Concentration of PAHs in biota and sediment

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Riaghaltas na h-Alba
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Key message

Polycyclic aromatic hydrocarbon (PAHs) concentrations in shellfish and sediment in Scottish biogeographic regions remain below the threshold at which adverse effects occur in marine life. Mean concentrations are stable or decreasing over the assessment period (1999 – 2018).

Mussels feeding

Background

Polycyclic aromatic hydrocarbons (PAHs) are natural components of coal and oil, and are also formed during the combustion of fossil fuels and organic material. PAHs occur as a result of natural processes such as forest fires. PAHs enter the marine environment through atmospheric deposition, road run-off, industrial discharges and as a result of oil spills.

PAHs often end up in marine sediment, where they may be trapped in lower layers unless the sediments are disturbed. PAHs can also accumulate in shellfish, because they are taken in either directly from the marine environment or indirectly through food consumption. In contrast, fish metabolise PAHs and therefore concentrations in fish are lower. Although this is the case, exposure to PAHs can be screened for by the measurement of PAH bile metabolites in the gall bladders of fish. The problems caused by PAHs in the marine environment vary considerably from tainting the taste of fish and shellfish to being potentially carcinogenic to humans and animals.

Due to their persistence, potential to accumulate and toxicity, analysis of PAHs in sediment and shellfish is required for the OSPAR Coordinated Environmental Monitoring Programme (CEMP), the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD). To fulfil these monitoring and assessment commitments, analysis of PAHs are undertaken as part of the UK Clean Seas Environment 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

PAH concentrations are measured in sediment and shellfish samples and bile metabolites in fish, taken between 1999 and 2018 from four biogeographic regions (Figure 1), 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. Shellfish (blue mussel) were collected in coastal and estuarine areas only whilst sediment and fish were collected from coastal and more offshore areas.

PAH concentrations in sediment and shellfish and the PAH metabolite in 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 PAHs. In addition, PAH concentrations in shellfish (and PAH metabolite for fish) were compared to Environmental Assessment Criteria (EAC) and concentrations in sediment compared to the United States Environmental Protection Agency's Effects Range-Low (ER-L). Adverse effects on marine organisms are rarely observed when concentrations are below the EAC or ER-L value.

There were insufficient sites for the regional assessment of status and trends of PAHs in sediment and biota from Scottish Continental Shelf and for bile metabolites in the Scottish Continental Shelf, Irish Sea (Clyde and Solway) (only status assessment possible) and Minches and Western Scotland. Concentrations in sediment and shellfish were lowest in the Minches and Western Scotland region, although still above background for shellfish. Highest PAH concentrations in sediment and shellfish were in the Irish Sea (Clyde and Solway), which includes the Clyde, the most industrialised and urbanised Scottish sea area. Concentrations for all PAHs were above the BACs but below the ER-L or EACs (Figure 2). Bile metabolites were assessed in the Northern North Sea and Irish Sea (Clyde and Solway). Mean regional concentrations were highest in the Irish Sea (Clyde and Solway) but both regions were above the BACs but below the EACs. Therefore adverse biological effects in marine species are unlikely. However, there are still single sites where the EAC/ER-L is breached. For example, 9 out of 28 sediment sites and 9 out of 28 shellfish sites in the Irish Sea (Clyde and Solway) and Northern North Sea still report concentrations of at least one PAH compound that are not acceptable (> EAC/ER-L).

Trends in PAH concentrations were assessed in biogeographic regions where there were at least five years of data (Figure 3). Three regions were assessed for trends in shellfish and sediment and one for fish. Across all PAHs, concentrations in sediment, shellfish and fish were stable except for shellfish in the Northern North Sea, where there was a significant downward trend. However, yearly changes in sediment in the Northern North Sea and Minches and Western Scotland region were positive with mean %-yearly changes of 0.93% and 2.62%, respectively, whilst in the Irish Sea (Clyde and Solway) there was a mean %-yearly change of -0.74%. Positive yearly changes were also observed in shellfish in the Minches and Western Scotland (1.07%) and for fish in the Northern North Sea (7.86%).

