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MEASUREMENT OF CHEMICAL CONTAMINANTS IN SHELLFISH FROM SCOTTISH WATERS

FSA (Scotland) Project Code: SO2013

FINAL REPORT

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January 2003

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CUSTOMER: FOOD STANDARDS AGENCY (SCOTLAND)

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SUMMARY

Samples of blue mussels (*Mytilus edulis*), oysters (*Crassostrea gigas*) and scallops (*Pecten maximus*) from sites around Scotland were collected during March and April 2002 with a second sampling round conducted during August and September 2002.

A total of 52 shellfish samples, comprising 28 mussel samples, 9 oyster samples and 15 scallop samples, were collected during either winter or summer 2002. The concentration and composition of polycyclic aromatic hydrocarbon (PAH), trace metals (TM), chlorobiphenyl (CB) and organochlorine pesticide (OCP) was determined in the soft tissues in all three species from the two sampling occasions.

The total measured PAH concentration in 23 of the 28 mussel samples analysed was less than 150 ng g^{-1} wet weight. On only two occasions was a concentration above 250 ng g^{-1} recorded. One sample (Loch Roag, summer) contained PAHs at a concentration, and with a relevant distribution, such that the product was at risk of being tainted.

All samples of oysters contained PAHs at a concentration less than 150 ng g^{-1} wet weight, regardless of season.

The PAH concentration in scallop gonad was, without exception, greater than in the corresponding adductor muscle. Furthermore, PAH concentrations were less in samples collected during the summer months compared to the winter period.

Trace metal distribution in mussels, scallops and oysters showed that the concentrations generally do not exhibit a high variance between sites. Some mussels exhibited Cu, Zn, Cd, Hg and Pb concentrations greater than the background concentrations proposed by OSPAR.

The CB concentrations determined in mussels were generally within the Ecotoxicological Assessment Criteria (EAC) established by OSPAR for mussels. An EAC has not been established for either oysters or scallops, but CB concentrations were within the EAC established for mussels.

BACKGROUND

The European Union (EU) Shellfish Hygiene Directive (79/923/EEC) includes the requirement to assess a range of elements of end product quality in shellfish offered for sale for human consumption. Therefore there is a need to conduct a targeted programme to provide current data on the concentrations of priority contaminants in harvested shellfish and to assess the contaminant levels in cultivated and natural populations of a number of shellfish species throughout Scottish coastal waters.

In support of the requirements for surveillance of chemical contaminants in shellfish under EEC Directives 79/923/EEC and 91/492/EEC, mussels (*Mytilus edulis*), scallops (*Pecten maximus*) and oysters (*Crassostrea gigas*), sampled on two occasions during 2002 from a number of production areas, were analysed to determine the tissue concentration of polycyclic aromatic hydrocarbon (PAH), trace metal (TM), chlorobiphenyl (CB) and organochlorine pesticide (OCP) residues. This provides the Food Standards Agency Scotland (FSAS) with information on the levels of PAH, HM, CB and pesticide contamination in these shellfish species in Scottish coastal waters.

MATERIALS AND METHODS

SAMPLING AND SAMPLE PROCESSING:

The mussel, oyster and scallop sampling sites selected for this first monitoring exercise were chosen to reflect the commercial importance of the products. The locations reflect the distribution of shellfish and scallop harvesting areas representative of the Scottish shellfish industries (Figure 1a, for mussels, oysters and scallops with Figure 1b giving greater detail in relation to the scallop harvesting grounds). The regions referred to for mussels and oysters are as described in the FRS Scottish Shellfish Farms Annual Production Survey, 2000 and the scallops grounds are those used by the FSAS for the shellfish toxin monitoring programme.

The sampling locations and dates are summarised in Table 1; 40 samples were collected during winter 2002 with 12 samples collected during summer 2002.

Environmental Health Officers (EHOs) in relevant regions were first contacted in February 2002, to outline the requirements of this project. Sampling instructions and sample containers were dispatched to the relevant contact persons in the regions. The samples of mussels and oysters were double wrapped in aluminium foil, placed in plastic sealable bags within a polypropylene box with lid, labelled with sample point, and date collected, wrapped securely in packaging paper and returned to FRS ML. This process was repeated in July for the second sampling round.

At Fisheries Research Services Marine Laboratory (FRS ML), twenty mussels from each sample were measured and the lengths recorded. The shells were then opened and the wet tissue shucked into a solvent washed aluminium can and homogenised for subsequent PAH and CB/OCP analyses. A further twenty mussels were measured, opened and the wet tissue shucked into a plastic vial and homogenised for HM analysis. All homogenates were labelled and stored at -20^{o}C (±2^{o}C) until required for analyses.

Five individuals oysters were opened and the wet tissue shucked into a solvent cleaned aluminium can and homogenised for PAH and CB/OCP analyses. A further sample of five oysters was opened and the wet tissue shucked into a plastic vial and homogenised in preparation for HM analysis. All homogenates were labelled and stored at -20^{o}C (±2^{o}C) until required for analyses.

The FSAS selected the scallop sampling locations (Figures 1a and 1b) and chartered commercial fishing vessels to provide trawled scallop samples for this exercise. On delivery to the FRS ML, between five and ten scallops (depending on the size of the individual animals in the sample supplied) were opened and the adductor muscle and gonad tissue removed. Both muscle and gonad tissues were homogenised separately and stored as above.

ANALYTICAL METHODS:

POLYCYCLIC AROMATIC HYDROCARBONS

To a sample of homogenised tissue (10 g), deuterated aromatic standards (naphthalene, biphenyl, dibenzothiophene, anthracene, pyrene and benzo[*a*]pyrene) were added. The sample was then saponified and the non-saponifiable material isolated. The PAHs were isolated from the aliphatic hydrocarbons by isocratic, normal phase HPLC and concentrated prior to analysis. Appropriate procedural blanks were performed at regular intervals and these were taken into account when determining the hydrocarbon concentrations in the shellfish tissues (Webster *et al.,* 1997).

The concentration and composition of the PAHs were determined by GC-MSD using an HP6890 Series gas chromatograph interfaced with an HP5973 MSD and fitted with a cool, on-column injector. A non-polar methylsilicone column was used for the analyses (ZB5, 30 m x 0.25 mm id, 0.25 :m film thickness; Phenomenex, Cheshire, United Kingdom). The carrier gas was helium, which was controlled using the constant flow mode at 0.7 ml min^{-1}. Injections were made at 50^oC and the oven temperature was held constant for 3 minutes. Thereafter, the temperature was raised at 20^oC *per* minute up to 100^oC. This was followed by a slower ramp of 4^oC *per* minute up to a final temperature of 270^oC. The MSD was set for selective ion monitoring (SIM) with a dwell time of 50 ms. A total of 25 ions plus the six internal standard ions (Topping *et al*., 1997) were measured over the period of the analysis. The analysis therefore incorporated 2- to 6-ring, parent and branched PAHs. The limit of detection, based on three times the standard deviation of the mean value from 6 procedural blanks, was <0.2 ng g^{-1} for benzo[*k*]fluoranthene and benzo[*a*]pyrene and <0.3 ng g^{-1} for chrysene. A laboratory reference material (LRM) was included with each batch of samples. The data obtained from the LRM was transferred onto NWA Quality Analyst software and Shewart charts with standard warning and action limits were drawn. Good reproducibility was generally obtained for individual PAHs. Further quality assurance was provided through successful participation in the PAH programme of the QUASIMEME (Quality Assurance of Information for Marine Environmental Monitoring in Europe) Laboratory Performance Study scheme (QUASIMEME Laboratory Performance Study, BT-4).

TRACE METALS

Approximately 0.5 g (wet weight) of homogenised mussel tissue was accurately weighed into a teflon digestion vessel (HF50) and Analar concentrated nitric acid (HNO_3;5 ml) was added. Digestion was carried out in a Perkin-Elmer Multiwave. Digestion was completed, beginning at low power, gradually ramping up to high power over five minutes and remaining at high power for ten minutes. After cooling for ten minutes, the digests were quantitatively transferred into vials and diluted to 25 ml with ultrapure, deionised water. Aliquots (2 ml) of the digests were spiked with an internal standard mixture of Scandium (Sc), Germanium (Ge) and Rhodium (Rh), in 1% (v/v) HNO_3 matrix, and diluted 5-fold prior to analysis.

The measurements were carried out on a Perkin-Elmer Sciex Elan 6100 ICP-MS with peristaltic pump and AS-90 autosampler. Solutions were aspirated via a cross-flow nebuliser. Operating conditions for the ICP-MS have been optimised to obtain good sensitivity to meet or exceed FRS performance criteria under the quality management system. Blank solutions were prepared by following all the steps in the sample procedure. The internal standards (Sc, Rh, and Ge) were used to monitor and correct instrument drift. Spectral interferences were accounted for by predetermined correction factors. External calibration was done with four standard solutions containing 5, 10, 50 and 100 :g l^{-1} multi-element standards and the same acid concentration as in the diluted samples.

A certified reference material (CRM) was included in each analytical batch. The data obtained from the CRM compared favourably with the certified values. Detection limits for individual elements are included in Tables 5 - 7, calculated from replicate analysis of low standards. Quality assurance is further demonstrated through successful participation in QUASIMEME Laboratory Performance Studies.

CHLOROBIPHENYLS AND PESTICIDES

Mussel tissue samples (0.5 – 3.0 g) were ground with anhydrous sodium sulphate (~ 10 x weight of sample). The dried tissue was put into a cellulose thimble, previously cleaned for four hours with methyl *t*-butyl ether (MTBE), and placed into a soxhlet apparatus. A recovery standard, CB 209 (Promochem, Welwyn Garden City, Herts, UK), was added prior to extraction. The tissues were extracted with MTBE (180 ml) for 12 – 16 hours. An aliquot of the extract was taken for determination of the extractable lipid content. A further aliquot, containing 50 – 200 mg of lipid, was removed and transferred into hexane before passing through alumina and silica columns. The internal standards (2,4-dichlorobenzyl alkyl hexyl ether with C_6 and C_{16} alkyl chains) were added to both extracts before concentrating using a turbovap system.

