northern North Sea. See Introduction to SMA2020 for more about the areas used.

Results

Hg, Cd and Pb concentrations are measured in sediment and biota (shellfish and fish) samples taken between 1999 and 2017 (sediment) or 2018 (biota) from four biogeographic regions (Figure 2), in cycles varying from annually to every six years. Only biogeographic regions with at least three stations with a reasonable geographic spread were included in the regional assessment of status and trends. There were insufficient sites for the regional assessment of status and trends of metals in sediment and biota from Scottish Continental Shelf. Shellfish (blue mussel) were collected in coastal and estuarine areas only, whilst sediment and fish were collected from coastal and more offshore areas.

Heavy metal concentrations in sediment and biota (blue mussels and fish) were compared to the OSPAR Background Assessment Concentration (BAC). BACs are used to assess whether concentrations are near background values for naturally occurring substances, such as heavy metals. In addition, metal concentrations in shellfish and fish were compared to the EC Maximum Permissible Concentrations (MPC) and concentrations in sediment compared to the United States Environmental Protection Agency's Effects Range-Low (ER-L) (Figure 3). Adverse effects on marine organisms are rarely observed when concentrations are below the ER-L value.

The highest Hg and Pb concentrations in sediment were in the Irish Sea (Clyde and Solway), with mean regional concentrations exceeding the ER-L. The Irish Sea (Clyde and Solway) includes the Clyde, the most industrialised and urbanised Scottish sea area. Cd in sediment was at background in all three assessed regions. Hg and Pb in sediment were at background in the Northern North Sea along with Hg in sediment in the Minches and Western Scotland region. Heavy metal concentrations in biota were similar in all three biogeographic regions, with mean regional concentrations for all three metals being above background but below the MPC.

Trends in heavy metal concentrations were assessed in biogeographic regions where there were at least five years of data (Figure 4). Three regions were assessed for trends in sediment and biota, where concentrations were either stable or declining, except for Cd in sediment in the Minches and Western Scotland region. Although there was a significant increasing trend for Cd in sediment in the Minches and Western Scotland region, concentrations are still at background (<BAC). Hg concentrations are declining in sediment in)all three regions. Metal concentrations are stable in biota in all regions assessed. Similar to sediment, a positive %yearly change was observed for biota in the Minches and Western Scotland region, however in this case the increase was not significant.