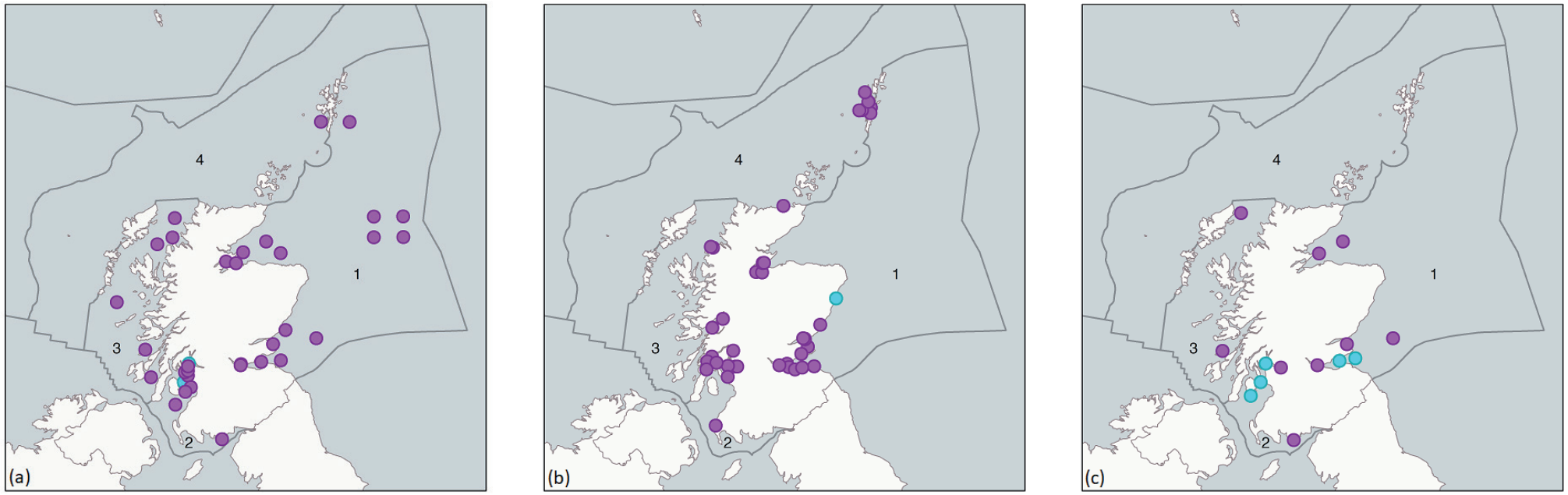


Figure 1:
Monitoring stations used to assess PAH/ PYR1OHEQ concentrations in (a) sediment, (b) shellfish and (c) fish per biogeographic region (grey lines). Magenta dots = stations used for status and trend assessments. Cyan dots = stations used for status assessment only. 1, Northern North Sea; 2, Irish Sea (Clyde and Solway); 3, Minches and Western Scotland; 4, Scottish Continental Shelf.

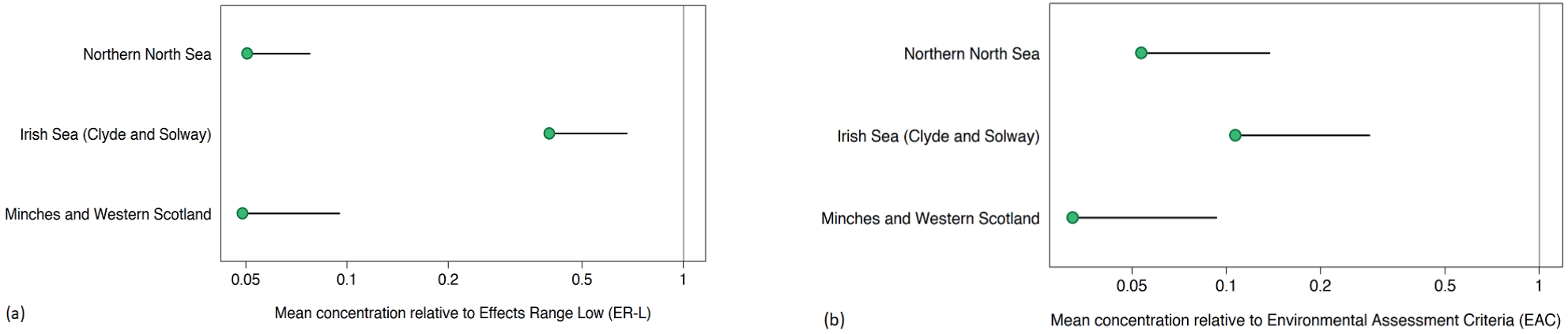
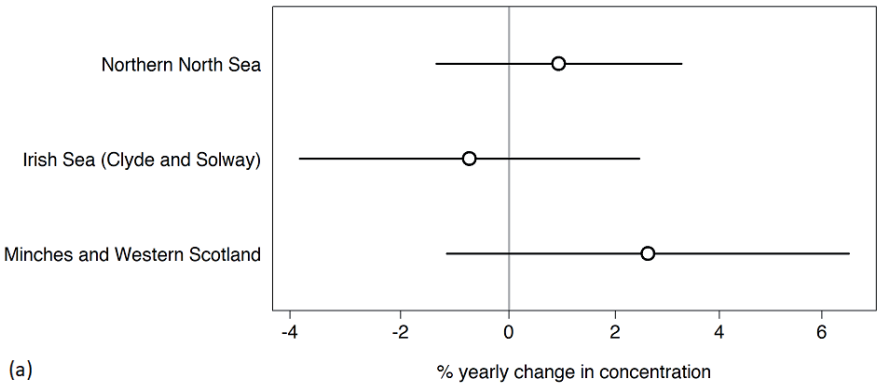