The concentrations and composition of 28 CB congeners (CB 31, **28**, **52**, 49, 44, 70, 74, **101**, 99, 97, 110, 149, **118**, **153**, 132, 105, 137, **138**, 158, 187, 183, 128, 156, 157, **180**, 189, 170 and 194; numbers in **bold** comprise the ICES 7 CB congeners) and selected organochlorine pesticides (∀-HCH, (-HCH, ∀-chlordene, (-chlordene, ∀-chlordane, (-chlordane, oxychlordane, *trans*-nonachlor, heptachlor, heptachlor epoxide, dieldrin, endrin, o,p'-DDE, o,p'-DDD, o,p'-DDT, p,p'-DDD, p,p'-DDE and p,p'-DDT – for full listing of compounds, see Appendix 1) were determined by gas chromatography with electron capture detection (GC-ECD) using either a Varian 3500 GC (Varian, Walton-on-Thames, Surrey, UK) or a PE GC autosystem (Perkin-Elmer, Beaconsfield, UK) fitted with a cool, on-column injector. A medium polarity column was used for the analysis (HP 5, 60 m x 0.25 mm i.d., 0.25 :m film thickness; Agilent, Stockport, England, UK) along with an uncoated pre-column (2.5 m x 0.53 mm i.d.). The carrier gas was hydrogen (1-3 ml min^{-1}) and the make-up gas was nitrogen (30 ∀ 5 ml min^{-1}). The initial oven temperature was 80^{o}C which was held for 1 min. The temperature was raised at 15 ^{o}C min^{-1} up to 180 ^{o}C and held at this temperature for 12 minutes. Thereafter the temperature was raised at 3 ^{o}C min^{-1} up to a final temperature of 290 ^{o}C and held at this temperature for 20 minutes. The chromatograph was calibrated using a series of external standards and the two 2,4-dichlororbenzyl alkyl ethers. The data were quantified using a Client Server Turbochrom data system (Perkin-Elmer, Beaconsfield, UK).

Procedural blanks and laboratory reference materials (LRM) were analysed with each batch of samples. The LRM results were monitored using Shewhart charts. Further quality control was assured through successful analyses of CBs and pesticides in biological tissue in the QUASIMEME Laboratory performance studies. The limit of detection was less than 0.03 :g kg^{-1} wet weight for all the 28 CBs. The detection limit was less than 0.05 :g kg^{-1} wet weight for all pesticides.

All methods are accredited by UKAS under ISO 17025.

RESULTS and DISCUSSION

POLYCYCLIC AROMATIC HYDROCARBONS

The PAH concentrations determined in the tissues from the three species sampled from the named areas within each region on the two sampling occasions have been summarised as follows:

- Mussels: Tables 2a and 2b
- Oysters: Tables 3a and 3b,
- Scallop muscle and gonad tissue: Tables 4a and 4b

Of the twenty-two mussels samples analysed from the winter sampling round (Table 2a), fourteen (63.6%) returned total measured PAH concentrations less than 50 ng g^{-1} wet weight, five (22.7%) samples contained between 50 and 150 ng g^{-1} wet weight PAH and 2 (9.1%) samples contained between 150 and 250 ng g^{-1} wet weight PAHs. Only one (4.5%) sample returned a concentration greater than 250 ng g^{-1}.wet weight PAH. [The full data set is presented in McIntosh *et al*., 2002]

The PAH concentrations determined in the mussels from Strathclyde were significantly different ($p=0.002$) from those obtained for the Western Isles, Highland, Shetland and Orkney. There were no significant differences between the PAH concentrations determined in mussels from Highland, Western Isles, Shetland and Orkney.

Of the six mussel samples analysed during the summer sampling round, two (33.3%) samples returned total measured PAH concentrations less than 50 ng g^{-1} wet weight, two (33.3%) samples contained between 50 and 150 ng g^{-1} wet weight PAHs, one (16.7%) sample contained between 150 and 250 ng g^{-1} wet weight PAHs and one (16.7%) sample returned a concentration greater than 250 ng g^{-1} (Table 2b). At the three Strathclyde sites and the Shetland site where samples were taken both early in the year and during the summer months, the total PAH concentration decreased, but at both the Orkney site (Scapa Flow) and, more dramatically, the Western Isles site (Loch Roag) the total PAH concentration increased (Figure 2). In the case of Loch Roag, the PAH concentration increased from 16.7 ng g^{-1} wet weight in the winter sample to 629.5 ng g^{-1} wet weight in the mussels collected during the summer. The PAH percentage composition of the two Loch Roag samples were distinct (Figure 3). The winter PAH percentage composition shows a ‘typical’ mussel PAH profile compared to the summer percentage composition where the naphthalenes and phenanthrene composition are about the same, the DBT has doubled and there is a significant reduction in the proportion of the 4- to 6-ring PAH compounds. The data is consistent with an acute petrogenic input, most likely an oil spill, impacting on the area from where the mussels were sampled. PAH concentrations of this magnitude, where there has been a high proportion of naphthalenes, have resulted in a taint in *Nephrops norvegicus* and a suspect taint in mussels.

It is interesting to note that although the mussels in Loch Roag show the highest PAH concentration, the individual concentrations of benz[*a*]anthracene, benzo[*a*]pyrene and dibenz[*a,h*]anthracene are very low, especially when you compare them to the mussels obtained from Loch Leven at the same time of year, when their total PAH concentration was approximately 25% of the Loch Roag mussels, or collected from Loch Fyne, Loch Striven and Loch Etive earlier in the year.

Mussels from Loch Leven exhibit a particular PAH pattern, specifically a predominance of 5-ring PAHs. This is a direct result of the historical PAH input from an aluminium smelter. The difference between Loch Leven and the other sites is more pronounced during the summer months (Table 2b) than during the winter months (Table 2a).

Of the six oyster samples analysed from the winter sampling round, only one (16.7%) sample returned a total measured PAH concentration less than 50 ng g^{-1} wet weight. The others five (83.3%) samples all contained between 50 and 150 ng g^{-1} wet weight PAH (Table 3a). Three sites were re-sampled during the summer and all showed a net decrease in the total measured PAH concentration (Table 3b and Figure 2). Only one (33.3%) sample collected august/September 2002 contained between 50 and 150 ng g^{-1} wet weight PAH (Table 3b and Figure 2).

The PAH percentage composition of the oyster samples collected in winter exhibited a typical profile for PAH in molluscs (Figure 4). The percentage composition of the samples collected in summer generally returned a similar profile. There was an increase in the contribution of the naphthalenes and phenanthrene. In the case of the sample from Kyle of Tongue (Highland Region), the percentage dibenzothiophenes increased from 6.7% to 24.9% (Figure 4). The percentage contribution of the 4- and 5-ring compounds decreased from winter to summer with the Highland Region sample showing the 4-ring compounds decreasing from 41.5% to 8.5%. The 6-ring composition increased from winter to summer in two of the three samples. There were only trace quantities determined for the 6-ring compounds in the Orkney summer sample.

The twelve scallop muscle tissue samples analysed from the winter sampling round and the three scallop muscle tissue samples analysed from the summer sampling round all returned total measured PAH concentrations less than 50 ng g^{-1} wet weight (Table 4a.1 and 4b.1). The five ring PAHs comprised greater than 40% in 11 of the 15 tissue samples analysed with the 4- to 6-ring PAHs comprising greater than 80% for all samples and greater than 90% for 6 of the tissue samples. The 5-ring PAH dominance was not nearly so obvious in the scallop gonad tissue (Tables 4a.2 and 4b.2). Gonads, due to their higher lipid content, tend to contain more PAHs than the adductor muscle from the same samples. This was the case without exception for all the samples analysed. Of the twelve scallop gonad tissue samples analysed from the winter sampling round only one sample returned a total measured PAH concentration less than 50 ng g^{-1} wet weight. Of the other samples, nine out of the twelve (75%) samples contained between 50 and 150 ng g^{-1} wet weight total measured PAH concentrations. One gonad tissue sample, from the winter sampling round, returned a total measured PAH concentration greater than 250 ng g^{-1}. The three gonad samples analysed from the summer sampling round returned values less than 50 ng g^{-1}.

In all the samples of mussels, scallops and oysters analysed, the PAH compounds benz[*a*]anthracene, benzo[*a*]pyrene and dibenz[*a,h*]anthracene, considered to be of greatest concern in terms of human health, were less than 15 ng g^{-1} wet tissue, the guideline limit value advised by the Committee on Toxicology of Chemicals in Food, Consumer Products and the Environment (CoT). The calculated B[*a*]PE (benzo[*a*]pyrene equivalent) values, a means of weighting relative potencies of PAH against the carcinogenic potency of benzo[*a*]pyrene, ranged from 0.15 ng g^{-1} to 28.7 ng g^{-1} for mussels, the highest value being recorded from Loch Leven. The B[*a*]PE values for oysters ranged from 0.13 ng g^{-1} to 8.43 ng g^{-1}. For scallop muscle tissue, the B[*a*]PE values ranged from 0.3 ng g^{-1} to 7.6 ng g^{-1} and for scallop gonad tissue from 0.8 ng g^{-1} to 15.3 ng g^{-1}.

The values for mussels reported here are generally in line with PAH concentrations recorded and reported previously (Davies, *et al*., 2001).

Trace Metals

The analytical data sets for the trace metals determined in the tissues from the three species sampled from the named areas within each region on the two sampling occasions are presented in:

- Mussels: Tables 5a and 5b
- Oysters: Tables 6a and 6b,
- Scallop muscle and gonad tissue: Tables 7a and 7b

The background reference concentrations (B/RCs) for blue mussels (OSPAR, 2000), previous data on metal concentrations in mussels (Brown and Balls, 1997), maximum levels for contaminants in specific foodstuffs (Commission Regulation 466/2001) and Guideline and Imperative limits for shellfish in Scotland (Henderson and Davies, 2001) are detailed in Table 8. The data in Tables 5 - 7 covers 12 elements, although previous study data and food/environmental standard limits are only available for some of these elements.

Trace metal distribution in mussels (Tables 5a and 5b) showed that metal concentrations generally do not exhibit high variance between sites.