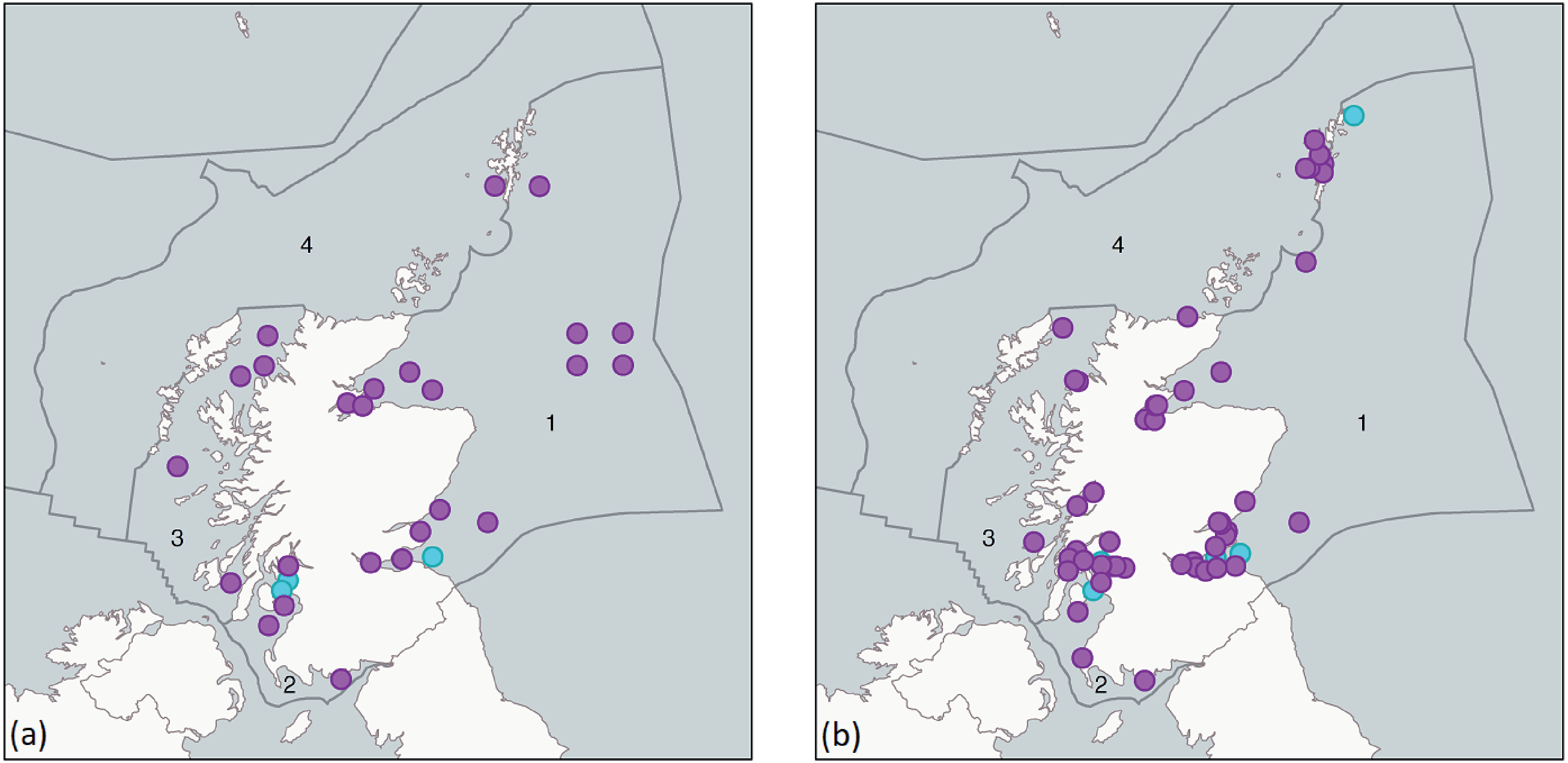
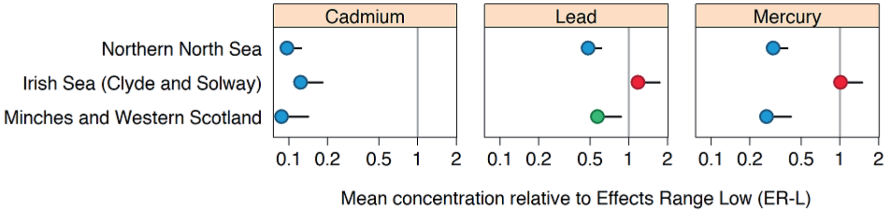
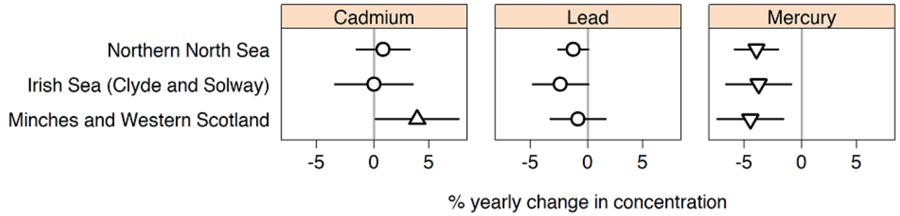