Figure 2:

Status assessment; mean PAH concentration in (a) sediment and (b) shellfish in each Scottish biogeographic region relative to the ER-L for sediment and EAC for shellfish (with 95 % confidence limits), where the EAC/ER-L value is 1. Concentrations are significantly below the EAC/ER-L 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 EAC, ER-L.



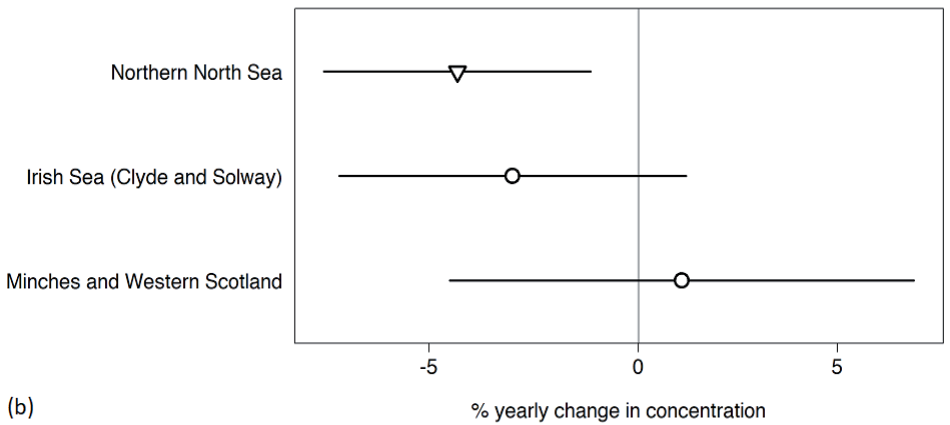


Figure 3:
Trend assessment; percentage yearly change in PAH concentrations in each Scottish biogeographic region for (a) sediment and (b) shellfish. There is a significant trend if the confidence limits does not cut the vertical line at 0. Upward trends (upwards triangle), downward trends (downwards triangle), no change (circle) and 95 % confidence limits (lines).

Conclusion

Mean PAH concentrations in sediment and shellfish and bile metabolites in fish were above background concentrations in the assessed Scottish biogeographic regions. Mean PAH concentrations were below the ER-L or EAC in all regions and therefore are unlikely to cause adverse effects in marine organisms. In addition, across all PAHs the concentrations were stable except for biota from the Northern North Sea where there was a significant downward trend.

Although concentrations were stable, PAH concentrations need to be kept under surveillance, as concentrations for a small number of PAHs in sediment and shellfish were increasing in all areas, and some PAH compounds exceeded the EACs/ER-Ls. Even though there are natural sources of PAHs, the results from this assessment show that many are above BACs. Therefore regulation is still needed to limit losses from emissions from combustion processes..

Knowledge gaps

There were 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.

The ER-L was used in the assessment of PAHs in sediment, as there are no OSPAR EACs currently available. There is a need for EACs to be developed for both alkylated and parent PAH in sediment. More research may be needed to identify the specific sources of PAHs that are resulting in concentrations being above BAC and not decreasing in sediment in some areas.

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.