The concentration range for individual trace metals in mussels in the samples were:

	Winter collected		Summer collected
Cr:	0.320 – 1.200 µg g^{-1}	Cr:	0.168 – 0.516 µg g^{-1}
Mn:	0.780 – 4.650 µg g^{-1}	Mn:	0.829 – 2.840 µg g^{-1}
Co:	<LoD – 0.092 µg g^{-1}	Co:	<LoD – 0.069 µg g^{-1}
Ni:	0.507 – 1.380 µg g^{-1}	Ni:	0.142 – 0.602 µg g^{-1}
Cu:	0.740 – 1.930 µg g^{-1}	Cu:	0.774 – 1.670 µg g^{-1}
Zn:	6.880 – 31.50 µg g^{-1}	Zn:	8.350 – 14.90 µg g^{-1}
As:	1.000 – 5.080 µg g^{-1}	As:	1.380 – 2.770 µg g^{-1}
Se:	0.320 – 1.700 µg g^{-1}	Se:	0.572 – 1.100 µg g^{-1}
Ag:	<LoD – 0.176 µg g^{-1}	Ag:	<LoD – 0.304 µg g^{-1}
Cd:	0.094 – 0.312 µg g^{-1}	Cd:	0.087 – 0.192 µg g^{-1}
Hg:	<LoD – 0.022 µg g^{-1}	Hg:	<LoD – 0.020 µg g^{-1}
Pb:	0.088 – 1.350 µg g^{-1}	Pb:	<LoD – 0.537 µg g^{-1}

LoD – Limit of analytical Detection

The trace metal concentrations measured in mussels from the winter sampling were generally within the ranges reported for mussels from Scottish coastal waters (Brown and Balls, 1997) but there were some exceptions to this; Cu, Zn, Cd, Hg and Pb exhibited a higher maximum range of concentrations than those reported as background concentration ranges by OSPAR, 2000 (Table 8). Cu and Zn were slightly greater than have been reported, Cd and Hg were two and three times respectively the values reported while Pb had a maximum concentration seven times that reported by Brown and Balls (1997). The Ni concentration (1.38 µg g^{-1}) for the sample taken at Kyle of Tongue was greater than the EC Directive Guideline concentration (1.0 µg g^{-1}).

The winter to summer ratios of the metals Cr, Ni and Pb showed these to be higher in the winter compared to the summer. The ratios for the other metals indicated that there was little difference between winter and summer values.

The trace metal distribution in oysters generally showed little difference between sites (Tables 6a and 6b). Concentrations of Mn were generally slightly higher with a maximum Mn concentration of 11.600 µg g^{-1} determined in oysters collected from Loup Bay during August/September (Table 6a and 6b). The Zn concentrations in oysters from Loup Bay and

Bay of Firth did not change significantly between the winter and summer samples but the concentration of Zn in oysters from Kyle of Tongue were reduced by about one third in the summer sample compared to that from the winter. The Hg concentrations in all oyster samples from the winter sampling were less than the limit of detection. In the summer, two out of the three samples returned values greater than the limit of detection.

The concentrations of trace metals determined in scallop muscle and gonad tissues (Table 7a.1 and 7b.2) were all, with one exception, within the given Guideline and Imperative values (Table 8). The exception was the zinc in one sample (of two) from scallop gonad tissue from the Moray Firth, which contained 103 :g g^{-1} wet weight (Figure 5). The zinc concentrations in adductor muscle tissue from scallop samples taken from three locations in the summer were all less than the concentration from the equivalent samples taken in the winter. In contrast, the zinc concentrations in the gonad tissues were all greater in the summer compared to the winter samples.

Mercury concentrations in all fifteen samples of scallop muscle tissue were below the analytical detection limit. Mercury concentrations above the analytical detection limit were found in 20% of gonads, all of which were collected during March/April 2002. All values determined were well below the EC Regulation 466/2002 maximum value of 0.5 :g g^{-1}.

Measurable lead values in all shellfish ranged from 0.09 - 1.35 :g g^{-1}, the maximum concentration being determined in mussels from Loch Sunart, possibly due to historical mining activity in the area. This was the only sample with a Pb concentration greater than the EC Regulation 466/2002 maximum of 1 :g g^{-1} EC limit. Pb concentrations in scallop muscle tissue were all below the detection limit.

CHLOROBIPHENYLS (CBs) AND ORGANOCHLORINE PESTICIDES (OCPs)

The analytical data sets for the CBs and OCPs determined in the tissues from the three species sampled from the named areas on the two sampling occasions within each region are presented in:

- Mussels: Tables 9a and 9b
- Oysters: Tables 10a and 10b,
- Scallop muscle and gonad tissue: Tables 11a and 11b

An Ecotoxicological Assessment Criteria (EAC) can be used to assess data and identify potential areas of environmental concern based on the ICES 7 CBs (CBs 28, 52, 101, 118, 153, 138 and 180, which have been recommended by the European Union Community Bureau of Reference due to their relatively high concentrations in technical mixtures and their wide chlorination range). The EAC for the sum of the ICES 7 CBs for blue mussels is in the range 0.75 ng g^{-1} to 7.5 ng g^{-1} wet weight. All samples of mussels returned values less than 10 ng g^{-1}, with the exception of the sample from Loch Striven (Table 9a) which contained a total of 13.9 ng g^{-1} wet weight. The data from the winter and summer sampling occasions are shown as a box and whisker plot in Figure 6. The sum of 28 CB congeners for the same samples is presented in Figure 7.

These values compare favourably with total CB values reported in mussels from sites on the east and west coasts of the Scottish mainland (Kelly and Campbell, 1994).

National Monitoring Site	ΣCB $_{\text{ICES 7}}$ (µg kg^{-1} wet weight)
Forth Estuary	
Blackness	0.644
Fernyness	0.632
Clyde Estuary	
Port Glasgow	3.200
Ardmore	1.160
Cardross	1.280
Woodhall	1.600
Cloch Point	1.000
Dunoon East	1.280
Lunderston Bay	2.440
Gourock	1.280

Sum of ICES 7 CB congeners in the Firth of Forth were 0.644 and 0.632 ng g^{-1} wet weight. The values from the Clyde and Clyde estuary ranged from 1.0 ng g^{-1} to 3.2 ng g^{-1} (mean=1.66 ng g^{-1}; SD=0.77 ng g^{-1}; n=8) wet weight.

The concentrations of the ICES 7 CB congeners in oysters sampled in winter were slightly greater than the values for the summer. By contrast, the total measured CB value was slightly greater in the summer compared to the winter sampled oysters.

The total measured 28 CB congeners in scallop adductor muscle sampled in winter ranged from 0.67 ng g^{-1} (M10) to 4.77 ng g^{-1} (NM15) (Table 11a; Figure 8). The total CB measured in scallop gonad tissue in winter ranged from 0.13 ng g^{-1} (H9) to 5.95 ng g^{-1} (J5) (Table 11b; Figure 8). In the summer the range was 1.32 ng g^{-1} to 4.65 ng g^{-1} for the ICES 7 congeners and 2.7 ng g^{-1} to 10.13 ng g^{-1} total CB in scallop adductor muscle tissue (Figure 8). Of the twelve scallop samples taken in winter, five (42%) showed a ratio of adductor muscle to gonad tissue greater than 1. The remainder of the twelve sampled in winter and those from the summer sampling (64.3%) returned a ratio of less than 1. The greatest difference between the winter and summer samples was seen in the sample from the Moray Firth (M2) (Figure 8). The adductor muscle and gonad tissue from the winter sample had a value of 3.0 ng g^{-1} and 1.62 ng g^{-1} respectively, compared to 10.13 ng g^{-1} and less than detection threshold for the same samples from the summer sampling.

Pesticide concentrations determined in mussel samples are shown in Table 9a and 9b. The sum of the DDTs ranged from 0.25 ng g^{-1} in mussel from the Kyle of Tongue to 4.51 ng g^{-1} wet weight in the sample from Loch Striven. The sum of the chlordanes ranged from less than detection threshold (Loch Etive) to 1.69 ng g^{-1} wet weight in the sample from Sandsound in Shetland.

It may be of interest to note that HCB was measured in mussels in the Firth of Forth (NMP Report) with a value of 0.31 ng g^{-1}. HCB was only detectable in two out of sixty-seven shellfish samples analysed during this present study, in scallop muscle tissue from the south Minch (SM10) and the Clyde (C4) with values of 0.095 ng g^{-1} and 0.097 ng g^{-1} wet weight tissue respectively Table 11a.1).

The concentrations of other pesticides determined were generally low ranging from less than detection threshold to less than 1.0 ng g^{-1} wet weight tissue.

CONCLUSIONS

A total of 52 shellfish samples, comprising 28 mussel samples, 9 oyster samples and 15 scallop samples, were collected during either winter or summer 2002. The concentration of PAHs, trace metals, CBs and OCPs was determined in the soft tissues.

The total measured PAH concentration in 23 of the 28 mussel samples analysed was less than 150 ng g^{-1} wet weight. On only two occasions was a concentration above 250 ng g^{-1} recorded. Atypical results, either with respect to PAH concentration (i.e. Loch Roag summer sample) or PAH distribution (i.e. Loch Leven), were readily accounted for either in terms of known historical input to the area or on the basis of a defined PAH pattern indicating a probable recent source of PAHs.

One sample (Loch Roag, summer) contained PAHs at a concentration, and with a relevant distribution, such that the product was at risk of being tainted.

All samples of oysters contained PAHs at a concentration less than 150 ng g^{-1} wet weight, regardless of season.

The PAH concentration in scallop gonad was, without exception, greater than in the corresponding adductor muscle. Furthermore, PAH concentrations were less in samples collected during the summer months compared to the winter period.

Trace metal distribution in mussels, scallops and oysters showed that the concentrations generally do not exhibit a high variance between sites.

Some mussels exhibited Cu, Zn, Cd, Hg and Pb concentrations greater than the background concentrations proposed by OSPAR.

For all shellfish analysed, the mercury content was generally low. Only 12 out of the 67 shellfish samples analysed (mussels, 28; oysters, 9; scallop adductor muscle, 15; scallop gonad, 15) contained Hg above the analytical limit if detection (0.015 µg g^{-1}).

The CB concentrations determined in mussels were generally within the Ecotoxicological Assessment Criteria established by OSPAR for mussels (0.75 – 7.5 ng g^{-1} wet weight for the sum of the ICES 7). An EAC has not been established for either oysters or scallops, but CB concentrations were within the EAC established for mussels.

Although OCPs were detected in all shellfish analysed, often this was restricted to gamma-HCH, dieldrin and endrin. DDTs and chlordanes were detected, but concentrations were generally less than 3 ng g^{-1} wet weight.

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Tables and Figures

Table 1 Details of sampling locations. This Table should be read in conjunction with Figures 1a and 1b which show the geographical location and Shellfish Hygiene Directive monitoring boxes respectively.