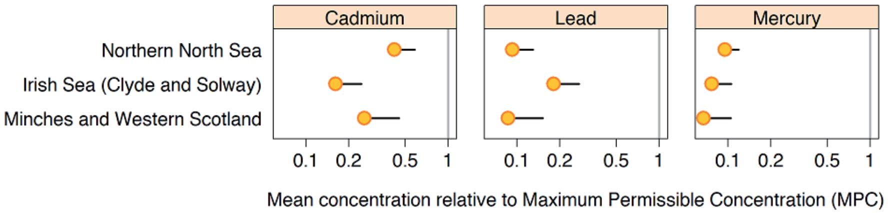
Figure 2:
Monitoring stations used to assess heavy metal (Cd, Hg and Pb) concentrations in (a) sediment and (b) biota (shellfish and fish) per biogeographic region (grey lines). Magenta dots = stations used for trend and status assessments. Cyan dots = stations used for status assessment only. 1, Northern North Sea; 2, Irish Sea (Clyde and Solway); 3, Minches and Western Scotland; 4, Scottish Continental Shelf.



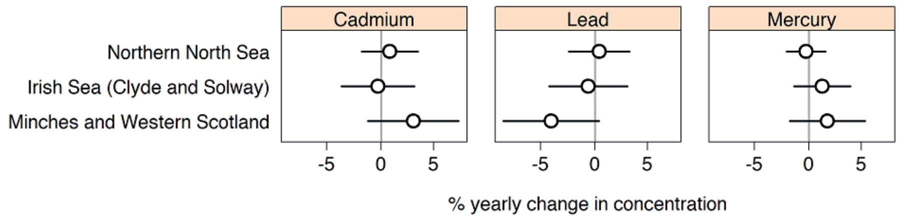
(a)



(a)



(b)



(b)

Figure 3:
Status assessment; mean Hg, Cd and Pb concentration in (a) sediment and (b) biota (fish and shellfish) in each Scottish biogeographic region relative to the ER-L (sediment) or European Commission Food Limit (MPC; biota) (with 95 % confidence limits), where the ER-L or MPC is 1. Concentrations are significantly below the ER-L/MPC if the upper confidence limit is below 1. Blue = statistically significantly below the BAC. Green = at or above the BAC but statistically significantly below the ER-L. Orange = at or above the BAC but statistically significantly below the MPC. Red = statistically significantly above the ER-L/MPC. Orange is used rather than green due to the uncertainties in using the EC Maximum Permissible Concentrations (MPC) for contaminants in foodstuffs for environmental assessments.

Figure 4:
Trend assessment; percentage yearly change in Hg, Cd and Pb concentrations in each Scottish biogeographic region for (a) sediment and (b) biota (fish and shellfish). There is a significant trend if the confidence limits does not cut the vertical line at 0. Upward trends (upwards triangle), downward trends (downwards triangle), no change (circle) and 95 % confidence limits (lines).

Conclusion

Mean concentrations for all three metals in biota were above background concentrations but below the EC food safety level. The uncertainties in the assessment criteria used (MPC for contaminants in foodstuffs) means there is low confidence in concentrations in biota being acceptable. Further work is needed to develop suitable assessment criteria for metals in biota to improve understanding of the effects of the metals on the marine environment.

For sediments, concentrations were at background for all three metals in the Northern North Sea, for Cd and Hg in the Minches and Western Scotland and for Cd in the Irish Sea (Clyde and Solway). Pb and Hg concentrations were unacceptable in the Irish Sea (Clyde and Solway) (>ER-L). However, concentrations of Hg are decreasing in sediment in all three regions.

Metal concentrations need to be kept under surveillance, as concentrations exceeded the ER-L in some areas, and there is an increasing trend for Cd in sediment in Minches and Western Scotland. Besides anthropogenic sources, heavy metals can also come from natural sources and therefore they will always be found in the marine environment. However, better use of emission control technology in combustion processes could improve the situation further.

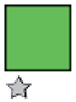
Knowledge gaps

There are a lack of monitoring data, particularly for sediment in the Scottish Continental Shelf. This is partly due to difficulties sampling in this area and the sediment type which is mainly sandy or rock and therefore not suitable for contaminant monitoring.