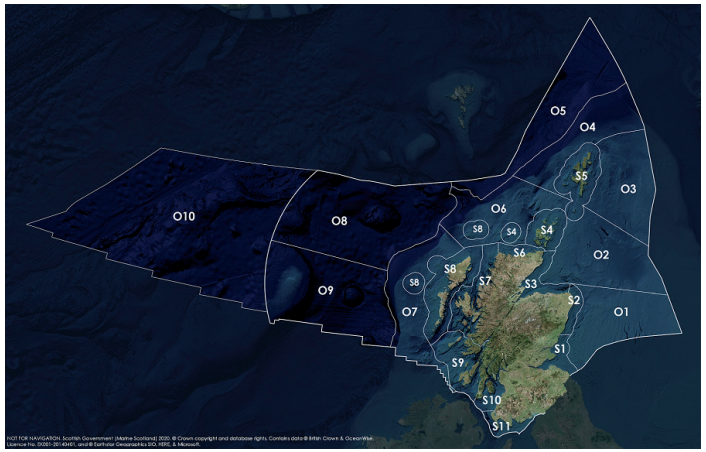
Region assessed	Status with confidence	Trend with confidence	Comments
Irish Sea (Clyde and Solway)			Green square with red triangle for status indicates few or no concerns as a whole, but many local concerns, particularly in the Clyde, with some sites exceeding the EAC/EAC-proxy. Two stars for confidence 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)		Trend assessment (for Clean and safe, Healthy and biologically diverse and Productive assessments)	
	Many concerns		No / little change
	Some concerns		Increasing
	Few or no concerns		Decreasing
	Few or no concerns, but some local concerns		No trend discernible
	Few or no concerns, but many local concerns		All trends
	Some concerns, but many local concerns	**Confidence assessment**	
	Lack of evidence / robust assessment criteria	**Symbol**	**Confidence rating**
	Lack of regional evidence / robust assessment criteria, but no or few concerns for some local areas		Low
	Lack of regional evidence / robust assessment criteria, but some concerns for some local areas		Medium
	Lack of regional evidence / robust assessment criteria, but many concerns for some local areas		High

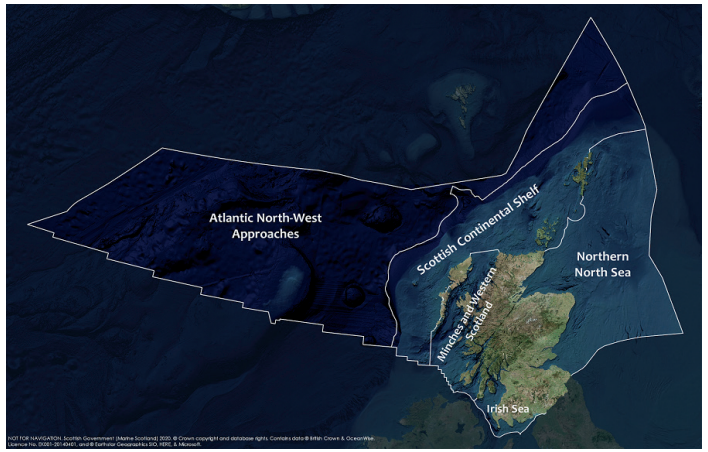
Overal confidence

Assessment regions

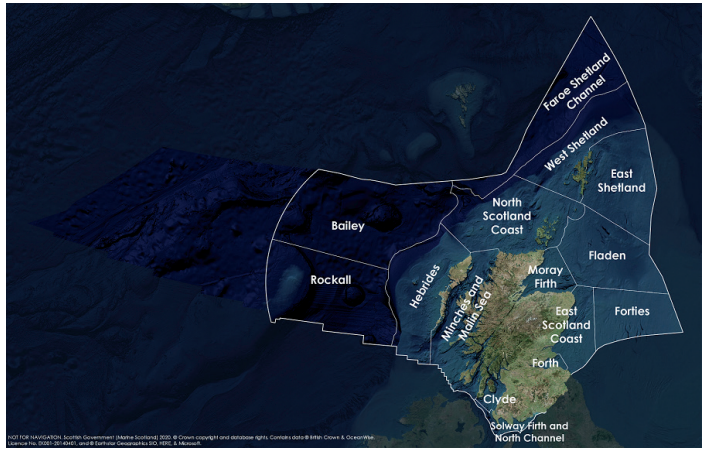


The Scottish Marine Regions (SMRs; S1 – S11) and the Scottish Offshore Marine Regions (OMRs, O1 – O10)

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.

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

JNCC
Joint Nature Conservation Committee

SEPA
Scottish Environment Protection Agency

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