			Date samples received at FRS ML	
Region	Number of Sites	Location	Winter 2002	Summer 2002
		Mussel Sites		
Strathclyde	5	Loch Fyne	7 March	
		Loch Striven	7 March	14 September
		Loup Bay	12 March	
		Loch Etive	13 March	21 August
		Loch Leven	13 March	21 August
Western Isles	3	Loch Leurbost	18 March	
		West Loch Roag	19 March	4 September
		Loch Carnan	26 March	
Highland	9	Kyle of Tongue	11 March	
		Broadford Bay	11 March	
		Inverkirkaig (Lochinver)	11 March	
		Loch Kishorn	12 March	
		Loch Ewe	12 March	
		Loch Sunart	13 March	
		Loch Ceantraig (Ardtoe)	13 March	
		Loch Ailort	13 March	
		Loch Ainort	26 March	
Shetland	4	Sandsound	11 March	30 August
		Scarfataing	11 March	
		East of Linga	11 March	
		Busta Voe	11 March	
Orkney	1	Scapa Flow	13 March	18 July
		Oyster sites		
Strathclyde	3	Loch Fyne	7 March	
		Loch Gruinart (Islay)	18 April	
		Loup Bay	12 March	28 August
Highland	2	Kyle of Tongue	11 March	27 August
		Loch Ailort	10 April	
Orkney	1	Bay of Firth	20 March	5 September
Area		**Scallop Sites**		
East Coast	1	E1	5 March	9 September
Moray Firth	1	M2	5 March	9 September
Moray Firth	1	M10	5 March	
North Minch	1	NM15	6 March	
South Minch	1	SM10	10 April	
South Minch	1	SM12	10 April	9 September
Outer Hebrides	1	H9	4 March	
Irish Sea	1	IS5	5 March	
Jura	1	J5	14 March	
Clyde	1	C4	14 March	
Orkney	1	O10	24 April	
Shetland	1	S14	27 March	

Table 2a Total PAH (ng g^{-1} wet weight tissue) in mussels from sites around Scotland collected March/April 2002

	Total measured PAH	3-ring PAH(1)		4- to 6-ring PAH(2)		5-ring PAH(3)		Other measurements			
		Total	% composition	Total	% composition	Total	% composition	B[*a*]A	B[*a*]P	D[*a*,*h*]A	B[*a*]PE
Strathclyde											
Loch Fyne	105.1	17.2	16.4	79.8	75.9	27.7	26.4	2.7	1.1	0.3	4.29
Loch Striven	277.7	40.9	14.7	211.8	76.3	73.2	26.4	4.8	3.8	1.2	13.68
Loup Bay	75.2	26.0	34.6	36.5	48.5	8.4	11.2	1.0	0.3	ND	0.82
Loch Leven	232.7	19.4	8.3	204.3	49.3	114.7	49.3	5.8	7.4	2.7	28.03
Loch Etive	79.7	17.3	21.7	52.1	21.7	17.3	21.7	1.4	0.6	0.2	2.67
Western Isles											
Loch Leurbost	32.7	7.0	21.4	20.7	63.3	6.0	18.4	0.5	0.4	ND	0.81
Loch Roag	16.7	4.2	25.2	9.8	58.7	3.1	18.6	0.2	TR	ND	0.21
Loch Carnan	167.7	70.9	42.3	51.2	30.5	9.9	5.9	0.7	0.4	0.2	1.99
Highland											
Kyle of Tongue	18.2	4.5	24.7	11.2	61.5	3.0	16.5	0.2	TR	ND	0.15
Loch Kishorn	33.6	10.1	30.1	17.9	53.3	5.8	17.3	0.6	0.2	ND	0.55
Loch Sunart	45.5	10.2	22.4	29.5	64.8	9.7	21.3	0.6	0.2	ND	0.70
Loch Ewe	26.7	6.7	25.1	16.3	61.0	4.9	18.4	0.4	TR	ND	0.28
Ardtoe	32.9	8.3	25.2	20.7	62.9	6.6	20.1	0.5	0.2	ND	0.59
Loch Ailort	32.5	6.3	19.3	23.7	72.9	8.5	26.2	0.6	0.6	ND	1.11
Loch Ainort	23.2	4.7	20.3	15.2	65.5	6.0	25.9	0.2	TR	0.2	1.36
Broadford Bay	31.2	7.5	24.0	20.0	64.1	6.2	19.9	0.4	TR	ND	0.35
Lochinver	27.4	10.6	38.7	13.7	50.0	4.6	16.8	0.4	0.2	ND	0.44
Shetland											
Sandsound	53.7	7.8	14.5	36.4	67.8	14.5	27.0	0.6	0.5	0.3	2.93
Scarfataing	22.8	4.9	21.5	13.3	58.3	5.7	25.0	0.2	TR	TR	0.36
East of Linga	36.2	9.7	26.8	20.6	56.9	7.6	21.0	0.4	0.3	ND	0.71
Busta Voe	97.5	35.1	36.0	30.7	31.5	9.9	10.2	0.5	0.2	TR	0.77
Orkney											
Scapa Flow	41.3	13.0	31.5	21.2	51.3	6.0	14.5	0.5	TR	ND	0.34

(1) includes acenaphthylene, acenaphthene and fluorene; (2) 4-ring *m/z* 202 and *m/z* 228; (3) includes dibenz[*a,h*]anthracene (D[*a,h*]A)

ND = not detected (< 0.04 ng g^{-1}); TR = trace (0.04 – 0.14 ng g^{-1})

B[*a*]A = benz[*a*]anthracene; B[*a*]P = benzo[*a*]pyrene; B[*a*]PE = benzo[*a*]pyrene equivalent value

Table 2b Total PAH (ng g^{-1} wet weight tissue) in mussels from sites around Scotland collected July, August and September 2002

	Total measured PAH	3-ring PAH[(1)]		4- to 6-ring PAH		5-ring PAH		Other measurements			
		Total	% composition	Total	% composition	Total	% composition	B[*a*]A	B[*a*]P	D[*a,h*]A	B[*a*]PE
Strathclyde											
Loch Striven	78.3	23.0	29.4	37.6	48.0	7.8	10.0	0.6	0.3	TR	0.82
Loch Leven	158.2	6.5	4.1	148.9	94.1	88.3	55.8	9.4	6.5	3.3	28.7
Loch Etive	42.6	12.6	29.6	19.6	46.0	7.7	18.1	0.2	0.3	TR	0.73
Western Isles											
Loch Roag	629.5	245.9	39.1	62.8	10.0	6.7	1.1	0.4	0.2	TR	0.62
Shetland											
Sandsound	24.7	9.2	37.2	9.1	36.8	2.4	9.7	TR	TR	ND	0.16
Orkney											
Scapa Flow	116.9	47.0	40.2	25.8	22.1	4.2	3.6	0.3	TR	0.7	3.78

(1) see Table 2a for legend

Table 3a Total PAH (ng g^{-1} wet weight tissue) in oysters from sites around Scotland collected March/April 2002

	Total measured PAH	3-ring PAH(1)		4- to 6-ring PAH		5-ring PAH		Other measurements			
		Total	% composition	Total	% composition	Total	% composition	B[*a*]A	B[*a*]P	D[*a,h*]A	B[*a*]PE
Strathclyde											
Loch Fyne	129.4	18.8	14.5	99.7	77.1	35.3	27.3	2.8	2.6	0.7	8.43
Loch Gruinart	39.5	8.8	22.3	24.9	63.0	7.8	19.8	0.5	TR	TR	0.59
Loup Bay	114.4	28.1	24.6	75.7	66.2	21.3	18.6	2.0	1.4	ND	2.99
Highland											
Kyle of Tongue	62.4	13.2	21.2	38.8	62.2	10.7	17.2	0.8	TR	0.2	1.74
Loch Ailort	79.0	17.3	21.9	55.0	79.6	23.3	29.5	1.0	4.4	0.4	7.60
Orkney											
Bay of Firth	91.3	25.1	27.5	55.6	60.9	13.6	14.9	1.3	0.9	0.3	3.41

(1) see Table 2a for legend

Table 3b Total PAH (ng g^{-1} wet weight tissue) in oysters from sites around Scotland collected August/September 2002

	Total measured PAH	3-ring PAH(1)		4- to 6-ring PAH		5-ring PAH		Other measurements			
		Total	% composition	Total	% composition	Total	% composition	B[*a*]A	B[*a*]P	D[*a,h*]A	B[*a*]PE
Strathclyde											
Loup Bay	20.0	4.8	24.0	11.1	55.5	4.0	20.0	0.2	TR	0.3	1.80
Highland											
Kyle of Tongue	10.2	2.7	26.5	5.0	49.0	1.7	16.7	TR	ND	ND	0.13
Orkney											
Bay of Firth	58.3	21.7	37.2	22.8	39.1	3.8	6.5	0.4	0.2	ND	0.53

(1) see Table 2a for legend

Table 4a.1 Total PAH (ng g^{-1} wet weight tissue) in scallop muscle tissue from sites around Scotland collected in March/April 2002

	Total Measured PAH	3-ring PAH(1)		4- to 6-ring PAH		5-ring PAH		Other measurements			
		Total	% composition	Total	% composition	Total	% composition	B[*a*]A	B[*a*]P	D[*a,h*]A	B[*a*]PE
East Coast											
E1	18.2	2.1	11.5	15.5	85.2	8.5	46.7	0.4	0.5	0.0	1.0
Moray Firth											
M2	9.1	1.1	12.1	7.4	81.3	3.7	40.7	ND	TR	0.0	0.3
M10	15.2	1.3	8.6	12.6	82.9	6.1	40.1	0.2	0.2	1.4	7.6
North Minch											
NM15	27.7	1.1	4.0	26.4	95.3	14.8	53.4	0.4	0.9	0.0	1.8
South Minch											
SM10	21.0	1.7	8.1	19.1	91.0	10.0	47.6	0.3	TR	0.3	2.1
SM12	23.4	1.7	7.3	21.7	92.7	11.3	48.3	0.3	0.3	0.4	3.0
Outer Hebrides											
H9	37.4	2.5	6.7	31.9	85.3	9.6	25.7	0.4	0.4	0.0	0.9
Irish Sea											
IS5	36.4	2.9	8.0	32.3	88.7	15.3	42.0	1.2	1.4	0.0	2.4
Jura											
J5	31.7	1.9	6.0	29.6	93.4	14.0	44.2	0.9	1.2	0.0	2.1
Clyde											
C4	36.4	2.2	6.0	33.6	92.3	13.0	35.7	1.1	1.2	0.0	2.0
Orkney											
O10	32.0	2.8	8.8	27.1	84.7	8.4	26.3	1.5	0.2	0.4	2.6
Shetland											
S14	24.9	3.7	14.9	20.0	80.3	9.6	38.6	0.3	0.6	0.0	1.2