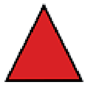
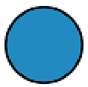
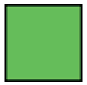
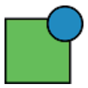
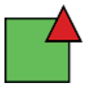
There are no OSPAR EACs available for heavy metals in biota, therefore the European Commission Food Limit was used as an EAC-proxy. There is no clear evidence to link these limits to environmental harm in sea life. The confidence in assessment for trace metals in biota is low. There is a need to develop EACs for metals in biota.

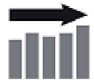
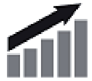
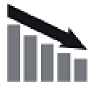
Status and trend assessment

This status and trend assessment is an overall assessment for Contaminants in sediment and biota (PAHs, PCBs, PBDEs and metals in sediment and biota) and Biological effects of contaminants.

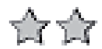
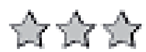
Region assessed	Status with confidence	Trend with confidence	Comments
Irish Sea (Clyde and Solway)			Green square with red triangle for status indicates few or no concerns as a whole, but many local concerns, particularly in the Clyde, with some sites exceeding the EAC/EAC-proxy. Two stars for confidence in the status is due to lack of suitable assessment criteria for some determinands (metals in biota and some biological effects measurements)
Minches and Western Scotland			Two stars for confidence in the status is due to lack of suitable assessment criteria for some determinands (metals in biota and some biological effects measurements). In addition there is limited fish sites which impacts on the ability to make biological effects assessments.
Northern North Sea			Two stars for confidence in the status is due to lack of suitable assessment criteria for some determinands (metals in biota and some biological effects measurements)
Scottish Continental Shelf			One star for confidence in the status is due to lack of suitable assessment criteria for some determinands (metals in biota and some biological effects measurements). In addition this region could not be assessed for all determinand/matrix combinations due to the lack of sites

Status and trend assessment legend

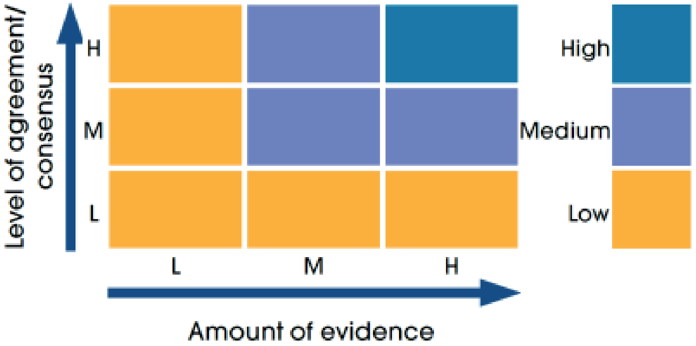
Status assessment (for Clean and safe, Healthy and biologically diverse assessments)	
	Many concerns
	Some concerns
	Few or no concerns
	Few or no concerns, but some local concerns
	Few or no concerns, but many local concerns
	Some concerns, but many local concerns
	Lack of evidence / robust assessment criteria
	Lack of regional evidence / robust assessment criteria, but no or few concerns for some local areas
	Lack of regional evidence / robust assessment criteria, but some concerns for some local areas
	Lack of regional evidence / robust assessment criteria, but many concerns for some local areas

Trend assessment (for Clean and safe, Healthy and biologically diverse and Productive assessments)	
	No / little change
	Increasing
	Decreasing
	No trend discernible
	All trends