(1) see Table 2a for legend

Table 4a.2 Total PAH (ng g^{-1} wet weight tissue) in scallop gonad tissue from sites around Scotland collected in March/April 2002

	Total Measured PAH	3-ring PAH(1)		4- to 6-ring PAH		5-ring PAH		Other measurements			
		Total	% composition	Total	% composition	Total	% composition	B[*a*]A	B[*a*]P	D[*a,h*]A	B[*a*]PE
East Coast											
E1	139.5	29.4	21.1	96.7	69.3	28.8	20.6	3.3	2.0	2.2	15.3
Moray Firth											
M2	47.0	9.4	20.0	31.9	67.9	12.2	26.0	0.8	0.4	ND	1.4
M10	66.5	14.6	22.0	42.2	63.5	14.5	21.8	ND	0.6	ND	1.6
North Minch											
NM15	102.5	13.2	12.9	85.9	83.8	33.6	32.8	2.9	1.9	0.3	5.9
South Minch											
SM10	98.7	11.4	11.6	82.5	83.6	35.4	35.9	2.3	0.3	0.8	7.1
SM12	90.7	11.3	12.5	75.3	83.0	32.3	35.6	2.1	0.9	0.8	7.4
Outer Hebrides											
H9	83.4	13.3	15.9	64.0	76.7	25.7	30.8	ND	1.4	ND	2.9
Irish Sea											
IS5	258.3	36.3	14.1	208.2	80.6	74.1	28.7	1.2	4.8	0.4	10.7
Jura											
J5	123.1	17.0	13.8	102.5	83.3	33.5	27.2	4.6	2.8	0.2	6.5
Clyde											
C4	222.8	2.2	12.6	186.3	83.6	56.7	25.4	8.0	6.7	0.4	13.0
Orkney											
O10	69.8	18.0	25.8	43.0	61.6	13.3	19.1	0.4	0.2	ND	0.8
Shetland											
S14	148.3	37.7	25.4	82.2	55.4	25.7	17.3	2.2	1.4	ND	3.4

(1) see Table 2a for legend

Table 4b.1 Total PAH (ng g^{-1} wet weight tissue) in scallop muscle tissue from sites around Scotland collected in September 2002

	Total Measured PAH	3-ring PAH(1)		4- to 6-ring PAH		5-ring PAH		Other measurements			
		Total	% composition	Total	% composition	Total	% composition	B[*a*]A	B[*a*]P	D[*a*,*h*]A	B[*a*]PE
East Coast											
E1	4.0	0.3	7.5	3.5	87.5	2.1	52.5	ND	TR	ND	0.11
Moray Firth											
M2	6.1	0.3	4.9	5.8	95.1	3.2	52.5	ND	TR	TR	0.22
South Minch											
SM12	10.6	0.9	8.5	8.9	84.0	4.6	43.4	TR	0.2	TR	0.49

(1) see Table 2a for legend

Table 4b.2 Total PAH (ng g^{-1} wet weight tissue) in scallop gonad tissue from sites around Scotland collected in September 2002

	Total Measured PAH	3-ring PAH(1)		4- to 6-ring PAH		5-ring PAH		Other measurements			
		Total	% composition	Total	% composition	Total	% composition	B[*a*]A	B[*a*]P	D[*a*,*h*]A	B[*a*]PE
East Coast											
E1	13.9	2.3	16.6	9.1	65.5	4.2	30.2	TR	0.8	TR	1.04
Moray Firth											
M2	16.1	2.2	13.7	8.5	52.8	4.8	29.8	TR	0.2	0.3	2.01
South Minch											
SM12	39.2	5.0	12.8	30.2	77.0	14.6	37.2	0.5	0.7	0.2	2.71

(1) see Table 2a for legend

Table 5a Trace Metal concentration (:g g^{-1} wet weight) in mussels from sites around Scotland collected March/April 2002

	Concentration of trace metals in mussels (:g g^{-1} wet weight)											
	Cr	Mn	Co	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
LoD	0.0879	0.1076	0.06017	0.1080	0.1770	0.5170	0.0797	0.1760	0.1184	0.0753	0.0151	0.0865
Strathclyde												
Loch Fyne	0.633	3.230	0.082	0.894	1.270	13.40	2.610	0.738	< LoD	0.145	0.017	0.109
Loch Striven	0.692	3.150	0.073	1.030	0.740	6.880	1.880	0.345	< LoD	0.112	< LoD	0.088
Loup Bay	0.463	2.140	0.092	0.879	1.190	15.50	3.860	0.554	< LoD	0.152	< LoD	0.178
Loch Leven	0.474	1.050	< LoD	0.540	1.010	11.20	2.410	0.555	0.176	0.150	< LoD	0.393
Loch Etive	0.354	0.781	< LoD	0.507	0.938	7.860	0.995	0.315	< LoD	0.105	< LoD	< LoD
Western Isles												
Loch Leurbost	0.415	1.770	0.062	1.040	1.210	17.200	2.840	0.733	< LoD	0.098	0.017	0.197
Loch Roag	0.414	1.480	< LoD	0.882	1.390	16.800	2.630	0.825	0.129	0.094	< LoD	0.191
Loch Carnan	0.491	1.070	< LoD	0.670	1.880	22.600	2.970	0.593	< LoD	0.158	< LoD	0.361
Highland												
Kyle of Tongue	1.200	1.590	< LoD	1.380	0.778	7.380	2.460	0.316	< LoD	0.127	< LoD	0.165
Loch Kishorn	0.825	1.790	0.061	0.921	0.903	9.210	2.980	0.561	< LoD	0.312	0.017	0.270
Loch Sunart	0.601	2.650	< LoD	0.872	1.200	15.100	2.490	0.622	< LoD	0.145	< LoD	1.350
Loch Ewe	0.547	1.690	< LoD	0.800	1.020	9.870	2.880	0.567	< LoD	0.200	< LoD	0.174
Ardtoe	0.603	2.110	0.080	1.090	1.190	21.400	3.800	0.763	< LoD	0.267	< LoD	0.324
Loch Ailort	1.130	1.520	0.092	1.120	0.931	18.300	3.200	0.623	< LoD	0.282	0.022	0.327
Loch Ainort	0.524	0.966	< LoD	0.735	1.100	14.100	3.500	0.731	< LoD	0.105	< LoD	0.168
Broadford Bay	0.527	1.590	< LoD	0.600	0.993	14.400	2.630	0.678	< LoD	0.133	< LoD	0.144
Lochinver	0.480	4.650	0.067	0.808	1.170	12.600	2.070	0.805	< LoD	0.107	< LoD	0.249
Shetland												
Sandsound	0.454	1.880	0.081	1.110	1.930	26.000	5.080	1.700	< LoD	0.170	< LoD	0.315
Scarfataing	0.501	1.720	0.064	1.030	1.420	22.500	3.210	0.905	< LoD	0.136	< LoD	0.239
East of Linga	0.321	1.630	< LoD	0.670	1.620	30.500	2.210	0.501	< LoD	0.119	< LoD	0.346
Busta Voe	0.592	0.810	< LoD	0.716	1.600	31.500	2.850	0.749	< LoD	0.182	< LoD	0.269
Orkney												
Scapa Flow	0.994	1.340	< LoD	1.090	0.896	19.600	2.580	0.490	< LoD	0.210	< LoD	0.341

< LoD = below limit of analytical detection

[a] Silver is not presently covered by UKAS accreditation.

Table 5b Trace Metal concentration (µg g^{-1} wet weight) in mussels from sites around Scotland collected July, August/September 2002

	Concentration of trace metals in mussels (µg g^{-1} wet weight)											
	Cr	Mn	Co	Ni	Cu	Zn	As	Se	Ag[a]	Cd	Hg	Pb
LoD	0.0879	0.1076	0.06017	0.1080	0.1770	0.5170	0.0797	0.1760	0.1184	0.0753	0.0151	0.0865
Strathclyde												
Loch Striven	0.516	1.080	0.069	0.305	1.670	12.600	2.030	0.711	< LoD	0.109	< LoD	0.141
Loch Leven	0.168	2.840	< LoD	0.142	1.430	10.900	2.770	1.100	< LoD	0.191	0.038	0.168
Loch Etive	0.313	0.906	< LoD	0.323	0.951	8.350	1.380	0.763	0.132	0.087	0.020	< LoD
Western Isles												
Loch Roag	0.270	1.030	< LoD	0.187	1.130	11.200	1.920	0.671	< LoD	0.088	< LoD	0.140
Shetland												
Sandsound	0.299	0.829	< LoD	0.208	1.350	14.800	1.390	0.572	< LoD	0.188	< LoD	0.125
Orkney												
Scapa Flow	0.476	0.953	0.064	0.602	0.774	14.900	2.120	1.330	0.304	0.192	0.029	0.537

< LoD = below limit of analytical detection

[a] Silver is not presently covered by UKAS accreditation.

Table 6a Trace Metal concentration (µg g^{-1} wet weight) in oysters from sites around Scotland collected March/April 2002

	Concentration of trace metals in oysters (µg g^{-1} wet weight)											
	Cr	Mn	Co	Ni	Cu	Zn	As	Se	Ag[a]	Cd	Hg	Pb
LoD	0.0879	0.1076	0.06017	0.1080	0.1770	0.5170	0.0797	0.1760	0.1184	0.0753	0.0151	0.0865
Strathclyde												
Loch Fyne	0.328	4.100	< LoD	0.649	24.400	241.00	1.550	0.413	1.270	0.370	< LoD	< LoD
Loch Gruinart	0.871	5.760	< LoD	1.130	12.000	222.00	2.990	0.466	0.865	0.274	< LoD	0.112
Loup Bay	0.764	4.710	< LoD	1.170	10.600	251.00	2.890	0.397	0.510	0.239	< LoD	< LoD
Highland												
Kyle of Tongue	0.294	3.630	< LoD	0.565	17.300	343.10	2.040	0.353	1.430	0.256	< LoD	0.118
Loch Ailort	0.516	8.240	< LoD	0.733	9.680	240.00	3.320	0.552	0.696	0.410	< LoD	0.112
Orkney												
Bay of Firth	0.423	4.590	< LoD	0.690	8.580	255.00	3.700	0.531	0.593	0.352	< LoD	0.136

< LoD = below limit of analytical detection

[a] Silver is not presently covered by UKAS accreditation.

Table 6b Trace Metal concentration (µg g^{-1} wet weight) in oysters from sites around Scotland collected August/September 2002

	Concentration of trace metals in oysters (µg g^{-1} wet weight)											
	Cr	Mn	Co	Ni	Cu	Zn	As	Se	Ag[a]	Cd	Hg	Pb
LoD	0.0879	0.1076	0.06017	0.1080	0.1770	0.5170	0.0797	0.1760	0.1184	0.0753	0.0151	0.0865
Strathclyde												
Loup Bay	0.153	11.600	0.084	0.180	17.000	269.00	4.310	0.850	0.826	0.306	0.020	0.108
Highland												
Kyle of Tongue	< LoD	3.740	< LoD	< LoD	4.350	108.00	2.530	1.220	0.187	0.192	< LoD	< LoD
Orkney												
Bay of Firth	0.399	4.410	< LoD	0.214	9.920	243.00	3.810	0.952	0.596	0.262	0.029	0.128

< LoD = below limit of analytical detection

[a] Silver is not presently covered by UKAS accreditation

Table 7a.1 Trace Metal concentration (µg g^{-1} wet weight) in scallop muscle tissue from sites around Scotland collected March/April 2002

	Concentration of trace metals in scallop muscle tissue (µg g^{-1} wet weight)											
	Cr	Mn	Co	Ni	Cu	Zn	As	Se	Ag[a]	Cd	Hg	Pb
LoD	0.0879	0.1076	0.06017	0.1080	0.1770	0.5170	0.0797	0.1760	0.1184	0.0753	0.0151	0.0865
South Minch												
SM 10	0.215	2.980	< LoD	0.296	0.524	12.400	1.320	0.311	0.154	0.357	< LoD	< LoD
SM 12	0.243	1.930	< LoD	0.263	0.219	13.300	2.050	0.199	0.148	0.235	< LoD	< LoD
North Minch												
NM 15	0.259	3.590	< LoD	0.266	0.241	13.200	1.830	0.352	< LoD	0.360	< LoD	< LoD
East Coast												
E 1	0.153	10.000	< LoD	0.372	0.233	16.600	1.230	0.223	< LoD	0.331	< LoD	< LoD
Moray Firth												
M 2	0.265	3.520	< LoD	0.635	0.248	13.300	1.240	0.261	< LoD	0.383	< LoD	< LoD
M 10	0.238	2.980	< LoD	0.332	0.297	15.100	1.500	0.454	< LoD	0.215	< LoD	< LoD
Outer Hebrides												
H 9	0.263	2.680	< LoD	0.367	0.438	12.200	1.910	0.215		0.137	< LoD	< LoD
Irish Sea												
IS 5	0.258	3.880	< LoD	0.281	0.232	12.600	1.230	< LoD	< LoD	0.530	< LoD	< LoD
Jura												
J 5	0.189	3.740	< LoD	0.242	0.234	11.500	1.870	0.243	< LoD	0.156	< LoD	< LoD
Clyde												
C 4	0.182	0.937	< LoD	0.252	0.232	9.810	1.450	0.299	< LoD	0.146	< LoD	< LoD
Orkney												
O 10	0.185	0.290	< LoD	0.234	0.217	8.810	1.800	0.180	< LoD	0.114	< LoD	< LoD
Shetland												
S 14	0.280	0.312	< LoD	0.281	0.330	11.700	1.580	0.215	0.202	0.229	< LoD	< LoD

< LoD = below limit of analytical detection

[a] Silver is not presently covered by UKAS accreditation.

Table 7a.2 Trace Metal concentration (µg g^{-1} wet weight) in scallop gonad tissue from sites around Scotland collected March/April 2002

	Concentration of trace metals in scallop gonad tissue (µg g^{-1} wet weight)											
	Cr	Mn	Co	Ni	Cu	Zn	As	Se	Ag[a]	Cd	Hg	Pb
LoD	0.0879	0.1076	0.06017	0.1080	0.1770	0.5170	0.0797	0.1760	0.1184	0.0753	0.0151	0.0865
South Minch												
SM 10	0.429	13.000	< LoD	0.669	2.620	45.400	3.840	0.768	1.680	0.197	< LoD	0.113
SM 12	0.504	13.200	< LoD	0.769	2.250	33.500	3.350	0.687	0.237	0.222	< LoD	0.121
North Minch												
NM 15	0.412	12.900	0.063	0.850	2.410	43.700	3.680	0.945	0.224	0.358	< LoD	0.143
East Coast												
E 1	0.475	< LoD	< LoD	0.603	2.900	55.700	3.220	0.907	0.322	0.322	< LoD	0.131
Moray Firth												
M 2	0.838	15.100	< LoD	0.674	2.800	47.900	3.140	0.774	0.220	0.883	0.020	0.136
M 10	0.532	< LoD	0.081	0.933	2.760	103.00	2.830	0.971	0.227	0.406	< LoD	0.270
Outer Hebrides												
H 9	0.201	14.400	< LoD	0.553	2.110	32.400	2.110	0.479	0.174	0.161	< LoD	0.101
Irish Sea												
IS 5	1.030	13.000	0.093	1.010	3.160	31.800	3.880	0.843	1.220	0.604	0.019	0.251
Jura												
J 5	0.608	0.294	0.088	0.681	2.260	68.000	2.550	0.834	0.133	0.198	0.050	0.386
Clyde												
C 4	0.425	21.600	< LoD	0.633	2.740	49.400	2.310	0.825	0.124	0.167	< LoD	0.151
Orkney												
O 10	0.302	8.400	< LoD	0.407	1.870	41.800	2.390	0.498	< LoD	0.142	< LoD	0.131
Shetland												
S 14	1.020	5.010	< LoD	0.631	2.650	52.700	3.270	0.849	< LoD	0.553	< LoD	0.101

< LoD = below limit of analytical detection

[a] Silver is not presently covered by UKAS accreditation.

Table 7b.1 Trace Metal concentration (µg g^{-1} wet weight) in scallop muscle tissue from sites around Scotland collected September 2002

	Concentration of trace metals in scallop gonad tissue (µg g^{-1} wet weight)											
	Cr	Mn	Co	Ni	Cu	Zn	As	Se	Ag[a]	Cd	Hg	Pb
LoD	0.0879	0.1076	0.06017	0.1080	0.1770	0.5170	0.0797	0.1760	0.1184	0.0753	0.0151	0.0865
South Minch												
SM 12	< LoD	2.360	< LoD	< LoD	0.190	9.620	1.310	0.374	< LoD	0.105	< LoD	< LoD
East Coast												
E 1	< LoD	2.450	< LoD	< LoD	0.203	10.200	1.320	0.453	< LoD	0.142	< LoD	< LoD
Moray Firth												
M 2	< LoD	0.954	< LoD	< LoD	0.220	10.500	1.660	0.569	< LoD	0.103	< LoD	< LoD

< LoD = below limit of analytical detection

[a] Silver is not presently covered by UKAS accreditation.

Table 7b.2 Trace Metal concentration (µg g^{-1} wet weight) in scallop gonad tissue from sites around Scotland collected September 2002

	Concentration of trace metals in scallop gonad tissue (µg g^{-1} wet weight)											
	Cr	Mn	Co	Ni	Cu	Zn	As	Se	Ag[a]	Cd	Hg	Pb
LoD	0.0879	0.1076	0.06017	0.1080	0.1770	0.5170	0.0797	0.1760	0.1184	0.0753	0.0151	0.0865
South Minch												
SM 12	0.439	74.700	0.145	0.297	2.280	59.500	2.750	0.866	0.213	0.317	< LoD	0.380
East Coast												
E 1	0.512	42.900	0.078	0.207	1.970	67.800	3.790	0.764	0.122	0.320	< LoD	0.216
Moray Firth												
M 2	0.401	33.800	< LoD	0.248	1.560	51.100	3.920	1.280	0.158	0.241	< LoD	0.224

< LoD = below limit of analytical detection

[a] Silver is not presently covered by UKAS accreditation.

Table 8 Background concentrations and regulation limits for trace metals in shellfish

	Blue mussel background concentration ranges, :g g^{-1} wet weight (OSPAR, 2000)	Trace metal concentrations in mussels, :g g^{-1} wet weight (Brown and Balls, 1997)		Maximum trace metal levels in mussels, :g g^{-1} wet weight (Commission Regulations 466/2002)	Directive 79/923/EEC Standards for shellfish, :g g^{-1} wet weight * (Henderson and Davies, 2001)	
		Range	Mean		Guideline	Imperative
Cr	NDA	NDA	NDA	NDA	1.2	4
Mn	NDA	NDA	NDA	NDA	ND	ND
Co	NDA	NDA	NDA	NDA	ND	ND
Ni	NDA	NDA	NDA	NDA	1.0	3.0
Cu	0.76 - 1.10	0.50 - 27.74	2.19	NDA	3.0	6.0
Zn	11.6 - 30	3.23 - 290	22.4	NDA	50	100
As	NDA	1.38 - 28.4	7.1	NDA	6.0	20
Se	NDA	NDA	NDA	NDA	ND	ND
Ag	NDA	NDA	NDA	NDA	0.2	0.6
Cd	0.07 - 0.11	0.085 - 0.205	0.106	1.0	1.0	3.0
Hg	0.005 - 0.010	0.01 - 0.02	0.01	0.5	0.2	0.6
Pb	0.010 - 0.190	0.08 - 0.80	0.273	1.0	3.0	10

* = dry weight values divided by five to convert to wet weight values
NDA = no data available

Table 9a Chlorobiphenyl concentrations, sum of the ICES 7 congeners and sum of all 28 congeners studied (ng g^{-1} wet weight); organochlorine pesticide concentrations, sum of the DDTs and sum of chlordanes (ng g^{-1} wet weight) in mussels from sites around Scotland collected March/April 2002