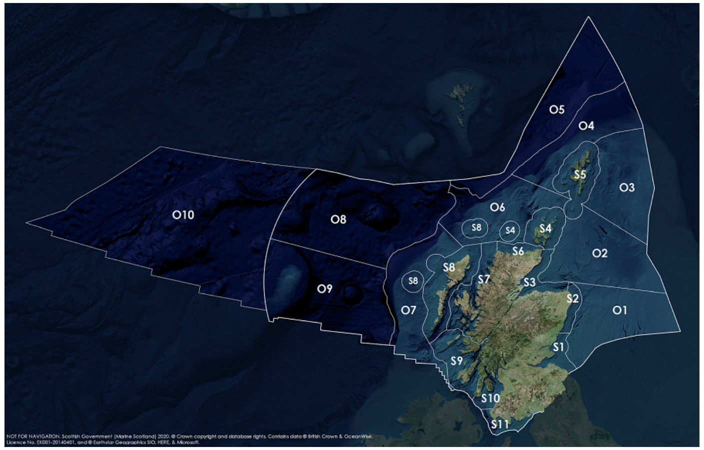
Confidence assessment

Symbol	Confidence rating
	Low
	Medium
	High

Overal confidence

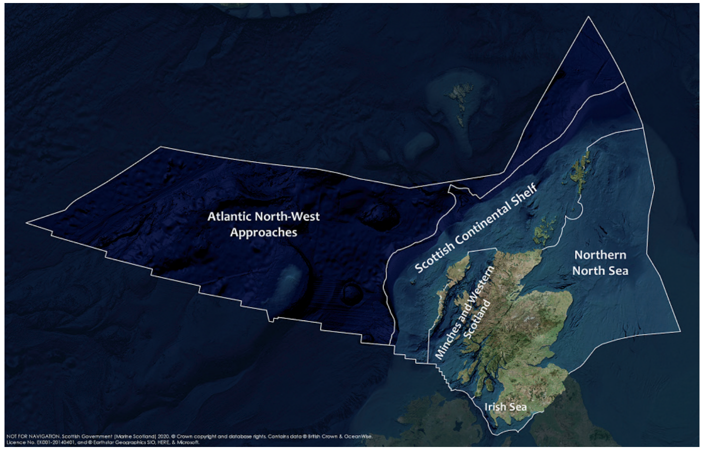


Assessment regions

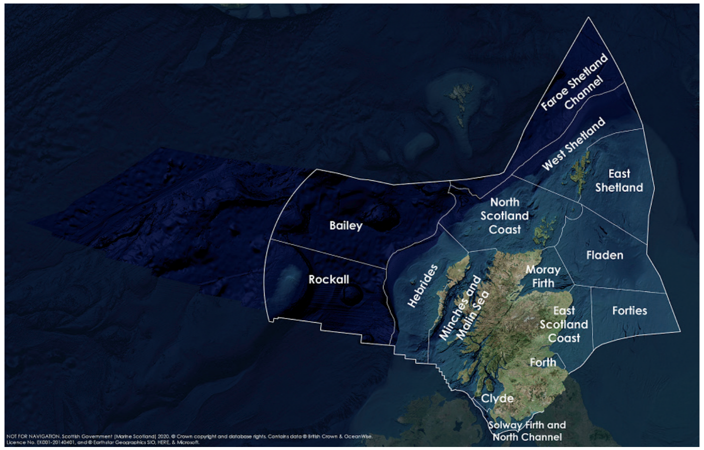


The Scottish Marine Regions (SMRs; S1 – S11) and the Scottish Offshore Marine Regions (OMRs, O1 – O10)

Key: S1, Forth and Tay; S2, North East; S3, Moray Firth; S4 Orkney Islands, S5, Shetland Isles; S6, North Coast; S7, West Highlands; S8, Outer Hebrides; S9, Argyll; S10, Clyde; S11, Solway; O1, Long Forties, O2, Fladen and Moray Firth Offshore; O3, East Shetland Shelf; O4, North and West Shetland Shelf; O5, Faroe-Shetland Channel; O6, North Scotland Shelf; O7, Hebrides Shelf; O8, Bailey; O9, Rockall; O10, Hatton.



Biogeographic, Charting Progress 2 (CP2) Regions. These have been used as the assessment areas for hazardous substances.



Scottish Sea Areas as used in Scotland's Marine Atlas 2011. These are sub divisions of the biogeographic, or Charting Progress 2 (CP2), Regions.

Scottish Government
Riaghaltas na h-Alba
gov.scot
marinescotland

NatureScot
Scotland's Nature Agency
Buidheann Nàdair na h-Alba

JNCC
Joint Nature Conservation Committee

Marine Alliance Science Technology Scotland

SEPA
Scottish Environment Protection Agency

This material was published on the Scottish Marine Assessment 2020 portal, December 2020