	Chlorobiphenyl concentrations (ng g^{-1} wet weight)		Organochlorine pesticide concentrations, sum of DDTs and sum of chlordanes (ng g^{-1} wet weight)							
	ICES 7$^{(1)}$	Total CB$^{(2)}$	HCB	∀-HCH	(-HCH	Dieldrin	Endrin	Sum Heptachlor	Sum DDT$^{(3)}$	Sum Chlordanes$^{(4)}$
Strathclyde										
Loch Fyne	6.44	12.74	< DT	< DT	0.177	0.720	0.166	< DT	2.51	1.02
Loch Striven	13.93	28.85	< DT	< DT	0.171	0.989	< DT	< DT	4.51	0.47
Loup Bay	1.25	2.10	< DT	< DT	0.139	0.597	0.119	< DT	0.53	0.35
Loch Leven	2.54	5.10	< DT	< DT	0.217	0.281	0.175	< DT	0.95	0.74
Loch Etive	5.07	9.82	< DT	< DT	0.124	0.299	< DT	< DT	1.01	< DT
Western Isles										
Loch Leurbost	1.74	3.33	< DT	< DT	0.003	< DT	< DT	< DT	0.42	0.23
Loch Roag	1.84	3.42	< DT	< DT	0.062	0.155	< DT	0.28	0.66	1.23
Loch Carnan	5.52	8.94	< DT	< DT	0.145	0.158	0.184	< DT	0.85	0.92
Highland										
Kyle of Tongue	2.12	3.94	< DT	< DT	< DT	0.139	0.084	< DT	0.25	0.47
Loch Kishorn	3.00	5.40	< DT	< DT	0.134	0.063	0.139	< DT	0.76	0.12
Loch Sunart	2.04	3.75	< DT	< DT	0.180	0.541	0.166	< DT	1.22	0.53
Loch Ewe	2.25	4.30	< DT	< DT	0.134	0.579	0.152	< DT	1.55	0.55
Ardtoe	1.92	4.89	< DT	< DT	0.244	0.567	0.141	< DT	1.54	0.81
Loch Ailort	1.09	2.51	< DT	< DT	0.091	0.448	< DT	< DT	0.99	0.44
Loch Ainort	6.14	12.12	< DT	< DT	0.111	0.140	0.143	<DT	0.50	0.31
Broadford Bay	1.79	3.45	< DT	< DT	0.130	0.379	0.222	< DT	2.01	0.58
Lochinver	1.86	3.76	< DT	< DT	< DT	0.153	0.096	0.00	0.19	0.00
Shetland										
Sandsound	1.68	3.34	< DT	< DT	M	0.234	0.135	0.50	0.79	1.69
Scarfataing	2.72	4.92	< DT	< DT	< DT	< DT	0.136	< DT	0.61	0.31
East of Linga	3.01	5.65	< DT	< DT	0.084	0.195	0.189	< DT	0.48	0.33
Busta Voe	3.08	5.98	< DT	< DT	< DT	0.221	< DT	< DT	0.36	0.45
Orkney										
Scapa Flow	2.15	4.18	< DT	< DT	0.102	0.483	< DT	0.360	1.060	0.660

(1) ICES 7 CBs; CBs 28, 52, 101, 118, 153, 138 and 180

(2) Total CBs = ICES 7 CBs + CBs 31, 49, 44, 74, 70, 99, 97, 110, 149, 132, 105, 137, 158, 187, 183, 128, 156, 157, 170, 189 and 194

(3) Sum DDT = sum of o,p’-DDE, p,p’-DDE, o,p’-DDD, p,p’-DDD, o,p’-DDT and p,p’-DDT

(4) Sum Chlordanes = sum of ∀-chlordene, (-chlordene, ∀-chlordane, (-chlordane, Heptachlor, Heptachlor epoxide, Oxychlordane and trans-Nonachlor

DT = Detection Threshold

Table 9b Chlorobiphenyl concentrations, sum of the ICES 7 congeners and sum of all 28 congeners studied (ng g^{-1} wet weight); organochlorine pesticide concentrations, sum of the DDTs and sum of chlordanes (ng g^{-1} wet weight) in mussels from sites around Scotland collected July, August/September 2002

	Chlorobiphenyl concentrations (ng g^{-1} wet weight)		Organochlorine pesticide concentrations, sum of DDTs and sum of chlordanes (ng g^{-1} wet weight)							
	ICES 7$^{(1)}$	Total CB$^{(2)}$	HCB	∀-HCH	(-HCH	Dieldrin	Endrin	Sum Heptachlor	Sum DDT$^{(3)}$	Sum Chlordanes$^{(4)}$
Strathclyde										
Loch Striven	7.63	14.94	< DT	0.147	0.296	1.328	< DT	< DT	3.63	0.58
Loch Leven	4.63	9.01	< DT	< DT		0.345	< DT	< DT		
Loch Etive	3.53	7.01	< DT	< DT	0.178	0.330	< DT	< DT	1.67	0.16
Western Isles										
Loch Roag	3.04	6.09	< DT	< DT	0.094	0.088	< DT	0.11	0.38	0.11
Shetland										
Sandsound	3.42	6.24	< DT	0.091	0.612	0.244	0.095	< DT	1.27	0.49
Orkney										
Scapa Flow	4.23	8.62	< DT	< DT	0.383	0.432	< DT	0.08	2.20	2.21

(1) ICES 7 CBs; CBs 28, 52, 101, 118, 153, 138 and 180

(2) Total CBs = ICES 7 CBs + CBs 31, 49, 44, 74, 70, 99, 97, 110, 149, 132, 105, 137, 158, 187, 183, 128, 156, 157, 170, 189 and 194

(3) Sum DDT = sum of o,p'-DDE, p,p'-DDE, o,p'-DDD, p,p'-DDD, o,p'-DDT and p,p'-DDT

(4) Sum Chlordanes = sum of ∀-chlordene, (-chlordene, ∀-chlordane, (-chlordane, Heptachlor, Heptachlor epoxide, Oxychlordane and trans-Nonachlor

DT = Detection Threshold

Table 10a Chlorobiphenyl concentrations, sum of the ICES 7 congeners and sum of all 28 congeners studied (ng g^{-1} wet weight); organochlorine pesticide concentrations, sum of the DDTs and sum of chlordanes (ng g^{-1} wet weight) in oysters from sites around Scotland collected March/April 2002

	Chlorobiphenyl concentrations (ng g^{-1} wet weight)		Organochlorine pesticide concentrations, sum of DDTs and sum of chlordanes (ng g^{-1} wet weight)							
	ICES 7(1)	Total CB(2)	HCB	∀-HCH	(-HCH	Dieldrin	Endrin	Sum Heptachlor	Sum DDT(3)	Sum Chlordanes(4)
Strathclyde										
Loch Fyne	5.5	9.58	< DT	0.147	0.167	0.466	0.133	< DT	1.81	0.13
Loch Gruinart	3.88	6.01	< DT	< DT	0.113	0.221	0.161	0.12	0.41	0.72
Loup Bay	4.02	6.55	< DT	< DT	0.107	0.429	0.119	< DT	1.22	0.17
Highland										
Kyle of Tongue	4.01	7.30	< DT	< DT	< DT	0.342	0.204	< DT	1.80	0.45
Loch Ailort	3.25	6.49	< DT	< DT	0.132	0.215	0.149	< DT	1.49	0.29
Orkney										
Bay of Firth	3.55	6.14	< DT	< DT	0.147	0.022	0.142	< DT	1.10	2.38

(1) ICES 7 CBs; CBs 28, 52, 101, 118, 153, 138 and 180

(2) Total CBs = ICES 7 CBs + CBs 31, 49, 44, 74, 70, 99, 97, 110, 149, 132, 105, 137, 158, 187, 183, 128, 156, 157, 170, 189 and 194

(3) Sum DDT = sum of o,p'-DDE, p,p'-DDE, o,p'-DDD, p,p'-DDD, o,p'-DDT and p,p'-DDT

(4) Sum Chlordanes = sum of ∀-chlordene, (-chlordene, ∀-chlordane, (-chlordane, Heptachlor, Heptachlor epoxide, Oxychlordane and trans-Nonachlor

DT = Detection Threshold

Table 10b Chlorobiphenyl concentrations, sum of the ICES 7 congeners and sum of all 28 congeners studied (ng g^{-1} wet weight); organochlorine pesticide concentrations, sum of the DDTs and sum of chlordanes (ng g^{-1} wet weight) in oysters from sites around Scotland collected August/September 2002

	Chlorobiphenyl concentrations (ng g^{-1} wet weight)		Organochlorine pesticide concentrations, sum of DDTs and sum of chlordanes (ng g^{-1} wet weight)							
	ICES 7(1)	Total CB(2)	HCB	∀-HCH	(-HCH	Dieldrin	Endrin	Sum Heptachlor	Sum DDT(3)	Sum Chlordanes(4)
Strathclyde										
Loup Bay	2.97	5.93	< DT	< DT	0.135	0.276	0.130	< DT	0.73	< DT
Highland										
Kyle of Tongue	4.21	8.71	< DT	0.84	0.127	0.297	0.143	< DT	0.79	0.66
Orkney										
Bay of Firth	2.61	7.23	< DT	< DT	0.196	0.124	< DT	< DT	0.88	1.11

Table 11a.1 Chlorobiphenyl concentrations, sum of the ICES 7 congeners and sum of all 28 congeners studied (ng g^{-1} wet weight); organochlorine pesticide concentrations, sum of the DDTs and sum of chlordanes (ng g^{-1} wet weight) in scallop muscle tissue from sites around Scotland collected March/April 2002

	Chlorobiphenyl concentrations (ng g^{-1} wet weight)		Organochlorine pesticide concentrations, sum of DDTs and sum of chlordanes (ng g^{-1} wet weight)							
	ICES 7(1)	Total CB(2)	HCB	∀-HCH	(-HCH	Dieldrin	Endrin	Sum Heptachlor	Sum DDT(3)	Sum Chlordanes(4)
South Minch										
SM 10	1.97	3.62	0.095	< DT	0.098	0.155	< DT	0.09	1.05	0.30
SM 12	1.95	3.21	< DT	< DT	0.089	0.147	0.002	< DT	1.23	< DT
North Minch										
NM 15	2.17	4.77	< DT	< DT	< DT	0.147	< DT	< DT	0.78	< DT
East Coast										
E 1	1.05	2.07	< DT	< DT	0.135	< DT	< DT	< DT	0.58	< DT
Moray Firth										
M 2	1.87	3.00	< DT	< DT	0.095	0.145	< DT	< DT	0.81	0.24
M 10	0.41	0.67	< DT	< DT	< DT	0.124	< DT	< DT	0.52	0.19
Outer Hebrides										
H 9	0.60	1.23	< DT	< DT	0.082	0.126	< DT	< DT	1.17	0.13
Irish Sea										
IS 5	0.76	1.58	< DT	< DT	< DT	0.189	< DT	< DT	0.69	0.06
Jura										
J 5	0.68	1.09	< DT	< DT	< DT	0.125	< DT	< DT	0.61	0.24
Clyde										
C 4	0.62	0.83	0.097	< DT	< DT	0.153	< DT	0.10	0.79	0.58
Orkney										
O 10	1.30	2.14	< DT	< DT	< DT	0.100	0.143	< DT	0.76	0.11
Shetland										
S 14	1.34	2.42	< DT	< DT	< DT	0.095	< DT	< DT	0.53	0.11

(1) ICES 7 CBs; CBs 28, 52, 101, 118, 153, 138 and 180

(2) Total CBs = ICES 7 CBs + CBs 31, 49, 44, 74, 70, 99, 97, 110, 149, 132, 105, 137, 158, 187, 183, 128, 156, 157, 170, 189 and 194

(3) Sum DDT = sum of o,p’-DDE, p,p’-DDE, o,p’-DDD, p,p’-DDD, o,p’-DDT and p,p’-DDT

(4) Sum Chlordanes = sum of ∀-chlordene, (-chlordene, ∀-chlordane, (-chlordane, Heptachlor, Heptachlor epoxide, Oxychlordane and trans-Nonachlor

DT = Detection Threshold

Table 11a.2 Chlorobiphenyl concentrations, sum of the ICES 7 congeners and sum of all 28 congeners studied (ng g^{-1} wet weight); organochlorine pesticide concentrations, sum of the DDTs and sum of chlordanes (ng g^{-1} wet weight) in scallop gonad tissue from sites around Scotland collected March/April 2002

	Chlorobiphenyl concentrations (ng g^{-1} wet weight)		Organochlorine pesticide concentrations, sum of DDTs and sum of chlordanes (ng g^{-1} wet weight)							
	ICES 7(1)	Total CB(2)	HCB	∀-HCH	(-HCH	Dieldrin	Endrin	Sum Heptachlor	Sum DDT(3)	Sum Chlordanes(4)
South Minch										
SM 10	3.17	5.36	< DT	< DT	0.153	0.438	0.183	< DT	0.74	0.49
SM 12	3.17	5.34	< DT	< DT	0.155	0.409	0.139	< DT	1.05	0.66
North Minch										
NM 15	1.73	2.43	< DT	< DT	0.150	0.373	0.144	< DT	0.65	0.10
East Coast										
E 1	0.27	0.27	< DT	< DT	0.113	0.331	0.107	< DT	3.340	< DT
Moray Firth										
M 2	1.15	1.62	< DT	< DT	0.133	0.393	0.183	< DT	0.48	< DT
M 10	0.35	0.48	< DT	< DT	0.087	0.298	0.112	< DT	3.45	0.07
Outer Hebrides										
H 9	0.13	0.13	< DT	< DT	< DT	0.201	0.126	< DT	3.28	0.10
Irish Sea										
IS 5	1.31	2.03	< DT	< DT	0.206	0.766	0.164	< DT	3.18	0.11
Jura										
J 5	3.73	5.95	< DT	< DT	< DT	0.449	0.000	< DT	1.23	0.70
Clyde										
C 4	3.48	5.49	< DT	< DT	0.213	1.172	0.112	< DT	1.76	0.27
Orkney										
O 10	1.49	2.53	< DT	< DT	< DT	0.000	< DT	< DT	0.76	0.30
Shetland										
S 14	2.72	4.54	< DT	< DT	< DT	0.361	0.238	< DT	1.24	0.69

Table 11b.1 Chlorobiphenyl concentrations, sum of the ICES 7 congeners and sum of all 28 congeners studied (ng g^{-1} wet weight); organochlorine pesticide concentrations, sum of the DDTs and sum of chlordanes (ng g^{-1} wet weight) in scallop muscle tissue from sites around Scotland collected September 2002

	Chlorobiphenyl concentrations (ng g^{-1} wet weight)		Organochlorine pesticide concentrations, sum of DDTs and sum of chlordanes (ng g^{-1} wet weight)							
	ICES 7(1)	Total CB(2)	HCB	∀-HCH	(-HCH	Dieldrin	Endrin	Sum Heptachlor	Sum DDT(3)	Sum Chlordanes(4)
South Minch										
SM 12	1.34	2.70	< DT	< DT	< DT	< DT	< DT	< DT	0.15	< DT
East Coast										
E 1	1.32	3.05	< DT	< DT	< DT	< DT	< DT	< DT	0.16	< DT
Moray Firth										
M 2	4.65	10.13	< DT	< DT	< DT	0.085	< DT	< DT	1.05	< DT

(1) ICES 7 CBs; CBs 28, 52, 101, 118, 153, 138 and 180

(2) Total CBs = ICES 7 CBs + CBs 31, 49, 44, 74, 70, 99, 97, 110, 149, 132, 105, 137, 158, 187, 183, 128, 156, 157, 170, 189 and 194

(3) Sum DDT = sum of o,p’-DDE, p,p’-DDE, o,p’-DDD, p,p’-DDD, o,p’-DDT and p,p’-DDT

(4) Sum Chlordanes = sum of ∀-chlordene, (-chlordene, ∀-chlordane, (-chlordane, Heptachlor, Heptachlor epoxide, Oxychlordane and trans-Nonachlor

DT = Detection Threshold

Table 11b.2 Chlorobiphenyl concentrations, sum of the ICES 7 congeners and sum of all 28 congeners studied (ng g^{-1} wet weight); organochlorine pesticide concentrations, sum of the DDTs and sum of chlordanes (ng g^{-1} wet weight) in scallop gonad tissue from sites around Scotland collected September 2002

	Chlorobiphenyl concentrations (ng g^{-1} wet weight)		Organochlorine pesticide concentrations, sum of DDTs and sum of chlordanes (ng g^{-1} wet weight)							
	ICES 7(1)	Total CB(2)	HCB	∀-HCH	(-HCH	Dieldrin	Endrin	Sum Heptachlor	Sum DDT(3)	Sum Chlordanes(4)
South Minch										
SM 12	3.17	6.34	< DT	< DT	< DT	0.148	< DT	< DT	0.72	0.34
East Coast										
E 1	1.85	4.00	< DT	< DT	< DT	0.020	< DT	< DT	0.23	0.25
Moray Firth										
M 2	< DT	< DT	< DT	< DT	< DT	< DT	< DT	< DT	< DT	< DT

Figure 6 Total measured ICES 7 CB congeners in mussels from five coastal regions around Scotland sampled winter and summer 2002

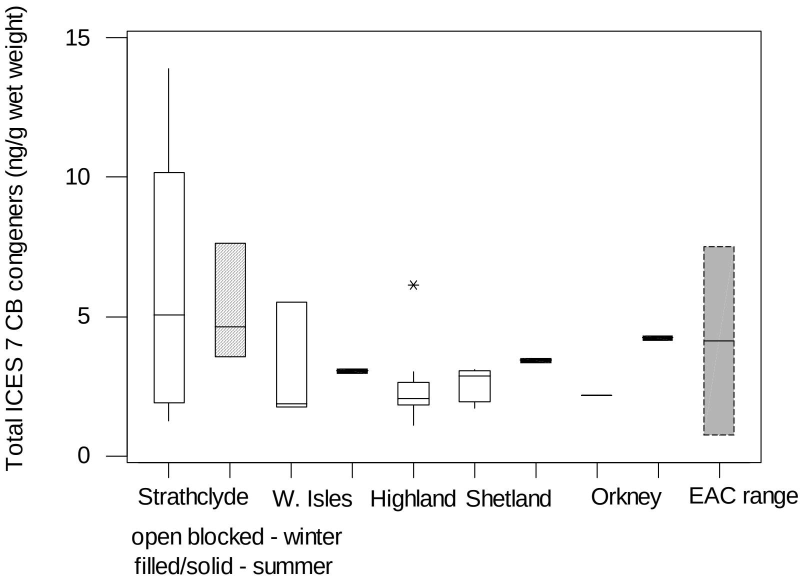
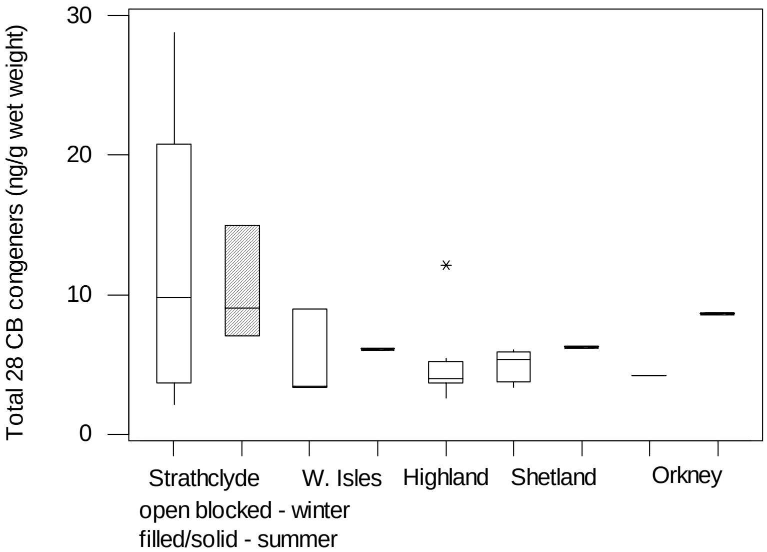


Figure 7 Total measured CB congeners in mussels from five coastal regions around Scotland sampled winter and summer 2002



In the above diagrams, the median is represented by the middle horizontal line in the box, with the upper and lower quartiles being the lines above and below, respectively. The distance between the upper and lower quartiles is called the inter-quartile range. The vertical lines show the spread of the data beyond the inter-quartile range. The * represents an outlying observation.

Appendix 1

Listing of chlorobiphenyl congeners determined and quoted

ICES 7 chlorobiphenyl congeners

CB 28
CB 52
CB 101
CB 118
CB 153
CB 138
CB 180

Other chlorobiphenyl congeners determined and quoted

CB 31
CB 49
CB 44
CB 74
CB 70
CB 99
CB 97
CB 110
CB 149
CB 132
CB 105
CB 137
CB 158
CB 187
CB 183
CB 128
CB 156
CB 157
CB 170
CB 189
CB 194

Listing of organochlorine pesticides determined and quoted

HCB	hexachlorobenzene
∀-HCH	alpha hexachlorohexane
(-HCH	gamma hexachlorohexane (Lindane)
Heptachlor	
Heptachlor epoxide	
Oxychlordane	
∀-chlordene	
(-chlordene	
∀-chlordane	
(-chlordane	
trans-Nonachlor	
DDE	dichlorodiphenyldichloroethylene (o – ortho; p – para)
DDD	dichlorodiphenyldichloroethane
DDT	dichlorodiphenyltrichloroethane